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U.S. Photovoltaic Patents: 1951-1983

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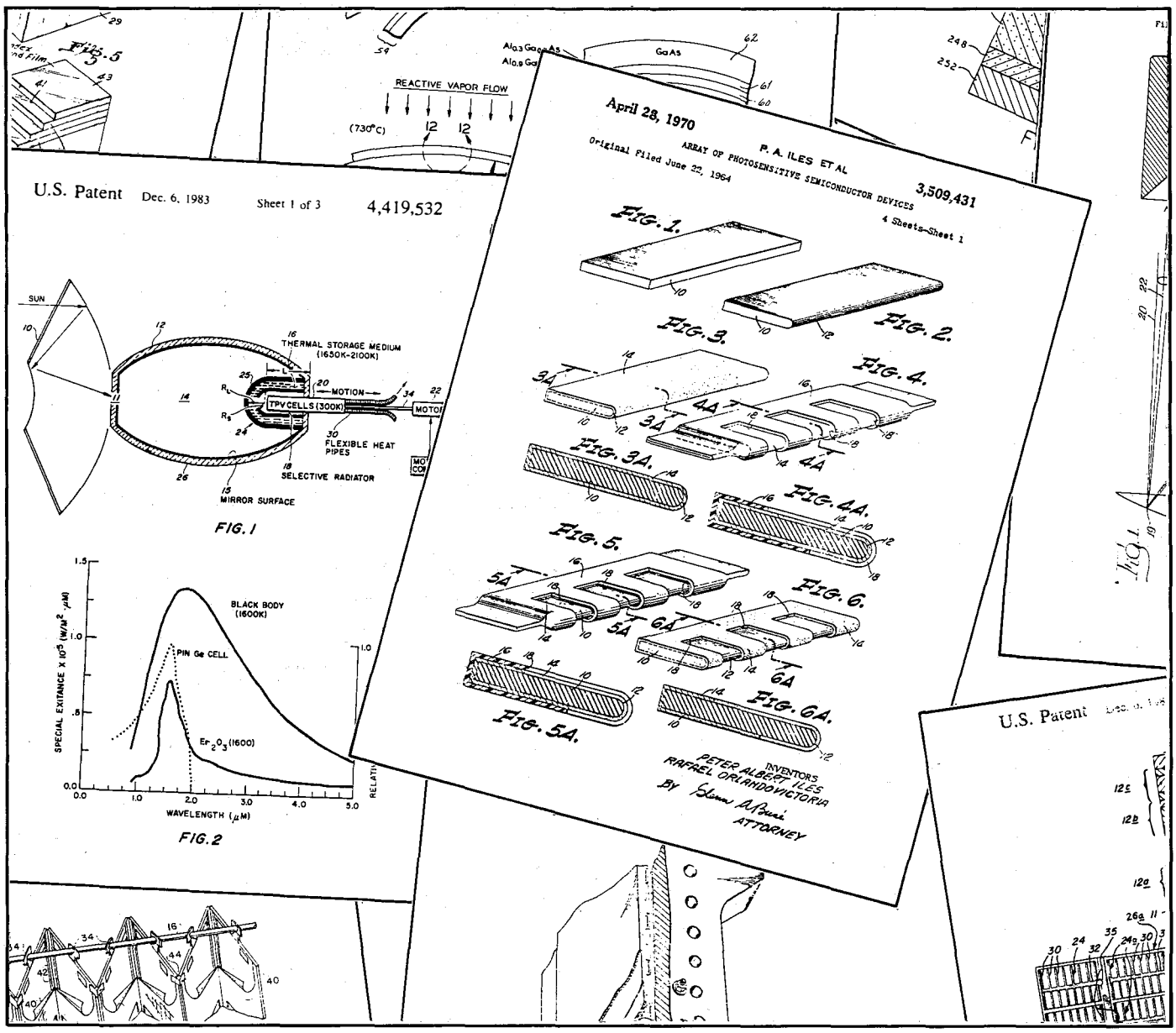

Introduction

This document comprises 1,487 U.S. patents on terrestrial-power photovoltaic applications, systems, components, materials, manufacturing, and support functions. These patents were issued from 1951 through 1983; no patents were found in 1950. Entries were isolated by searching USPA, the data base of the U.S. Patent Office. The final search strategy retrieved all patents under the class "Batteries, Thermoelectric and Photoelectric" and the subclasses "Photoelectric," "Testing," and "Applications" as well as patents which contained the words "photovoltaic(s)" or "solar cell(s)" and their derivatives. A manual search of patents in the Solar Energy Research Institute (SERI) Patent File augmented the data base search. After the initial list was compiled, patents for the following categories were excluded: space photovoltaic technology, use of the photvoltaic effect for detectors, and subjects only peripherally concerned with photovoltaics.

How to Use This Publication

Patents are arranged by patent number in ascending order, earliest to most recent, with divisions by year. Entries for each patent include inventor(s), assignee, title, and date. Abstracts are available for 1,323 patents; early patents did not include abstracts. These abstracts are cited generally as found on the patent except for modifying statements referring to specific diagrams since illustrations do not appear in this document. The early patents without abstracts are cited and indexed.

Three indexes complete this publication: Inventor, Assignee, and Subject. The patents in each index are listed in ascending order by year and patent number.

The Subject Index has seventeen categories which are grouped under three major divisions: Cells and Materials, Collectors, and Systems. The subject categories are

Cell and Materials

- Single Crystal Silicon Cells
- Polycrystalline and Ribbon Silicon Cells
- Amorphous Silicon Cells
- Cells from III-V Materials
- Cells from II-VI Materials
- Other PV Devices and Concepts
- Cell Components (metalization, substrates, conductive coatings, antireflective coatings)
- Cell Enhancement Techniques (surface and grain boundary passivation, annealing)
- Materials Production and Processes (purification, deposition, doping)
- Characterization and Analysis

Collectors

- Flat Plate Collectors (design, components, production)
- Concentrator Collectors (design, components, production)
- Optics and Trackers (lenses, reflectors, tracking devices, and related components)

Systems

- Utility Interactive Systems and Interface Technologies (power conditioning)
- Utility Independent Systems and Storage Technologies
- PV-Hybrid Systems (PV-thermal, photoelectrochemical)
- Systems Support (testing, maintenance, operation, and control)

Patents are indexed under as many categories as appropriate; most are indexed under two categories.

To Order a Copy of any U.S. Patent

Copies of patents can be obtained from the Patent and Trademarks Office. A check or money order of $1.00 per patent, payable to the Commissioner of Patents and Trademarks must accompany each request. The request must include the patent number(s) desired written legibly. Requests should be addressed to:

U.S. Department of Commerce
Patent and Trademarks Office
Washington, DC 20231

Photovoltaic Patents
1951-1953

1951

2,537,255
Brattain, Walter H., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Light-Sensitive Electric Device*. January 9, 1951.

2,537,256
Brattain, Walter H., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Light-Sensitive Electric Device*. January 9, 1951.

2,537,257
Brattain, Walter H., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Light-Sensitive Electric Device*. January 9, 1951.

2,554,225
Taylor, Clement F., inventor; General Electric Company, assignee. *Calibration of Photovoltaic Cells*. May 22, 1951.

1952

2,588,254
Lark-Horovitz, Karl; Benzer, Seymour; Davis, Robert E., inventors; Purdue Research Foundation, assignee. *Photoelectric and Thermoelectric Device Utilizing Semiconducting Material*. March 4, 1952.

2,622,117
Benzer, Seymour, inventor; Purdue Research Foundation, assignee. *Photovoltaic Device*. December 16, 1952.

1953

2,631,356
Sparks, Morgan; Teal, Gordon K., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Method of Making P-N Junctions in Semiconductor Materials*. March 17, 1953.

2,643,277
Falkenthal, Erwin E., inventor. *Photovoltaic Cell*. June 23, 1953.

1955

2,711,379
Rothstein, Jerome, inventor; The United States of America as represented by the Secretary of the Army, assignee. *Method of Controlling the Concentration of Impurities in Semiconducting Materials*. June 21, 1955.

1957

2,780,765
Chapin, Daryl M.; Fuller, Calvin S.; Pearson, Gerald L., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Solar Energy Converting Apparatus*. February 5, 1957.

2,794,846
Fuller, Calvin S., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Fabrication of Semiconductor Devices*. June 4, 1957.

1958

2,820,841
Carlson, Allan E.; Shiezawa, Lebo R.; Finegan, Joel D., inventors; Clevite Corporation, assignee. *Photovoltaic Cells and Methods of Fabricating Same*. January 21, 1958.

2,844,640
Reynolds, Donald C., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Cadmium Sulfide Barrier Layer Cell*. July 22, 1958.

2,847,585
Christian, Schuyler M., inventor; Radio Corporation of America, assignee. *Radiation Responsive Voltage Sources*. August 12, 1958.

2,861,018
Fuller, Calvin S.; Tanenbaum, Morris, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Fabrication of Semiconductive Devices*. November 18, 1958.

2,861,909
Ellis, Sidney G., inventor; Radio Corporation of America, assignee. *Semiconductor Devices*. November 25, 1958.

2,862,160
Ross, Bernd, inventor; Hoffman Electronics Corporation, assignee. *Light Sensitive Device and Method of Making the Same*. November 25, 1958.

1959

2,873,303
Rittner, Edmund S., inventor; North American Philips Company, Inc., assignee. *Photovoltaic Device*. February 10, 1959.

2,874,341
Biondi, Frank J.; Cleveland, Hugh M.; Sullivan, Miles V., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Ohmic Contacts to Silicon Bodies*. February 17, 1959.

2,877,284
Schultz, Melvin L., inventor; Radio Corporation of America, assignee. *Photovoltaic Apparatus*. March 10, 1959.

2,889,490
Paradise, Maurice E., inventor; Hoffman Electronics Corporation, assignee. *Solar Powered Light Source or the Like*. June 2, 1959.

2,894,173
Paradise, Maurice E., inventor; Hoffman Electronics Corporation, assignee. *Solar Powered Light Source or the Like*. July 7, 1959.

2,903,631
Perotte, Laurence F., inventor; General Electric Company, assignee. *Selenium Cells*. September 8, 1959.

2,904,613
Paradise, Maurice Elliott, inventor; Hoffman Electronics Corporation, assignee. *Large Area Solar Energy Converter and Method for Making the Same*. September 15, 1959.

2,915,578
Pensak, Louis, inventor; Radio Corporation of America, assignee. *Photovoltaic Device*. December 1, 1959.

2,919,298
Regnier, Norman J.; Shaffer, Marlin R., inventors; Hoffman Electronics Corporation, assignee. *Light Sensitive Voltage Producing Device or the Like*. December 29, 1959.

2,919,299
Paradise, Maurice Elliott, inventor; Hoffman Electronics Corporation, assignee. *High Voltage Photoelectric Converter or the Like*. December 29, 1959.

2,919,353
Paradise, Maurice Elliott, inventor; Hoffman Electronics Corporation, assignee. *Solar Powered Portable Radio Receiver or the Like*. December 29, 1959.

1960

2,929,859
Loferski, Joseph J., inventor; Radio Corporation of America, assignee. *Semiconductor Devices*. March 22, 1960.

2,932,592
Cameron, Angus E., inventor. *Method for Producing Thin Films and Articles Containing Same*. April 12, 1960.

2,938,938
Dickson, Donald C., Jr., inventor; Hoffman Electronics Corporation, assignee. *Photo-Voltaic Semiconductor Apparatus or the like*. May 31, 1960.

2,944,165
Stuetzer, Otmar M., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Semiconductive Device Powered by Light*. July 5, 1960.

2,945,417
Caryl, Coleman R.; Helmick, Walter E., inventors. *Apparatus and Mechanism for Concentrating Solar Rays on Objects to be Tested*. July 19, 1960.

2,946,945
Regnier, Norman J.; Schmidt, Lawrence W.; Kefes, Donn E., inventors; Hoffman Electronics Corporation, assignee. *Solar Energy Converting Apparatus or the Like*. July 26, 1960.

2,949,498
Jackson, Edmond D., inventor; Texas Instruments Incorporated, assignee. *Solar Energy Converter*. August 16, 1960.

2,951,163
Shaffer, Marlin R.; Weisbrich, Robert L., inventors; Hoffman Electronics Corporation, assignee. *Versatile Solar Powered Radio Receiver or the Like*. August 30, 1960.

2,953,621
Schultz, Melvin L., inventor; Radio Corporation of America, assignee. *Photovoltaic Apparatus*. September 20, 1960.

2,960,094
Small, Samuel N., inventor; Alfred G. Cohen and Paul Weiss, assignees. *Solar Actuated Umbrella Raising Mechanism*. November 15, 1960.

2,962,539
Daniel, Arthur F., inventor; The United States of America as represented by the Secretary of the Army, assignee. *Solar Cell Array*. November 29, 1960.

1961

2,972,521
Vees, Walter, inventor; Lonza Electric and Chemical Works Limited, assignee. *Production of Pure Silicon*. February 21, 1961.

2,981,777
Reynolds, Donald C., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Cadmium Sulfide Barrier Layer Cell*. April 25, 1961.

2,986,591
Swanson, John A.; Horton, Paul V., inventors; International Business Machines Corporation, assignee. *Photovoltaic Cell*. May 30, 1961.

2,989,575
Wallace, Clarence L., Jr., inventor; International Rectifier Corporation, assignee. *Solar Battery and Mounting Arrangement*. June 20, 1961.

2,993,945
Huth, John H., inventor; The Rand Corporation, assignee. *Solar Cell and Method of Making*. July 25, 1961.

2,995,473
Levi, Clifford A., inventor; Pacific Semiconductors, Inc., assignee. *Method of Making Electrical Connection to Semiconductor Bodies*. August 8, 1961.

2,997,415
Halsted, Richard E., inventor; General Electric Company, assignee. *Method for Making Flexible Luminescent, Photoconducting or Photovoltaic Films of Large Area*. August 22, 1961.

2,999,240
Nicoll, Frederick H., inventor; The United States of America as represented by the Secretary of the Army, assignee. *Photovoltaic Cells of Sintered Material*. September 5, 1961.

3,009,006
Kostelec, Jozé, inventor; General Aniline & Film Corporation, assignee. *Photoelectric Cell*. November 14, 1961.

3,009,841
Faust, John W., Jr., inventor; Westinghouse Electric Corporation, assignee. *Preparation of Semiconductor Devices Having Uniform Junctions*. November 21, 1961.

1962

3,015,590
Fuller, Calvin S., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Method of Forming Semiconductive Bodies*. January 2, 1962.

3,015,762
Shockley, William, inventor. *Semiconductor Devices*. January 2, 1962.

3,018,313
Gattone, Daniel H., inventor. *Light Gathering Power Converter*. January 23, 1962.

3,023,079
Kulifay, Stanley M., inventor; Monsanto Chemical Company, assignee. *Method for the Preparation of Selenides and Tellurides*. February 27, 1962.

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Kulifay, Stanley M., inventor; Monsanto Chemical Company, assignee. *Method for the Preparation of Selenides and Tellurides*. February 27, 1962.

3,025,335
Ralph, Eugene L., inventor; Hoffman Electronics Corporation, assignee. *Flexible Solar Energy Converter Panel*. March 13, 1962.

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Kulifay, Stanley M., inventor; Monsanto Chemical Company, assignee. *Method for the Preparation of Tellurides and Selenides*. March 20, 1962.

3,031,520
Clampitt, Bert H.; German, Dale E., inventors; Boeing Airplane Company, assignee. *Solar to Electrical Energy Conversion System*. April 24, 1962.

3,039,896
Van Cakenberghe, Jean Leon; Gilles, Jean-Marie F., inventors; Union Carbide Corporation, assignee. *Transparent Electrically Conductive Film and Method of Making the Same*. June 19, 1962.

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Matlow, Sheldon L.; Ralph,Eugene L., inventors; Hoffman Electronics Corporation, assignee. *Method of Making a Large Area Solar Cell Panel*. June 26, 1962.

3,046,323
Wildi, Bernard S., inventor; Monsanto Chemical Company, assignee. *Photoelectric Device*. July 24, 1962.

3,046,324
Matlow, Sheldon L., inventor; Hoffman Electronics Corporation, assignee. *Alloyed Photovoltaic Cell and Method of Making the Same*. July 24, 1962.

3,046,459
Anderson, Richard L.; O'Rourke, Mary J., inventors; International Business Machines Corporation, assignee. *Multiple Junction Semiconductor Device Fabrication*. July 24, 1962.

3,051,636
Kaspaul, Alfred F., inventor; Minnesota Mining and Manufacturing Company, assignee. *Electrolytic Preparation of Cadmium Salts*. August 28, 1962.

3,053,923
Stearns, Mary Beth, inventor; General Dynamics Corporation, assignee. *Solar Power Source*. September 11, 1962.

3,053,926
Ben-Sira, Moshe Y.; Pratt, Baruch, inventors; International Rectifier Corporation, assignee. *Silicon Photoelectric Cell*. September 11, 1962.

3,057,945
Rinnovatore, James V.; Laws, Kenneth L., inventors; The Electric Storage Battery Company, assignee. *Solid Electrolyte Battery*. October 9, 1962.

3,057,947
Calvin, Melvin; Kearns, David Richard, inventors. *Photoelectric Cell using Organic Materials*. October 9, 1962.

1963

3,072,507
Anderson, Richard L.; Marinace, John C.; Silvey, Gene A., inventors; International Business Machines Corporation, assignee. *Semiconductor Body Formation*. January 8, 1963.

3,076,861
Samulon, Henry A.; Robison, Paul C., inventors; Space Technology Laboratories, Inc., assignee. *Electromagnetic Radiation Converter*. February 5, 1963.

3,077,539
Blau, Henry H., Jr.; Davis, Richard S., inventors; Arthur D. Little, Inc., assignee. *Radiation Reference Standard*. February 12, 1963.

3,078,328
Jones, Lloyd E., inventor; Texas Instruments Incorporated, assignee. *Solar Cell*. February 19, 1963.

3,081,370
Miller, Solomon L., inventor; Raytheon Company, assignee. *Solar Cells*. March 12, 1963.

3,082,283
Anderson, Richard L., inventor; International Business Machines Corporation, assignee. *Radiant Energy Responsive Semiconductor Device*. March 19, 1963.

3,085,565
Macauley, Bill T., inventor; Sundstrand Corporation, assignee. *Solar Energy Device*. April 16, 1963.

3,089,070
Ralph, Eugene L., inventor; Hoffman Electronics Corporation, assignee. *Photoelectric Converter or the Like*. May 7, 1963.

3,091,555
Smythe, Robert L., inventor; Texas Instruments Incorporated, assignee. *Method for Forming Low Reflectance Coatings of Critical Thickness on Silicon Solar Energy Converters*. May 28, 1963.

3,092,725
Grimmeiss, Hermann Georg; Koelmans, Hein, inventors; North American Philips Company, assignee. *Blocking-Layer Photo-Electric Cell*. June 4, 1963.

3,094,436
Schröder, Hubert, inventor; Jenaer Glaswork Schott & Gen., assignee. *Transparent, Conductive, Reflection-Reducing Coatings on Non-Conductive Objects and Method*. June 18, 1963.

3,094,439
Mann, Alfred E.; Dubey, Michael B.; Wolf, Martin; Ralph, Eugene L.; Oliver, Robert L.; Shuster, Saul, inventors; Spectrolab, a Division of Textron Electronics, Inc., assignee. *Solar Cell System*. June 18, 1963.

3,095,324
Cusano, Dominic A.; Sernberger, Richard L., inventors; General Electric Company, assignee. *Method for Making Electrically Conducting Films and Article*. June 25, 1963.

3,102,828
Courvoisier, Jean, inventor; North American Philips Company, assignee. *Method of Manufacturing Semiconductor Bodies*. September 3, 1963.

3,104,188
Moncrieff-Yeates, Alexander J., inventor; Giannini Controls Corporation, assignee. *Solid State Solar Generator*. September 17, 1963.

3,106,489
Lepselter, Martin P., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Semiconductor Device Fabrication*. October 8, 1963.

3,108,021
Stanley, Howard E., inventor; International Rectifier Corporation, assignee. *Cadmium Sulfide Photo-Cell*. October 22, 1963.

3,111,611
Hunter, Lloyd P., inventor; International Business Machines Corporation, assignee. *Graded Energy Gap Semiconductor Devices*. November 19, 1963.

3,112,230
Rudenberg, Hermann Gunther, inventor; Transitron Electronic Corporation, assignee. *Photoelectric Semiconductor Device*. November 26, 1963.

3,113,047
Lasser, Marvin E.; Zaromb, Solomon, inventors; Philco Corporation, assignee. *Radiant Energy Chargeable Electric Cell*. December 3, 1963.

3,114,658
Zaromb, Solomon, inventor; Philco Corporation, assignee. *Electric Cell*. December 17, 1963.

3,115,424
Eannarino, George, inventor; International Rectifier Corporation, assignee. *Process for the Passivation of Semiconductors*. December 24, 1963.

1964

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Stead, Raymond Cecil Towler, inventor. *Photo-Cell Generator System for Charging Storage Devices*. March 31, 1964.

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Gault, John M.; Moross, John R., inventors; International Rectifier Corporation, assignee. *Method of Making a Semiconductor Device*. April 7, 1964.

3,129,061
Dermatis, Steve N.; Faust, John W., Jr., inventors; Westinghouse Electric Corporation, assignee. *Process for Producing an Elongated Unitary Body of Semiconductor Material Crystallizing in the Diamond Cubic Lattice Structure and the Product So Produced*. April 14, 1964.

3,132,057
Greenberg, Leon S., inventor; Raytheon Company, assignee. *Graded Energy Gap Semiconductive Device*. May 5, 1964.

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Henker, Heinz, inventor; Siemens & Haiske Aktiengesellschaft, assignee. *Photoelectric Semiconductor Device*. May 26, 1964.

3,146,138
Shirland, Fred A., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Vacuum Evaporated Barrier for a CdS Crystal*. August 25, 1964.

3,147,414
Pelfrey, Lowell S.; Kadelburg, Kurt; Macha, Milo V., inventors; International Rectifier Corporation, assignee. *Silicon Solar Cells with Attached Contacts*. September 1, 1964.

3,148,084
Hill, James E.; Chamberlin, Rhodes R., inventors; The National Cash Register Company, assignee. *Process for Making Conductive Film*. September 8, 1964.

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Mann, Alfred E.; Dubey, Michael B.; Wolf, Martin; Ralph, Eugene L.; Oliver, Robert L.; Shuster, Saul, inventors; Spectrolab, a Division of Textron Electronics, Inc., assignee. *Solar Cell System*. September 22, 1964.

3,150,999
Rudenberg, Hermann G.; Dale, Brian, inventors. *Radiant Energy Transducer*. September 29, 1964.

3,151,378
Finn, George B., Jr., inventor; International Rectifier Corporation, assignee. *Process for the Manufacture of Pure Tin Alloyed Contact for Diffused Silicon Devices*. October 6, 1964.

3,151,379
Escoffery, Charles A., inventor; International Rectifier Corporation, assignee. *Solar Battery and Method of Making It*. October 6, 1964.

3,152,926
Power, Roy B., inventor; Tung-Sol Electric Inc., assignee. *Photoelectric Transducer*. October 13, 1964.

1965

3,172,791
Allegretti, John E.; Gutsche, Heinrich; McAleer, William J., inventors; Merck & Co., Inc., assignee. *Crystallographic Orientation of a Cylindrical Rod of Semiconductor Material in a Vapor Deposition Process to Obtain a Polygonal Shaped Rod*. March 9, 1965.

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Kleinman, David A., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Solar Energy Converting Apparatus*. March 30, 1965.

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Dunlap, William Crawford, Jr., inventor; The Bendix Corporation, assignee. *Energy Converter*. June 1, 1965.

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Gorski, Daniel A., inventor; The Harshaw Chemical Company, assignee. *Photovoltaic Cell*. June 1, 1965.

3,194,700
Grimmeiss, Hermann Georg; Memming, Rüdiger; Koelmans, Hein, inventors; North American Philips Company, Inc., assignee. *Gas Heating and Cooling in the Manufacture of Semiconductor Devices*. July 13, 1965.

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Venables, John D., inventor; Union Carbide Corporation, assignee. *Solid State Devices Constructed from Semiconductive Whiskers*. August 17, 1965.

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Pliskin, William A.; Conrad, Ernest E., inventors; International Business Machines Corporation, assignee. *Method of Forming a Glass Film on an Object and the Product Produced Thereby*. October 19, 1965.

3,215,571
Frieser, Rudolf G., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Fabrication of Semiconductor Bodies*. November 2, 1965.

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Ruehrwein, Robert A., inventor; Monsanto Company, assignee. *Altering Proportions in Vapor Deposition Process to Form a Mixed Crystal Graded Energy Gap*. December 21, 1965.

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Hugle, Frances B.; Hugle, William B., inventors; D. H. Baldwin Company, assignee. *Semi-Conductive Films and Method of Producing Them*. December 28, 1965.

1966

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Lessley, Robert L., inventor; Aerojet-General Corporation, assignee. *Solar Energy Collector*. January 18, 1966.

3,229,682
Perlmutter, Morris; Howell, John R., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Device for Directionally Controlling Electromagnetic Radiation*. January 18, 1966.

3,232,795
Gillette, Roger.B.; Snyder, Howard E.; Tallent, Ralph J., inventors; The Boeing Company, assignee. *Solar Energy Converter*. February 1, 1966.

3,247,392
Thelen, Alfred J., inventor; Optical Coating Laboratory, Inc., assignee. *Optical Coating and Assembly Used as a Band Pass Interference Filter Reflecting in the Ultraviolet and Infrared*. April 19, 1966.

3,247,428
Perri, John A.; Riseman, Jacob, inventors; International Business Machines Corporation, assignee. *Coated Objects and Methods of Providing the Protective Coverings Therefor*. April 19, 1966.

3,252,023
Schmidt, Lawrence W., inventor; Hoffman Electronics Corporation, assignee. *Zero Torque-Producing Motor*. May 17, 1966.

3,253,951
Marinaccio, Louis P.; Lepselter, Martin P., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Method of Making Low Resistance Contact to Silicon Semiconductor Device*. May 31, 1966.

3,255,047
Escoffery, Charles A., inventor; International Rectifier Corporation, assignee. *Flexible Fabric Support Structure for Photovoltaic Cells*. June 7, 1966.

3,261,074
Beauzée, Claude, inventor; North American Philips Company, Inc., assignee. *Method of Manufacturing Photoelectric Semiconductor Devices*. July 19, 1966.

3,261,726
Ruehrwein, Robert A., inventor; Monsanto Company, assignee. *Production of Epitaxial Films*. July 19, 1966.

3,262,694
O'Farrell, Herbert W., inventor; TRW, Inc., assignee. *Solar Cell Module Assembly Jig*. July 26, 1966.

3,264,707
Elie, George T., inventor; Radio Corporation of America, assignee. *Method of Fabricating Semiconductor Devices*. August 9, 1966.

3,268,366
Guyot, Paul, inventor; North American Philips Company, Inc., assignee. *Photo-Electric Cell*. August 23, 1966.

3,278,337
Gault, John M., inventor; International Rectifier Corporation, assignee. *Device for Converting Radiant Energy into Electrical Energy*. October 11, 1966.

3,278,811
Mori, Hiroshi, inventor; Hayakawa Denki Kogyo Kabushiki Kaisha, assignee. *Radiation Energy Transducing Device*. October 11, 1966.

3,284,241
Lasser, Marvin E.; Lucovsky, Gerald, inventors; Philco Corporation, assignee. *Photo-Emissive Device Including Emitter and Insulator of Less than Mean Free Path Dimensions*. November 8, 1966.

3,284,252
Grimmeiss, Hermann Georg; Kischio, Werner; Memming, Rüdiger, inventors; North American Philips Company, Inc., assignee. *Method of Manufacturing Semiconductor Systems Comprising Cadmium Chalcogenide Semiconductors*. November 8, 1966.

3,290,175
Cusano, Dominic A.; Sormberger, Richard L., inventors; General Electric Company, assignee. *Semiconductor Photovoltaic Devices*. December 6, 1966.

1967

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Weisbeck, Roland; Brockes, Andreas, inventors; Farbenfabriken Bayer Aktiengesellschaft, assignee. *Photoresistors and Photoelements Having Increased Sensitivity in the Short-Wave Region of the Spectrum*. March 14, 1967.

3,310,439
Seney, John S., inventor; E. I. du Pont de Nemours and Company, assignee. *Photovoltaic Cell with Wave Guide*. March 21, 1967.

3,311,510
Mandelkorn, Joseph, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Making a Silicon Semiconductor Device*. March 28, 1967.

3,317,809
Bowers, Grover W.; Kennedy, Francis H., inventors. *Self-Contained Electrical Lighting Unit*. May 2, 1967.

3,322,575
Ruehrwein, Robert A., inventor; Monsanto Company, assignee. *Graded Energy Gap Photoelectromagnetic Cell*. May 30, 1967.

3,325,723
Grayson, Jerome H., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Voltage-Current Characteristic Simulator*. June 13, 1967.

3,330,700
Golub, Seymour; Sequeira, Edward A., inventors; Electro-Optical Systems, Inc., assignee. *Solar-Cell Panels*. July 11, 1967.

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Werth, John J., inventor; General Motors Corporation, assignee. *Thermo-Photovoltaic Converter with Radiant Energy Reflective Means*. July 18, 1967.

3,334,217
Bickler, Donald B.; Rauschenbach, Hans S., inventors; Hoffman Electronics Corporation, assignee. Simulation of Solar Radiation. August 1, 1967.

3,340,096
Mann, Alfred E.; Shuster, Saul, inventors; Spectrolab, a Division of Tektron Electronics Inc., assignee. *Solar Cell Array*. September 5, 1967.

3,340,599
Ellis, Sidney G., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Simple Method of Making Photovoltaic Junctions*. September 12, 1967.

This invention relates to an improved method for preparing gallium arsenide solar cells by the deposition of an inversion layer at its surface. The method can be performed at relatively low temperature and is simple to control. Briefly, the invention comprises the steps of depositing a relatively thin, transparent, conductive layer of cuprous iodide on a relatively thin n-type polycrystalline layer previously deposited on a conducting substrate, and heating the cuprous iodide layer with iodine vapor to lower its resistance.

3,344,334
Rubin, Irwin, inventor; International Rectifier Corporation, assignee. *Photovoltaic Cell Battery Charger*. September 26, 1967.

A portable battery charger having a pivotally mounted platform which contains openings for supporting batteries to be charged. The platform is pivoted into and out of a casing which carries contacts on its inner surfaces. When the platform is moved inwardly, electrical contact is made to the opposite terminals of the battery. An exterior solar cell connected to the fixed contacts causes a flow of charging current into the battery when the cells are exposed to radiation.

3,346,419
Forehand, Le Roy; Rodner, William H., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Mounting*. October 10, 1967.

3,350,234
Ule, Louis A., inventor; Hoffman Electronics Corporation, assignee. *Flexible Solar-Cell Concentrator Array*. October 31, 1967.

3,350,635
Mesch, Hans G., inventor; International Rectifier Corporation, assignee. *Solar Cell and Test Circuit*. October 31, 1967.

3,350,775
Iles, Peter Albert, inventor; Hoffman Electronics Corporation, assignee. *Process of Making Solar Cells or the Like*. November 7, 1967.

3,351,516
Weisbeck, Roland; Brockes, Andreas; Nassenstein, Heinrich, inventors; Farbenfabriken Bayer Aktiengesellschaft, assignee. *Photoconductive Structural Element and Process of Manufacturing Same*. November 7, 1967.

3,353,191
Dahly, Harold W., inventor. *Cooling Unit for a Hat*. November 21, 1967.

A hat and a cooling unit therefor including a motor operated fan mounted on the crown and a solar cell for driving the motor for circulating air within the hat.

3,357,857
Provisor, Henri; Lapluye, Gerard, inventors; North American Philips Company, Inc., assignee. *Method of Passivating Supports for Semiconductor Sulphides, Selenides and Tellurides*. December 12, 1967.

Passivating the substrate for receiving a semiconductor sulphide, selenide or telluride to avoid contamination thereof, by first applying to the substrate surface an inorganic metal compound different from the semiconductor material, and thereafter heating the substrate at a temperature of at least 400°C. The metal constituent of the compound is selected from the group of beryllium, magnesium, calcium, strontium, barium, aluminum, zinc, and cadmium.

3,359,137
Kaye, Stephen; Garasi, Louis, inventors; Electro-Optical Systems, Inc., assignee. *Solar Cell Configuration*. December 19, 1967.

A solar cell wherein the rear surface of a semiconductor crystal body is highly doped to form a first surface region of the same conductivity type. A second thin, highly doped, light gathering surface region of the opposite conductivity type extends across all but a small perimetric portion of the front surface, the semiconductor bulk material defining an intermediate region having a pillar-like edge portion terminating in the front surface to provide a back contact at the front surface of the device.

1968

3,361,594
Iles, Peter Albert; Ross, Bernd, inventors; Globe-Union, Inc., assignee. *Solar Cell and Process for Making the Same*. January 2, 1968.

3,368,125
Pasierb, Edward F., inventor; Radio Corporation of America, assignee. *Semiconductor Gallium Arsenide with Germanium Connecting Layer*. February 6, 1968.

3,369,939
Myer, Jon H., inventor; Hughes Aircraft Company, assignee. *Photovoltaic.Generator*. February 20, 1968.

3,370,986
Amsterdam, Michael F.; Shaikh, Mohammed S.; Tarneja, Krishan, S. inventors; Westinghouse Electric Corporation, assignee. *Photovoltaic Series Array Comprising P/N and N/P Cells*. February 27, 1968.

3,373,059
Augustine, Frank, inventor; Clevite Corporation, assignee. *Method of Making Photosensitive Elements*. March 12, 1968.

3,373,321
Tarneja, Krishan S.; Shaikh, Mohammed S., inventors; Westinghouse Electric Corporation, assignee. *Double Diffusion Solar Cell Fabrication*. March 12, 1968.

3,374,108
Keramidas, Basilio G., inventor; Kewanee Oil Company, assignee. *Formation of Barrier Layers in Cadmium Sulfide Solar Cells*. March 19, 1968.
This invention comprises a process for applying a "barrier layer" on a cadmium sulfide body designed for use as a photovoltaic cell comprising the steps of immersing the cadmium sulfide body in an aqueous solution of cuprous ions for a sufficient period of time, and, after removal of the cadmium sulfide body from the solution, removing any residual liquid adhering to the surface. The resultant barrier layer, which is believed to be cuprous sulfide, imparts a uniformly high efficiency to the photovoltaic cell.

3,375,141
Julius, Richard F., inventor; Aiken Industries, Inc., assignee. *Solar Cell Array*. March 26, 1968.

3,376,163
Abrahamsohn, Ilse, inventor; Itek Corporation, assignee. *Photosensitive Cell*. April 2, 1968.

3,376,164
Bachwansky, Peter, inventor; Globe-Union Inc., assignee. *Photovoltaic Power Assembly*. April 2, 1968.

This invention relates to a photovoltaic power assembly and more particularly relates to such an assembly for mounting a plurality of semiconductor elements in electrical series relationships.

3,376,165
Abbot, Charles G., inventor. *Apparatus for Converting Solar Energy to Electricity*. April 2, 1968.

3,378,407
Keys, Richard V., inventor; Globe-Union Inc., assignee. *Solar Cell Module*. April 16, 1968.

A solar cell module having a metallic grid to which the bottom contacts of a plurality of solar cells are connected and a metallic bar connecting the contact strips of the cells, the grid having a tab that extends past the cells for connection to the bar of the next module.

3,382,099
Montmory, Robert, inventor; Centre National de la Recherche Scientifique, assignee. *Process for the Epitaxial Growth of Semiconductor Layers on Metal Supports*. May 7, 1968.

A process for epitaxial growth of semiconductor layers on a mica split support cleaved along the (001) plane by first epitaxially depositing cubic face-centered silver or copper (111), thereover epitaxially depositing cubic face-centered gold or platinum (111), thereover epitaxially depositing body-centered metals such as chromium, molybdenum, tungsten, tantalum or columbium, selectively dissolving away the first layer (111) while separating the mica split and thereafter epitaxially depositing diamond-type cubic semiconductor such as germanium or silicon on the remaining cubic body-centered layer.

3,383,246
Ferreira, Paul F., inventor. *Rotatable Solar Energy Converter*. May 14, 1968.

A plurality of circumferentially spaced photo-voltaic solar cells mounted on the peripheral, heat conductive rim of a rapidly rotating wheel, the speed of which is selected so that each solar cell is intermittently exposed to concentrated rays of the sun for short intervals exceeding however the minimum time required for the energy conversion process to be completed. Optical solar light traps concentrate the sun's rays at focal points lying on the peripheral rim of the wheel beyond the solar cells.

3,384,806
Hartman, David J., inventor; Honeywell, Inc., assignee. *Power Conditioning System*. May 21, 1968.

An adaptive system for maximum electric power transfer from a source of electric power to an electric load. A switching element is provided between the source and the load and is periodically switched between its conductive and non-conductive states. The ratio of the conductive time to the non-conductive time is controlled as a function of the derivative of the output power with reference to output current to achieve maximum power transfer from the source to the load.

3,390,576
Yellott, John I., inventor. *Solar Radiation Measuring Device*. July 2, 1968.

3,396,057
Ellis, Sidney G., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Electrolytically Binding a Layer of Semiconductors Together*. August 6, 1968.

This invention teaches a method of binding a layer of semiconductor particles together. Electro-deposition is used to form an insulating film that holds the particles together. The particles can be used in making solar cells, photoelectric cells and other semiconductor products. Essentially, the particles are deposited on the surface of mercury. The particles float on the mercury. They are compacted and then covered with an electrolyte. One electrode is inserted in the electrolyte while the mercury serves as the other electrode. After the layer is formed, the level of the mercury is lowered so that the now formed layer will adhere to a base member previously submerged in the mercury.

3,411,952
Ross, Bernd; Herbst, Austin H., inventors; Globe-Union Inc., assignee. *Photovoltaic Cell and Solar Cell Panel*. November 19, 1968.

3,416,044
Dreyfus, Bertrand Alain; Tavernier, Jean, inventors; Societe d'Electronique et d'Automatisme, assignee. *Opto-Electronic Device Having a Transparent Electrode Thereon and Method of Making Same*. December 10, 1968.

A high transparency ohmic contact low resistance film electrode is coated on a face of a body of semi-conductor material at a location which is near to an impurity obtained junction within the body near said face. The film electrode is made of a semi-conductor material which is distinct from that of the body and such electrode is doped with impurities identical to the ones in the region of the junction in the body. The method of deposition of the electrode on the body is such that the doping impurities diffuse from the film to the junction zone or conversely from the junction zone to the film.

3,416,956
Keramidas, Basilio G.; Schaefer, James C., inventors; Kewanee Oil Company, assignee. *Process for Forming a Barrier in a Cadmium Sulfide Solar Cell*. December 17, 1968.

This invention comprises a process for forming the barrier layer in a CdS solar cell by depositing a copper sulfide barrier layer on the voltaic cell by immersing the CdS into a solution of a cuprous compound, preferably cuprous chloride, at a temperature of 25-97°C, the solution concentration of cuprous compound being 5-20 percent by weight and the total period of immersion being not more than the maximum value indicated by a chart having time in minutes plotted against temperatures in °C.

3,418,170
Amsterdam, Michael F.; Shaikh, Mohammed S.; Tarneja, Krishan S., inventors; The United States of America as represented by the Secretary of the Air Force, assignee. *Solar Cell Panels from Nonuniform Dendrites*. December 24, 1968.

A solar cell panel, made with a nonuniform width N-type dendrite semiconductive material webbing, has a doped layer of P-type material extending over the top, one edge and a portion of the bottom of the panel. A contact for the P-type material extends from the top at one end of the panel over the edge and a portion of the bottom at the other end of the panel. The width of the contact, at the narrow end of the dendrite semiconductive webbing, is equal to the difference in width of the two ends of the dendrite webbing. A contact for the N-type material is provided on the bottom of the panel adjacent the other edge.

3,419,433
Slifer, Luther W., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell and Circuit Array and Process for Nullifying Magnetic Fields*. December 31, 1968.

3,419,434
Colehower, Edgar Warren, inventor; Martin Marietta Corporation, assignee. *Solar Cell Assemblies*. December 31, 1968.

A metal sheet is formed in stair-like, or zig-zag corrugations defining two sets of parallel webs. The surfaces of one set of webs are covered with solar cells in heat transferring relationship. The surfaces of the other set of webs are reflective for reflecting incident radiation onto the solar cells. Heat from the solar cells is transmitted through the metal sheet and radiated from the reflective surfaces of the other set of webs. The reflective surfaces may

be given a coating that is transparent to radiant energy within the useful range of the solar cells but that is highly emissive to radiant energy outside that range.

3,419,484
Ammerman, Frank E.; Schindehette, Donald J., inventors; Chrysler Corporation, assignee. *Electrolytic Preparation of Semiconductor Compounds*. December 31, 1968.

An electrodeposition process for directly preparing antimonide, arsenide, telluride semiconductor compounds. The process comprises placing into simultaneous solution as cations the two or more elements which comprise the compound to be synthesized. One of these elements is one of the semi-metals of tellurium, arsenic or antimony and the other element any substance which has a deposition potential less noble than that of the semi-metal when both elements are in solution. The solution is then supplied with electrons with the result that the desired compound is formed and deposited on the electron source.

1969

3,421,943
Shaikh, Mohammed S.; Tarneja, Krishan S.; Riel, Robert K., inventors; Westinghouse Electric Corporation, assignee. *Solar Cell Panel Having Cell Edge and Base Metal Electrical Connections*. January 14, 1969.

3,421,946
Shaikh, Mohammed S.; Tarneja, Krishan S.; Amsterdam, Michael F., inventors; Westinghouse Electric Corporation, assignee. *Uncompensated Solar Cell*. January 14, 1969.

3,42
Gault, John M., inventor; International Rectifier Corporation, assignee. *Method of Manufacture of High Voltage Solar Cell*. January 21, 1969.

A high voltage output solar cell is formed by stacking at least 100 wafers, each of which contains a junction and each of which has a thickness of about 0.004 inch, and soldering the wafers together with the P-N junctions therein having the same direction. The assembled stack is then longitudinally sliced to form a plurality of slabs having leads connected to the ends thereof, with each slab having a transverse thickness of about 0.12 inch.

3,426,212
Klaus, Ruth Elizabeth Barry, inventor. *Radiation Converter Comprising Transparent Parallel Layers Containing Fluorescent Substances*. February 4, 1969.

A radiation converter is disclosed comprising at least two substantially parellel layers each comprising (a) solid polymeric material that is substantially transparent at least in the near ultraviolet and visible regions of the spectrum, and (b) fluorescent substance, said layers containing different fluorescent substances and disposed in optical relationship and adjacent to each other. In its simplest embodiment, the radiation converter is useful for converting electromagnetic radiation of wavelength between about 2900 A and about 15,000 A into radiation of different wavelength; in more sophisticated embodiments, the radiation converter is useful for converting electromagnetic radiation into electrical energy, for effecting useful chemical reactions, and for other purposes.

3,427,200
Lapin, Ellis E.; Ernest, Alan W.; Sollow, Philip A., inventors; Aerojet-General Corporation, assignee. *Light Concentrator Type Photovoltaic Panel Having Clamping Means for Retaining Photovoltaic Cell*. February 11, 1969.

This disclosure concerns a photovoltaic device which comprises a plurality of photovoltaic modules, each including a solar cell having its own individual reflecting surfaces. The cell of each module is disposed in a pocket formed by the lower ends of the walls providing the reflecting surfaces therefor. The walls include an inwardly crimped portion at the lower ends thereof which overlaps the upper edge of the cell so as to clamp and retain the cell in proper position in the pocket without requiring an adhesive cement.

3,427,459
Truffert, Alain Philippe, inventor; Societe Anonyme de Telecommunications, assignee. *Transducer Having a Conversion Characteristic of a Predetermined Formation*. February 11, 1969.

This invention relates to a thermo-electric or photo-electric transducer of which the conversion characteristic output voltage incident energy is a predetermined function: this transducer consists essentially of a cascade of transducing units, with rectifiers being connected with reverse polarity across the said transducing units: these transducing units are arranged to have, for a different incident energy, respective short-circuit currents of different, conveniently stepped values.

3,427,797
Kimura, Kenjiro; Negoro, Akio; Kojima, Yasuo; Saiji, Tsutomu, inventors. *Timepiece Using a Solar Battery as the Power Source*. February 18, 1969.

This invention concerns an improved timepiece utilizing solar cells as the energy source which enables the construction of a compact, attractive and dependable device wherein an opening extends through each said solar cell and said opening having on its wall a diffusion layer to connect layers on each side of said solar cell.

3,431,150 **2,527**
Dolan, Russell P., Jr.; Buchanan, Bobby L.; Roosild, Sven A., inventors; The United States of America as represented by the United States Air Force, assignee. *Process for Implanting Grids in Semiconductor Devices*. March 4, 1969.

A method of making field effect semiconductor devices with buried grids including the steps of bombarding a semiconductor substrate with monoenergetic ions after a gold mask has been etched through a photo resist located thereon.

3,433,676
Stein, Frank S., inventor; General Motors Corporation, assignee. *Thermophotovoltaic Energy Convertor with Photocell Mount*. March 18, 1969.

Mounting structure for flat cells in radiant energy convertors including a hollow polygonal mounting member having parallel rows of flat steps for receiving the cells in facial contact therewith through an insulative adhesive. Flat steps may be formed on member or on inserts held by member.

3,433,677
Robinson, Thomas L., inventor; Cornell Aeronautical Laboratory, Inc., assignee. *Flexible Sheet Thin-Film Photovoltaic Generator*. March 18, 1969.

3,434,885
Mandelkorn, Joseph; Broder, Jacob, inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Making Electrical Contact on Silicon Solar Cell and Resultant Product*. March 25, 1969.

An electrode connection for an n on p silicon solar cell is made by depositing a layer of cerium on the surface of the cell and then depositing a layer of silver on the cerium. The solar cell with the two layers deposited thereon is then sintered at a temperature between 500°C and 800°C.

3,435,328
Allen, Walter E., inventor; The United States of America as represented by the Secretary of the Navy, assignee. *Electronic Solar Cell Array Simulator*. March 25, 1969.

Method and apparatus for accurately simulating, electronically, the electrical characteristics of any size solar cell array at any desired array temperature and solar incidence angle. A darkened, temperature controlled solar cell is employed as a control element and is effectively illuminated by a shunt connected programmable constant current supply,such that the basic current-voltage characteristics of an illuminated solar cell are produced. Circuitry is provided for taking into account the number of solar cells that are connected in series and parallel in the array being simulated.

3,436,275
Tsao, Thomas K.; Yu, Michael, inventors. *Method of Treating Solar Cells*. April 1, 1969.

A method of treating solar cells to improve the current response characteristics thereof comprising (1) placing a solar cell in an electric field of the same polarity as the cell (2) simultaneously subjecting the solar cell to constant heat and (3) maintaining the solar cell in the electric field at elevated temperature to obtain the desired current response characteristics.

3,436,625
Newman, Peter Colin, inventor; North American Philips Company, Inc., assignee. *Semiconductor Device Comprising III-V Epitaxial Deposit on Substitutional III-V Substrate*. April 1, 1969.

A semiconductor device comprising a III-V compound or substituted compound epitaxially deposited on a substituted III-V compound substrate formed by diffusion of a III or V element, especially useful as a photosensitive device or epto-electronic transistor.

3,437,328
Kennedy, Kurt David; Smith, Hugh R., Jr., inventors; Air Reduction Company, Incorporated, assignee. *Powder Crucibles*. April 8, 1969.

Apparatus is described for evaporation of material from a molten pool, by surface heating. The apparatus utilizes an inert material in particulate form between the molten pool and a cooled outer receptacle to prevent the material in the pool from forming a thermal "short circuit" to the outer receptacle.

3,437,527
Iles, Peter Albert, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method for Producing a Solar Cell Having an Integral Protective Covering*. April 8, 1969.

3,438,120
Amsterdam, Michael F.; Shaikh, Mohammed S.; Tarneja, Krishan S., inventors; The United States of America as represented by the Secretary of the Air Force, assignee. *Method of Making Solar Cell*. April 15, 1969.

A photovoltaic solar cell panel is made from nonuniform width dendrite N-type semiconductive webbing by cutting the dendrite webbing into panels of predetermined lengths; cleaning the panel; doping a surface layer of the panel with boron to provide a P-N junction; masking the panel; sand blasting the bottom of the panel with an aluminum oxide abrasive to remove the boron doped material; removing the masking material; lapping the other edge of the panel with silicon carbide grit to remove the doped material; masking the panel; evaporating aluminum onto the unmasked areas of the panel; removing the masking material; electroplating nickel onto the aluminum layers, solder dipping the panel to coat the nickel layers with solder and adjusting the thickness of the solder.

3,442,007
Griffin, Thomas A.; Humrick, Richard J.; Hill, Edwin R., inventors; Kewanee Oil Company, assignee. *Process of Attaching a Collector Grid to a Photovoltaic Cell*. May 6, 1969.

Process for affixing a collector grid on the barrier of a cadmium sulfide solar cell by means of heat and pressure applied to the collector grid as it is superimposed on the barrier. Preferably the heat and pressure is applied incrementally to the collector grid and barrier, advantageously by passing through heated rolls.

3,444,946
Waterbury, Nelson J., inventor; one-half to Nicholas R. duPont, assignee. *Self-Eiectric-Powered Vehicle*. May 20, 1969.

An electric motor driven vehicle having at least one electric motor to supply power to said vehicle, the improvement which comprises a system associated with each electric motor to supply electric power thereto comprising batteries arranged in series, and either a solar cell supplying energy to said battries, a power-generating means with paddle wheel and venturi tube or both adapted to supply power to said batteries. The above combination may be used either alone or in conjunction with a conventional internal combustion engine.

3,446,676
Ritchie, Donald W.; Goldsmith, John V., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Battery with Interconnecting Means for Plural Cells*. May 27, 1969.

A large solar sensitive area for a solar battery is provided by grouping a plurality of individual solar cells in side by side juxtaposed relationship on a flat insulative substrate. Electrical conductive members include a plurality of tynes which project through the insulative substrate and are mechanically biased against the surface of the solar cells so as to hold them in place on the substrate. The tynes of each electrical conductive member are electrically connected to the solar cells they contact in order to form an electrical parallel circuit. Certain electrically conductive members are further electrically connected to additional solar cells so as to form series electrical circuits for the appropriate solar cells. The series electrical circuits provide required voltages from the solar battery; whereas, the parallel electrical circuits provide required electrical current from the solar battery.

3,447,234
Reynolds, Frederick W.; Meixner, Arthur E., inventors; Singer-General Precision Inc., assignee. *Photoconductive Thin Film Cell Responding to a Broad Spectral Range of Light Input*. June 3, 1969.

The process of making a photoconductor photocell comprising the steps of depositing an indium thin film bonding agent on a glass substrate; depositing a gold thin film on the glass substrate over the indium thin film, the indium thin film serving to bond the gold thin film thereto; forming electrodes from the gold film by etching away narrow sections thereof to define the boundaries of a cadmium selenide photoconductive cell; depositing an extremely thin film of cadmium selenide material over the defined boundaries as well as at least partially over the electrodes; and depositing a suitable acceptor impurity over the cadmium selenide layer.

3,448,575
Grohoski, Theodore, inventor; The United States Time Corporation, assignee. *Solar Cell Recharging Means for a Battery Operated Watch*. June 10, 1969.

An electric timing device, such as a watch, is powered by a rechargeable battery cell. The battery is charged by a solar cell which may be the dial plate of the timing device. The solar cell

controls the operation of a switch, which switch disconnects the solar cell from the battery in the absence of sufficient light to charge the battery.

3,450,568
Mann, Alfred E., inventor; Textron Electronics, Inc., assignee. *Solar Cell with Wrap-Around Electrodes*. June 17, 1969.

A substantially co-planar solar cell array includes solar cells each having first electrode means in ohmic contact with its top solar sensitive surface and second electrode means in ohmic contact with its bottom surface, the second electrode means extending around the cell to overlie a top portion of the cell without ohmic contact so as to be in electrically separated relationship to the first electrode means. By so providing rear or bottom electrodes which wrap around the cell to the top, both positive and negative connecting points of power take-off means can be effected on the top surface and thus will be clearly visible and accessible. The disclosure also contemplates unique interconnecting means for four adjacent corners of cells in an array to provide a proper series-parallel matrix with sufficient flexibility in the interconnections to accommodate thermal strains and other mechanical shocks which might otherwise damage the array.

3,454,774
Wizenick, Richard J., inventor; Globe-Union Inc., assignee. *Electrical Connector for Semiconductor Devices*. July 8, 1969.

An electrical connector for semiconductor devices, such as solar cells, composed of a thin and flexible electrically conductive sheet, preferably a metal having a coefficient of thermal expansion close to that of the semiconductor device. The sheet has one or more sections which have several apertures arranged so that there are no straight-line stress paths between the points where the semiconductor device is attached to the connector. Several semiconductor devices mounted to one or more connectors can be adhesively mounted on a panel in series or parallel.

3,457,427
Tarneja, Krishan S.; Rossi, Vito A.; Maddalena, Joseph R., inventors; Westinghouse Electric Corporation, assignee. *Lightweight Solar Cell Panel Structure*. July 22, 1969.

A substrate for supporting a plurality of webbed dendritic solar cells is formed from one piece of metal having a thickness of from 5 to 15 mils. The substrate has the necessary strength and rigidity but is light in weight.

3,457,467
Amsterdam, Michael F.; Whigham, Dale M., inventors; Westinghouse Electric Corporation, assignee. *Heterojunction Solar Cell with Shorted Substrate*. July 22, 1969.

This invention provides a solar cell wherein a substrate acts only as a support member. Material for the solar cell is deposited on the substrate. A wrap around electrical contact shunts, or short circuits, any P-N junction formed by the deposited material and the substrate but not the P-N junction of the solar cell. The electrical contact is alloyed to the substrate and to the deposited material at the same time that the diffusion of a region of desired semiconductivity is taking place in the deposited material to form the diode of the solar cell.

3,459,597
Boron, Wilfred R., inventor; TRW Inc., assignee. *Solar Cells with Flexible Overlapping Bifurcated Connector*. August 5, 1969.

A bifurcated clip having the desired thickness and strength is located at the junction of solar cells for mechanically maintaining series cells in an overlapping relationship with respect to each other and adjacent cells. The clip not only mechanically supports overlapping series cells with adjacent cells but also electrically interconnects mechanically supported cells with each other. Each clip has an expansion joint in a series direction and in a transverse direction thereby providing flexibility in fitting the solar cell module to a complex arcuate form.

3,460,240
Tarneja, Krishan S.; Ernick, Fred G.; Rossi, Vito A., inventors; Westinghouse Electric Corporation, assignee. *Manufacture of Semiconductor Solar Cells*. August 12, 1969.

This disclosure relates to a method of manufacturing a solar cell which comprises growing layers of a semiconductor material on a foreign substrate.

3,462,311
Ross, Bernd, inventor; Globe-Union, Inc., assignee. *Semiconductor Device Having Improved Resistance to Radiation Damage*. August 19, 1969.

A semiconductor device having a drift field therein for increasing minority carrier diffusion length. The drift field is established either in an epitaxially grown region or in the bulk by diffusion of lithium. This presence of the drift field and or the lithium makes a photovoltaic solar cell especially resistant to radiation damage.

3,466,198
Yasui, Robert K., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Matrix*. September 9, 1969.

A novel configuration of a conductor for connecting cells in parallel to form submodules, which are in turn connected in series to form a cell matrix. The conductor has segments interconnected in series with the entire combinations flexible to provide the desired matrix flexibility. Each conductor segment has a plurality of perforated pads used to form an electrical contact with one electrode or terminal of a cell in one submodule. The segment also includes at least one contact strip used to form contact with an electrode of a cell in an adjacent submodule and thereby produce the series interconnection between submodules.

3,471,924
Iles, Peter Albert, inventor; Globe-Union Inc., assignee. *Process for Manufacturing Inexpensive Semiconductor Devices*. October 14, 1969.

Treating silicon bodies of differing resistivities and conductivity types with lithium to convert them into bodies of N-type conductivity and uniform resistivity.

3,472,690
Hill, Edwin R., inventor; Kewanee Oil Company, assignee. *Process of Preparing a Flexible Rear Wall Photovoltaic Cell*. October 14, 1969.

This invention comprises the process of preparing a flexible rear wall cadmium sulfide solar cell by the steps of exposing a copper-coated flexible substrate, such as molybdenum or other suitable metal, or suitable non-metal such as plastic, to an atmosphere of hydrogen sulfide at 500-700°C for a sufficient period to convert the copper to cuprous sulfide, and thereafter exposing the resultant cuprous sulfide to cadmium sulfide vapors in such a manner that the cadmium sulfide condenses on the cuprous sulfide to form a cadmium sulfide component of a cadmium sulfide photovoltaic cell. By attachment of electrodes directly or indirectly to the cadmium sulfide layer and to the cuprous sulfide barrier, or the metallic substrate, and exposing the cell to light, a voltage of at least about 0.40 volts is readily obtained.

3,472,698
Mandelkorn, Joseph, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Silicon Solar Cell with Cover Glass Bonded to Cell by Metal Pattern*. October 14, 1969.

Cover glasses are attached to solar cells without using adhesives. Each cover glass is metallized in a pattern identical to the top contract pattern of a solar cell. The glass is bonded to the cell only within the metallized regions of glass and cell.

3,475,609
Schneider, Martin V., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Optical Energy Conversion Devices*. October 28, 1969.

A more efficient device for coupling optical energy into a bulk material is effected by providing the metal electrodes on the surface of the material with apertures which are resonant or nearly resonant at the frequency of the incident energy.

3,479,573
Garwacki, Walter, inventor; General Electric Company, assignee. *Wide Band Gap Semiconductor Devices Having Improved Temperature Independent Non-Rectifying Contacts*. November 18, 1969.

Improved semiconductor bodies useful as light emitting diodes and solar cells include a body of P-type compound semiconductor of the II-VI class such as zinc telluride and an ohmic or non-rectifying contact made to one surface of the body. The contact includes a first region containing an alkali metal such as lithium surface diffused therein, a second region overlapping the first region and comprising chemically reacted gold at the surface of the wafer, and a wetted contact to first and second regions and to the overlapped region made by an alloy of a conductive metal having non-rectifying or P-conductivity type characteristics as for example, an alloy of indium and silver. The semiconductor body may be entirely P-type or may contain a P-N junction.

3,480,473
Tanos, Andrew B., inventor; Kewanee Oil Company, assignee. *Method of Producing Polycrystalline Photovoltaic Cells*. November 25, 1969.

This invention comprises a method of producing an improved polycrystalline photovoltaic cell, preferably of polycrystalline cadmium sulfide, by etching the surface of the polycrystalline semiconductive material such as cadmium sulfide with hydrochloric acid, or preferably sulfuric acid, before the barrier is formed thereon. Photovoltaic cells made by the process of this invention have an output efficiency 30-50 percent higher than efficiencies of the same cells in which the etching step is omitted.

3,480,781
Mandalakas, John N., inventor; Westinghouse Electric Corporation, assignee. *Temperature Compensated Solar Cell Light Sensor*. November 25, 1969.

A temperature compensated solar cell light sensor wherein two solar cells of substantially identical characteristics are mounted on a thermal equalizing plate with a temperature sensitive resistor. The cells and the resistor are exposed to the same light and temperature conditions. In order to obtain precise measurements of the light intensity, temperature compensation of the light sensor is obtained by subtracting a temperature dependent part of the output of one cell from the entire output of the other. The temperature sensitive resistor, in close thermal contact with the thermal equalizing plate, permits compensation in a suitable circuit. One such suitable circuit includes an emitter follower configuration controlled by an operational amplifier to maintain substantially short-circuit conditions across each solar cell.

3,480,818
Te Velde, Ties Siebolt, inventor; U.S. Philips Corporation, assignee. *Electrical Monograin Layers Having a Radiation Permeable Electrode*. November 25, 1969.

An electrical device comprising a layer of electrically active grains substantially one grain thick provided with electrodes, of which one of the electrodes which is intended to permit radiation to pass through it to the grains or radiation from the grains through it to the outside includes first regions located over the spaces between the grains and second regions located over the grains. The first regions have high electrical conduction but low permeability to the radiation, whereas the second regions have lower electrical conduction but higher radiation permeability. In one embodiment, the second regions located over the grains are thinner than the first regions located over the grain spaces.

3,483,037
Wagle, Joseph A., inventor; General Motors Corporation, assignee. *Isotope Powered Photovoltaic Device*. December 9, 1969.

A radiant energy conversion device includes a pair of interconnected evacuated spheres. One carries an array of photovoltaic cells concentric with a radiant body. Heat is supplied to the radiant body from a mass of radiocative isotopes in the other sphere through a mass of graphite. Thermal insulation and biological shielding are provided around the isotope mass.

3,483,038
Hui, William L. C.; Auth, George R., inventors; RCA Corporation, assignee. *Integrated Array of Thin-Film Photovoltaic Cells and Method of Making Same*. December 9, 1969.

An integrated array of serially connected, thin-film, photovoltaic cells comprises a plurality of similar multi-layered cells integrally formed on, and united to, a flexible substrate of insulating plastic material. Each of the multi-layered cells in the integrated array is fabricated by a novel method wherein similar layers of each of the cells are deposited simultaneously from a common source of material, preferably from the vapor phase. The multi-layered cells are also interconnected simultaneously by electrodes, deposited preferably from the vapor phase.

3,483,039
Gault, John M., inventor; International Rectifier Corporation, assignee. *Silicon Cell Construction and Method of Manufacture Therefor*. December 9, 1969.

A solar cell formed of a thin wafer of silicon in which spaced parallel strips of P-type material are disposed immediately below the surface of an N-type wafer. The strips reach the wafer surface at the rear of the wafer to receive an upper electrode and a lower electrode is connected to the bottom of the wafer. The P-type strips define totally enclosed and embedded junctions within the wafer to improve radiation resistance and to permit a decrease in internal cell resistance and an increase in both open circuit voltage and short circuit current for the cell.

3,483,040
Parkins, William E., inventor; North American Rockwell Corporation, assignee. *Nuclear Battery Including Photocell Means*. December 9, 1969.

A nuclear battery or electrical power supply using a radioactive source whose radiation is converted to electromagnetic radiation by a fluorescent gas, which is then converted to electrical energy in photocells such as photoelectric or photovoltaic cells.

3,484,606
Masi, James V., inventor; Mid-Continent Manufacturing Co., assignee. *Radiation Responsive Electrical Device Having an Extended Spectral Response Characteristic*. December 16, 1969.

Spectral response of a radiation responsive electrical element is extended through conversion of incident radiation wavelengths to radiation wavelengths usable by the electrical element. Wavelength conversion is effected by luminescent material which fluoresces in response to excitation by incident radiation to emit radiation of relatively longer wavelengths that effect a change in the electrical characteristic of the element. The combined effect

of wavelength conversion with transmission of radiation of wavelengths to which the electrical element responds extends the spectral response characteristic of the composite electrical device.

1970

3,489,615
Mann, Alfred E.; Ralph, Eugene L., inventors; Spectrolab, assignee. *Solar Cells with Insulated Wraparound Electrodes*. January 13, 1970.

A solar cell for use in a solar cell array is provided with a top electrode on its photosensitive surface extending about a side of the solar cell to overlap a second electrode on the bottom surface of the cell. The overlapped portions are held electrically separate by suitable insulating means. By using insulation means, a large bottom electrode may be used to cover a larger area of the bottom surface of the cell thereby decreasing its resistance. Further, freedom in the arrangement of the electrodes on the bottom surface is realized so that flexible interconnecting tabs for an array of cells can all lie in substantially the bottom plane of the cells.

3,490,950
Myer, Jon H., inventor; Hughes Aircraft Company, assignee. *Selective Conversion of Solar Energy with Radiation Resistant Solar Energy Converter Array*. January 20, 1970.

Selective conversion of solar energy to electrical energy in the presence of damaging nuclear radiation by use of a radiation resistant solar cell array having support wall structure arranged to shield cells from direct nuclear radiation and to reflect solar radiation onto the cell.

3,490,965
Wysocki, Joseph J., inventor; Administrator of the National Aeronautics and Space Administration, assignee. *Radiation Resistant Silicon Semiconductor Devices*. January 20, 1970.

The herein disclosed process includes forming a P/N junction in a high-resistivity, floating-zone purified N-type silicon body having a low oxygen content and a low donor impurity concentration. Lithium is then added by diffusion doping at temperatures as low as 300-500°C, for example, and the product is further heated if necessary to diffuse the lithium through the N region of the product. Finally, contacts are added to the structure. Alternatively, the oxygen content of the silicon does not have to be low; neither does the resistivity have to be low. However, after a thusly formed product has been exposed to radiation it loses some of its radiation resistance and must be annealed to regain it.

3,491,237
Tillert, Stephen S., inventor. *Optical Structures*. January 20, 1970.

An optical structure is disclosed which has a layer of discrete, transparent particles located upon a surface of a transparent body. Each of the particles is in direct contact with the surface and is bonded in place. The particles can be of a type capable of transmitting any specific illumination, or of fluorescing in response to a predetermined illumination. The particles may contact one another, or be spaced from one another.

3,492,187
Nakayama, Nobuo; Yamaguchi, Kazufumi; Hirota, Euchi, inventors; Matsushita Electrical Industrial Co., assignee. *Photovoltaic Cell and Method of Making the Same*. January 27, 1970.

A photovoltaic cell and a method of making it. The cell has an N-type cadmium sulfide sintered plate with an electrochemically deposited P-type thin layer on one surface thereof. The layer is a CdS-like structure with an accompanying copper sulfide structure. Electrodes are applied to the opposite faces of the cell. The cell is made by applying a D.C. current across the sintered plate as a cathode with an anodic copper electrode in an aqueous solution of cupric sulfate.

3,493,437
Yasui, Robert K., inventor; Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Submodule*. February 3, 1970.

A multicell submodule is provided, in which a first busbar has portions thereof electrically connected to a first terminal of each of the cells in the submodule, with raised portions of the first busbar being present between the portions thereof which are in contact with the cell's first terminals. A second busbar, which is electrically connected to the second terminals of the various cells in the submodule, includes a plurality of tabs which extend from the second busbar. These tabs are adapted to be connected to the raised portions of a first busbar of another submodule in order to form a multisubmodule cell matrix.

3,493,822
Iles, Peter Albert, inventor; Globe-Union, Inc., assignee. *Solid State Solar Cell with Large Surface for Receiving Radiation*. February 3, 1970.

A photovoltaic device, such as a solar cell, in which the entire upper surface, with the exception of grid lines, is available for receiving radiation and the entire bottom surface is available for making an ohmic contact to the bulk region. Insulating material covers a small portion of the top surface, continues around one edge, and extends a small distance onto the bottom surface. Contact material, overlaying the insulating material, makes electrical contact with the grid lines on the top surface of the device, continues around the edge, and extends over a portion of the insulating material on the bottom surface of the device.

3,496,024
Ruehrwein, Robert A., inventor; Monsanto Company, assignee. *Photovoltaic Cell with a Graded Energy Gap*. February 17, 1970.

Disclosed herein are articles of manufacture for use in semiconductor devices wherein the active component comprises a substrate material comprising III-V, II-VI, or I-VII compounds, Si or Ge and having superposed thereon at least one epitaxial film having a graded energy gap and having the general formula $M_xR_{1-x}T_yZ_{1-y}$, where M and R are Group II elements, T and Z are Group VI elements and x and y represent integers from zero to one inclusive.

3,500,135
Li, Chou H., inventor. *Surface-Contoured, Energy-Transforming Solid-State Device*. March 10, 1970.

The invention relates to improving the performance of energy-transforming solid-state device by differentially expanding the peripheral surface of the junction region and nearby cooperative, optoelectrically active region into special geometrical shape so as to turn a significant portion of parallel light rays thereon into non-parallel reflected rays convergent onto selected location on the light-collecting junction region surface thereby achieving both device surface stabilization and efficiency enhancement.

3,502,507
Mann, Alfred E., inventor; Textron, Inc., assignee. *Solar Cells with Extended Wrap-Around Electrodes*. March 24, 1970.

A solar cell is provided with a top solar sensitive surface wrapping around at least one edge portion of the cell to lie in close electrically separated relationship with a second electrode means on the bottom surface of the cell. The geometry of the electrodes is such that interconnecting tab or strip-like conductors can extend across the bottom electrode to effect pairs of positive and negative connection points, the connections in each pair being in close relationship to each other and the pairs themselves being

at spaced portions of the cell remote from each other. With this arrangement, the risk of circuit discontinuity should the cell crack is minimized. Further, the interconnecting means lies substantially in the plane of the bottom of the cell thereby enabling the cells to be packed relatively closely to each other.

3,507,706
Hermann, Allen M.; Rembaum, Alan, inventors; James E. Webb, Administrator of the National Aeronautics and Space Administration, assignee. *Method of Using Photovoltaic Cell Using Poly-N-Vinyl-Carbazole Complex*. April 21, 1970.

A method of producing an output voltage from a photovoltaic cell utilizing poly-N-vinylcarbazole complexed with iodine as the photovoltaic material.

3,508,063
Granger, Jean-Claude; Raynaud, Jacques, inventors; Societe Industrielle Bull-General Electric, assignee. *Plural Cell Photoelectric Structure*. April 21, 1970.

For the purpose of forming devices for reading marks or perforations on or in recording media or the like, each photoelectric element comprises a cell, for examle a photovoltaic cell, of parallelepipedic form, a first metal lug soldered to a portion of the light-sensitive face and a second lug partly soldered to the opposite face of the cell. This structure lends itself to the simultaneous production of a number of elements, in which each set of lugs is cut out of a common metal strip, which remains at the time of the soldering of the lugs to the cells, which is effected in a single operation. The elements are thereafter separated either partially or completely.

3,508,126
Newman, Peter Colin; Beer, Andrew Francis, inventors; U.S. Philips Corporation, assignee. *Semiconductor Photodiode with P-N Junction Spaced from Heterojunction*. April 21, 1970.

A semiconductor photodiode having a heterojunction between portions of different bandgaps and a p-n junction between regions of opposite conductivity type. The p-n junction is located wholly within the smaller bandgap portion spaced from the heterojunction such that the depletion region lies in the smaller bandgap portion of smaller absorption length. The radiation received is impinged on the larger bandgap portion and passes through same to become absorbed in the smaller bandgap portion within or near the depletion region.

3,509,355
Wallace, Wesley Perry; Foss, Colby A., inventors. *Solar Radiation Integrator Mounting*. April 28, 1970.

A solar radiation integrator in which solar cells or meters are mounted on a pair of plates forming a dihedral plate assembly supported from a shock mounted base plate and in which the cells are mounted behind isolating or scalloped openings which provide for ventilation and do minimize heat conduction from the metal plate to the cell or meter, and thereby, improving thermal and temperature isolation and characteristics for the radiation integrator, and for providing a small pitch of approximately 10° between the dihedral plate and the base metal plate for preventing the collection and puddling of water such as would occur on a level cell mounted plate and for decreasing cosine error especially at low sun angles.

3,509,431
Iles, Peter Albert; Victoria, Rafael Oriando, inventors; Globe-Union Inc., assignee. *Array of Photosensitive Semiconductor Devices*. April 28, 1970.

A semiconductor device having an array of separate photosensitive regions which are isolated from each other and arranged on the surface and/or edges of a silicon body so as to permit flush-mounting of collimators, covers or the like.

3,509,712
Grohoski, Theodore S., inventor; Timex Corporation, assignee. *Photoelectric Conversion System in a Horological Device*. May 5, 1970.

3,513,040
Kaye, Stephen; Garasi, Louis; Rolik, Geza P., inventors; Xerox Corporation, assignee. *Radiation Resistant Solar Cell*. May 19, 1970.

Method for fabricating radiation resistant solar cell by alloying a graded base region to a low resistivity substrate of semiconductor material of the same conductivity type, the graded base region being substantially thinner than the substrate and increasing in resistivity away from the substrate, and providing a thin region of the opposite conductivity type atop the graded base region.

3,513,317
Binks, Albert Edward; Sharples, Allan, inventors; Ilford Limited, assignee. *High-Impedance Photosensitive Devices Comprising Electrodes of Polyolefin Oxide*. May 19, 1970.

This application describes a photosensitive device which comprises a photosensitive element, which is either a photosensitive substance or a photosensitive junction, having attached thereto electrodes the improvement which comprises providing that the electrodes are composed of a polyolefin oxide which is composed of units of the general formula: $[(CH_2)n\text{-}O]$ where n is 2, 3 or 4.

3,513,536
Lambert, Vernon L., inventor; Avco Corporation, assignee. *Method of Delineating P-N Junctions in Indium Antimonide Diffused Junction Devices*. May 26, 1970.

The invention comprises a method of delineating p-n junctions in photovoltaic diodes by placing a sample wafer, in which doping elements have already been diffused, in an evacuated container with a charge of a Group VI-A element, such as sulfur, selenium or tellurium, and heating the container to diffuse one of said additional elements therein, removing the diffused wafer and then bias-cutting or angle-lapping it, thereby to enable the junction to be clearly perceived visually. Measurements from this sample can be applied to other diodes derived from the batch from which the sample is taken and the p-n junctions thereby accurately located.

3,515,594
Samuels, Ronald L., inventor; TRW Inc., assignee. *Radiant Energy Driven Orientation System*. June 2, 1970.

The specification discloses apparatus for automatically orienting a solar cell array toward the sun. A sensing panel having an absorbing surface to be exposed generally toward the sun and a radiating surface shielded from the sun but thermally connected to the absorbing surface is variably covered by a sensor shutter which is controlled by passive, bimetallic, radiation direction sensitive means connected to the solar cell array. A power drive unit including a thermally expansive fluid-filled cylinder and piston connected therewith is mounted on the panel and drives an array orienting mechanism in response to the temperature of the sensing panel as determined by its angle of exposure toward the sun, the degree of its shielding therefrom as by the sensing shutter, and the rate of thermal radiation from the sensing panel. The power drive element may also drive the second shutter for variable shielding of the panel for additional feedback control of the system.

3,520,732
Nakayama, Nobuo; Hirota, Eiichi; Shiraishi, Tadashi; Yamanaka, Tadashi, inventors; Matsushita Electric Industrial Co., assignee. *Photovoltaic Cell and Process of Preparation of Same*. July 14, 1970.

Photovoltaic cells are provided comprising a combination of a p-type semiconductor plate in single crystal or poly-crystal form and an n-type semiconductor plate in single crystal or polycrystal form. Said cells are produced by hot-pressing the said p-type semiconductor plate and the n-type semiconductor plate into a single laminated body at a temperature ranging from 300°C to 600°C and at a pressure of 10 to 1000 kg/cm^2.

3,521,350
Knippenberg, Wilhelmus Franciscus; Verspui, Gerrit, inventors; U.S. Philips Corporation, assignee. *Method of Manufacturing Semiconductor Devices*. July 21, 1970.

This invention relates to the manufacture of semiconductor devices consisting of a coherent foil of an insulating material in which granules of a semiconducting material are embedded in such manner that their surfaces which are free from insulating material protrude on either side of the foil which is covered with electrode layers electrically connecting together protruding portions of the granules.

3,527,619
Miley, David C., inventor; Itek Corporation, assignee. *Solar Cell Array*. September 8, 1970.

A solar cell array formed of a plurality of solar cells in coplanar row and column relationship and interconnected at their corners with adjacent cells. Each solar cell has an upper solar sensitive surface which covers all but two adjacent corners of the solar cell and a conductive lower surface. Further, each corner of the upper surface of the solar cell has a terminal area, the terminal areas in the uncovered corners being spaced from the solar sensitive surface edge. The two terminal areas on the covered corners are connected to current pick-up means extending across the solar sensitive surface, and the two terminal areas on the uncovered corners are connected to the conductive lower surface.

3,530,007
Golubovic, Aleksandar, inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Solar Cell Including Aceanthraquinoxaline Photosensitive Material*. September 22, 1970.

A photoelectric device comprising a photoconductive organic layer disposed between and interconnected to two metal electrodes. Upon exposure to illumination, the photoconductive organic material generates a voltage between the electrodes, thus providing a system for use as a solar cell or a photosensitive circuit element. The cell is responsive to distinct wavelengths of incident radiation in the ultra violet, visible and infrared regions.

3,530,053
Scott, Richard F.; Strain, Robert J., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Method of Preparing a Cadmium Sulfide Thin Film from an Aqueous Solution*. September 22, 1970.

An improved photoconductive cadmium sulfide film is grown on a suitable substrate by contacting the substrate with an aqueous solution of ammonia, thiourea, a cadmium salt, and a copper salt, and by illuminating the solution during the growth process with a high intensity light.

3,531,335
Heyerdahl, Norman E.; Harvey, Donald J., inventors; Kewanee Oil Company, assignee. *Method of Preparing Films of Controlled Resistivity*. September 29, 1970.

This invention comprises a method of preparing a compound semiconductor film having controlled resistivity, involving the steps of supporting a substrate, such as glass, molybdenum, etc., in an atmosphere-controlled chamber, simultaneously vaporizing in said chamber a Periodic Group VI material such as sulfur, selenium or tellurium, and a Periodic Group II material such as zinc, cadmium or mercury, while said substrate is heated to a temperature between 150°C and 500°C, allowing said vaporized materials to form a compound film on an exposed surface of said substrate, and after formation of said compound film discontinuing vaporization of the Group VI material and allowing the film to cool while still being bombarded by vapor of said Group II material. The resultant films have low resistivity and serve as an efficient photovoltaic cell having a low ratio weight to external generated electrical energy.

3,532,551
Scott, Ralph R., inventor; James E. Webb, Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Including Second Surface Mirrors*. October 6, 1970.

A fused silica cover plate is bonded over a solar cell with portions of the plate overhanging the edges of the cell and a reflective coating is formed on the second or lower surface of the overhanging portions to reduce the amount of heat absorbed by the cell and hence reduce the overall temperature.

3,533,850
Tarneja, Krishan S.; Harding, William R., Jr., inventors; Westinghouse Electric Corporation, assignee. *Antireflective Coatings for Solar Cells*. October 13, 1970.

An antireflective coating consisting of a material selected from the group consisting of titanium dioxide, tantalum oxide, cerium oxide, zinc sulphide, and tin oxide is deposited on the surface of the shallow region of semiconductivity of a solar cell. A quartz cover is cemented to the antireflective coating and the electrical contact of the shallow region. The combination of a quartz cover and the antireflective coating provides for a more efficient solar cell.

3,539,883
Bedford, Stanley Harrison, inventor; Ion Physics Corporation, assignee. *Antireflection Coatings for Semiconductor Devices*. November 10, 1970.

This invention teaches that solar cells can be made to absorb and utilize more of the solar spectrum, in which such cells have peak efficiency, by applying a coating of cerium oxide between the cell and its cover slip.

3,541,679
Mandelkorn, Joseph, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Attaching a Cover Glass to a Silicon Solar Cell*. November 24, 1970.

Cover glasses are attached to solar cells without using adhesive. Each cover glass is metallized in a pattern identical to the top contact pattern of a solar cell. The glass is bonded to the cell only within the metallized regions of glass and cell.

3,546,460
Lally, Kenneth P., inventor; Hartman Systems Co., Inc., assignee. *Nonreciprocal Radiation Filter Device Having Fluorescent Material for Wavelength Conversion*. December 8, 1970.

Nonreciprocal filtering of radiation is effected by an assembly of filter elements with the several elements transmitting and absorbing radiation in dissimilar wavelength bands and with one filter element also effecting conversion of an absorbed wavelength

band to a transmitted wavelength band. Wavelength conversion is effected by fluorescent material excited by incident, absorbed radiation within one wavelength band to emit radiation within the other wavelength band. One filter element only transmits radiation within one wavelength band while another filter element only transmits radiation within the other wavelength band. With these two filter elements disposed at opposite sides of the fluorescent material, radiation will be transmitted through the filter in one direction only since incident radiation in the other wavelength band will be ineffective in exciting the fluorescent material to an emission state, and will be further totally absorbed by the two end filters.

3,546,542
Riel, Robert K.; Tarneja, Krishan S.; Ernick, Frederick G.; Kisinko, Paul M., inventors; Westinghouse Electric Corporation, assignee. *Integrated High Voltage Solar Cell Panel*. December 8, 1970.

This invention relates to high voltage solar cell panels. A body of semiconductor material is employed as a continuous substrate upon which an epitaxial layer is grown. The epitaxial layer is divided into a plurality of isolated areas effectively resulting in individual solar cells. The solar cells are then electrically joined together by evaporated metal electrical contacts to form a high voltage solar cell panel.

3,547,596
Kolb, Ernest D., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Method for Producing Substantially Trigonal Piezoelectric Selenium*. December 15, 1970.

Single crystals of trigonal selenium are known to exhibit electrooptic properties and electroacoustic properties. The present invention relates to a method for producing such crystals of a size and quality which enables their use in a variety of optical devices including electrooptic modulators, second harmonic generators and parametric amplifiers,mixers, etc.; in certain acoustic devices such as ultrasonic delay lines; and in rectifiers and photovoltaic cells. The method comprises growth from an aqueous solution containing a complex selenide-sulfide ion. The method may also be used for the growth of polycrystalline matter and small crystallites.

3,549,411
Bean, Kenneth E.; Gleim, Paul S., inventors; Texas Instruments Incorporated, assignee. *Method of Preparing Silicon Nitride Films*. December 22, 1970.

Disclosed is a method for adjusting various physical and chemical properties of chemically vapor deposited silicon nitride films by regulating the composition of the reactant gas stream. Among these properties are etch resistance, refractive index, relative dielectric constant, hardness, coefficient of thermal expansion, and thermal conductivity.

3,549,960
Wedlock, Bruce D., inventor; Massachusetts Institute of Technology, assignee. *Thermo-Photovoltaic Converter Having Back-Surface Junctions*. December 22, 1970.

A thermophotovoltaic energy converter comprising a germanium wafer with interdigital or finger junctions on the surface of the wafer opposite that on which radiant energy impinges is described. The germanium wafer may be intrinsic, in which case the fingers are p and n type. If the germanium wafer is n type, the fingers are p and ohmic junctions.

1971

3,553,030
Lebrun, Jean, inventor; U.S. Philips Corporation, assignee. *Radiation-Sensitive Semiconductor Device*. January 5, 1971.

A flexible panel provided with solar batteries characterized in that it comprises a flexible insulating support having on at least one of its faces metallic zones at least some of which are cut across the thickness of the support to form tags for the electric interconnection of said radiation-sensitive elements and at least partially for fixing said elements to said support.

3,562,020
Blevins, Ronald E., inventor; TRW Inc., assignee. *Solar Cell Assembly*. February 9, 1971.

A solar cell assemby which comprises a substrate, and a grid of electrically insulating material adhesively joined to a surface of the substrate. The grid is formed with an array of openings therein which are shaped to accommodate one or more solar cells along the lateral extent of each opening. Thus, according to one aspect of the invention, the grid serves as a jig for locating and assembling a multiplicity of solar cells in a desired array.

The solar cells are arranged within the openings so as to substantially fill the lateral extent of the openings, and are adhesively joined to the substrate surface. Means are provided for electrically connecting at least a plurality of the solar cells in circuit with each other.

3,565,719
Du Pont, Prestor S., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Panel Fabrication*. February 23, 1971.

This disclosure teaches how to precisely fabricate solar cells on a substrate. It teaches mounting solar cells face down in a flexible mat. The mat is then bent to the configuration the cells will have in final assembled form, and then a substrate is bonded to the backs of all the solar cells at one time.

3,568,306
Yamashita, Kazuo, inventor; Matsushita Electric Industrial Co., Ltd., assignee. *Method of Making Photovoltaic Device by Electroplating*. March 9, 1971.

A method of making a photovoltaic cell employing powdered polycrystalline photoelectric material, the method comprising, forming at least one electrode on a photoelectric layer and electroplating a p-type determining metal, such as copper, on said electrode at least partially through the photoelectric layer whereby the portion of said photoelectric layer subjected to said electroplating process is converted to p-type by the metal ions proceeding to the electrode, forming thereby a p-n junction therearound, and a photovoltaic cell thus formed.

3,571,915
Shirland, Fred A., inventor; Clevite Corporation, assignee. *Method of Making an Integrated Solar Cell Array*. March 23, 1971.

An integral battery of serially connected photovoltaic cells on a single insulating substrate. Metallized areas are formed on the substrate with semiconductive film such as cadmium sulfide vacuum evaporated upon each of the metallized areas. Barrier layers are formed on the cadmium sulfide films to produce PN junctions. Electrode leads extend from each metallized area under the semiconductor film to a top surface of the barrier layer of an adjacent semiconductor film.

3,573,177
McNeill, William, inventor; The United States of America as represented by the Secretary of the Army, assignee. *Electrochemical Methods for Production of Films and Coatings of Semiconductors*. March 30, 1971.

Articles bearing an anodically electrolytically formed coating on their surfaces, the coating comprising, in the main, a compound made from either zinc or cadmium or cadmium-zinc alloys and

sulfur and/or selenium, the compounds being eletrochemically formed as compounds, and methods therefor.

3,574,925
Schneider, Jens R. W.; Gehrke, Jörg S.; Lubbe, Werner, inventors; Licentia Patent-Verwaltungs-GmbH, assignee. *Soldering Process*. April 13, 1971.

3,575,721
Mann, Alfred E., inventor; Textron Inc., assignee. *Solar Cell Arrays and Connectors*. April 20, 1971.

An electrical connector arrangement for interconnecting an array of solar cells includes an elongated, flexible strip formed with laterally projecting tabs attached to adjacent rows of solar cells. The tabs are dimensioned and attached so as to preserve electrical continuity between various cells in the event that cell cracking occurs that otherwise would disrupt electrical continuity. The flexible strip incorporates short tabs projecting from one side for connection with a top electrode of one cell and at least one extended tab laterally projecting from the other strip side for connection with the bottom electrode of an adjacent cell. The extended tab bridges across the major portion of the bottom of the adjacent cell and is connected thereto only at points beyond the midpoint of the adjacent cell. Cracks splitting the cell in half are then prevented from completely incapacitating the solar cell.

3,582,923
Peletier, Daniel P.; Hogrefe, Arthur F., inventors. The United States of America as represented by the Secretary of the Navy, assignee. *Electronic Charge Monitor*. June 1, 1971.

The charging current supplied by a satellite solar cell array is monitored to produce a voltage signal proportional to the charging current. This voltage signal is then applied to a finite time integrator circuit whose output is, in turn, applied to a level detector. The level detector functions to clear the integrator circuit and generate an output pulse each time the integrated signal indicates that a predetermined amount of electrical charge has been supplied to the satellite battery by the solar array. The output pulses from the level detector circuit are first scaled down so that the satellite's telemetry system handles no more data than is necessary to indicate accurately the status of the satellite's power system and these scaled-down pulses are then interfaced into the satellite's telemetry system for transmission to a remote receiving station.

3,585,714
Li, Chou H., inventor. *Method for Making Solid-State Devices*. June 22, 1971.

This disclosure discloses a novel method for making new and/or improved solid-state devices which comprises surface-contouring the device junction or active region whereby the resultant peripheral surface of this region is differentially, and often greatly expanded into a desired geometrical shape or surface contour shape, such as a cylindrically or elliptically concave surface, another surface of revolution or, in general, a surface of oriented arcuate cross-section. This invention also describes methods that are particularly useful in connection with the surface-contouring operation, for precision solid-state material shaping, selective defective material removal, novel doping results, improved device mountings, and simple but reliable electrical interconnections.

3,586,541
Chamberlin, Rhodes R., inventor; The National Cash Register Company, assignee. *Photosensitive Devices Comprising Aluminum Foil*. June 22, 1971.

3,589,946
Tarneja, Krishan S.; Rossi, Vito A., inventors; Westinghouse Electric Corporation, assignee. *Solar Cell with Electrical Contact Grid Arrangement*. June 29, 1971.

This disclosure relates to a solar cell with an electrical grid structure which when affixed to a surface of the solar cell leaves exposed at least 95% of the surface for exposure to a radiant energy source.

3,591,420
Streed, Elmer R., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell*. July 6, 1971.

A solar cell utilizes phosphors in the cover glass which are excited to fluorescence by solar ultraviolet radiation and particulate radiation. This fluorescent energy passes through the interference filter for utilization in the solar cell, whereas the ultraviolet and other radiation would not normally be converted to electrical energy because the wavelength is not within the spectral response limits of the solar cell.

3,591,431
Pruett, George R., inventor; Texas Instruments Incorporated, assignee. *Diffused P-N Junction Diodes and Methods of Diffusion Therefor*. July 6, 1971.

A method of making a photovoltaic diode by diffusing copper into one surface of an n-type conductivity body of indium and diffusing cadmium into the same surface to form a p^+ pn type device.

3,599,059
Hou, Shou-Ling, inventor; Corning Glass Works, assignee. *Ion Implanted Cadmium Sulfide PN Junction Device*. August 10, 1971.

PN junction devices are made by bombarding the surface of a body of cadmium sulfide with the ions of an appropriate dopant element, and thereafter subjecting the cadmium sulfide body to an appropriate annealing schedule. The particular type of PN junction device and the characteristics thereof are determined by the particular schedule of annealing to which the implanted body is subjected.

3,600,599
Wright, Warren H.; Biess, John J., inventors; TRW, Inc., assignee. *Shunt Regulation Electric Power System*. August 17, 1971.

A regulated electric power system having load and return bus lines. A plurality of solar cells interconnected in power supplying relationship and having a power shunt tap point electrically spaced from the bus lines is provided. A power dissipator is connected to the shunt tap point and provides for a controllable dissipation of excess energy supplied by the solar cells. A dissipation driver is coupled to the power dissipator and controls its conductance and dissipation and is also connected to the solar cells in a power taping relationship to derive operating power therefrom. An error signal generator is coupled to the load bus and to a reference signal generator to provide an error output signal which is representative of the difference between the electric parameters existing at the load bus and the reference signal generator. An error amplifier is coupled to the error signal generator and the dissipation driver to provide the driver with controlling signals.

3,615,853
Paine, Thomas O., inventor. *Solar Cell Panels with Light-Transmitting Plate*. October 26, 1971.

A solar cell panel with a cover plate which defines a plurality of apertures with light-reflective surfaces. The shapes of the apertures and the spacings between them are chosen to vary the illumination level of the cells as a function of the degree of inclination of the plate with respect to the normal light direction.

3,615,854
Atem, Albert Christiaan, inventor; U.S. Philips Corporation, assignee. *Electrode System Employing Optically Active Grains*. October 26, 1971.

A radiation-responsive device, for example a radiation detector, photocell or photoresistor comprising a monolayer of electrically active grains embedded in a binder and a radiation permeable electrode covering one side of the grains. The grains are divided into two groups each of which has a different photosensitivity or characteristic. Grains of one group are doped with one dopant to produce a grain which has a given photocharacteristic or resistance as a function of incident radiation while grains of the other group are doped with a different dopant so as to have a different photocharacteristic of resistance as a function of the incident radiation.

3,615,855
Smith, Allen H., inventor; General Motors Corporation, assignee. *Radiant Energy Photovoltaic Device*. October 26, 1971.

A radiant energy conversion device which comprises a silicon slice, a silicon-to-germanium transitional region of a first conductivity type, a germanium layer of a second conductivity type and a pair of ohmic contacts. One form of the device includes an epitaxial deposition of a P-type transitional region onto a low resistivity P-type silicon slice. An N-type germanium layer is then epitaxially deposited on the transitional region. The transitional region contains an electrostatic drift field which improves the collection of charged particles. A current collecting grid is bonded to the silicon slice and a conductive support is bonded to the germanium layer.

3,615,877
Yamashita, Kazuo, inventor. *Photovoltaic Cell and Its Method of Manufacturing*. October 26, 1971. A method of making a photovoltaic cell employing powdered polycrystalline photoelectric material, the method comprising forming at least one electrode on a photoelectric layer and electroplating a P-type determining metal, such as copper, on said electrode at least partially through the photoelectric layer whereby the portion of said photoelectric layer subjected to said electroplating process is converted to P-type by the metal ions proceeding to the electrode, forming thereby a PN junction therearound, and a photovoltaic cell thus formed.

3,616,528
Hasbach, Walter A.; Goldsmith, John V., inventors. *Solid State Matrices*. November 2, 1971.

An electrically-connected matrix of discrete solar cell blanks is disclosed. Electrode contact receiving areas are provided on the light-sensitive surface of each blank and discrete continuous conducting layers are directly attached to said contact areas and extend between at least two of said blanks to form integral electrode contacts on and interconnections between said blanks. The cell blanks are disposed in separated, adjacent, side-by-side arrangements with their light-sensitive faces lying in substantially the same plane. Bridges for supporting the interconnection are placed in the separations. Portions of the blanks are masked and metal is deposited through said mask onto said bridges and surfaces to form integral electrode contacts on and interconnections between said separated blanks.

3,617,137
Meyers, Siegfried S., inventor; Madison College Foundation, Inc., assignee. *Lumen-Hour Integration Meters*. November 2, 1971.

A lumen-hour integration meter circuit for registering intensity of illumination in lumens, which includes a miniature direct current motor, a zero-adjusting rheostat, and either self-generating photovoltaic solar cell means or a switch and photoconductive cell, all connected in a series loop, together with a digital readout counter coupled to the motor to be driven by the motor, whereby the counter will register in units of lumen hours.

3,620,829
Beck, Roger W., inventor; General Motors Corporation, assignee. *Coatings for Germanium Semiconductor Devices*. November 16, 1971.

A means for stabilizing the recombination velocity at a germanium surface at a minimal value. The active surface of a germanium device is coated with a material that is nonvolatile under device-operating conditions and at least as ionic in character as water. Antimony trioxide provides a particular benefit as a surface recombination velocity stabilization coating in photovoltaic devices.

3,620,847
Wise, Joseph F., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Silicon Solar Cell Array Hardened to Space Nuclear Blast Radiation*. November 16, 1971.

A silicon solar cell array, having the substrate, the cell-supporting grid structure, the electrical connecting leads, the cell contacts, and the terminal connections all fabricated from low atomic material such a aluminum, beryllium, or magnesium, having glass, silicon oxide and anodized aluminum insulation; silicone adhesives; and having ultrasonic welded electrical connections provides a hardened silicon solar cell array that is relatively impervious to damage from space nuclear blast radiation.

3,626,198
Boehringer, Andreas, inventor; Dornier System GmbH, assignee. *Process and Apparatus for Optimizing the Product of Two Physical Magnitudes*. December 7, 1971.

The product of the two interdependent physical magnitudes is regulated by comparing measured instantaneous values of each magnitude in alternating manner with a stored part value of a previously measured peak value of the same magnitude and of switching over the magnitude from a decreasing to an increasing value while reversing the other magnitude from an increasing to a decreasing value upon the instantaneous value algebraically equaling the stored value.

3,630,015
Lehovec, Kurt, inventor. *Light Transformation Device*. December 28, 1971.

Incident light is transformed into electricity, which generates, or else modulates, outgoing light providing an optical contrast, and resulting in a self-powered display unit. The contrast is enhanced by modulation of the outgoing light intensity.

3,630,627
Low, George M., inventor. *Solar Cell Assembly Test Method*. December 28, 1971.

Defects in a solar cell assembly are located by measuring power generation from the assembly as selected cells are subjected to differential illumination either by shadowing the cell or by applying local higher intensity illumination to the cell.

1972

3,634,424
Golubovic, Aleksandar, inventor; The United States of America as represented by the Secretary of the United States Air Force, assignee. *Photoconductive Material and Method for Its Preparation*. January 11, 1972.

A photoelectric device comprising a photoconductive organic layer disposed between and interconnected to two metal electrodes. Upon exposure to illumination, the photoconductive organic material generates a voltage between the electrodes, thus providing a system for use as a solar cell or a photosensitive circuit element. The cell is responsive to distinct wavelengths of incident radiation in the ultra violet, visible and infrared regions.

3,636,539
Gaddy, Edward M., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Optimum Performance Spacecraft Solar Cell System*. January 18, 1972.

A spacecraft solar cell system including a switching circuit which comprises relay operated switches for changing a plurality of solar cells from a first series-parallel interconnection to a second series-parallel interconnection is disclosed. The relays are actuated by a command device which may be a telemetry receiver. A protection circuit comprising a photodiode is connected between the command device and the relays to ensure appropriate solar cell orientation when switching occurs. This prevents arcing across the relay switches.

3,643,260
Clarke, Stephen, inventor; International Rectifier Corporation, assignee. *Remotely Controlled Firing Circuit for Simultaneous Firing of Series Devices*. February 15, 1972.

The control electrodes of a plurality of series thyristors are connected to a radio receiver and simultaneously receive a firing impulse when a remote transmitter generates a firing signal. One or more of the devices may be arranged at high potential above ground and are provided with local power supplies for their respective control electrode circuits.

3,645,633
Kisatsky, Paul J.; Szabo, Louis R., inventors; The United States of America as represented by the Secretary of the Army, assignee. *Chromacorder*. February 29, 1972.

An instrument for the instantaneous measurement of the chromaticity of time variant spectral sources including a plurality of narrow band sensors or transducers that in combination encompass the visible spectrum. Each consists of an interference filter and a linear photovoltaic cell whose three output voltages have been "optimum multiplied" for the three tristimulus functions through a voltage divider network. The corresponding individual outputs of the sensors are added by a summing feedback amplifier to provide a voltage output proportional to the tristimulus values. These proportional outputs are then summed by a unity gain summing amplifier whose output in turn is applied to one input of a pair of ratio recorders. The other ratio recorder inputs receive one of the proportional outputs. Each ratio recorder inputs receive one of the proportional outputs. Each ratio recorder output, therefore, is one of the normalized chromaticity coordinates. The output coordinate values (x and y) are simultaneously fed into a chart recorder to derive a plot of the chromaticity coordinates vs. time.

The invention described herein may be manufactured, used and licensed by or for the Government for governmental purposes without the payment to us of any royalty thereon.

3,649,383
Akasaki, Isamu, inventor; Matsushita Electric Industrial Co., Ltd., assignee. *Process of Fabricating Electroluminescent Element*. March 14, 1972.

A process for fabricating an electroluminescent element of a semiconductor material consisting of two layers of mutually different conductivity types, particularly including the steps of coating grains of a p-type (for example) electroluminescent semiconductor crystal with insulating material, hot-pressing the coated grains into a single-grain layer, etching opposite surfaces of said layer to remove the insulating coating at the surfaces, and growing another layer of the semiconductor material of n-type, whereby the crystal grains in the first layer are insulated from one another in the transverse direction.

3,653,970
Iles, Peter Albert, inventor; National Aeronautics & Space Administration, assignee. *Method of Coating Solar Cell with Borosilicate Glass and Resultant Product*. April 4, 1972.

A lightweight protective glass coating over the radiation receiving surfaces of a solar cell is formed integrally with the cell by depositing a layer of glass particles to such surfaces and heating the cell and glass particles to an elevated temperature sufficient to fuse the glass particles and to form the coating. In another embodiment, a conventional protective glass slide is applied to the glass particles, prior to heating, and the cell, particles, and slide are heated to fuse the glass and form a fused glass bond between the cell and the slide.

3,653,971
Lidorenko, Nikolai Stepanovich; Landsman, Arkady Pavovich; Strebkov, Dmitry Semenovich; Zaitseva, Aita Konstantinovna; Zadde, Vitaly Viktorovich; Kosarev, Viktor Sergeevich, inventors. *Semiconductor Photoelectric Generator*. April 4, 1972.

A semiconductor photoelectric generator is formed of semiconductor photoelectric converters united into a solid-state matrix, each converter having the shape of a microminiature parallelepiped and containing: an alloy region; a base region; at least one P-N junction making an angle with an operating surface of the generator exposed to radiation; a metallic conductor on at least one of said regions making the same angle with the operative surface as the P-N junction and deposited all over the parallelepiped-surface uniting the parallelepipeds of the converters into a matrix; and wherein the width of a microminiature parallelepiped is approximately equal to the diffusion length of minority carriers in said base region.

3,654,036
Paine, Thomas O., inventor. *Apparatus for Applying Cover Slides*. April 4, 1972.

Apparatus for applying thin glass slides to solar cells in an assembly line manner including a conveyor belt, a cartridge feeder for consecutively feeding cells onto the conveyor belt, and rollers for feeding a long strip or coil of thin flexible glass along a path parallel to the conveyor belt. The cells and sheet are first sprayed with an adhesive, moved through a drying chamber, and moved together by rollers that press down the glass sheet. After the strip and cells have been pressed together, they pass through a drying chamber and are ready for separating. The strip is separated by applying hot wires to the strip around each cell to which it is held and thereafter breaking the strip at these parting lines.

3,658,596
Osborne, Bodwell D., inventor; Lockheed Missiles & Space Company, assignee. *Flexible Solar Cell Modular Assembly*. April 25, 1972.

A module for a solar cell panel with silicon photovoltaic cells fused between two sheets of FEP Teflon. The plastic is mounted on an aluminum frame with two side members adapted to interlock with similar modules. The side frame members also act as current carrying bass members.

3,664,874
Epstein, Joseph, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Tungsten Contacts on Silicon Substrates*. May 23, 1972.

Disclosed are a process whereby tungsten contact electrodes are formed on doped silicon substrates, such as integrated circuit chips and solar cells, and the resultant products. The method comprises depositing elemental tungsten on contact areas of doped silicon semiconductor devices, and thereafter processing the silicon devices to induce a chemical reaction between the

tungsten and the silicon. The resulting tungsten contact electrodes thereby include a transition region at the interface of the tungsten electrode and silicon device comprising tungsten-silicon compounds which are physically and chemically bonded to, and form an integral part of, both the tungsten electrode material and the silicon semiconductor material. A lead is bonded directly to the tungsten electrode.

3,670,202
Paine, Thomas O., inventor. *Ultrastable Calibrated Light Source*. June 13, 1972.

Light from an electrically powered light source is optically monitored by a transducer which converts the optical signal to an electrical error signal. The error signal is compared with a reference signal and a signal representing the difference between the reference and the error signals is generated. The difference signal is employed to control an electronic switching network which in turn regulates the electrical power input to the light source to maintain a constant light level at the optical monitor.

3,671,291
Miller, Richard G.; Cavitt, Roy L., inventors; PPG Industries, Inc., assignee. *Electroless Process for Forming Thin Metal Films*. June 20, 1972.

The invention described herein relates to an electroless process for forming thin metal films, particularly transparent films, on a reactive substrate. It particularly relates to a method of spraying two solutions, one, an acidic solution containing a metal salt and the other, an alkaline solution containing a boron reducing agent, onto a reactive substrate to form a metal film by reduction of the metal salt. More particularly, the invention relates to an electroless process for forming metal films of metals contained in Group Ib and Group VIII of the Periodic Table, especially iron, cobalt, and nickel, by forming a solution of soluble salts of said metals in an acidic, aqueous media, preferably including boric acid, and spraying said solution on a reactive substrate at substantially the same time that an alkaline solution of a boron-containing reducing agent, especially alkali metal borohydrides, is sprayed on the substrate. The invention has been found to be particularly useful for forming transparent films of cobalt, nickel, iron, and the like on sensitized transparent substrates such as glass and plastic.

3,675,026
Woodall, Jerry M., inventor; International Business Machines Corporation, assignee. *Converter of Electromagnetic Radiation to Electrical Power*. July 4, 1972.

The converter obtains an efficient conversion of solar electromagnetic radiation into electrical power. A p-n junction is fabricated close to an optical surface of a region of n-type GaAs which is receptive of the solar radiation. There is a window on the optical surface consisting of a window layer of $Ga_{1-x}Al_xAs$, where x is less than one and greater than zero with a composition to cause the window layer to contribute selectively to absorbing and transmitting certain components of the incoming solar radiation. The layer of $Ga_{1-x}Al_xAs$ is made nearly transparent to electromagentic radiation and is nearly absorbent of the energetic particle radiation content of the received solar radiation. The window layer is an integral part of the procedure for forming the p-n junction. It contributes the p-type doping species to the junction by diffusion into the n-type GaAs substrate. For certain applications, the $Ga_{1-x}Al_xAs$ window can be removed by etching with aqueous solution of HCl. If the window is removed, the ohmic contact is then made to the optical surface of the p-type GaAs. Illustratively, another structure provided by this disclosure includes a window of GaP of p-type conductivity on the surface of a region of n-type InP with a p-type transition region of InP therebetween.

3,679,949
Uekusa, Genzo; Tanimura, Shigeru; Higashi, Kazuhiro; Sumeto, Takao, inventors; Omron Tateisi Electronics Co., assignee. *Semiconductor Having Tin Oxide Layer and Substrate*. July 25, 1972.

A semiconductor composite having a rectifying characteristic is provided by depositing a tin oxide film on a semiconductor substrate. In view of the fact that the tin oxide film has high transparency and conductivity the composite can be used as an excellent photoelectric device. Preferably the tin oxide film is deposited on the substrate by reacting a halogenated organic tin compound with oxygen at an elevated temperature. Conductivity of the tin oxide film can be enhanced by incorporation of a small amount of antimony trichloride into the dimethyl tin dichloride. It was found that there are preferred reaction temperatures, time periods, and amount of mixed antimony trichloride for providing a composite having the desired characteristics. By depositing a plurality of separate tin oxide films on a single substrate by a photo-etching process of tin oxide film an integrated photoelectric apparatus is provided.

3,681,036
Schwarz, Rudolf; Meyer-Simon, Eugen, inventors; Deutsche Gold- und Silber-Scheideanstalt vormals Roessler, assignee. *Method of Making Silicon Halides*. August 1, 1972.

Silicon halides are formed in a continuous process by reacting silicon or a silicon-containing compound with hydrogen halide at a temperature between 350 and 1200°C. The silicon halide is then recovered and the hydrogen formed in the reaction is recycled in an amount to provide a ratio of partial pressures in the reaction mixture between hydrogen halide and hydrogen in the range between 1:1 and 1:50 at a predetermined reaction temperature within the stated range.

3,682,708
Bennett, Allan I., inventor; Westinghouse Electric Corporation, assignee. *Solar Cell*. August 8, 1972.

A solar cell with improved efficiency is provided with a convoluted PN junction whereby a higher proportion of carriers produced by exposure of the solar cell to a source of radiation will be collected by the PN junction rather than being lost by recombination and the solar cell has an increased resistance to radiation damage.

3,690,953
Wise, Joseph F., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Vertical Junction Hardened Solar Cell*. September 12, 1972.

A solar cell constructed from a slab of epitaxially grown silicon containing a plurality of very thin alternate N and P zones, cut, lapped, and polished to a thickness of approximately .010 inch, having a common deposited aluminum contact connecting on the back side of the cell to each of the N zones and another common deposited aluminum contact on the back side of the cell connecting to the P zones, and the cell oriented such that the direction of impingement of the solar energy on the front surface of the cell is in a direction generally parallel to the alternate zones of N and P material, provides a high efficiency, hardened solar cell.

3,694,739
Joubert, Alain Francois, inventor; Societe Anonyme de Telecommunications, assignee. *Testing Circuit for a Solar Battery Including a Voltage Source Controlled by the Battery's Terminal Voltage*. September 26, 1972.

The invention concerns a circuit for spot measuring the distinctive voltage-current characteristic of a solar battery subjected to a given degree of illumination, in which the charge circuit of the solar battery being tested comprises, in series, a fixed resistance whose terminal voltage is a measure of the strength delivered by the solar battery, and a voltage source whose instantaneous value

delivered by the solar battery, and a voltage source whose instantaneous value depends on that of the battery's terminal voltage and whose variations in value around a central value are opposite to and much greater than the terminal voltage variations of the solar battery around a predetermined value in conformity with the testing conditions.

3,695,910
Louderback, Anthony W.; Zook, Morris A., Jr., inventors. *Method of Applying a Multilayer Antireflection Coating to a Substrate*. October 3, 1972.

A method for vacuum depositing antireflection layers on a substrate using an electron beam is disclosed. All coating materials are placed in the vacuum chamber. A metallic oxide is evaporated onto the substrate as a first layer. A mixture of at least two oxides is evaporated onto the first layer and oxygen is directed from an oxygen source to the electron beam during the evaporation of the second layer. The metallic flouride is then evaporated onto the second layer.

3,696,286
Ule, Louis A., inventor; North American Rockwell Corporation, assignee. *System for Detecting and Utilizing the Maximum Available Power from Solar Cells*. October 3, 1972.

In a power solar cell array consisting of many solar cells connected to deliver useful electrical power, there is imbedded a smaller reference solar array consisting of solar cells connected in series with a Zener diode and load resistor so devised that the voltage that appears across the load resistor is equal to or a constant fraction of the voltage at which the power array, operating at the same temperature and solar exposure as the reference array, delivers maximum electrical power. The voltage difference between the large solar array or the given fraction thereof and the reference solar array is used directly as means to constrain the large array to operate at the voltage of maximum power, typically any excess power being used to charge a storage battery.

3,705,059
Kun, Zoltan K., inventor; Zenith Radio Corporation, assignee. *Methods of Producing P-Typeness and P-N Junctions in Wide Band Gap Semiconductor Materials*. December 5, 1972.

To produce a p-conductivity type wide band gap semiconductor material, a III-V compound semiconductor layer is first vacuum evaporated onto and then diffused into a crystalline II-VI compound semiconductor substrate, specifically a zinc chalcogenide. The resulting hybrid crystalline material is doped by simultaneous or sequential infusion of zinc atoms in substitution for atoms of the Group III element. The process may be used for the direct production of p-n junctions in zinc chalcogenides by employing an n-type rather than an intrinsic substrate.

1973

3,708,669
Work, George A., inventor; TRW, Inc., assignee. *Method and Apparatus for Calibrating a Solar Array*. January 2, 1973.

A method and apparatus for calibrating a solar array to predict its characteristic volt-ampere or I-V curve in outer space by periodically illuminating the array in rapid succession with a flashlamp whose radiation closely simulates natural solar radiation in outer space, and measuring the array current at short circuit, open circuit, and selected array voltage levels. The output of a standard cell which is illuminated concurrently with the solar array by each flash is recorded to permit correction for any variation from flash-to-flash.

3,713,893
Shirland, Fred A., inventor; Gould Inc., assignee. *Integrated Solar Cell Array*. January 30, 1973.

An integral battery of serially connected photovoltaic cells on a single insulating substrate. Metalized areas are formed on the substrate with a semi-conductive film such as cadmium sulfide vacuum evaporated upon each of the metalized areas. Barrier layers are formed on the cadmium sulfide films to produce PN junctions. Electrode leads extend parallel from each metalized area under the semi-conductor film to a top surface of the barrier layer of an adjacent semi-conductor film.

3,716,424
Schoolar, Richard B., inventor; The United States of America as represented by the Secretary of the Navy, assignee. *Method of Preparation of Lead Sulfide P-N Junction Diodes*. February 13, 1973.

Flat, uniform planar diodes of PbS are prepared by either (1) epitaxially growing an n-type layer onto a p-type layer by depositing one layer epitaxially onto the other in a vacuum of at least 5×10^{-5} Torr wherein the substrate is at a temperature between 200-350°C and the material to be deposited is at a temperature not lower than its sublimation point or (2) epitaxially growing a p-type layer on an n-type layer using the procedure described in (1) with the addition of vapors of a doping agent such as S, Se, or Te, in the system. This method may also be applied to the closely related compounds $Pb_xSn_{1-x}Se$ and $Pb_xSn_{1-x}Te$ where x varies from 0 to 1 inclusive, hereinafter referred to as the lead-tin salt alloys.

3,732,471
Hou, Shou-Ling; Marley, James A., Jr.; Beck, Kenneth O., inventors; Corning Glass Works, assignee. *Method of Obtaining Type Conversion in Zinc Telluride and Resultant P-N Junction Devices*. May 8, 1973.

A method of making p-n junction devices by bombarding a polished crystal of ZnTe with ions of an element selected from the Group VII A elements and p-n junction devices resulting from this method. When the crystal is held at an elevated temperature during the ion bombardment step, subsequent annealing is usually not necessary. When the crystal temperature is at room temperature or below during the ion bombardment step, type conversion can be obtained only by post implantation annealing. The particular type of p-n junction device and the characteristics thereof are determined by the particular schedule of annealing to which the implanted body is subjected.

3,734,632
Matsuda, Motonobu, inventor; Minolta Camera Kabushiki Kaisha, assignee. *Current Compensated Detection Circuits for Photovoltaic Cells*. May 22, 1973.

A circuit for detecting current generated by a light transducer such as a photovoltaic cell includes at least one P-N junction for biasing a transistor to compensate for the voltage drop of the base emitter junction thereof and includes feedback between the collector of the transistor and the biasing junction to compensate for temperature changes and changes in the amplification factor of the transistor whereby the linearity of the light transducer output is maintained.

3,736,180
Fischer, Horst; Gereth, Reinhard; Kreuzer, Karl-Heinz, inventors; Licentia Patent-Verwaltungs-GmbH, assignee. *Method of Producing Solar Cells*. May 29, 1973.

A method of producing solar cells includes subjecting the back contacts of the cells to a separate intensified intermediate sintering prior to the application of the front contact.

3,740,636
Hogrefe, Arthur F.; Sullivan, Ralph M., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Charge Regulator and Monitor for Spacecraft Solar Cell/Battery System Control*. June 19, 1973.

An electronic system for providing fully automatic control of a spacecraft solar cell/battery electrical power system, including

the provision of continuous telemetry monitoring of the battery charge state. Circuitry accurately measures, on an ampere-minute basis, the charging and discharging of the battery and functions to maintain the battery in a fully charged condition, with a provision for automatic reduction of the charge current to a temperature-dependent trickle value when the proper amount of charge has been returned to the battery after a previous discharge. A bipolar charge quantizer circuit is utilized to monitor battery charge and discharge operations and includes a finite time integrator circuit capable of supplying an output signal pulse each time the battery is charged or discharged by a predetermined amount. The quantizer is desigend with a predetermined offset factor to account for battery inefficiency. Temperature dependent maximum battery voltage limiting and maximum charge current limiting are also provided, along with means which operate to automatically shunt excess electrical power from the solar cell array into the spacecraft instrument package in order to provide temperature control therein.

3,743,847
Boland, Bernard W., inventor; Motorola, Inc., assignee. *Amorphous Silicon Film as a UV Filter*. July 3, 1973.

There is disclosed the use of a thin amorphous silicon film as a narrow-band rejection filter which is used either as a mask to UV light in semiconductor device processing or is used as a protective shield for solar cells which overheat in the presence of ultraviolet light.

3,747,327
Uchiyama, Hideaki, inventor; Kabushiki Kaisha Suwa Seikosha, assignee. *Watchdial Structure Incorporating Electrical Devices*. July 24, 1973.

The space required for electrical connections in small wrist watches incorporating electrical devices such as photo-electric elements or display elements is substantially reduced by the use of stressed metal members making firm contact with each other rather than conventional wiring and solder. This construction simplifies assembly of such watches and makes it easy to break and restore the electrical connections in the event that repair of such timepieces becomes necessary.

3,751,303
Kittl, Emil, inventor; The United States of America as represented by the Secretary of the Army, assignee. *Energy Conversion System*. August 7, 1973.

An energy conversion system is provided for converting thermal radiation energy into electricity. The system includes a source of thermal energy and a silicon cell spaced from the thermal energy source. A radiating solid material is positioned between and spaced from the thermal energy source and the silicon cell. The radiating solid material is capable of radiating a major portion of the heat received from the thermal energy source in the spectral band where the silicon cell shows its maximum spectral response. An interference filter is positioned between the radiating solid material and the silicon cell. The interference filter has its maximum reflectivity in the strongest emission band regions of the radiating solid material which are outside the maximum spectral response band of the silicon cell. The interference filter also has its highest transmission in the wavelength region where the silicon cell has good spectral response. This invention relates to an energy conversion system for converting thermal radiation energy to useful electrical energy.

3,757,511
Burgess, Ronald R.; Coleman, Michael G.; Grenon, Lawrence A., inventors; Motorola, Inc., assignee. *Light Emitting Diode Display for Electronic Timepiece*. September 11, 1973.

There is disclosed a light emitting diode timepiece display in which the output of the light emitting diode display is controlled with respect to ambient lighting conditions so as to provide the maximum amount of contrast with a minimum amount of power consumption. The contrast between the light emitted by the light emitting diodes and the ambient light in the immediate vicinity of the timepiece is enhanced by the use of absorption type filters, truncated pyramid type apertures in the display cover plate and a control circuit which adjusts the intensity of the output of the light emitting diodes to the ambient light conditions. There is further provided a series of solar cells on the face of the display, which recharge the timepiece batteries during ultra-high ambient light conditions and which supply additional power to the light emitting diodes during high ambient lighting conditions so as to increase the output of the light emitting diodes. This enhances the contrast of the diodes during high ambient lighting conditions while at the same time providing an additional source of power in parallel with that of the timepiece battery so as to increase the effective lifetime of the battery. Power distribution between the solar cells and the battery is controlled by the aforementioned control circuit. In addition, the control circuit varies the power available to the light emitting diodes such that in low ambient lighting conditions a lesser amount of power is delivered to the light emitting diodes while in high ambient lighting conditions, a larger amount of power is delivered to the diodes. In this manner the aforementioned contrast is kept constant and at that level which corresponds to the minimum level necessary for ready visibility. In addition, several structural embodiments are shown, all of which contribute to the enhancement of the light output of the light emitting diodes, the enhancement of display contrast, low power consumption, ease of fabrication, and mechanical stability of the final product.

3,758,348
Whigham, Dale M.; Amsterdam, Michael F., inventors; Westinghouse Electric Corporation, assignee. *Method for Preparing Solar Cells*. September 11, 1973.

This invention provides a process for making a solar cell. Material for the solar cell is deposited on the substrate. A wrap around electrical contact shunts or short circuits any P-N junction formed between the deposited material and the substrate but not the P-N junction within the deposited material. The wrap around electrical contact is alloyed to the substrate and to the deposited material at the same time that a diffusion is being carried out in the deposited material to form a P-N junction therein.

3,760,240
Bergt, Hans-Eberhard, inventor; Siemens Aktiengesellschaft, assignee. *Light-Sensitive Semiconductor Device*. September 18, 1973.

Light sensitive semiconductor device with several light sensitive elements, mutually separated from each other, arranged in the form of a matrix in rows and columns on a doped semiconductor substrate. Each of the light sensitive elements has a rectifying hetero junction, which is formed by a thin, light transparent semiconductor layer made as an antireflex layer, and a first semiconductor region diffused into the semiconductor substrate or a second partial region diffused into the first semiconductor region. The thin light transparent semiconductor layer extends in rows on the semiconductor substrate isolated from the latter by an isolating layer. The diffused first semiconductor region extends in columns, into the surface of the semiconductor substrate. The light sensitive semiconductor layers, extending in the rows, and the diffused first semiconductor regions, extending in columns, are provided with barrier free contacts at the edges.

3,764,325
Te Velde, Ties Siebolt, inventor; U.S. Philips Corporation, assignee. *Method for Making Electrical Monograin Layer*. October 9, 1973.

A method of making an electrical monograin layer device in which the layer of grains, usually of semiconductive material, are embedded in a photoresist layer, which is then exposed through the grains and developed. The photoresist portions sk9dowed by the grains remain unexposed and are removed by the developer, whereas the resist portions extending between the grains and exposed become hardened and bind the grains together. The exposed grain surface portions are then contacted with an electrode.

3,769,091
Leinkram, Charles Z.; Oaks, William D., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Shingled Array of Solar Cells*. October 30, 1973.

A method of mounting solar cells in an array, and a solar cell array, in which the cells are arranged on thermally conductive but electrically insulative wafer and prominences so that they overlap each other in a shingled structure but their bottom surfaces are supported and remain parallel to the top surface of the mounting wafer, the array structure permitting series wiring of the cells and providing a rugged structure having a thermally conductive path from the solar cells through the mounting elements.

3,769,558
Lindmayer, Joseph, inventor; Communications Satellite Corporation, assignee. *Surface Inversion Solar Cell and Method of Forming Same*. October 30, 1973.

An improved semiconductor device, particularly suitable as a solar cell, has a surface inversion layer with increased charge density. A p-type semiconductor material is covered with a layer comprising oxides of silicon and chromium. The addition of the chromium oxides increases the charge density of the inversion layer by orders of magnitude over that created by the silicon oxide alone. In the fabrication process, a silicon oxide is formed first, followed by a layer of elemental chromium. Both layers are oxidized by placing the device in an oxygen atmosphere at temperatures in excess of 800°C.

3,772,768
Fischer, Horst; Pschunder, Willi, inventors; Licentia Patent-Verwaltungs-GmbH, assignee. *Method of Producing a Solar Cell*. November 20, 1973.

An improved method of producing a solar cell wherein a liquid metal-conductor phase is produced on a semiconductor body which has been previously provided with a p-n junction, the liquid metal-semiconductor phase is allowed to remain for a certain time before cooling it and then electrodes are attached to the semiconductor body.

3,772,770
Arndt, Heinz-Herbert; Belke, Franz, inventors; licentia, Patent-Verwaltungs-GmbH, assignee. *Method of Manufacturing a Semiconductor Device*. November 20, 1973.

A method of manufacturing a semiconductor device, in particular a solar cell, in which after deposition of an electrode which approaches an edge of the semiconductor body on which it is deposited, the side surface next to that edge of the body is ground away to remove any electrode material which has been deposited thereon.

3,774,023
Cobarg, Claus Christian; Napierski, Reinhard, inventors; Braun Aktiengesellschaft, assignee. *Flashlight*. November 20, 1973.

A pocket size flashlight comprising a reflector having at least a pair of effective reflecting regions each having a different focal length but a common focal point, a light source placed in the focal point, the reflecting regions each forming a parabolic mirror, the reflector also including non-reflecting regions, additional reflectors having a focal point and being disposed to eliminate the non-reflecting effect.

3,774,865
Pinto, Olympio F., inventor. *Flying Saucer*. November 27, 1973.

A flying saucer type of aircraft or water vehicle is provided, which may take the form of a toy, or of an actual full-sized passenger and cargo carrying vehicle. The vehicle of the invention includes a circular-shaped body comprising an outer rim portion and an inner hub portion, and upper and lower groups of rotor helicopter-like blades, each formed into a disc-shaped configuration, and rotatable about the central vertical axis of the hub in the annular space between the hub and rim. The helicopter blades are mounted on fluid bearings in the body, and are rotatably driven by turbine action. The two groups of helicopter blades define a pressurized chamber therebetween. Exhaust ports are provided on the rim which may be selectively opened to control the attitude of the vehicle, as well as to maneuver and control the direction of movement of the vehicle, once it is airborne. The pitch of the rotor helicopter blades is controllable, so that the pressurized fluid in the aforesaid chamber may be directed through the top or bottom of the assembly to control the lift or descent of the vehicle.

3,778,684
Fischer, Horst; Justi, Eduard, inventors; Licentia Patent-Verwaltungs-GmbH, assignee. *Semiconductor Element and Method of Making It*. December 11, 1973.

A semiconductor element comprises a semiconductor body with at least one metal electrode mounted thereon, a conducting layer consisting at least partly of palladium, rhenium or rhodium being provided between the metal electrode and the semiconductor body. A method of manufacturing such a semiconductor element is also disclosed.

3,780,424
Forestieri, Americo F.; Broder, Jacob D.; Bernatowicz, Daniel T., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Making Silicon Solar Cell Array*. December 25, 1973. A heat sealable transparent plastic film, such as a fluorinated ethylene propylene copolymer, is used both as a cover material and as an adhesive for mounting a solar cell array to a flexible substrate.

3,780,519
Tokunaga, Ikuo, inventor; Kabushiki Kaisha Suwa Seikasha, assignee. *Timepiece Dial with Electrically Conducting Foot*. December 25, 1973.

In a timepiece driven by a cell which is charged by a solar battery, connection is made between the solar battery which is mounted in the dial and the cell which is interior to the timepiece by means of at least one electrically conducting foot which is part of the dial. The electrically conducting foot may be so constructed that it serves to connect one terminal of the solar battery to the cell or both terminals of the solar battery to the cell. A similar foot may be used for connecting the cell to other electrical components of said timepiece.

1974

3,786,624
Uchiyama, Hideaki, inventor; Kabushiki Kaisha Suwa Seikosha, assignee. *Solar Cell Watch Dial Having Calendar Display Window*. January 22, 1974.

A timepiece has a plurality of solar cell elements arranged on the surface of the dial thereof, the dial being formed with a window through which a time or calendar indication may be viewed. The portion of one or more of the solar cell elements in the region of the window is removed. The elements having portions removed are connected in parallel with each other if the total light receiving area thereof is not less than the light receiving area of other of said elements, otherwise, the elements having portions removed are electrically disconnected from the other of said elements.

3,793,069
Shimizu, Kazuo; Yoshida, Okio; Terakawa, Kazuo; Alhara, Satoshi, inventors; Tokyo Shibaura Electric Co., assignee. *Process for Preparing a Layer of Compounds of Groups II and VI*. February 19, 1974.

A process for preparing a layer of compounds of Groups II and VI characterized in that a layer of the compounds is formed on

the surface of a substrate, and the formed layer is heat-treated in an atmosphere comprising an inert gas, 0.1-10 percent by volume of oxygen on the basis of said inert gas and vapor of at least one element selected from a group consisting of sulfur, selenium and tellurium so that uniform grain growth with a narrow range grain size distribution is effected.

3,793,082
Roger, Jacques, inventor; Societe Anonyme de Telecommunications, assignee. *Process for Making Electrical Contacts of Solar Batteries and Solar Batteries Made According to this Process.* February 19, 1974.

The invention relates to a process for making solar batteries by means of which a photo-sensitive semiconductor part is produced and this part provided with two contact areas onto which, according to the invention, contact pieces are fixed by intermetallic diffusion between the two parts to be joined.

3,798,140
Sullivan, Thomas A.; Singleton, Eben L.; Johnson, Morris L., inventors; The United States of America as represented by the Secretary of the Interior, assignee. *Process for Producing Aluminum and Silicon from Aluminum Silicon Alloys.* March 19, 1974.

Aluminum-silicon alloy produced, for example, by smelting aluminum-silicate ore, is employed as the anode in electrolysis in a molten salt electrolyte of NaCl—KCl—$AlCl_3$ or NaCl—KCl—AlF_3. Molten aluminum is produced at the cathode. Anode residue is acid leached to produce metallurgical grade silicon.

3,802,920
Salles, Yvon; David, Gerard Robert, inventors; U.S. Philips Corporation, assignee. *Support for a Battery of Photoelectric Solar Cells.* April 9, 1974.

A support for a battery of photoelectric solar cells comprising two separate parts which form one assembly, a first part supporting the photoelectric cells, the second part supporting means for the mechanical connection of the assembly. The first part is a solid body mould about the second part. The second part has spaced sleeves with terminating collars and are connected by axial bars.

3,802,924
Pschunder, Willi, inventor; Licentia Patent-Verwaltungs-GmbH, assignee. *Thin Solar Cell with Rim and Metal Contact on Reverse Face.* April 9, 1974.

A solar cell comprises a semiconductor body with a p-n junction extending parallel to the front face of the cell and a recess in the reverse face of the cell surrounded by rim portions which are narrow as compared to the dimensions of the recess.

3,811,181
Leinkram, Charles Z.; Oaks, William D., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *New Approach to Shingling of Solar Cells.* May 21, 1974.

A method of mounting solar cells in an array in which the cells are arranged on thermally conductive but electrically insulative wafer and prominences so that they overlap each other in a shingled structure but their bottom surfaces are supported and remain parallel to the top surface of the mounting wafer, the array structure permitting series wiring of the cells and providing a rugged structure having a thermally conductive path from the solar cells through the mounting elements.

3,811,953
Nozik, Arthur Jack, inventor; American Cyanamid Company, assignee. *Light-Transmitting Electrically Conducting Cadmium Stannate and Methods of Producing Same.* May 21, 1974.

Cadmium stannate (Cd_2SnO_4) is shown to provide a light-transmitting electrically conducting composition in which the electrical conductivity can be varied from 10^{-7} ohm^{-1}cm^{-1} to 10^{4} ohm^{-1}cm^{-1} by controlling the oxygen vacancy concentration of the material. Amorphous and crystalline films of Cd_2SnO_4 can be disposed on cold and/or hot substrates and they exhibit high optical transparency as well as high electrical conductivity. Other useful forms and configurations of semiconducting Cd_2SnO_4 are disclosed.

3,811,954
Lindmayer, Joseph, inventor; Communications Satellite Corporation, assignee. *Fine Geometry Solar Cell.* May 21, 1974.

A fine geometry solar cell having a top surface contact comprising substantially more and finer metallic fingers spaced close together for collecting photocurrent. Junction depth and/or impurity concentration may be reduced significantly. The method for making the fine geometry solar cell, comprises in ordered steps, the processes of diffusion, oxidation, photolithography, metallization and plating.

3,818,691
Uchiyama, Hideaki, inventor; Kabushiki Kaisha Surva Seikosha, assignee. *Solar Cell for Timepiece.* June 25, 1974.

A solar cell utilized for operating a timepiece is improved in appearance by the application of a flatting paint to the light-sensitive surface thereof. The composition of the paint is such that the efficiency of the solar cell is not seriously decreased.

3,819,417
Haynos, Joseph G., inventor; Communications Satellite Corporation, assignee. *Mechanically Interlaced and Electrically Interconnected Silicon Solar Cells.* June 25, 1974.

In an assembly of solar cells the individual cells are arranged in a matrix of rows and columns. The cells in each row are electrically serially interconnected, with parallel electrical connections being made between all cells in a common column. A plastic strip with a metallic pattern, such as thin lines or diamond shaped pattern, on one surface thereof is woven in an interlaced manner over and under the cells in a common row. The metallic pattern extends from the top surface of a cell which the plastic strip overlays to the bottom surface of the preceeding adjacent cell which the strip passes under. The metallic pattern is on a single surface of the plastic strip facing downward and is either directly connected to the top surface of the cells or connected to an electrode bar on the edge of the top surface of the cells. The bottom surface of the cells is connected to the metallic pattern adjacent thereto by means of a metal strip which also serves to interconnect the cells in a common column. At least one other substantially identical plastic strip with similar metallic pattern thereon is interwoven through the row of cells in the opposite manner to the first plastic strip.

3,823,551
Riehl, Roger W., inventor; Riehl Electronics Corporation, assignee. *Solid State Electronic Timepiece.* July 16, 1974.

A wristwatch has a plurality of light emitting digital readout elements which are located along one end of the watch above the watchband. A hermetically sealed time capsule is enclosed within the watch case and includes an integrated circuit chip which divides the frequency output of a battery powered quartz crystal oscillator into a series of pulses which are counted and selectively interrogated to provide a series of electrical outputs corresponding to seconds, minutes, hours, days, months and years. The time capsule includes sealed control switches which are actuated by magnets slidably mounted on the case and which provide for selecting different outputs for visual display on the readout elements, corresponding to either hours and minutes, month and day or seconds. The electronic circuitry automatically compensates for twenty-eight, thirty and thirty-one day months as well as for leap years, and the readout may be selected for repetitive twelve hours or twenty-four hour display. When the

twelve hour readout is selected, the AM/PM indicating light is energized when the hours and minutes readout is selected. A solar cell is positioned on the top surface of the watch case and functions to control the intensity of the readout elements according to the intensity of ambient light, as well as to recharge the batteries. The control switches also provide for setting the watch by either changing the minutes output while holding the seconds output at zero, or by changing the hours output without changing the minutes, seconds and days outputs, or by changing the days output without changing the second, minutes, hours and months outputs.

3,833,425
Leinkram, Charles Z.; Oaks, William D.; Eisele, John A.; Faraday, Bruce J., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Solar Cell Array*. September 3, 1974.

A solar cell planar array fabricated by a method from the solar cells to the mounting panel. An electrically insulative, thermally conductive wafer is soft-soldered to the surface of the metallic mounting panel. The top surface of the wafer bears spaced electrically insulative, thermally conductive prominences thereon. The solar cells are attached on top of the prominences.

3,833,426
Mesch, Hans G., inventor; TRW, Inc., assignee. *Solar Array*. September 3, 1974.

A solar array having solar cells arranged in parallel strings at the front side of a supporting substrate with the corresponding cells in the several strings arranged in rows transverse to the strings. Each cell has a rear contact surface facing and exposed through an opening in the substrate and front contact and light sensitive surfaces. The cells in each cell string are connected in electrical series by series interconnectors, each passing between a pair of adjacent cells and through the substrate. Each interconnector is electrically joined at its front end to the front contact surface of the adjacent cell and at its rear end to the rear contact surface of the other adjacent cell through the corresponding substrate opening. The cells in each cell row are connected in electrical parallel by parallel interconnector strips electrically joined to the rear ends of the corresponding series interconnectors.

3,836,399
Pruett, George R., inventor; Texas Instruments Incorporated, assignee. *Photovoltaic Diode with First Impurity of Cu and Second of Cd, Zn, or Hg*. September 17, 1974.

A photodiode is disclosed which may be made by diffusing into N-type indium-antimonide a fast diffusing dopant impurity; such as copper; in a low concentration; e.g., below $5x10^{15}$ atoms per cubic centimeter; at the high conductivity surface; and a slowly diffusing dopant impurity; such as zinc, cadmium, or mercury; in a high concentration; e.g., $5x10^{17}$ atoms per cubic centimeter; at the high conductivity surface to form (a) a first region of uniform N-type conductivity indium-antimonide, (b) a second, or copper-diffused P-type conductivity, region contiguous with the N-type indium-antimonide and forming a P-N junction therewith and decreasing in concentration and conductivity toward the P-N junction, (c) a third, high conductivity, region containing both the slowly diffusing zinc, cadmium, or mercury, and the copper, spaced from the P-N junction, contiguous with the high conductivity portion of the copper-diffused region, being substantially thinner than the copper-diffused region, and being of P-type conductivity. Ohmic contacts are affixed to the first region and the third region.

3,837,924
Baron, Wilfred R., inventor; TRW, Inc., assignee. *Solar Array*. September 24, 1974.

A solar array and method of its fabrication wherein the solar cells are attached to a supporting substrate and electrically joined by interconnects having end terminals attached to the cell contacts with predetermined center distances between adjacent cell-substrate attachment points and the terminal attachment points of each interconnect, such that during thermal cycling of the solar array, each interconnect and the portion of the substrate between the adjacent cell-substrate attachment points undergo substantially equal thermal expansion and contraction so as to virtually eliminate stressing and flexing of the interconnects and thereby eliminate the need for flexibility in and avoid fatigue failure of the interconnects.

3,839,084
Cho, Alfred Yi; Panish, Morton B., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Molecular Beam Epitaxy Method for Fabricating Magnesium Doped Thin Films of Group III(A)-V(A) Compounds*. October 1, 1974.

In a molecular beam epitaxy method of fabricating a Mg doped thin film of a compound of the form $Al_xB_{1-x}C$, where B is a Group III(a) element and C is a Group V(a) element, the sticking coefficient of magnesium is a nonlinear, monotonically increasing function of the amount of aluminum. P-type thin films of $Al_xB_{1-x}C$:Mg having a predetermined carrier concentration are fabricated by including in the molecular beam(s) an appropriate amount of aluminum determined from said function.

3,844,840
Bender, Ray C., inventor. *Solar Energy Helmet*. October 29, 1974.

The substantially hemispherical portion of a cycle rider's helmet is covered with a plurality of solar energy electric current generating cells. Conductors, connected with the cells, are in turn connected to a junction plate for energizing a hearing aid or a small transistorized radio carried by the user.

3,844,843
Kay, Robert E.; Walwick, Earle R., inventors; Philco-Ford Corporation, assignee. *Solar Cell with Organic Semiconductor Contained in a Gel*. October 29, 1974.

A photovoltaic cell is fabricated from an active medium comprising an organic semiconductor in a gel. When a film of such material is sandwiched between transparent conducting electrodes a solar cell is obtained. The electrical output is greatly in excess of that obtained from prior art organic semiconductor solar cells of the same area.

3,845,494
Ameurlaine, Jacques François; Cohen-Solal, Gérard David, inventors; Societe Anonyme de Telecommunications, assignee. *HgTe-CdTe Photovoltaic Detectors*. October 29, 1974.

An HgTe-CdTe photovoltaic detector comprising an HgTe-CdTe semiconductor plate having two different doped regions separated by a junction, wherein said plate is coated, at least on the free faces of the plate, with a continuous film of a material which is impervious to mercury and does not effect, or possibly even enhances, the detecting properties of the crystals constituting the detector.

3,847,758
Te Velde, Ties Siebolt, inventor; U.S. Philips Corporation, assignee. *Method of Manufacturing an Electrode System*. November 12, 1974.

The invention relates to a method of manufacturing an electrode system having a monograin layer. On free grain surfaces of the monograin layer a first electrode layer is deposited. After a material-removing treatment, a deposition step is applied in which parts of enveloping layers of the grains and edges of cores of the grains adjoining pn-junctions are selectively covered with an insulating material and a second electrode layer is deposited on parts of the cores of the grains not covered.

3,849,880
Haynos, Joseph Gabrial, inventor; Communications Satellite Corporation, assignee. *Solar Cell Array*. November 26, 1974.

Individual solar cells are placed bottom down on preprinted areas of a substrate by means of an adhesive. The adhesive does not cover the entire bottom of the solar cell but leaves at least a region of the bottom of each cell which is to be welded to an interconnector free from adhesive. The substrate is pre-punched to have apertures therein at positions corresponding to the positions of contact between an interconnector and the bottom electrode of each cell. Thin electrical interconnectors are slid into position, each interconnector touching the top electrode of at least one cell and the bottom electrode of at least one adjacent cell. The interconnectors are welded directly to the top electrodes and through the pre-punched apertures to the bottom electrodes. Additional holding of the cells to the substrate is provided by bottom-type chemical/mechanical fasteners which extend from the bottom electrodes through additional pre-punched holes in the substrate and have sider regions below the substrate to mechanically and adhesively hold the substrate to the cells.

1975

Re. 28,610
Lindmayer, Joseph, inventor; Communications Satellite Corporation, assignee. *Fine Geometry Solar Cell*. November 11, 1975.

A fine geometry solar cell having a top surface contact comprising substantially more and finer metallic fingers spaced close together for collecting photocurrent. Junction depth and/or impurity concentration may be reduced significantly. The method for making the fine geometry solar cell comprises, in ordered steps, the processes of diffusion, oxidation, photolithography, metallization and plating.

3,865,625
Cho, Alfred Yi; Reinhart, Franz Karl, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Molecular Beam Epitaxy Shadowing Technique for Fabricating Dielectric Optical Waveguides*. February 11, 1975.

An optical waveguide, comprising a dielectric core (e.g., GaAs) surrounded by a relatively lower refractive index cladding (e.g., AlGaAs), is fabricated by molecular beam epitaxy in which a plurality of sources (e.g., Al and GaAs) are arranged to produce at least two molecular beams which form an angle with one another and which overlap on a growth surface or substrate. An obstruction is placed near to the surface to shadow a selected one of the molecular beams (e.g., the Al beam) so that the molecules of that beam do not impinge upon a preselected region of the surface and so that molecules of the other beams (e.g., the GaAs beam) do impinge on the region. Consequently, an epitaxial layer is grown on the surface which has laterally contiguous zones of material having different refractive indices (e.g., a zone of GaAs coextensive with the preselected region and laterally contiguous zones of AlGaAs). The cladding is completed by growing lower refractive index layers (e.g., AlGaAs) both before and after the shadowing step.

3,866,285
Clark, Harold A., inventor; Dow Corning Corporation, assignee. *Method of Constructing a Solar Energy Collector*. February 18, 1975.

A solar energy collector having a body of foamed plastic and a surface configuration of generally semicylindrical recesses in closely spaced parallel relationship, the surface of said recesses being covered with reflective or absorptive foil to reflect or transmit solar energy to receiving devices such as fluid conduits or solar cells. The collector is made by laying a plurality of half-pipes into a frame, covering them with foil, pouring curable foam plastic over the pipes and removing the composite from the pipes. The receiving devices are then mounted in the recesses and interconnected.

3,874,931
Haynos, Joseph Gabrial, inventor; Communications Satellite Corporation, assignee. *Solar Cell Array*. April 1, 1975.

Individual solar cells are placed bottom down on preprinted areas of a substrate by means of an adhesive. The adhesive does not cover the entire bottom of the solar cell but leaves at least a region of the bottom of each cell which is to be welded to an interconnector free from adhesive. The substrate is pre-punched to have apertures therein at positions corresponding to the positions of contact between an interconnector and the bottom electrode of each cell. Thin electrical interconnectors are slid into position, each interconnector touching the top electrode of at least one cell and the bottom electrode of at least one adjacent cell. The interconnectors are welded directly to the top electrodes and through the pre-punched apertures to the bottom electrodes. Additional holding of the cells to the substrate is provided by button-type chemical/mechanical fasteners which extend from the bottom electrodes through additional pre-punched holes in the substrate and have wider regions below the substrate to mechanically and adhesively hold the substrate to the cells.

3,879,228
Theodorou, Ignatius E.; Payne, Richard, inventors; The United States of America as represented by the Secretary of the Air Force, assignee. *Photo-Regenerative Electrochemical Energy Converter*. April 22, 1975.

A photoelectrochemical device for converting incident radiation energy to electrical energy through the utilization of a photochemically reversible galvanic cell. Basically, the device is constructed of a sealed transparent container into which is placed a chemically inert anode coated with a photo-responsive material and a chemically inert cathode. A compatible electrolytic solution is also disposed within the container and provides a conductivity path across the electrodes to complete the electrochemical circuit. Decomposition of the photo-responsive material is induced by incident radiation passing through the transparent container. The products of the photo reaction recombine electrochemically by passing an electric current through a resistance load connected externally to the anode and the cathode.

3,879,740
Mori, Chiharu; Kamasako, Shoji, inventors; Asahi Kogaku Kogyo Kabushiki Kaisha, assignee. *Light-Measuring Systems*. April 22, 1975.

A light-measuring system in which a photodiode is electrically connected with a logarithmic compression element in a circuit which includes a voltage source and a source follower circuit connected between the voltage source on the one hand and the photodiode and the logarithmic compression element on the other hand for providing approximately zero voltage across the photodiode.

3,880,633
Jordan, John F.; Lampkin, Curtis, inventors; D. H. Baldwin Company, assignee. *Method of Coating a Glass Ribbon on a Liquid Float Bath*. April 29, 1975.

A method of making low cost solar cells on a large scale basis by means of a continuous process of fabricating float glass and coating the float glass, in sequence, with tin oxide, cadmium sulphide, and copper sulphide, while the glass floats atop tanks of molten material in a furnace of proper temperature for each step of the process, the application of the coatings, in a preferred embodiment, being accomplished by depositing materials which form the coatings on contact with heated surfaces at such slow rates and, in the case of spray application, via drops of such uniformity that the float glass may (1) remain at uniform temperatures by virtue of the superior thermal conductivity of the molten material and retain those temperatures despite the abstraction of heat from the glass by evaporation of liquids and/or formation of crystalline layers, and (2) be substantially free of temperature gradients along the surface of the sheet glass.

3,884,779
Duy, Thuoc Nguyen; Palz, Wolfgang, inventors; Societe Anonyme de Telecommunications, assignee. *Method for the Controlled Formation of the Layer of Copper Sulphide of a Cadmium Sulphide Photocell*. May 20, 1975.

A method for the controlled formation of the layer of copper sulphide of a cadmium sulphide photocell by immersion in a solution of cuprous ions, wherein the photocell being produced is maintained throughout the duration of its immersion in said solution at a constant potential at least equal to that of a pure copper electrode immersed in the same solution.

3,885,058
Duy, Thuoc Nguyen; Palz, Wolfgang; Vedel, Jacques, inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Method of Manufacturing Cadmium Sulphide Photocells*. May 20, 1975.

A method for manufacturing a CdS photocell comprising a layer of Cu_2S to which there is adhered a collector grid, the adhesion producing oxidation of the Cu_2S layer, said method comprising dipping the photocell to which the grid has just been adhered into a solution of cuprous ions and withdrawing the photocell when the curve representing the variations with respect to time of the potential difference between the photocell and a pure copper electrode dipped into the same solution passes through its minimum value.

3,887,446
McEwan, William S.; Miles, Melvin, inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Electrochemical Preparation of Metallic Tellurides*. June 3, 1975.

Tellurides of cadmium lead and tin are prepared by an electrochemical method wherein a tellurium cathode and an anode of the metal which will form the positive ion of the telluride are used in conjunction with ammonium acetate-acetic acid buffer solutions. Mercury tellurides are prepared by using a tellurium anode and a platinum cathode to produce Te-ions and then adding a mercury salt. The tellurides prepared are useful as semiconductors and in other areas.

3,887,935
Fischer, Horst; Pschunder, Willi, inventors; Licentia Patent-Verwaltungs-GmbH, assignee. *Integrated Semiconductor Arrangement Including Solar Cell and a Schottky Diode*. June 3, 1975.

An integrated semiconductor arrangement comprises a semiconductor body with a solar cell and a rectifying metal contact, the contact having a metal coating split up into largely separated regions which are, however, electrically connected together.

3,887,995
Gauthier, André, inventor; Societe Anonyme de Telecommunications, assignee. *Process of Manufacture of Solar Cells*. June 10, 1975.

A solar cell comprising two electrodes, a collector grid, a copper sulphide layer and a cadmium sulphide layer, wherein the two electrodes are constituted by a single conductive film divided into two parts separated by an insulating material, said sulphide layers being deposited on one of said parts and surmounted by said collector grid which is electrically connected to said other part of the conductive film.

3,888,697
Bogus, Klaus; Mattes, Siegfried, inventors; Licentia-Patent-Verwaltungs-GmbH, assignee. *Photocell*. June 10, 1975.

A thin layer photocell comprises a semiconductor body of cadmium sulphide with a layer of cuprous sulphide thereon and then an additional layer containing metallic on the cuprous sulphide layer. A method for making such a photocell is also disclosed.

3,888,698
Lindmayer, Joseph; Curtin, Denis John; Haynos, Joseph Gabriel; Meulenberg, Andrew, Jr., inventors; Communications Satellite Corporation, assignee. *Infrared-Transparent Solar Cell*. June 10, 1975.

A semi-conductor solar cell having a back electrode which allows deep infrared light to pass out of the cell into space. The cell back electrode is formed in a pattern which covers less than 10 percent of the bottom surface of the cell. An insulating material having good optical matching characteristics covers the remainder of the bottom surface.

3,890,776
Urushida, Yoshihisa, inventor; Citizen Watch Company Limited, assignee. *Watch with Solar Cell Unit*. June 24, 1975.

A plurality of pie-shaped solar elements which comprise the face of the watch are positioned and secured by a holder in the form of a wagon wheel having two concentric rings joined by a plurality of spokes. The underside of each spoke has a downwardly projecting ridge which extends between adjacent solar elements to separate and locate the elements while providing a cover to hide the edges of each element.

3,891,326
Volz, Frederic E., inventor. *Multi-Channel Sun Photometer*. June 24, 1975.

A multi-channel sun photometer having a housing which contains therein a plurality of openings and filters optically aligned with a silicon photovoltaic photocell. A microammeter is operably connected to the photocell for providing a reading of the amount of light passing through the filters. In addition to the light measurements registered an angle or optical path length measurement can be obtained on a diopter pivotably mounted on the side of the photometer housing.

3,895,975
Lindmayer, Joseph, inventor; Communications Satellite Corporation, assignee. *Method for the Post-Alloy Diffusion of Impurities into a Semiconductor*. July 22, 1975.

A method of making a solar cell or other semiconductor junction devices including the process of diffusing an impurity of a first type conductivity into the front surface of a semiconductor bulk material while simultaneously alloying and diffusing an impurity of a second type conductivity into the back surface of the semiconductor bulk material from a metallic source. During this simultaneous doping, the back surface area of the semiconductor and the second type metallic impurity are in a molten alloy state.

3,896,368
Rym, Christian, inventor; ACEC (Ateliers de Constructions Electriques de Charleroi), assignee. *Voltage Regulating Device*. July 22, 1975.

Device for regulating the voltage of an electric energy source constituted of a group of solar cells gathered into modules. Each module has one terminal connected to a common conductor and another terminal connected through a diode to a distribution conductor. The device comprises electronic interrupters connected between the common conductor and the terminal of a module connected to the diode, so as to short-circuit the module. A proportional shunt is connected between a point at the distribution conductor potential and the common conductor . A differential amplifier is provided between the distribution conductor and a reference voltage generating device. An analog-digital converter the input of which is connected to the output of the differential amplifier and a part of the outputs of which control the electronic interrupters, the remaining outputs controlling the proportional shunt.

3,897,325
Aeshima, Sheichi; Asamaki, Tatsuo, inventors; Nippon Electric Varian, Ltd., assignee. *Low Temperature Sputtering Device*. July 29, 1975.

A sputtering device comprises a plurality of thin metal plates between the cathode and a holder for holding a plurality of objects on which the material of the cathode should be sputtered. The device further comprises a coil for providing magnetic field perpendicular to the electric field for producing a gas discharge for the sputtering. Alternatively, the device further comprises means for providing local electric or magnetic fields between the metal plates. The metal plates receive electrons produced during the sputtering and having their paths varied either by the coil magnetic field or by the local electric or magnetic fields.

3,899,689
Baker, Richard H., inventor; Massachusetts Institute of Technology, assignee. *Electric Power Source*. August 12, 1975.

An electric power source or system for delivering a controllable voltage to a load. It has low power loss and is capable of acting as a programmable source of electric energy, one which can be used, for example, to furnish a very high-voltage output from a lightweight system. The power source is a modular type structure in which the apparatus is made up of a number of identical stages or modules connected in cascade. Each stage includes a voltage supply and floating reference voltages derived from the supply. The voltage supply is connected to the output of the source through bilateral, solid-state switches along alternate electrically conductive paths which connect either one side or other of the voltage supply to the output. A bistable circuit serves to control the bilateral switches, triggering of the bistable circuit being effected by radiation impinged upon light sensitive devices, the devices being connected to perform a set-reset type function of the circuit. The floating reference voltages provide constant electric potential for switching purposes. The system can be used to step up a voltage; a form thereof can be used to step a voltage down; and the system can be triggered in an avalanche mode.

3,900,943
Sirtl, Erhard; Currin, Cedric G., inventors; Dow Corning Corporation, assignee. *Silicon Semiconductor Device Array and Method of Making Same*. August 26, 1975.

Silicon semiconductor device array, e.g., solar cell device or array of devices; formed from bulk silicon deposited in the form of columnar crystallites bounded by substantially vertical grain boundaries. The grain boundaries are made substantially nonconductive by diffusion from one side of the sheet. P^+ and n^+ layers are provided as contact areas for electrodes. Deposition of silicon takes place directly from decomposition of silicon-containing vapors onto a non-silicon substrate sheet.

3,900,945
Kay, Robert E.; Walwick, Earle R., inventors; Philco-Ford Corporation, assignee. *Organic Semiconductor Solar Cell*. August 26, 1975.

A photovoltaic cell is fabricated from an active medium comprising an organic semiconductor in a gel. When a film of such material is sandwiched between transparent conducting electrodes a solar cell is obtained. The electrical output is greatly in excess of that obtained from prior art organic semiconductor solar cells of the same area.

3,902,920
Jordan, John F.; Lampkin, Curtis M., inventors; D. H. Baldwin Company, assignee. *Photovoltaic Cell*. September 2, 1975.

A large area photovoltaic cell comprising a layer of multicrystalline cadmium sulfide, about 1 to 2 microns thick, formed by simultaneously spraying two suitably selected compounds on a uniformly heated plate of Nesa glass, therefter forming a coating of Cu_2S by spraying two suitable compounds over the cadmium sulfide layer while the latter is heated, to form a photovoltaic heterojunction, applying thereover a layer of $CuSO_4$, and applying electrodes of Cu and Zn, respectively, to separated areas of the layer of $CuSO_4$, and heating the cell to form a cuprous oxide rectifying junction under the copper electrode by reaction of the Cu electrode with the $CuSO_4$, while diffusing the zinc through the body of the cell. The diffusion of the zinc provides a negative electrode coplanar with the positive copper electrode, eliminating any need for introducing mechanically complex provision for making a connection to the Nesa glass, while the use of a rectifying positive electrode enables use of a layer of CdS only 1 to 2 microns thick, rather than the usual 20 microns, despite the fact that such thin layers tend to have pinholes, which in the prior art render the cells inoperative but in the present teaching do not.

3,903,324
Gukelberger, Thomas F., Jr.; Kleinfelder, Walter J., inventors; International Business Machines Corporation, assignee. *Method of Changing the Physical Properties of a Metallic Film by Ion Beam Formation*. September 2, 1975.

A deposited metallic film on a substrate is bombarded with high energy ions having an energy of at least 10 Kev with the ions being selected from the group of ions ranging between helium and argon. The selected ions depend upon the metal forming the film and the thickness of the film. This bombardment reduces the yield stress of the film in any area in which the ions strike and is particularly useful to form metallic lands on a semiconductor substrate.

3,903,427
Pack, George J., inventor; Hughes Aircraft Company, assignee. *Solar Cell Connections*. September 2, 1975.

The 10 percent increase in useful power from a photocell area without increasing the size or weight of the cell and with the capability to decrease the temperature of the cells themselves due to eliminaton of some of the power losses is obtained by taking the front leads through the cell to its back surface instead of across its surface.

3,903,428
Dejong, Pieter N., inventor; Hughes Aircraft Company, assignee. *Solar Cell Contact Design*. September 2, 1975.

At least an increase of four percent in useful output from a photocell area without increasing the size or weight of the cell results from feeding a connecting wire from the front side of the cell to its backside through a small, centrally located hole in the cell. Grid lines on the front side run radially to a ring of metal around the hole. Various means on the backside are used to connect the connecting wire to a bus or interconnect. Thus, not only the useful cell area but also the packing densities of a number of cells are increased.

3,904,453
Revesz, Akos George; Dendall, Robert John, inventors; Communications Satellite Corporation, assignee. *Fabrication of Silicon Solar Cell with Antireflection Film*. September 9, 1975.

A solar cell is fabricated having an anti-reflective coating formed of an oxide of niobium, zirconium, hafnium, or tantalum. The oxide is formed by oxidizing a layer of metal deposited on the surface of the semiconductor portion of the solar cell. A pattern for the top electrode of the solar cell is etched into the oxide layer by a technique which includes the formation of a metallic and a photoresist mask and also includes lift-off photolithography.

3,905,836
Epple, Richard, inventor; Telefunken Patentverwertungsgesellschaft m.b.H, assignee. *Photoelectric Semiconductor Devices*. September 16, 1975.

In a method of making p-n junction photoelectric semiconductor device from a semiconductor body, the step of producing

recombination centers in the interior of the body, whereby the maximum spectral sensitivity of the device may be chosen as a function of the number of recombination centers produced.

A photoelectric semiconductor body having a p-n junction on a first side and recombinaton centers in its interior.

3,907,595
Lindmayer, Joseph, inventor; Communications Satellite Corporation, assignee. *Solar Cells with Incorporate Metal Layer*. September 23, 1975.

The efficiency of a solar cell is improved by incorporating a metal layer beneath the P-N junction of the solar cell. The metal layer reflects back towards the junction light which would otherwise penetrate too deeply to contribute to the voltage and current output. The metal also produces charge carriers which are photo excited up to the conduction band of the semiconductor by light having photon energy less than the semiconductor band gap. The metal and the semiconductor material forming the solar cell are both highly ordered, thereby forming a barrier contact at the metal-semiconductor interface.

3,911,469
Wrobel, Joseph S., inventor; Texas Instruments Incorporated, assignee. *Method of Forming P-N Junction in PbSnTe and Photovoltaic Infrared Detector Provided Thereby*. October 7, 1975.

This disclosure is directed to a method of forming a P-N junction in PbSnTe material in providing an infrared radiation diode detector, wherein signal radiation is absorbed in a low carrier concentration n-layer such that a Burstein Shift is not exhibited, while the bulk of the P-N junction is p-type material of high carrier concentration to prevent surface inversion. The method employs diffusion of a defect compensating impurity such as cadmium or zinc into unannealed PbSnTe material dominated by n-type background impurities. The diffusion of cadmium or zinc has a compensating effect on the p-type stoichiometric defects found in unannealed PbSnTe which results in a substantial reduction in the adverse effect of surface inversion layers and surface leakage, thereby achieving an improved operating performance from PbSnTe photovoltaic detectors so made.

3,912,539
Magee, Vincent, inventor; Ferranti, Limited, assignee. *Solar Cells*. October 14, 1975.

An array of solar cells comprises a plurality of semiconductor devices, each semiconductor device comprising a solar cell and a protective diode, most solar cells being connected individually in parallel with a protective diode in a different semiconductor device, to provide a compact arrangement for the array, within each semiconductor device the radiation-sensitive P-N junction of the solar cell being isolated from the P-N junction of the protective diode.

3,912,540
Broder, Jacob D., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Covered Silicon Solar Cells and Method of Manufacture*. October 14, 1975.

An improved silicon solar cell has a transparent plastic film of fluorinated ethylene propylene copolymer for a binding agent to attach a cover glass.

3,912,931
Gravisse, Philippe Edouard Leon Alexis; Prevot, Michel, inventors. *Photovoltaic Device with Luminescent Layers of Differing Composition*. October 14, 1975.

Photovoltaic device comprising a conventional photovoltaic cell and a series of thin layers successively applied on the photocell surface, said layers being of different compositions and selected in such a manner that the light energy in a spectrum zone, falling on the outermost layer, may be transferred successively in cascade, through the intermediary of the various layers, up to the spectral sensitivity zone of the photovoltaic cell.

3,914,856
Fang, Pao-Hsien, inventor. *Economical Solar Cell for Producing Electricity*. October 28, 1975.

This invention relates to a method for economically and rapidly producing solar cells, made of either silicon or of germanium. Complete solar cells are deposited in a carrier substrate by processes geared to large scale production at high production rates not obtainable from the present state of art.

3,921,049
Mellors, Geoffrey W.; Powers, Robert A.; Sheffield, Glenn W., inventors; Union Carbide Corporation, assignee. *Charging Circuit for Battery-Operated Devices Powered by Solar Cells*. November 18, 1975.

A charging circuit for battery-operated devices powered by photovoltaic cells comprising a first diode means connected in parallel to a series-connected resistor and at least one photovoltaic cell, and in parallel to a series-connected second diode means and at least one secondary battery. The terminals of the components of the circuit are connected such that the current from the photovoltaic cells is limited by the first diode means so as to prevent overcharge of the secondary battery while the second diode means is connected so as to prevent reverse current through the photovoltaic cells when the voltage of the secondary battery is higher than that of said photovoltaic cells.

3,922,774
Lindmayer, Joseph; Allison, James Frederick, inventors; Communications Satellite Corporation, assignee. *Tantalum Pentoxide Anti-Reflective Coating*. December 2, 1975.

A solar cell, responsive to light in the short wavelength region, including a non-crystalline tantalum pentoxide, anti-reflective coating. A method for making a solar cell, responsive to light in the short wavelength region including a non-crystalline tantalum pentoxide, anti-reflective coating. The method includes placing the anti-reflective coating and a metallic current collector on the top surface of the solar cell using the technique of "lift-off" photolithography and the oxidation of elemental tantalum which is evaporated onto the solar cell.

3,925,103
Russell, Robert L., inventor; TRW Inc., assignee. *Radiation Hard Solar Cell and Array*. December 9, 1975.

A power generating solar cell for a spacecraft solar array is hardened against transient response to nuclear radiation while permitting normal operation of the cell in a solar radiation environment by shunting the cell with a second solar cell whose contacts are reversed relative to the power cell to form a cell module, exposing the power cell only to the solar radiation in a solar radiation environment to produce an electrical output at the module terminals, and exposing both cells to the nuclear radiation in a nuclear radiation environment so that the radiation induced currents generated by the cells suppress one another.

3,925,802
Watanabe, Jinzo; Terao, Noboru; Kamahara, Koichi; Miyashita, Kazuhisa; Fujihira, Kenji, inventors; Mitsubishi Denki Kabushiki Kaisha, assignee. *Semiconductor Device*. December 9, 1975.

A hollow circularly cylindrical N semiconductor substrate includes a P layer disposed on its outer peripheral surface to form a PN junction in the form of a circularly cylindrical surface within the substrate. Two circularly cylindrical electrodes are fitted onto and into the substrate respectively.

3,928,073
Besson, Jean Georges; Duy, Thuoc Nguyen; Palz, Wolfgang, inventors; Societe Anonyme de Telecommunications, assignee. *Solar Cells*. December 23, 1975.

A solar cell comprising a p-type doped semiconductor body in whose upper part, exposed to the incident light, there is provided a thin n-type doped zone, the battery being covered in its lower part by a metal electrode and in its upper part by a metal collector grid, wherein the n-type doped layer between the bars of the collector grid is covered by an insulating layer which is transparent to the incident radiation, said insulating layer being itself covered by a conductive layer which constitutes a third electrode and is also transparent to the incident radiation and insulated from the collector grid.

3,928,865
Yamashita, Akio, inventor; Matsushita Electric Industrial Co., Ltd., assignee. *Photo-Electrical Transducer*. December 23, 1975.

A photo-electrical transducer element comprising a semiconductor body, a rectifying barrier formed in the semiconductor body, and electrodes formed on said semiconductor body on both sides of said barrier. A deep-level-forming impurity is heavily doped in the neighborhood of the rectifying barrier.

3,928,960
Reese, Robert O., inventor; Time Computer, Inc., assignee. *Combination Wristwatch and Calculator*. December 30, 1975.

Disclosed is a combination wristwatch and calculator utilizing a common electro-optical digital display. A time and calendar circuit is combined with a calculator circuit, both formed by large scale integration, and used to actuate common display stations of a light emitting diode digital display. Time is constantly kept but the calculator circuit is only energized upon operation of a "calculate mode" switch to conserve battery energy. Also disclosed is a solar cell for recharging the battery and an inhibit timer for automatically extinguishing the display when the device is in the calculate mode but not in use.

3,929,510
Kittl, Emil, inventor; The United States of America as represented by the Secretary of the Army, assignee. *Solar Radiation Conversion System*. December 30, 1975.

A system for converting solar radiation into useful electrical energy is provided. The system includes a silicon cell and solar radiation conversion means integral with or spaced from the silicon cell. The solar radiation conversion means is characterized by a band-emission spectrum that provides a good spectral match with the spectral response of a silicon cell.

3,929,527
Chang, Leroy L.; Esaki, Leo; Ludeke, Rudolf, inventors; The United States of America as represented by the Secretary of the Army, assignee. *Molecular Beam Epitaxy of Alternating Metal-Semiconductor Films*. December 30, 1975.

Alternately repeated layers of metal epitaxy on semiconductor substrates and semiconductor epitaxy on metal substrates are grown in an ultra-high vacuum evaporation system by first depositing the metal film on the clean surface of the semiconductor over the temperature range between room temperature and 400°C; and then depositing the semiconductor film on the clean surface of the metal over the temperature range between 500°C and 600°C.

1976

3,935,031
Adler, Alan D., inventor; New England Institute, Inc., assignee. *Photovoltaic Cell with Enhanced Power Output*. January 27, 1976.

The photovoltage and photocurrent, and therefore, the power output of photovoltaic cells (solar cells) are markedly enhanced by depositing, on an exposed semiconductor surface of a solar cell, a layer of any one of a very large number of prophyrinic compounds.

3,936,319
Anthony, Thomas R.; Cline, Harvey E.; Winegar, Donald M., inventors; General Electric Company, assignee. *Solar Cell*. February 3, 1976.

A solar cell with improved efficiency is provided with a convoluted P-N junction whereby a higher proportion of carriers produced by exposure of the solar cell to a source of radiation will be collected by the P-N junction rather than being lost by recombination. The solar cell has an increased resistance to radiation damage. The solar cell is made from a body of semiconductor material in which two regions of opposite type conductivity are formed. The material of one region is substantially the same as the body and the material of the other region is recrystallized material of the first region having solid solubility of a metal therein to impart a selective type conductivity and resistivity thereto.

3,941,624
Cho, Alfred Yi, inventor; Bell Telephone Laboratories, Incorporated, assignee. *Sn-Doped Group III(A)-V(A) Ga-Containing Layers Grown by Molecular Beam Epitaxy*. March 2, 1976.

In order to insure that the doping profiles of Sn-doped Group III(a)-V(a) Ga-containing layers grown by molecular beam epitaxy follow relatively closely the time-intensity profile of the dopant beam, the substrate temperature should not exceed about 550°C.

3,943,003
Dendall, Robert John, inventor; Communications Satellite Corporation, assignee. *Padded Solar Cell Contacts*. March 9, 1976.

In a solar cell a pad of material is placed between the cell semiconductor surface and the portion of the top electrode which is bonded to an interconnector. The pad prevents destruction of the cell p-n junction during bonding. The pad may be the same as an anti-reflective coating and may be formed simultaneously with the formation of the anti-reflective coating.

3,943,726
Miller, John H., inventor; Lawrence Peska Associates, Inc., assignee. *Solar Cooling System for an Automobile*. March 16, 1976.

A solar energy cell system is used as an electric supply source to operate an air conditioner or a fan ventilation system contained within the interior chamber of an automobile. The electrical circuit comprises a series circuit consisting of: the solar energy cells, a voltage regulator, a storage battery, a thermostatic temperature control and a ventilation fan or an automobile air conditioner.

3,948,682
Bordina, Ninel Mineevna; Zadde, Vitaly Viktorovich; Zaitseva, Aita Konstantinovna; Landsman, Arkady Pavlovich; Strebkov, Dmitry Semenovich; Streltsova, Valentina Ivanovna; Unishkov, Vadim Alexeevich, inventors. *Semiconductor Photoelectric Generator*. April 6, 1976.

A semiconductor photoelectric generator comprising interconnected photocells with rectifying barriers, with isotype junctions in the base region and with current leads in the regions adjacent the rectifying barriers. Each photocell has a working surface, receiving incident radiation. The isotype junctions in the photocells are provided in direct proximity to the working surfaces of the photocells. At least one rectifying barrier in each photocell is provided at a distance from the working surface not exceeding the diffusion length of minority current carriers in the base region. The photocells can have the shape of microminiature

parallelepipeds having at least two dimensions commensurate with the diffusion length of minority current carriers in the base region.

3,949,463
Lindmayer, Joseph; Allison, James Frederick, inventors; Communications Satellite Corporation, assignee. *Method of Applying an Anti-Reflective Coating to a Solar Cell.* April 13, 1976.

A method of applying an anti-reflective coating, particularly a metal oxide coating to a solar cell during the manufacture of such cell.

3,952,323
Tanimura, Shigeru; Miura, Nobuaki; Miyamoto, Mikizo, inventors; Omron Tateisi Electronics Co., Ltd., assignee. *Semiconductor Photoelectric Device.* April 20, 1976.

A semiconductor photoelectric device of improved photoelectric and rectifying characteristics is provided by first forming a film or silicon dioxide on a main surface, having a crystallographic orientation of (100), of a semiconductor substrate of N-type silicon, the film being formed to a thickness less than 25Å, for example, and then further depositing thereon a tin oxide film. It was found that adoption of the abovementioned (100) orientation reduces the reverse saturation current and thus the dark current of the device, with the result that the open voltage of the device is accordingly increased. It was also found that proper choice of specific resistivity of the substrate improves linearity of the photoelectric characteristic.

3,952,324
Wolff, George; Brooks, Gilbert R.; Eakins, Thomas C., inventors; Hughes Aircraft Company, assignee. *Solar Panel Mounted Blocking Diode.* April 20, 1976.

An isolation or blocking diode for mounting alongside solar cells in solar cell panels such as used in flexible roll-up, rigid flat and cylindrical arrays, the diode having the thickness and shape of adjacent solar cells and functioning to prevent such problems as total solar panel failure in the event of shorts developing in a single solar cell group and a major power loss in case of partial shadowing of the panel.

3,953,876
Sirtl, Erhard; Currin, Cedric G., inventors; Dow Corning Corporation, assignee. *Silicon Solar Cell Array.* April 27, 1976.

Silicon semiconductor device array, e.g. solar cell device or array of devices; formed from bulk silicon deposited in the form of columnar crystallites bounded by substantially vertical grain boundaries. Junctions are formed across crystallites and along grain boundaries. The grain boundaries are made substantially nonconductive by diffusion from one side of the sheet. P^+ and n^+ layers are provided as contact areas for electrodes. Deposition of silicon takes place directly from decomposition of silicon-containing vapors onto a non-silicon substrate sheet.

3,956,017
Shigemasa, Junichiro, inventor; Sharp Kabushiki Kaisha, assignee. *Optoelectric Transducer.* May 11, 1976.

A metal layer made of a high heat conductivity material such as silver or aluminum is provided at the rear surface of a solar battery with the use of vacuum evaporation technology. A thermoelectric converter is attached to the metal layer in a manner to convert solar energy into electric energy by means of not only the optoelectric effect but also the thermoelectric effect. The solar battery can be maintained at its preferred operative temperature by the metal layer and the thermoelectric converter.

3,956,687
Lindenman, Gerald A., inventor; Hughes Aircraft Company, assignee. *Staggered Stage Shunt Regulator.* May 11, 1976.

A regulator which shunts excess current from a solar cell array in which zener diodes of different values are used to separate the control signal into divisions. The control signal, now divided, is used to separate array current into divisions. Each of the divisions of current is shunted by a separate power transistor stage, which is active only over a limited portion of the entire current range. The advantage of having each of the power stages active only over a particular range is to reduce the power dissipation in the shunt regulator by a significant amount and thereby allow greater mechanical design flexibility and lower overall weight.

3,956,765
Fischer, Horst; Pschunder, Willi, inventors; Licentia Patent-Verwaltungs-GmbH, assignee. *Integrated Semiconductor Arrangement.* May 11, 1976.

An integrated semiconductor arrangement comprises a semiconductor body having a solar cell and a rectifying metal-semiconductor contact. The invention also includes a method of making such an arrangement.

3,957,537
Baskett, Arthur Colin; Riddle, Peter Michael, inventors; Imperial Chemical Industries Limited, assignee. *Modules Comprising Photocells.* May 18, 1976.

Modules comprising photo-cells encapsulated in laminates comprising at least one rigid member and at least one transparent member laminated together by a transparent hot melt adhesive such as plasticised polyvinylbutyral or an ethylene copolymer. The preferred members are glass sheets and the preferred ethylene copolymer is a terpolymer of ethylene, methylmethacrylate and methacrylic acid. In a modification of the invention the hot melt adhesive need not be transparent provided that in the laminate it merely surrounds the photo-cell and does not cover its light-sensitive surface.

3,958,970
Auzel, Francois E., inventor. *Method of Casting Fluorescent Lenses.* May 25, 1976.

Fluorescent material for the optical frequency conversion of near infrared radiation from 0.85 to 1.06 μm into visible radiation. The constituents of the material are (i) vitrifying fluorides of lead, beryllium, and magnesium, (ii) devitrifying and activating fluoride of ytterbium and (iii) doping fluoride of erbium for a green and red response and doping fluoride of thulium for a blue response. The content of ytterbium fluoride controls the form of the material, either glassy ceramic or polycrystalline. Proper preparation conditions allow to prepare either a glass material or a ceramic material.

3,960,620
Ettenberg, Michael, inventor; RCA Corporation, assignee. *Method of Making A Transmission Mode Semiconductor Photocathode.* June 1, 1976.

A flat substrate body of a single crystalline semiconductor material which is transparent to radiation but which can disassociate when subjected to heat is first coated on one surface with a coating of a transparent, anti-reflective material which will protect the body from disassociation. One or more layers of a single crystalline semiconductor material are then epitaxially deposited on another surface of the body under temperature conditions which could cause the disassociation of the material of the body. The last epitaxial layer deposited is of a material which is capable of generating electrons in response to incident radiation. A layer of a work function reducing material is then coated on the last epitaxial layer.

3,961,472
Riehl, Roger W., inventor; Ragen Semiconductor, Inc., assignee. *Solid State Electronic Timepiece*. June 8, 1976.

A wristwatch has a plurality of light emitting digital readout elements which are located along one end of the watch above the watchband. A hermetically sealed time capsule is enclosed within the watch case and includes an integrated circuit chip which divides the frequency output of a batter powered quartz crystal oscillator into a series of pulses which are counted and selectively interrogated to provide a series of electrical outputs corresponding to seconds, minutes, hours, days, months and years. The time capsule includes sealed control switches which are actuated by magnets slidably mounted on the case and which provide for selecting different outputs for visual display on the readout elements, corresponding to either hours and minutes, month and day or seconds. The electronic circuitry automatically compensates for 28, 30 and 31 day months as well as for leap years, and the readout may be selected for repetitive 12 hour or 24 hour display. When the 12 hour readout is selected, the AM/PM indicating light is energized when the hours and minutes readout is selected. A solar cell is positioned on the top surface of the watch case and functions to control the intensity of the readout elements according to the intensity of ambient light, as well as to recharge the batteries. The control switches also provide for setting the watch by either changing the minutes output while holding the seconds output at zero, or by changing the hours output without changing the minutes, seconds and days outputs, or by changing the days output without changing the seconds, minutes, hours and months outputs.

3,961,997
Chu, Ting L., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Fabrication of Polycrystalline Solar Cells on Low-Cost Substrates*. June 8, 1976.

Low-cost polycrystalline silicon cells supported on substrates are prepared by depositing successive layers of polycrystalline silicon containing appropriate dopants over supporting substrates of a member selected from the group consisting of metallurgical-grade polycrystalline silicon, graphite and steel coated with a diffusion barrier of silica, borosilicate, phosphosilicate, or mixtures thereof such that p-n junction devices are formed which effectively convert solar energy to electrical energy.

3,961,998
Scharnhorst, Kurt Peter; Bis, Richard F.; Dixon, Jack R.; Houston, Bland B., Jr.; Brown, Richard W.; Riedl, Harold R., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Vacuum Deposition Method for Fabricating an Epitaxial PbSnTe Rectifying Metal Semiconductor Contact Photodector*. June 8, 1976.

A junction photodetector employing $Pb_{1-x}Sn_xTe$ in narrow film strips grown epitaxially on an appropriate substrate. An appropriate metal overlaps the film to form a metal-semiconductor contact.

3,964,155
Leinkram, Charles Z.; Oaks, William D.; Eisele, John A.; Faraday, Bruce J., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Method of Planar Mounting of Silicon Solar Cells*. June 22, 1976.

A method of mounting silicon solar cells in a planar array that not only yields electrical insulation between cells but allows for a multifold increase in thermal dissipation of the cell array, comprising metallizing a wafer of beryllium oxide on each side so that the outer surface is copper, etching the wafer on one side so that the only metallized parts which remian are those on which the solar cells are to be mounted or wiring is to be attached, soldering the solar cells on the unetched copper prominences, coating the aluminum panel on which the cells are mounted with a copper layer, soldering the underside of the wafer on the upper surface of the aluminum panel with soft solder such as indium, and covering all remaining passive surfaces with a teflon F.E.P. tape the underside of which carries a layer of silver and then a layer of inconel metal.

3,966,499
Yasui, Robert K.; Berman, Paul A., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Grid Patterns*. June 29, 1976.

A grid pattern for a solar cell of the type including a semiconductive layer doped to a first polarity and a top counter-doped layer. The grid pattern comprises a plurality of concentric conductive grids of selected geometric shapes which are centered about the center of the exposed active surface of the counter-doped layer. Connected to the grids is one or more conductors which extend to the cell's periphery. For the pattern area, the grids and conductors are arranged in the pattern to minimize the maximum distance which any injected majority carriers have to travel to reach any of the grids or conductors. The pattern has a multiaxes symmetry with respect to the cell center to minimize the maximum temperature differentials between points on the cell surface and to provide a more uniform temperature distribution across the cell face.

3,969,163
Wakefield, Gene Felix, inventor; Texas Instruments Incorporated, assignee. *Vapor Deposition Method of Forming Low Cost Semiconductor Solar Cells Including Reconstitution of the Reacted Gases*. July 13, 1976.

The disclosure relates to a method of upgrading metallurgical grade silicon to semiconductor grade for making low cost silicon devices and particularly solar cells. This is accomplished by passing conductive fibers such as graphite or the like which are compatible with the later processing steps through an area which is cooled below 700°C and which contains silicon difluoride and a proper N-type dopant. At these temperatures, the silicon difluoride gas will break down into pure silicon which will deposit onto the fiber with the formation of silicon tetrafluoride gas which is then recycled into a further chamber. In the further chamber, the gaseous silicon tetrafluoride is mixed with the impure metallurgical grade silicon at temperatures above 700°C to form the silicon difluoride gas which is then fed into the former chamber for deposition of pure silicon onto the continuously moving fibers of graphite or the like. A p-type layer can then be formed over the n-type layer in any standard manner, such as by then passing the coated fibers through a further reaction chamber wherein p-type dopant is diffused into the top surface of the n-type layer that has been formed. The dopants alternatively could be added in the gas stream of SiF_4 or the p-layer formed by ion implantation. In this way, relatively inexpensive p-n junction devices are formed without the requirement of purifying, cutting and polishing a silicon slice in the standard manner.

3,969,746
Kendall, Don Leslie; Padovani, Francois Antoine; Bean, Kenneth Elwood; Matzen, Walter Theodore, inventors; Texas Instruments Incorporated, assignee. *Veritcal Multijunction Solar Cell*. July 13, 1976.

Disclosed is a method of fabricating a vertical multijunction cell and the solar cell produced thereby, utilizing an orientation dependent etch to selectively provide parallel grooves in monocrystalline silicon body, followed by the introduction of doping impurities of the opposite conductivity type from the silicon body to provide PN junctions. In some instances the grooves are filled with silicon of the same conductivity type as the silicon body.

3,971,454
Waterbury, Nelson J., inventor. *System for Generating Electrical Energy to Supply Power to Propel Vehicles*. July 27, 1976.

Solar radiant energy and high-intensity light are converted to electrical energy to supply electrical power for propelling vehicles in a safe, economical and efficient manner.

The radiant energy can be beamed from outer space by the use of satellites with collecting surfaces which can produce and store electrical power and which can distribute the electrical power to earth stations for redistribution to high-intensity light sources. High-intensity light-receiving cells or panels are fixed to the surface of a vehicle to collect the high-intensity light and to convert the light into useful electric power to operate the vehicle. Energy can be stored in batteries for subsequent use.

A vehicle can also be powered by hybrid means including solar cells and gas turbines.

3,971,672
Lampkin, Curtis M., inventor; D. H. Baldwin Company, assignee. *Light Diffuser for Photovoltaic Cell*. July 27, 1976.

A photovoltaic system in which strips of active photovoltaic cells are coated on one side of a sheet of glass, the glass being illuminated by the sun from the other side of the sheet and the strips being separated by inactive areas devoted to electrodes, in which light diffusing areas are provided on said other side of the sheet of glass in superposition of the inactive areas in order to refract sunlight which would otherwise fall wholly on the inactive areas, on large part to the active areas of the cells.

3,972,732
Hausler, Rudolf H., inventor; UOP Inc., assignee. *Electrochemical Cell*. August 3, 1976.

An electrochemical cell having a catalytic electrode which comprises a refractory oxide having a surface area of from 1 to 500 square meters per gram and a carbonaceous pyropolymer consisting of carbon and hydrogen forming at least a monolayer on said refractory oxide, said electrode having a conductivity at room temperature of from 10^0 to 10^2 inverse ohm-centimeters.

3,973,994
Redfield, David, inventor; RCA Corporation, assignee. *Solar Cell with Grooved Surface*. August 10, 1976.

A thin layer of active semiconductor material is on the flat surface of a transparent substrate. The opposite surface of the substrate is grooved, and is coated with a layer of reflective material. Light that passes through the active semiconductor material and is incident on the reflective layer is reflected back to the active layer at such an angle as to cause the light to be totally internally reflected at the surface of the active layer. The angle at which the light is reflected back to the active layer is determined by the angle of the surface of the grooves.

3,973,996
Kennedy, Paul B., inventor; The Boeing Company, assignee. *Diffusion Welded Solar Cell Array*. August 10, 1976.

A method of mounting and interconnecting solar cells to form a solar cell array particularly suited to space applications. In the present invention, the solar cells, which are already silver plated on the underside, are diffusion welded to a suitably plated polymide film substrate. The attachment area and current conductor patterns are provided in the plating on the substrate and electrical connection of the solar cells is accomplished by soldering or diffusion welding directly to the plated pattern on the substrate.

3,974,002
Casey, Horace Craig, Jr.; Cho, Alfred Yi; Panish, Morton, B., inventors; Bell Telephone Laboratories, Incorporated, assignee. *MBE Growth: Gettering Contaminants and Fabricating Heterostructure Junction Lasers*. August 10, 1976.

In the fabrication of double heterostructure GaAsAl-GaAs junction lasers by molecular beam epitaxy,it has been found that suitably annealing the entire heterostructure increases the external quantum efficiency of the laser and reduces the room temperature threshold for lasing. Also described is a technique using relatively uncollimated beams to deposit continuously on the interior walls of the vacuum chamber fresh layers which getter deleterious contaminants. In addition, pyrolytic boron nitride, rather than graphite, effusion cells are utilized in order to reduce the amount of CO formation in the system.

3,975,211
Shirland, Fred A., inventor; Westinghouse Electric Corporation, assignee. *Solar Cells and Method for Making Same*. August 17, 1976.

Solar cell elements are produced in accordance with the present invention in which a Cu_2S thin film is epitaxially formed on a CdS film by vacuum deposition in a heterojunction forming relationship. By a first method a Cu_2S layer on the order of 1/100 micron in thickness is formed on a CdS polycrystalline thin film by dipping in a solution of cuprous ions. The CdS film itself is less than 5 microns thick and rests on a conductive substrate. After the dipping step the Cu_2S film is increased to a thickness on the order of 1/10 micron by vapor evaporation of an additional amount of Cu_2S. By a second method both the CdS and Cu_2S are entirely vapor deposited on a substrate to achieve approximately the same final structure as the first method.

3,975,555
Ladany, Ivan; Limm, Albert Chang; O'Brien, James Thomas, inventors; RCA Corporation, assignee. *Method of Making Electrical Contacts Having a Low Optical Absorption*. August 17, 1976.

An electrical contact having low electrical resistance and low optical absorption is fabricated on a semiconductor electroluminescent article of III-V semiconductor material having a P-type region and an N-type region contiguous to each other, with a P-N junction therebetween. In the method of forming the contact, Zn is diffused into a surface of the P-type region opposite the PN junction. Then, a layer of gold is evaporated onto the Zn diffused surface while the device is at a temperature of approximately 400°C.

3,975,632
Glass, Alastair Malcolm; Von Der Linde, Dietrich, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Photovoltaic Generation and Device*. August 17, 1976.

Photovoltaic generation of voltages well above the bandgap results upon absorption of radiation by a dipolar dopant within a transparent polarized pyroelectric body. Generation is by a charge transfer mechanism in accordance with which electrons are transferred from excited absorbing species. A photovoltage of greater than a thousand volts has been observed in Fe^{2+}-doped $LiNbO_3$.

3,976,508
Mlavsky, Abraham I., inventor; Mobil Tyco Solar Energy Corporation, assignee. *Tubular Solar Cell Devices*. August 24, 1976.

Tubular solar cells are provided which can be coupled together in series and parallel arrays to form an integrated structure. Solar energy concentrators are combined with the solar cells to maximize their power output. The solar cells may be cooled by circulating a heat exchange fluid through the inerior of the solar cells and the heat captured by such fluid may be utilized, for example, to provide hot water for a heating system. The coolant circulating system of the solar cells also may be integrated with a solar

thermal device so as to form a two-stage heating system, whereby the coolant is preheated as it cools the solar cells and then is heated further by the solar thermal device.

3,977,904
Köhler, Franz, inventor; Messerschmitt-Bolkow-Blohm GmbH, assignee. *Semi-Conductor Battery*. August 31, 1976.

The battery is of the type including a plurality of laminar semiconductor bodies arranged on a dielectric support in parallel relation to each other and each comprising respectively layers of two different but oppositely conducting semi-conductor material forming a photovoltaic junction, with the layer adjacent the support being of the same conducting type in all of the semi-conductor bodies, and including contact strips electrically interconnecting oppositely conducting layers of adjacent semi-conductor bodies and extending throughout the length thereof. The support has one surface thereof formed with a plurality of V-shape notches extending parallel to each other and separated by lands, and the semiconductor bodies are applied directly to the lands. The contact strips extend in the notches between two adjacent lands and are, along the edge of one land, in electrical contact with the inner layer of the respective semi-conductor body on the one land and which is directly adjacent the support. Along the other edge, each contact strip is in electrical contact with the outer layer of the respective semiconductor body on the other land and which is remote from the support. The support is preferably flexible and the opposite surface of the support is divided into individual, juxtaposed cylindrical segments with each land being associated with a single respective segment. The outer layer of each semiconductor body is covered with a layer of contact material electrically connected to that contact strip which is electrically connected to the outer layer, and the notched surface is covered with an electrically insulating protective layer which preferably is elastic.

3,977,905
Revesz, Akos G.; Lindmayer, Joseph, inventors; Communications Satellite Corporation, assignee. *Solar Cell with Niobium Pentoxide Anti-Reflective Coating*. August 31, 1976.

A niobium pentoxide (Nb_2O_5) anti-reflective coating for use on a solar cell responsive to light in the short wavelength region.

3,977,934
Lesk, Arnold, inventor; Motorola, Inc., assignee. *Silicon Manufacture*. August 31, 1976.

A method of producing monocrystalline semiconductor material in web form from a source of polycrystalline semiconductor material. The source material is heated to form a molten zone on the end thereof, which is contacted by a thermal profile shaping member formed from the same type of semiconductor material as the semiconductor material to be produced. A monocrystalline seed crystal of the shape of the web desired then contacts the molten end of the source material near the shaping member and is withdrawn therefrom as monocrystalline semiconductor material forms on the end thereof.

3,978,333
Crisman, Everett; Armitage, William F., Jr., inventors. *Photovoltaic Device Having Polycrystalline Base*. August 31, 1976.

A photovoltaic device comprising a polycrystalline base having an electrically conductive grid affixed to the surface of the device to which illumination is to be applied, said grid effecting a rectifying junction with the base and at the same time functioning as a current carrying contact, said grid being arranged so that substantially all of the individual crystallites are contacted at least once thereby, while at the same time maintaining the coverage of the base by said grid to a minimum.

3,978,510
Kasper, Horst Manfred; Migliorato, Piero; Shay, Joseph Leo; Wagner, Sigurd, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Heterojunction Photovoltaic Devices Employing I-III-VI Compounds*. August 31, 1976.

Photovoltaic devices are constructed from a principal body of copper indium selenide ($CuInSe_2$) upon which is deposited a hetero-epitaxial layer of a high bandgap semiconductor, such as an n-type layer of cadmium sulfide (CdS). When made with a high-resistance intermediate region, the device is a photovoltaic detector for modulated radiation and has a response time as low as 5 nsec for a reverse bias of approximaely two to three volts. When made without a high-resistance intermediate region (e.g., an abrupt p-n heterojunction) the device is a useful solar cell. In these forms of the device, absolute photovoltaic detector for modulated radiation and has a response time as low as 5 nsec for a reverse bias of approximaely two to three volts. When made without a high-resistance intermediate region (e.g., an abrupt p-n heterojunction) the device is a useful solar cell. In these forms of the device, absolute photovoltaic quantum efficiencies up to 70 percent have been observed. The quantum efficiency of the solar cell type of device is reasonably flat between 0.55 and 1.25 μm. With forward bias, the device is a light-emitting diode with external electroluminescent quantum efficiency of 1×10^{-4} at room temperature and 1×10^{-2} at 77° K, liquid nitrogen temperature.

3,979,656
Takeda, Shuji; Otake, Tsutomu, inventors; Kabushiki Kaisha Suwa Seikosha, assignee. *Battery Charging Circuit*. September 7, 1976.

A battery charging circuit for effecting efficient charging of a battery by a solar energy source is provided. A voltage detecting circuit is coupled in parallel with a battery for detecting each state of charge of same, the detecting circuit including a constant voltage element. Transistor by-pass circuitry includes first and second current path electrodes connected in parallel with the battery. The transistor by-pass circuitry further includes a third control electrode coupled to the detecting circuit, and in response to the state of charging of the battery detected thereby, respectively effects one of an increase and decrease in the current carried by said current path electrodes.

3,980,915
Chapman, Richard A.; Johnson, Mile R.; Morris, Henry B., inventors; Texas Instruments Incorporated, assignee. *Metal-Semiconductor Diode Infrared Detector Having Semi-Transparent Electrode*. September 14, 1976.

This disclosure is directed to a photovoltaic detector having specific response to the infrared range, wherein the detector comprises a metal-semiconductor diode having a semi-transparent electrode and disposed on a specially prepared substrate of a narrow band gap semiconductor material or on an epitaxial layer or evaporated film of such material provided on a substrate. In a specific example, the narrow band gap semiconductor material of the substrate is specially prepared (Pb,Sn)Te or an epitaxial layer or evaporated film of (Pb,Sn)Te on a (Pb,Sn)Te substrate. The detected radiation is transmitted through the semitransparent electrode on top of the photovoltaic detector.

3,982,260
Wald, Fritz, inventor; Mobil Tyco Solar Energy Corporation, assignee. *Light Sensitive Electronic Devices*. September 21, 1976.

The invention provides light sensitive electronic devices wherein cadmium telluride films are supported on iron substrates.

3,982,265
Johnston, Wilbur Dexter, Jr., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Devices Containing Aluminum-V Semiconductor and Method for Making*. September 21, 1976.

A high efficiency solar cell having n-type aluminum arsenide grown on a p-type gallium arsenide substrate and protected by a layer of anodic oxide. The aluminum arsenide is deposited by vapor

phase epitaxy by reacting high purity arsine, hydrogen chloride and aluminum at approximately 1000° C in an all-alumina reactor tube system. The aluminum arsenide layer is protected from deterioration by first anodizing it in pure water and phosphoric acid at pH 2.0 with a current density of 2-8 milliamperes per square centimeter at room temperature. Second, the anodic oxide so formed is annealed at about 450°C for at least twenty minutes in dry nitrogen. The oxide layer also acts as an antireflective coating. A portion of the oxide layer is etched away to expose a region of the aluminum arsenide to which an electrical contact is applied. The other contact is made to the substrate.

3,982,963
Mahoney, Edmund J.; Natanson, Paul S., inventors; Solar Power Corporation, assignee. *Solar Battery Maintainer*. September 28, 1976.

A device for converting sunlight into electrical energy which can be used to maintain a charge in a battery includes at least one translucent panel having a plurality of individual electrically connected solar cells mounted therein. The translucent panel is mounted in a frame which can support the panel on a mounting surface. This frame includes a peripheral support wall and a panel support surface extending therebetween. The peripheral support wall has an upper edge and the support surface is located at a level below the upper edge of the peripheral wall thereby to support the panel within the confines of the wall.

3,982,964
Lindmayer, Joseph; Allison, James Frederick, inventors; Communications Satellite Corporation, assignee. *Dotted Contact Fine Geometry Solar Cell*. September 28, 1976.

An improvement in a fine geometry solar cell having a top surface contact comprising substantially more and finer metallic fingers spaced close together for collecting photo current is disclosed. The improvement comprises a reduction in the ohmic contact area of the fine metallic fingers with the light-incident surface of the solar cell. The improved solar cell is constructed by etching a fine line pattern into the anti-reflective coating of the solar cell and then depositing a fine line electrode onto the surface of the solar cell but oriented perpendicular to the etched fine line pattern in the anti-reflective coating. Due to the 90° rotation between the etched fine line pattern in the anti-reflective coating and the fine line electrode, only point contacts are made between the fine line electrode and the exposed light-incident surface of the solar cell.

3,984,256
Fletcher, James C., inventor. *Photovoltaic Cell Array*. October 5, 1976.

A photovoltaic cell array consisting of parallel columns of silicon filaments, each being doped to produce an inner region of one polarity type and an outer region of an opposite polarity type to thereby form a continuous radial semi-conductor junction. Spaced rows of electrical contacts alternately connect to the inner and outer regions to provide a plurality of electrical outputs which may be combined in parallel or in series.

3,985,579
Rahilly, William P., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Rib and Channel Vertical Multijunction Solar Cell*. October 12, 1976.

A vertical multijunction solar cell fabricated with the junction channels perpendicular to a ribbed electrical grid structure provides an improved vertical multijunction solar cell having increased mechanical strength and decreased electrical resistance.

3,988,166
Beam, Benjamin H., inventor; Beam Engineering, Inc., assignee. *Apparatus for Enhancing the Output of Photovoltaic Solar Cells*. October 26, 1976.

An array of photovoltaic cells and a parabolic concentrator for concentrating solar energy onto the cells. A watertight chamber including a solar energy pervious window adjacent the focus of the parabolic concentrator. The solar cell array is disposed within the chamber in alignment with the window. A quantity of water is disposed in the chamber, the quantity being sufficient to absorb heat energy so as to limit the temperature rise of the solar cell array during periods of solar energy impingement thereon. The watertight chamber has sufficient external surface area that the heat energy stored therein is transferred away during non-solar energy producing periods of the diurnal cycle.

3,988,167
Kressel, Henry; Dalal, Vikram L., inventors; RCA Corporation, assignee. *Solar Cell Device Having Improved Efficiency*. October 26, 1976.

A body of semiconductor material in a solar cell device has a means for collecting electron-hole pairs with an incident surface through which solar radiation enters. The collecting means can be a P-N junction between two regions of opposite conductivity of the semiconductor body, or a partially transparent metallic film on the semiconductor body providing a metal to semiconductor material surface barrier rectifying junction. On a surface opposite the incident surface of the collecting means is a non-continuous oxide layer. The oxide layer is non-continuous because of openings extending through the oxide layer to the opposite surface. The openings are distributed across the opposite surface. In the openings at the opposite surface and on the oxide layer is a reflecting contact which functions both as an electrical contact and as a reflector to solar radiation in the semiconductor body.

3,988,172
Bachmann, Klaus Jurgen; Buehler, Ernest; Shay, Joseph Leo; Wagner, Sigurd, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Annealing Solar Cells of InP/CdS*. October 26, 1976.

Solar cells showing improved efficiency, amounting to about 14 percent for overall solar power conversion, are obtained by annealing InP/CdS solar cells in a slightly reducing atmosphere for about 15 minutes in a temperature range preferably from about 550°C to about 600°C. In an annealing temperature range from 400°C to 625°C an inversely dependent adjustment of annealing time is found desirable. The atmosphere preferably comprises mainly a substantially inert component and typically comprises an $H_2 + N_2$ mixture, such as forming gas (15% H_2 + 85% N_2).

3,989,541
Brandhorst, Henry W., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Assembly*. November 2, 1976.

An improved solar cell assembly is provided for use under high intensity illumination conditions where heat is a problem.

The solar cell assembly includes a solar cell having an overlay of a semi-transparent coating of a metal, such as aluminum or silver, which covers the entire surface thereof. The purpose of the coating is to lower the amount of incident radiation on the cell and thereby lower cell temperature. The use of the semi-transparent coating over the entire cell surface uniformly limits incident radiation and hence reduces cell heat without any temperature gradients. The coating also lowers series cell resistance. The coating may be directly deposited on the cell surface or on the undersurface of a cover plate bonded to the cell.

3,990,097
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Silicon Solar Energy Cell Having Improved Back Contact and Method Forming Same*. November 2, 1976.

A silicon solar energy cell having a diffusant junction extending inwardly from one surface, an aluminum-silicon junction of the opposite polarity extending inwardly from the other surface, and a film of aluminum-oxygen-diffusant formed over the aluminum-silicon junction. The structure is formed by diffusing an unprotected wafer, coating the diffusant glass so formed on one side of the wafer with aluminum, and heating the wafer.

3,990,100
Mamine, Takayoshi; Matsushita, Takeshi, inventors; Sony Corporation, assignee. *Semiconductor Device Having an Antireflective Coating*. November 2, 1976.

A polycrystalline silicon layer provides an antireflective coating on a semiconductor surface of a photosensitive detector, the polycrystalline silicon layer containing from 25 to 45 atomic percent of oxygen and having a refractive index intermediate that of the semiconductor crystal and the exterior environment.

3,990,101
Ettenberg, Michael; Kressel, Henry, inventors; RCA Corporation, assignee. *Solar Cell Device Having Two Heterojunctions*. November 2, 1976.

A body of semiconductor material of a solar cell device has a surface, a portion of which is exposed to incident solar radiation, and a surface opposite the incident surface. At the incident surface and in the body is a first region having a bandgap energy greater than 2.1 eV and thus is substantially transparent to solar radiation. Spaced from the first region and at the opposite surface is a second region which is of a material having a bandgap energy in the range of 1.5 eV to 1.9 eV. Between and in contact with both first and second regions is a third region of a material having a bandgap energy less than either the first or second regions. The third region is the most active region of the device,and the second region is substantially transparent to solar radiation not absorbed by the third region. The junction between the third region and each of the first and second regions are heterojunctions. On the opposite surface of the body is an electrode capable of reflecting back into the body of the device solar radiation passing through the second region which was not absorbed by the active region.

3,990,914
Weinstein, Harold; Lee, Ray H., inventors; Sensor Technology, Inc., assignee. *Tubular Solar Cell*. November 9, 1976.

High efficiency, low cost solar energy conversion is facilitated by using tubular photovoltaic solar cells situated at the focus of a line-generated paraboloidal reflector. Advantageously, each solar cell comprises a pair of concentric glass tubes that are hermetically sealed at the ends. A photovoltaic junction is formed over the entire inside surface of one of the concentric tubes. For example, this may comprise an inner electrically conductive film, contiguous layers of Cu_2S and CdS forming a heterojunction, and an outer film of optically transparent but electrically conductive material. The conductive films provide electrical connection to the junction via external contacts that are symmetrically disposed at the ends of the tubular cell. In other embodiments the photovoltaic junction is formed in a crystalline silicon layer that is grown in situ on one of the glass tubes. Techniques for promoting oriented semiconductor crystalline growth are disclosed. These include providing minute crystalline islands in a metal matrix to serve as growth centers, surface alignment using a wavy layer deposited at an acute angle onto the glass substrate,surface seeding and normalization growth atop a fluid-like thin film deposition substrate.

3,991,741
Northrup, Leonard L., Jr.; O'Neill, Mark J., inventors. *Roof-Lens Solar Collector*. November 16, 1976.

An array of linear lenses is used as a combination roof-skylight-solar collector. The lenses are oriented at a given latitude to face the most remote of the earth's poles inclined by the local latitude angle. Moving absorbers are used to receive the sunlight at the focal spot of each lens. The absorbers move back and forth during the day as the sun's position changes, causing the focal spots to move.

3,992,233
Farrow, Robin Frederick Charles, inventor; The Secretary of State for Defence in Her Britannic Majesty's Government of the United Kingdom of Great Britain and Northern Ireland, assignee. *Surface Treatment of III-V Compound Crystals*. November 16, 1976.

Group III-V compound substrates are heat cleaned under vacuum conditions by heating above their congruent temperature and subjecting the substrate to at least one molecular beam of the material preferentially evaporating from the substrate thereby maintaining surface stoichiometry. Surfaces so cleaned may then have an epitaxial layer grown thereon under similar conditions from molecular beams. Alternatively the cleaned surface may be coated with cesium and oxygen to form a photocathode.

3,993,505
Pack, George J., Sr., inventor; Hughes Aircraft Company, assignee. *Interconnector for Components such as Solar Cells or the Like*. November 23, 1976.

A thin conductive sheet having elongated openings extending inward from the edges to define a connecting arm extending from one end of one connecting surface to the diagonally opposite end of a second connecting surface. In one embodiment, the connecting arm extends directly from one corner to the diagonally opposite corner. In a second embodiment, the connecting arm changes direction to define a generally Z-shaped, reverse diagonal connecting path. Ties are provided across the elongated openings to hold the interconnector together during assembly, but which later break to permit the elongated openings to open up to define the connecting arm. One or more slits may be provided in the connecting arm to reduce buckling out of plane. The interconnector may be chrome plated in the central area to keep solder from flowing into the elongated openings and slits. To minimize the stress transition from the plated to the unplated portion, the plating terminates in a sine-wave-like wavy line which is 180° out of phase with the corresponding wavy line on the reverse side.

3,993,506
Moon, Ronald L., inventor; Varian Associates, assignee. *Photovoltaic Cell Employing Lattice Matched Quaternary Passivating Layer*. November 23, 1976.

A photovoltaic cell has an active portion comprising at least one active layer of a IIIA-VA compound having a p-n junction adjacent an upper surface thereof and an overlying epitaxially grown passivating layer of the quaternary alloy AlGaAsP. The passivating layer has a substantially higher bandgap than the active layer so that it is transparent to photons to which the active layer is sensitive. The lattice constant of this passivating layer can be made the same as that of the active layer, thereby to improve efficiency and device performance by reducing surface recombinations of generated carriers, such that a greater percentage of generated carriers will reach the p-n junction and provide useful output electrical energy. The active portion comprises a GaAs layer covered by an AlGaAsP passivating layer, and the AlGaAsP passivating layer can be lattice matched to the GaAs layer.

3,993,533
Milnes, Arthur G.; Feucht, Donald L., inventors; Carnegie-Mellon University, assignee. *Method for Making Semiconductors for Solar Cells*. November 23, 1976.

The invention relates to a method for producing a desired thin semiconductor film for use in solar cells. The desired semiconductor is grown epitaxially on a second semiconductor film which may be epitaxial on a third semiconductor. The second semiconductor has a lower melting point than the desired semiconductor. The temperature of the second semiconductor is increased. This creates a molten state in the second semiconductor and the desired semiconductor is stripped away from the second semiconductor. The desired film may be detached by dissolving the second semiconductor with a chemical agent that dissolves the second semiconductor.

3,994,012
Warner, Raymond M., Jr., inventor; The Regents of the University of Minnesota, assignee. *Photovoltaic Semi-Conductor Devices*. November 23, 1976.

Apparatus and method for constructing by means of standard high-yield microelectronic batch fabrication processes, reliable, monolithic high-voltage photovoltaic cells and highly efficient photovoltaic arrays therewith. A thin layer of single-crystalline semiconductor material containing a plurality of sublayers defining one or more active junctions in planes parallel to an upper irradiated surface thereof, overlies a supportive insulating substrate body. Widely spaced pairs of elongate heavily doped zones of opposite conductivity types produced by two short diffusion steps extend into the thin layer, defining photovoltaic cells therebetween and providing low-impedance conductive paths for photovoltaic carriers generated in the thin layer to the upper irradiated surface. By overlapping opposite-conductivity pairs of the heavily doped elongate zones, simultaneous dielectric isolation and series connection of adjacent cells is achieved. The elongate zones of individual cells can be interdigitated to decrease parasitic series resistance of the cells. A dielectric barrier interposed between adjacent cells can also be used to isolate the cells from one another. Means for creating an inversion layer at the irradiated surface, reflective means for causing multiple passes of received solar energy through the photovoltaic devices and use of an underlying junction formed by heavily and lightly doped regions of the same conductivity type can readily be employed to further increase cell efficiency.

3,996,067
Broder, Jacob D., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Silicon Nitride Coated, Plastic Covered Solar Cell*. December 7, 1976.

A non-oxide anti-reflective coating is used with a transparent plastic cover of fluorinated ethylene propylene copolymer on a silicon solar cell to increase the resistance to damage caused by electron bombardment.

3,998,659
Wakefield, Gene Felix, inventor; Texas Instruments Incorporated, assignee. *Solar Cell with Semiconductor Particles and Method of Fabrication*. December 21, 1976.

Generally spherical shaped semiconductor particles comprising an inner core of one conductivity type and a thin peripheral layer of opposite conductivity type are produced in a fluidized bed reactor. Silicon particles introduced into the reactor are built up to a desired nominal diameter by vapor deposition from a silicon and dopant containing atmosphere introduced into the reactor; by changing the dopant constituent, the outer peripheral layer is then deposited. One use of such particles is in fabrication of a solar cell, wherein an array of the particles is located on an insulating sheet and overlying conductive layers, insulated from each other, make contact respectively with the peripheral layers and with areas of the core regions, exposed by etching. The particles also may be used to fabricate semiconductor devices, e.g., by use of orientation dependent etches to define flat surfaces on the particles parallel to specific crystallographic planes. Use of other semiconductor materials, e.g., germanium and cadmium sulfide also is described.

3,999,283
Dean, Raymond H.; Napoli, Louis S.; Liu, Shing-Gong, inventors; RCA Corporation, assignee. *Method of Fabricating a Photovoltaic Device*. December 28, 1976.

Solar radiation is concentrated on a solar cell of a photovoltaic device in the range of 500 to 1600 suns. The photovoltaic device includes a plurality of solar cells on a flat surface of a heat sink, and means for concentrating solar radiation on the solar cells. The solar cells have a surface on which the solar light is incident. This high concentration of solar energy on the solar cell will increase the solar cell operating temperature. The dimensions of the solar cells and the center to center spacing between solar cells is such that good thermal dissipation is maintained in the photovoltaic device.

4,000,505
Epstein, Arnold S.; Share, Stewart, inventors; The United States of America as represented by the Secretary of the Army, assignee. *Thin Oxide MOS Solar Cells*. December 28, 1976.

A semiconductor device comprising a first layer of semiconductor material havng a bulk region of p-type conductivity and an inversion surface of n-type conductivity which forms a p-n junction with said bulk region, a covering layer on said inversion surface of oxides of silicon in a thickness of about 20-50 angstroms, and metallic contacts placed over said oxide layer.

1977

Des. 245,330
Salles, Yvon, inventor; U.S. Philips Corporation, assignee. *Solar Cell Panel*. August 9, 1977.

The ornamental design for a solar cell panel, as shown.

4,001,863
Kobayashi, Yoshinori; Shibata, Yoshitaka; Hasegawa, Akira; Iwatsuki, Yoshiharu, inventors; Minolta Camera Kabushiki Kaisha, assignee. *Resin-Sealed Type Semiconductor Device*. January 4, 1977.

A semiconductor device highly resistant to the normal ambient atmosphere includes a semiconductor element such as a photoconductor element which is fully covered by an adherent layer of a transparent epoxy resin which in turn is coated by a thin layer or film of a transparent chlorinated polypropylene or vinylidene chloride resin. Conductor leads extend from electrodes on the semiconductor element and pass through and are hermetically sealed to the resin layers.

4,001,864
Gibbons, James F., inventor. *Semiconductor P-N Junction Solar Cell and Method of Manufacture*. January 4, 1977.

There is described efficient semiconductor p-n junction solar cells which can be made from defect-rich semiconductor material. The solar cells include an extended electric field surrounding the p-n junction for extracting the photo-generated carriers in the presence of defects which would otherwise reduce the efficiency of the cell. There is also described a method of fabricating efficient semiconductor p-n junction solar cells.

4,002,031
Bell, Ronald L., inventor; Varian Associates, Inc., assignee. *Solar Energy Converter with Waste Heat Engine*. January 11, 1977.

A solar energy converter uses gallium arsenide photovoltaic cells to convert light to direct current. Optical concentrators reduce the needed area of cells. Galluim arsenide retains high conversion efficiency up to several hundred degrees, so the waste heat may be used to produce mechanical power in a Rankine cycle engine.

4,002,499
Winston, Roland, inventor; The United States of America as represented by the United States Energy Research and Development Administration, assignee. *Radiant Energy Collector*. January 11, 1977.

An electromagnetic energy collection device is provided which does not require a solar tracking capability. It includes an energy receiver positioned between two side walls which reflect substantially all incident energy received over a predetermined included angle directly onto the energy receiver.

4,003,756
Abrams, Eugene, inventor; Solar Dynamics Corporation, assignee. *Device for Converting Sunlight into Electricity*. January 18, 1977.

An arrangement practical by its efficiency and cost of materials, for converting sunlight into electricity using silicon solar cells. The cells are disposed in facing relation such that sunlight in concentrated form, as provided by a cooperating sunlight-gathering lens, impinges thereon and also is inter-reflected between the cells, so that the electrical output is significantly enhanced.

4,003,770
Janowiecki, Richard J.; Willson, Michael C.; Harris, Douglas H., inventors; Monsanto Research Corporation, assignee. *Plasma Spraying Process for Preparing Polycrystalline Solar Cells*. January 18, 1977.

Polycrystalline silicon films useful in preparing solar cells primarily for terrestrial application are prepared by a plasma spraying process. A doped silicon powder is injected into a high temperature ionized gas (plasma) to become molten and to be sprayed onto a low-cost substrate. Upon cooling, a dense polycrystalline silicon film is obtained. A p-n junction is formed on the sprayed film by spray deposition, diffusion or ion implantation. A sprayed junction is produced by plasma spraying a thin layer of silicon of opposite polarity or type over the initially deposited doped film. In forming a diffused junction, dopant is applied over the surface of the initial plasma-sprayed film usually from the vapor phase and heat is used to cause the dopant to diffuse into the film to form a shallow layer of opposite polarity to that in the original film. A junction is also formed by implanting dopant ions in the surface of the originally deposited film by the use of electrical fields. When used in conjunction with ohmic contacts and electrical conductors, the p-n junctions produced using plasma-sprayed polycrystalline silicon films are formed into solar cells which are useful for directly converting sunlight into electricity by means of the photovoltaic effect.

4,004,342
Park, Yoon Soo; Yu, Phil Won, inventors; The United States of America as represented by the Secretary of the Air Force, assignee. *Fabrication of Ion Implanted P-N Junction Devices*. January 25, 1977.

Light emitters and photovoltaic detectors are fabricated by ion implantation of cadmium, zinc, bromine or chlorine ions into a p-type $CuInSe_2$ substrate so as to form a p-n semiconductor junction.

4,004,949
Lesk, Israel Arnold, inventor; Motorola, Inc., assignee. *Method of Making Silicon Solar Cells*. January 25, 1977.

Solar cells having rounded edges are provided by ion implantation of a semiconductor body having rounded edges. Individual cells can be fabricated or a continuous ribbon of semiconductor material, the ribbon having rounded edges, can be subjected to ion implantation at its surfaces and scribed to provide discrete cells.

4,005,468
Tanimura, Shigeru; Miura, Nobuaki; Miyamoto, Mikizo, inventors; Omron Tateisi Electronics Co., assignee. *Semiconductor Photoelectric Device with Plural Tin Oxide Heterojunctions and Common Electrical Connection*. January 25, 1977.

A semiconductor photoelectric device of improved photoelectric and rectifying characteristics is provided by first forming a film of electrically insulating material such as silicon dioxide of a substantial thickness on a main surface of a semiconductor substrate so as to have a plurality of portions of said main surface exposed through a corresponding plurality of square or rectangle openings laid out at right angles, said openings being defined by said insulating material film, depositing a tin oxide film on the open areas of the semiconductor substrate, removing a portion of said tin oxide film just overlying the said insulating film for separating the respective barrier regions formed between the tin oxide film and the substrate, and providing a metal layer on said insulating film for connecting the end portion of the tin oxide film of the adjacent barrier regions. The resultant photoelectric device, even if a total light receiving area is increased, shows an improved photoelectric characteristic at low and high illumination.

4,006,583
Vuilleumier, Raymond, inventor; Centre Electronique Horloger S. A., assignee. *Electronic Display Device for Timepiece and the Like*. February 8, 1977.

Disclosed is a light emitting diode display system powered by ambient light. This solid state electronic display device comprises an ambient irradiated photovoltaic battery energizing through an electronic adapter circuit light emitting diodes selectively chosen to display the desired information. The adapter circuit transforms the electrical power continuously supplied by the photovoltaic battery into energy pulses which are periodically applied to the display. In addition, the adapter circuit automatically adjusts the display brightness in accordance with the ambient illumination level. At low and zero light levels, the electronic display device maintains a visible display by deriving power from a secondary energy source.

4,009,051
Kazis, Earle W.; Mark, Robert; Wetherell, Thomas J., inventors; General Solar Power Corporation, assignee. *Solar Power Pack Apparatus*. February 22, 1977.

Solar power pack apparatus adaptable for powering emergency equipment at remote locations includes a solar cell array, a rechargeable battery pack, a long shelf-life primary battery pack and switching circuitry interconnecting these elements to provide upon demand immediate and continuous supply of electrical power over extended periods of time notwithstanding environmental conditions which would render unsuitable conventional emergency-use reserve power packs.

4,009,054
Gochermann, Hans; Rüsch, Dieter, inventors; Licentia Patentverwaltungs-GmbH, assignee. *Terrestrial Solar Cell Generator*. February 22, 1977.

A terrestrial solar cell generator including a plurality of solar cells mounted in a housing and interconnected by a plurality of leads with the solar cells being protected against adverse environmental conditions. The housing is entirely formed of the same radiation resistant material and encloses the solar cells and the connecting leads on all sides.

4,009,535
Stock, William, inventor. *Illuminated House Number Sign*. March 1, 1977.

A self contained house number sign which charges an internal battery from photovoltaic cells during daylight. The battery is connected to a lamp via a phototransistor for energizing the lamp at night. The lamp edge lights a plastic template having cutout house number indicia.

4,011,149
Nozik, Arthur Jack, inventor; Allied Chemical Corporation, assignee. *Photoelectrolysis of Water by Solar Radiation*. March 8, 1977.

Photoelectrolysis of water by solar radiation to produce hydrogen is achieved using semiconducting thin film electrodes. The cell comprises (a) an electrode comprising at least one thin film semiconducting layer disposed on a substrate, each layer having a bandgap which ranges from about 1.3 to 4.0 eV; (b) a counter electrode; (c) an electrolyte disposed between the thin film semiconducting electrode and the counter-electrode; (d) external bias means between the electrode for biasing the electrode with from 0 to about 1 V; and (e) means for collecting hydrogen produced.

4,011,578
Bollen, Lambertus Jacobus Maria; Damen, Cornelus Petrus Theodorus Maria, inventors; U.S. Philips Corporation, assignee. *Photodiode*. March 8, 1977.

The invention relates to a photodiode having a semiconductor body comprising regions of opposite conductivity types which are separated by a p-n junction and of which at least one region has an anti-reflective layer. The anti-reflective layer consists of tin-doped indium oxide and forms an ohmic connection with the one region.

4,015,117
Wicklund, Joseph B., Jr., inventor; Opcon, Inc., assignee. *Unbiased Modulated Photo Sensing Systems*. March 29, 1977.

The outputs of one or more interconnected, unbiased photovoltaic devices mounted to receive light generated by one or more modulated light sources are connected via a long cable to the input of a balanced low impedance differential input line preamplifier. When multiple photovoltaic devices are included, their outputs can be directly interconnected and the thusly combined output will provide information about the intensity of light impinging on their photo conductive surfaces. The balanced low impedance differential input line preamplifier comprises a differential amplifier and a pair of common base input stages, one connected to each input of the differential amplifier. In a DC decoupling embodiment, capacitors are used to couple the common base input stages to the differential amplifier. The output of the balanced low impedance differential input line preamplifier is connected to a detector that provides an output indicative of the state of the output of the photovoltaic devices.

4,015,280
Matsushita, Takeshi; Mamine, Takayoshi, inventors; Sony Corporation, assignee. *Multi-Layer Semiconductor Photovoltaic Device*. March 29, 1977.

A semiconductor photovoltaic device is comprised of 2n layers of alternating p-type and n-type material having respective PN junctions between adjacent layers, wherein n is an integer greater than 1. Each layer has a thickness which is less than the diffusion length of a minority carrier therein. The PN junctions are excited by light which is incident on the device to thereby cause majority carriers to be accumulated in the respective layers so as to forward bias all of the PN junctions. As a result of this forward biasing, minority carriers are injected across a first PN junction from one layer into an adjacent layer and then traverse the next PN junction into the next succeeding layer. The photovoltaic device thus is adapted to supply a voltage and a current to a load.

4,016,586
Anderson, Richard L.; Clifton, Jack K.; Masi, James V.; Merrin, Seymour, inventors; Innotech Corporation, assignee. *Photovoltaic Heterojunction Device Employing a Wide Bandgap Material as an Active Layer*. April 5, 1977.

A semiconductive heterojunction device particularly useful as a photovoltaic device such as a solar cell comprises a heterojunction formed between a first layer of semiconductor material exhibiting one type of electronic conductivity (N or P) and a second layer of a compositionally different material exhibiting the other type of electronic conductivity (P or N), which second layer has an energy bandgap relatively wider than that of the semiconductor material and an electron affinity less than or equal to the electron affinity of the semiconductor. Preferably, the wider bandgap material is a glassy amorphous material which possesses or is doped to possess a low resistivity below about 10^7 ohm-cm. In devices employing N-type wider bandgap layers, the conduction band energy level of the wider bandgap material is preferably at substantially the same energy level as the conduction band energy level of the narrower bandgap material at electrical neutrality. In devices employing P-type wider bandgap layers, the valence band energy level of the wider bandgap material is preferably at substantially the same energy level as the valence band energy level of the narrower bandgap material.

4,016,589
Tanimura, Shigeru; Miura, Nobuaki; Asano, Osamu, inventors; Omron Tateisi Electronics Co., Ltd., assignee. *Semiconductor Device*. April 5, 1977.

A semiconductor composite having a rectifying characteristic is provided by first forming an insulating film of a semiconductor compound such as SiO_2 on a semiconductor substrate of N-type Si to a uniform thickness of 27Å to 500Å, for example, and then further depositing thereon a tin oxide film. The intermediate insulating film between the SnO_2 film and the semiconductor substrate decreases the reverse leakage current, raises the reverse breakdown voltage and makes uniform the reverse breakdown voltage. The semiconductor composite of the present invention, as subjected to a predetermined value of light energy, shows an excellent switching characteristic with respect to a voltage applied to the composite in a reverse direction. Also the semiconductor composite of the present invention, as supplied with a certain value of reverse bias voltage or with no bias, shows an excellent switching characteristic with respect to light energy applied to the composite.

4,017,332
James, Lawrence W., inventor; Varian Associates, assignee. *Solar Cells Employing Stacked Opposite Conductivity Layers*. April 12, 1977.

A cell for converting received light energy to electrical energy comprises, in the simplest embodiment, four layers of differing types of semiconductive material stacked so as to form three opposite conductivity junctions. The outer two, "active", junctions are formed of confronting layers with matched lattice constants so as to provide a plurality of energy converters. The center, "connective", junction is formed by two confronting intermediate layers which have purposely mismatched lattice constants so as to provide a lattice defect site surrounding the center junction. Majority carriers (electrons and holes) will recombine at the lattice defects. This will cause the connective junction, although of apparently reverse-biased opposite conductivity type layers, to act as a low resistance ohmic connection or substantial short circuit so as to connect the energy converting portions in series. Due to the stacked arrangement of junctions in which the layers forming the active junctions have increasingly lower bandgaps toward the bottom of the stack, incident photons are converted to electrical energy with far greater efficiency than in a single-junction arrangement. Preferably the stacked layers are formed of

suitably-doped epitaxially-grown layers of compounds of III-V elements (Ga, In, Al, As, P, Sb). The number of active junctions is preferably made greater than two, e.g., six is currently regarded as a practical maximum. Low resistance interconnections between the energy converting portions formed by active junctions are provided by connective junctions which are formed of lattice constant mismatched and opposite conductivity confronting layers.

4,017,725
Roen, Stephen A., inventor; Litton Business Systems, Inc., assignee. *Solar Powered Portable Calculator*. April 12, 1977.

A portable calculator utilizing a solar panel array which can be either slidably moved within the calculator's housing or pivotally connected to it and which when exposed to incident light provide power for the calculator.

4,018,626
Schwuttke, Guenter H.; Yang, Kuei-Hsiung, inventors; International Business Machines Corporation, assignee. *Impact Sound Stressing for Semiconductor Devices*. April 19, 1977.

Methods of making semiconductor devices using the technique of impact sound stressing are disclosed. Impact sound stressing (ISS) is a mechanical acoustical technique to damage, in a known and controlled manner, semiconductor wafers. Wafers are subjected to ISS on the backsides before semiconductor processing steps. The application of ISS before the first high temperature application will control the generation and subsequent direction of flow (gradient) of vacancies (interstitials) generated through all device high temperature processing steps including ion implantation. ISS redirects the flow of vacancies/interstitials into the backside away from the device area of the wafer. Thus, the device area is swept clean in a gettering action of vacancy/interstitials and their complexes which are detrimental to device performance. The technique of impact sound stressing finds application in improving the performance of all semiconductor devices, specifically dynamic memories, bipolars, solar cells and power devices.

4,019,884
Elmer, Thomas H.; Walters, Helen, inventors; Corning Glass Works, assignee. *Method for Providing Porous Broad-Band Antireflective Surface Layers on Chemically-Durable Borosilicate Glasses*. April 26, 1977.

A method for providing broad-band antireflective surface layers on a chemically durable borosilicate glass which comprises phase-separating the glass by heat treatment at 630°—660°C, removing a siliceous surface layer from the glass, and treating the glass in an aqueous solution containing both H^+ ions and F^- ions for a time sufficient to produce the antireflective surface layer, is described. Antireflective surface layers exhibiting reflectances as low as 0.5% throughout the wavelength range from about 0.4-2.0 microns have been produced.

4,019,924
Kurth, William T., inventor; Mobil Tyco Solar Energy Corporation, assignee. *Solar Cell Mounting and Interconnecting Assembly*. April 26, 1977.

A solar cell assembly comprises a plurality of solar cells mounted on a laminate comprising a base electrically-insulative sheet, an electrically-conductive layer disposed on the base sheet in a predetermined pattern so as to provide first and second cell-connecting sections electrically insulated from one another, and a second electrically-insulative sheet having a plurality of openings and being disposed over the conductive layer so that selected portions of the conductive layer are exposed through the openings. The laminate is provided with a plurality of bent tabs, each of which includes an exposed portion of the first cell-connecting section so that the exposed portion can be attached to the top surface electrode of a solar cell. At least one exposed portion of a second cell-connecting section of the conductive layer is attached to the bottom surface electrode of the same cell. Various circuit patterns of the electrically-conductive layer are described for connecting the cells in a series or parallel array and for use in width-limited systems, such as solar concentrators.

4,021,267
Dettling, Joseph R., inventor; United Technologies Corporation, assignee. *High Efficiency Converter of Solar Energy to Electricity*. May 3, 1977.

Apparatus is disclosed which permits the use of a large proportion of the solar spectrum in the conversion of solar energy to electricity by means of photovoltaic cells. The apparatus comprises a collecting element which concentrates the incident radiation, a collimating element which forms the concentrated incident radiation into a beam of parallel photons, a spectral separation element, such as a prism, prism plate or diffraction grating which spectrally separates the solar radiation in the collimated beam and a plurality of photovoltaic cells disposed in the separated spectrum, the energy gap of the cells being matched to the energy of the photons in that portion of the spectrum in which the cells are located.

4,021,323
Kilby, Jack S.; Lathrop, Jay W.; Porter, Wilbur A., inventors; Texas Instruments Incorporated, assignee. *Solar Energy Conversion*. May 3, 1977.

Solar energy conversion is provided by a structure formed of a plurality of photovoltaic sources. An electrolyte wets the sources. Upon exposure to light the photovoltaic sources cause a current to flow in the electrolyte producing an electrochemical reaction. The products of this reaction may then be collected and stored. In a preferred embodiment the electrolyte is an aqueous solution of hydrogen iodide, and the hydrogen produced by the electrochemical reaction may be stored, burned as a fuel or used in a fuel cell to produce electrical energy.

4,023,368
Kelly, Donald A., inventor. *High Density-Third Dimension Geometry Solar Panels*. May 17, 1977.

The high density, third dimension geometry solar panels consist of closely placing any type of conventional solar cells in an in depth, oblique attitude to the sun's normal rays. In one panel arrangement, highly polished side reflectors are applied to reflect the sun's rays into the underside groups of solar cells so that a minimum of surface area is required for a higher than normal electrical power yield from the high density cells. The most effective geometric shape for these reflected type solar panels is the triform, or tri-panel, and modifications of the triform cross-section. Another type of high density solar panel is the V form, or Vee cavity form in which the individual solar cells must have reflective surfaces, for mutual reflection and solar energy concentration.

4,024,558
Merrin, Seymour, inventor; Innotech Corporation, assignee. *Photovoltaic Heterojunction Device Employing a Glassy Amorphous Material as an Active Layer*. May 17, 1977.

A semiconductive heterojunction device particularly useful as a photovoltaic device such as a solar cell comprises a heterojunction formed between a first layer of semiconductor material exhibiting one type of electronic conductivity (N or P) and a second layer of a compositionally different glassy amorphous material exhibiting the other type of electronic conductivity (P or N), which second layer has an energy bandgap relatively wider than that of the semiconductor material. Preferably, the wider bandgap glassy amorphous material possesses or is doped to possess a low resistivity below about 10^7 ohm-cm.

4,024,852
L'Esperance, Paul M.; Pavlak, Alex, inventors. *Solar Energy Reflector-Collector*. May 24, 1977.

A system including a non-tracking reflector-collector for the concentration and collection of solar energy. An energy-collecting plate is disposed upright along a substantially horizontal axis substantially coincident with the east-west direction of the earth. The collector plate is positioned within a semi-tubular reflector having parabolic sidewalls. The reflector surfaces on opposite sides of the collector plate are parabolic surfaces, each having a focal point approximately coincident with the upper terminal edge of the collector plate. The axes of the parabolas which define the respective surfaces are rotated about or diverge from their common focal point at a substantial angle. The reflector sides are of laminated construction having a base portion of a lightweight rigid plastic sheet, an underlayer of plastic corrugated board and a reflective film on the interior surface. The collector plate receives energy entering the aperture between the reflective surfaces. In one of the preferred embodiments, the plate elevates the temperature of a heat exchange medium flowing therethrough. The heat exchange medium provides for storage and use of the collected energy. In a second embodiment, the collector plate receives solar energy which is converted into electrical energy for storage and use.

4,025,786
Hamilton, George Henry, inventor. *Solar Energy Power Generating Array*. May 24, 1977.

A multi-layer array of power converting elements for converting electromagnetic energy such as sunlight incident on the array to electricity is disclosed. The array is suitable for use in integrated circuit arrays as well as discrete circuit arrays. The array comprises an upper layer of photocells with spaces between the photocells. At least one other layer of photocells is disposed below the upper layer and is illuminated by the penumbra of the upper layer. Lower layers are separated from upper layers by a distance defined by the width of the cells in the immediate upper layer, the distance between the array and the source of electromagnetic energy and the width of the source of electromagnetic energy.

4,025,944
Moon, Ronald L., inventor; Varian Associates, assignee. *Ohmic Contacts to p-Type Indium Phosphide*. May 24, 1977.

A body of p-type indium phosphide, which was heretofore difficult to contact in a reliable low resistance manner, is ohmically contacted by an alloy contact of bismuth with preferably 2% zinc. The alloy contact is effected by placing a small pellet of the Bi-Zn alloy on the surface of the p-type InP body and then alloying at a preferred temperature of 360°C for 20 seconds.

4,027,053
Lesk, Israel A., inventor; Motorola, Inc., assignee. *Method of Producing Polycrystalline Silicon Ribbon*. May 31, 1977.

A method of producing a ribbon of polycrystalline silicon, which includes contacting a moving surface carrying a layer of particulate semiconductor silicon, with a gaseous silicon source, is disclosed. The gaseous silicon source permeates the layer of particulate silicon and, with heat applied, deposits silicon that knits the silicon particles together to a continuous, coherent polycrystalline ribbon. The ribbon is then separated from the moving surface for further processing, for example, conversion to monocrystalline silicon.

4,028,151
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Impregnating a Semiconductor with a Diffusant and Article so Formed*. June 7, 1977.

Crystalline silicon wafers have an electrical junction formed at a surface thereof by impregnating the surface with a diffusant, such as phosphorus, in an atmosphere that includes significant quantities of helium.

4,028,206
King, William James, inventor. *Method for Cool Deposition of Layers of Materials onto a Substrate*. June 7, 1977.

In systems in which material is deposited on a substrate in such a way that substantial heating of the substrate by radiant transmission occurs, such heating is reduced by first depositing a material capable of reflecting a significant fraction of the incident thermal radiation.

4,028,720
Pankove, Jacques Isaac, inventor; RCA Corporation, assignee. *Photovoltaic Device*. June 7, 1977.

A body of a photovoltaic device is of silicon having gallium and arsenic paired molecular impurities of a concentration on the order of 10^{18} atoms/cm^3 or greater.

4,029,518
Matsutani, Toshinobu; Nishida, Keiichi, inventors; Sharp Kabushiki Kaisha, assignee. *Solar Cell*. June 14, 1977.

A P-type diffusion layer is formed on an N-type silicon semiconductor wafer to establish a P-N junction in a solar cell, the diffusion layer being exposed to radiation. A pair of electrodes are formed on the surfaces of the diffusion layer and the semiconductor wafer in a desired configuration in order to provide output of electric energy generated by the solar cell. The diffusion layer is formed in such a manner that the layer has a thickness of around 3 μm at areas where the electrode is formed and has a thickness of around or below 0.5 μm at regions on which the electrode is not formed. With such an arrangement, radiation having a wavelength of about or shorter than 400 mμm[sic] can be used for performing optoelectric generation.

4,029,519
Schertz, William W.; Zwerdling, Solomon, inventors; The United States of America as represented by the United States Energy Research and Development Administration, assignee. *Solar Collector Having a Solid Transmission Medium*. June 14, 1977.

There is provided a radiant energy transmission device capable of operation in a concentrative mode in which energy incident on an entrance area is directed toward and concentrated on an exit area of smaller area than the entrance area. The device includes a solid radiant energy transmission medium having surfaces coincident with the entrance and exit areas and particularly contoured reflective side walls. The surface coinciding with the entrance area is coupled to a cover plate formed of a radiant energy transmissive material. An energy transducer is coupled to the surface of the medium coinciding with the exit area.

4,031,385
Zerlaut, Gene A.; Heiskell, Robert F., inventors; Desert Sunshine Exposure Tests, Inc., assignee. *Solar Tracking Device*. June 21, 1977.

A solar tracking system is disclosed, utilizing a photovoltaic device, for following the changing solar position. When the sun ceases to be the brightest object in the sky, such as during periods of partial cloud cover, and the system seeks to acquire the brightest spot in preference to the sun, the photovoltaic device is automatically overridden. The override system is clockdriven and moves the tracking system to approximate the solar position so that the sun can be immediately reacquired by the photovoltaic device when the sun re-energizes as the brightest object in the sky.

4,035,197
Raychaudhuri, Pranab Kumar, inventor; Eastman Kodak Company, assignee. *Barrier Type Photovoltaic Cells with Enhanced Open-Circuit Voltage, and Process of Manufacture*. July 12, 1977.

A cadmium telluride photovoltaic cell is produced with increased conversion efficiency arising from enhanced open-circuit voltage. Such voltage is achieved by altering the surface of the crystalline cadmium telluride that contacts the barrier metal by heating the cadmium telluride in the presence of oxygen prior to depositing the barrier metal.

4,036,645
Pinder, Russell Stuart; Clark, Leslie, inventors; International Research and Development Company Limited, assignee. *Photodetectors and Thin Film Photovoltaic Arrays*. July 19, 1977.

A photovoltaic heterojunction is formed by chemical conversion of surface regions of a sheet of one conductivity type into material of a second conductivity type, the areas which are not to be converted being covered by a developed photo-resist layer which has previously been exposed to light through a mask. Electrical contacts are deposited on the regions of the second type and contacts to the material of the first type are formed by a layer deposited on a substrate under the sheet of material of the first type. This deposited layer of electrically-conductive material can also form the mask for initial exposure of the photo-resist layer.

4,036,666
Mlavsky, Abraham I., inventor; Mobil Tyco Solar Energy Corporation, assignee. *Manufacture of Semiconductor Ribbon*. July 19, 1977.

A method is provided for producing flat substantially monocrystalline ribbons, e.g. silicon ribbons for use in making flat solar cells. The ribbons are produced by growing substantially monocrystalline flat hollow tubes, and then excising the edge portions of the tubes so that the flat sides of the tubes form discrete ribbons.

4,037,029
Anderson, John Harland, inventor. *Photoelectrogenerative Cell*. July 19, 1977.

Photoelectrogenerative cell means comprising, in combination, cell means including an anolyte cell and a catholyte cell, with means being provided for the transmission of solar radiation into the anolyte cell. The anolyte cell includes an electroconductor solution, along with a photoelectrogenerative compound in admixture therewith, the photoelectrogenerative material being dispersed or dissolved in the electroconductive solution. The catholyte cell comprises an electroconductor in solution, and an electrolytically permeable cell isolation means separates the anolyte cell from the catholyte cell. Electrically conductive electrodes are immersed in each of the respective anode compartments and cathode compartments, and are arranged in electrical contact with the respective anolytes and catholytes. This photoelectrogenerative cell recovers energy produced by photoelectrochemical reactions when placed in a cell configuration.

4,038,104
Tsutomu, Otake, inventor; Kabushiki Kaisha Suwa Seikosha, assignee. *Solar Battery*. July 26, 1977.

A solar battery is manufactured by forming individual cells in a wafer, mounting the wafer on a substrate and separating the cells by the use of a thin saw. The channel thus formed between the cells is filled with an insulating material to prevent the accidental entry of stray material which might result in unwanted conduction between the cells. Preferably the insulating material between the cells is the same color as the cells in the interest of enhanced appearance.

4,039,357
Bachmann, Klaus Jürgen; Bottini, Manfred Hermann; Buehler, Ernest; Shay, Joseph Leo; Wagner, Sigurd, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Etching of III-V Semiconductor Materials with H_2S in the Preparation of Heterodiodes to Facilitate the Deposition of Cadmium Sulfide*. August 2, 1977.

A hydrogen transport process for cleaning the surface of an indium or gallium based semiconductor material and for depositing n-type cadmium sulfide on the cleaned semiconductor material is disclosed. The cleaning and deposition can be accomplished in sequence or simultaneously. The process entails adding hydrogen sulfide to a hydrogen gas flow in a chemical vapor deposition process. Single crystalline photovoltaic cells of p-InP/n-CdS with a 13% efficiency have been reproducibly fabricated. An efficiency of 4.6% has been obtained with a thin layer polycrystalline p-InP/n-CdS cell. Additionally, a p-GaAs/n-CdS heterodiode cell has been produced.

4,040,566
Chiarelli, Carl, inventor. *Pollution-Free Heating System*. August 9, 1977.

What follows is a description of a system for heating a building by solar energy, and providing heated water for domestic use. A roof-mounted solar heating panel, which includes a clear specially shaped covering panel to intensify the solar energy striking the elements of the heating panel, heats a circulating liquid, which in turn heats air circulated within the building. Surplus heat is stored for a limited time by heating additional quantities of liquid. Also, solar heat is stored for an indefinite time by using a roof-mounted solar battery to power an electrolytic cell used to produce hydrogen and oxygen from water. The hydrogen and oxygen is stored and used as fuel in a furnace which heats the heat transfer liquid in the system as required.

4,040,867
Forestieri, Americo F.; Ratajczak, Anthony F.; Sidorak, Leroy G., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Shingle*. August 9, 1977.

A solar cell shingle may be made of an array of solar cells on a lower portion of a substantially rectangular shingle substrate made of fiberglass cloth or the like. The solar cells may be encapsulated in flourinated ethylene propylene (FEP) or some other weatherproof translucent or transparent encapsulant to form a combined electrical module and a roof shingle. The interconnected solar cells are connected to connectors at the edge of the substrate through a connection to a common electrical bus or busses. An overlap area is arranged to receive the overlap of a cooperating similar shingle so that the cell portion of the cooperating shingle may overlie the overlap area of the roof shingle. Accordingly the same shingle serves the double function of an ordinary roof shingle which may be applied in the usual way and an array of cooperating solar cells from which electrical energy may be collected.

4,041,271
Lorans, Dominique Y., inventor; Societe Anonyme de Telecommunications, assignee. *Machine for Welding Solar Cell Connections*. August 9, 1977.

Machine for welding a connection wire over a solar cell electrode which comprises a base, a welding mount for the solar cell which is supported on the base, means for holding the solar cell on the welding mount, welding electrodes, means to lower the welding electrodes over the solar cell and the connection wire superimposed thereon, means for applying electric current pulses to said welding electrodes, and it is characterized by the fact that it further comprises means for imparting to said mount an alternating transverse movement in relation to said base before and during the welding operation.

4,041,307
Napoli, Louis Sebastian; Marx, Richard Everet, inventors; RCA Corporation, assignee. *Positioning a Platform with Respect to Rays of a Light Source*. August 9, 1977.

An opaque open-ended cylindrical tube, with a flange on one end, has its other end connected to a surface of a platform with the axis of the cylinder normal to the surface. When rays of the sun are substantially normal to the surface, a lens causes a concentrated illumination of a group of tracking photocells carried on the surface within the cylinder. In response to the concentrated illumination, the tracking photocells provide signals that cause the platform to rotate in a direction that maintains the surface substantially normal to the rays of the sun. Additionally, outside of the cylinder and adjacent thereto, a group of acquisition photocells are shielded by the flange from the sun when the rays thereof are substantially normal to the surface. When there is a large angle between a normal to the surface and the rays of the sun, the acquisition photocells provide signals that cause the platform to rotate in a direction that reduces the angle.

4,041,389
Oades, John Willson, inventor; GTE Automatic Electric Laboratories Incorporated, assignee. *Nonfrequency-Converting Microwave Radio Repeater Using a Low Power Consumption Amplifier*. August 9, 1977.

A novel nonfrequency-converting microwave radio repeater for use in multichannel telecommunications is disclosed. A single microwave amplifier provides the requisite gain for two different angle-modulated radio frequency signals. Bandpass filters and circulators permit duplex operation by channeling the received signals through the repeater. The two radio frequency signals are amplified simultaneously in the same amplifier and then separated to be retransmitted at the same frequency in the proper path direction.

4,042,417
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *Photovoltaic System, Including a Lens Structure*. August 16, 1977.

A photovoltaic or solar cell generator includes a plurality of unit solar cells each having one or more p-n junctions. An optical light-focusing system, which includes an array of lens elements, focuses the incoming radiation into a series of preferably narrow beams that are incident on the surfaces of the unit solar cells at locations lying immediately adjacent but spaced from the p-n junctions.

4,042,418
Biter, William J., inventor; Westinghouse Electric Corporation, assignee. *Photovoltaic Device and Method of Making Same*. August 16, 1977.

An integrated array of solar cells is produced in continuous layers of photovoltaic junction forming semiconductor materials. Adjacent solar cells are sufficiently isolated by virtue of a relatively high resistivity in the semiconductor layers. The solar cells are connected in series by shorting the junction at selected points.

4,042,447
Reitz, Norman E., inventor; Sotec Corporation, assignee. *Crystallizing a Layer of Silicon on a Sodium Thallium Type Crystalline Alloy Substrate*. August 16, 1977.

Relates to a method for producing a product comprising crystalline silicon on a sodium thallium type substrate by application of silicon atoms gradually to that substrate whereby oriented overgrowth occurs and also to the product produced by said method. The product is useful in semiconductor and solar cell applications.

4,042,758
Weinstein, David H.; Keeney, Joe W.; Haas, Gregory M., inventors; The Superior Oil Company, assignee. *Photochemical Cell*. August 16, 1977.

A photochemical cell is disclosed which includes an anode of titanium, a cathode of platinum, and a suitable electrolyte. The anode has a thin film of titanium dioxide formed on it, and the anode and cathode are suitably configured in the electrolyte, which is normally a very basic potassium hydroxide solution. When the anode is exposed to light of wavelength shorter than 415 nm, an emf of about 1 volt is found between the anode and the cathode so that an external current will flow from the cathode to the anode when they are connected. The cell also extracts O_2 from a mixture of O_2 and any other gases present.

4,043,834
Rüsch, Dieter, inventor; Licentia Patent-Verwaltungs-GmbH, assignee. *Flexible Solar Generator Panel*. August 23, 1977.

A solar generator panel for satellite and terrestrial energy supply systems comprises a flexible support having a plurality of solar cells mounted on the support and being rollable and foldable therewith. Connector means are provided for electrically interconnecting the cells in either parallel or series. At least one conducting layer is applied to the opposite side of the support from the solar cells and is adapted to be grounded to the associated satellite or to the earth for the purpose of eliminating charged carriers. The back of the assembly is advantageously provided with a layer of adhesive mixed with electrically conducting particles and particularly silver powder particles which serve to connect the solar cells through to the satellite. The proportion of the electrically conductive particles in the adhesive layer is preferably about 50%.

4,044,372
Weinstein, Harold, inventor; Sensor Technology, Inc., assignee. *Photovoltaic Cell Having Controllable Spectral Response*. August 23, 1977.

The spectral response of a photovoltaic cell is controlled by modifying the minority carrier transport characteristics of the cell semiconductor body. Recombination centers are provided in the body that reduce the lifetime or diffusion distance of minority carriers. Thus a reduced percentage of minority carriers produced deep in the body by absorption of relatively long wavelength photons reach the cell junction, as compared with carriers produced at lesser depth by absorption of shorter wavelength photons. The result is a shift in the peak spectral response of the cell toward shorter wavelengths.

4,045,245
Coleman, Michael G.; Pryor, Robert A., inventors; Motorola, Inc., assignee. *Solar Cell Package*. August 30, 1977.

A solar cell package includes a plurality of solar cells within a space formed by a support member and a transparent cover member. A first conductor is positioned between the support member and the solar cells and makes electrical contact to a first surface of each of the solar cells. A second conductor is essentially coplanar with the first conductor and makes electrical contacts to a second surface of each of the solar cells. The output terminals of the solar cell package are connected to the first and second conductors. The first and second conductors are electrically isolated from each other and are also insulated from the support member and from the solar cells insulative means which is electrically insulated but thermally conductive to facilitate dissipation of thermal power dissipated in the solar cells.

4,045,246
Mlavsky, Abraham I.; Winston, Roland, inventors; Mobil Tyco Solar Energy Corporation, assignee. *Solar Cells with Concentrators*. August 30, 1977.

The invention provides a unique arrangement for cooling solar cells that are associated with collectors for collecting solar radiation and concentrating the same on the solar cells. The solar energy concentrators are each characterized by having a chamber with a solar radiation transmissive entrance wall, sidewalls adapted to concentrate solar radiation, one or more solar cells disposed in each chamber, and means for passing a dielectric, transparent cooling fluid through each chamber. The cooling fluid has an index of refraction which promotes solar energy concentration onto the solar cells in addition to that provided by the sidewalls.

4,045,663
Young, Danny J., inventor; Fair, James W., assignee. *Rechargeable Flashlight Assembly*. August 30, 1977.

A flashlight assembly including a flashlight bulb and an accessory device, such as a two-way wireless radio, operated by the same rechargeable battery. Recharging circuitry provides for sure, ready recharging of the battery, and low-current drain flashing circuitry provides for long flashing life for a given battery charge. All of the components are mounted in a casing, the casing having a handle affixed thereto for facilitating ready manipulation and utilization of the flashlight bulb and accessory device.

4,046,594
Tarui, Yasuo; Sakamoto, Tsunenori; Komiya, Yoshio, inventors; Agency of Industrial Science and Technology, assignee. *Solar Battery*. September 6, 1977.

Disclosed is a solar battery comprising a multi-layered "p-n" junction structure, which has a plurality of inwardly converging recesses to partially expose the inner "p-n" junctions to the sun light.

4,048,372
Ando, Hiei; Haacke, Gottfried, inventors; American Cyanamid Company, assignee. *Coating of Cadmium Stannate Films onto Plastic Substrates*. September 13, 1977.

Light transmissive, electrically conductive cadmium stannate films on plastic substrates are greatly improved with respect to their adherence to the substrate if the film is deposited on a substrate which has been precoated with a metal oxide, such as silicon dioxide or titanium dioxide.

4,050,907
Brimhall, George H., inventor. *Organic Waste Treating and Conversion System*. September 27, 1977.

An aparatus for treating any type of organic waste such as sewage, garbage, weeds and surplus crops to convert them into useful products, has a treatment tank or plurality of such tanks, a conduit circuit for carrying a heating fluid therethrough, vibrators to vibrate the conduit to homogenize and mix the tank contents, a furnace for supplying heat to the conduit circuit with the fuel for the furnace being the gaseous product recovered from the treatment tank or tanks, and solar cells and microwave heating units to balance and maintain the supply of heat when the fuel supply to the furnace is low. Radiation diffusers may be positioned about the tank or tanks to assist in the conversion process.

4,052,181
Wang, Taylor G.; Elleman, Daniel D., inventors. The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Acoustic Energy Shaping*. October 4, 1977.

A suspended mass is shaped by melting all or a selected portion of the mass and applying acoustic energy in varying amounts to different portions of the mass. In one technique for forming an optical waveguide slug, a mass of oval section is suspended and only a portion along the middle of the cross-section is heated to a largely fluid consistency. Acoustic energy is applied to opposite edges of the oval mass to press the unheated opposite edge portions together so as to form bulges at the middle of the mass. In another technique for forming a ribbon of silicon for constructing solar cells, a cylindrical thread of silicon is drawn from a molten mass of silicon, and acoustic energy is applied to opposite sides of the molten thread to flatten it into a ribbon.

4,052,228
Russell, Charles R., inventor. *Optical Concentrator and Cooling System for Photovoltaic Cells*. October 4, 1977.

An optical concentrator and cooling system in which a photovoltaic cell array is immersed in a liquid inside an elongated tube having a curved transparent wall for incident radiation, said liquid having a refractive index suitable for concentrating the incident radiation onto the photovoltaic cell array.

4,052,657
Kleiner, Charles T.; Hochwald, Walter, inventors; Rockwell International Corporation, assignee. *Distribution System for A.C. Electrical Energy Derived from D.C. Energy Sources*. October 4, 1977.

Apparatus for providing alternating current electrical energy to a load wherein an alternating current energy source includes one or more direct current energy sources coupled to one or more inverters each having at least one switching element therein. Switching elements are controlled to provide alternating current waveforms having a relatively low harmonic content. A preferred embodiment has two alternating current sources. The two alternating current sources are coupled to the load in a manner which causes their output voltages to be summed vectorially across the load. The phase difference between the output voltages of the two sources is controlled to regulate the resultant load voltage by controlling the operation of the switching elements in the inverters.

4,052,782
Weinstein, Harold; Lee, Ray H., inventors; Sensor Technology, Inc., assignee. *Tubular Solar Cell and Method of Making Same*. October 11, 1977.

High efficiency, low cost solar energy conversion is facilitated by using tubular photovoltaic solar cells situated at the focus of a line-generated paraboloidal reflector. Advantageously each solar cell comprises a pair of concentric glass tubes that are hermetically sealed at the ends. A photovoltaic junction is formed over the entire inside surface of one of the concentric tubes. For example, this may comprise an inner electrically conductive film, contiguous layers of Cu_2S and CdS forming a heterojunction, and an outer film of optically transparent but electrically conductive material. The conductive films provide electrical connection to the junction via external contacts that are symmetrically disposed at the ends of the tubular cell. In other embodiments the photovoltaic junction is formed in a crystalline silicon layer that is grown in situ on one of the glass tubes. Techniques for promoting oriented semiconductor crystalline growth are disclosed. These include providing minute crystalline islands in a metal matrix to serve as growth centers, surface alignment using a wavy layer deposited at an acute angle onto the glass substrate, surface seeding and normalization growth atop a fluid-like thin film deposition substrate.

4,053,326
Forrat, Francis, inventor; Commissariat a l'Energie Atomique, assignee. *Photovoltaic Cell*. October 11, 1977.

A photovoltaic cell includes a metal support which is coated with a metal having a low melting point on which a crystalline layer of a semiconductive material is deposited, the material being doped to form a p-n semiconductor. In preferred embodiments the metal support may be a cell plate, the metal having a low melting point may be tin, and the semiconductive material may be silicon. According to the method of manufacturing the cell a gaseous compound containing a material adapted to form the semiconductive crystalline layer is decomposed in a chamber containing a metal support coated with a metal having a low melting point, the temperature of the metal having a low melting point is then raised to a value such that the metal is in a liquid state and forms a liquid metal substrate on which the crystalline layer forms by epitaxy, and finally the gaseous compound is suitably doped so that the semiconductive layer has a p-n type structure.

4,053,327
Meulenberg, Andrew, Jr., inventor; Communications Satellite Corporation, assignee. *Light Concentrating Solar Cell Cover*. October 11, 1977.

A cover slide for a solar cell comprises a plurality of converging lenses arranged to focus the incident light so that it does not fall on the grid lines of the front electrode of the solar cell.

4,053,918
Stirn, Richard J., inventor. The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *High Voltage, High Current Schottky Barrier Solar Cell*. October 11, 1977.

A Schottky barrier solar cell is disclosed, consisting of a layer of wide band gap semiconductor material such as AlGaAs on which a very thin film of semi-transparent metal is deposited to form a Schottky barrier. The layer of the wide band gap semiconductor material is on top of a layer of narrower band gap semiconductor material, to which one of the cell's contacts may be attached directly or through a substrate. The cell's other contact is a grid structure which is deposited on the thin metal film.

4,055,442
Crosher, Frederick K., inventor; Optical Coating Laboratory, Inc., assignee. *Silicon Solar Cell Construction Having Two Layer Antireflection Coating*. October 25, 1977.

Silicon solar cell construction having a two layer antireflection coating overlying the silicon cell and being disposed between the silicon solar cell and the cement which is utilized for securing the silicon solar cell cover to the silicon solar cell.

4,056,404
Garone, Lynne C.; Ravi, Kramadhati Venkata, inventors; Mobil Tyco Solar Energy Corporation, assignee. *Flat Tubular Solar Cells and Method of Producing Same*. November 1, 1977.

The invention provides solar cells in the form of substantially flat oval tubes, i.e., cells having a substantially flat oval ring cross-section.

4,056,405
Varadi, Peter F., inventor; Solarex Corporation, assignee. *Panel for Solar Energy Cells*. November 1, 1977.

A panel for mounting solar energy cells, and particularly those cells upon which light is to be concentrated, includes an enclosure for holding the cells and has at least one wall formed from a good conductor of heat. The cells are mounted within the enclosure on a resinous cushion that is a relatively good conductor of heat and a poor conductor of electricity, so that when heat is generated by impingement of light on the cells, it will be carried by the cushion to the enclosure wall and dissipated therefrom.

4,056,879
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Forming Silicon Solar Energy Cell Having Improved Back Contact*. November 8, 1977.

A silicon solar energy cell having a diffusant junction extending inwardly from one surface, an aluminum-silicon junction of the opposite polarity extending inwardly from the other surface, and a film of aluminum-oxygen-diffusant formed over the aluminum-silicon junction. The structure is formed by diffusing an unprotected wafer, coating the diffusant glass so formed on one side of the wafer with aluminum, and heating the wafer.

4,057,439
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Solar Panel*. November 8, 1977.

A solar panel having solar cells adhered to the base surface thereof by a single component, room temperature vulcanizing silicone resin and encapsulated in a multicomponent silicone resin with desirable optical properties.

4,058,418
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Fabrication of Thin Film Solar Cells Utilizing Epitaxial Deposition onto a Liquid Surface to Obtain Lateral Growth*. November 15, 1977.

A method to manufacture thin film solar cells in which a solar cell to convert directly light to electricity is formed by depositing silicon material on a carrier substrate having a coating which is liquid on the deposition temperature. An article manufactured according to this method. A machine for the manufacture of thin film solar cells.

4,059,461
Fan, John C. C.; Zeiger, Herbert J., inventors; Massachusetts Institute of Technology, assignee. *Method for Improving the Crystallinity of Semiconductor Films by Laser Beam Scanning and the Products Thereof*. November 22, 1977.

A method is disclosed for improving the crystallinity of semiconductor films by scanning the surface of such films with a shaped, focused laser beam. The laser is matched to the film so that the beam delivers sufficient energy thereto to heat the film above a temperature at which crystallization occurs along the scan track.

4,060,426
Zinchuk, Michael, inventor; Polaroid Corporation, assignee. *Tin Indium Oxide and Polyvinylcarbazole Layered Polarized Photovoltaic Cell*. November 29, 1977.

A polarized photosensitive transducer is provided with a substantially transparent substrate over which there is preferably deposed a substantially transparent electroconductive layer of tin oxide-indium oxide. Overlying the electroconductive layer, there is provided a substantially transparent photoconductive layer comprised of a polymerized vinylcarbazole compound. A second transparent electroconductive layer consisting of tin oxide-indium oxide is thereafter sputtered in overlying relation with respect to the photoconductive layer such that all the layers overlying the substrate cooperatively define a substantially transparent polarized photosensitive transducer.

4,061,555
Miyatani, Kazuo; Sato, Isao, inventors; RCA Corporation, assignee. *Water Photolysis Apparatus*. December 6, 1977.

A nickel cathode has a nickel oxide layer on its surfaces. A plurality of spaced apart grooves are in the nickel oxide layer and extend into the nickel. The cathode can be utilized in a water photolysis

apparatus which also includes an N type photocatalytic semiconductor anode. Both the cathode and anode are in an aqueous basic electrolyte solution. The anode and cathode are electrically biased by a solar cell. The biasing potential of the solar cell raises the voltage potential of the cathode and lowers the Fermi level of the anode.

4,062,034
Matsushita, Takeshi; Hayashi, Hiaso; Shibasaki, Mitsuru, inventors; Sony Corporation, assignee. *Semiconductor Device Having a Hetero Junction*. December 6, 1977.

A semiconductor device comprising a silicon substrate with an oxygen doped polycrystalline or amorphous silicon layer formed on the substrate so as to form a heterojunction therewith. A transistor formed according to the invention has an emitter-base heterojunction and has a high current gain.

4,062,038
Cuomo, Jerome John; DiStefano, Thomas Herman; Rosenberg, Robert, inventors; International Business Machines Corporation, assignee. *Radiation Responsive Device*. December 6, 1977.

The practice of this disclosure obtains a relatively high efficiency operation for a crystalline semiconductor solar cell containing various defects of the linear and planar types. Linear defects include screw dislocations as well as full and partial dislocations. Planar defects include twins, stacking faults, grain boundaries and surfaces. Such defects normally contain recombination centers at which electrons and holes generated in the semiconductor region recombine with loss to the external current of the charge carried thereby. Through application of the principles of this invention, especial dopant concentrations and conductivity regions are established in a finite region around the linear and planar defects so that electrons and holes which are generated in the semiconductor region by incident radiation are substantially collected for external current as consequence thereof.

4,062,102
Lawrence, John E.; Wu, Icheng, inventors; Silicon Material, Inc., assignee. *Process for Manufacturing a Solar Cell from a Reject Semiconductor Wafer*. December 13, 1977.

A process for manufacturing a solar cell from a reject semiconductor wafer comprising stripping all external layers from the wafer, etching the surfaces of the wafer so as to effectively remove all P/N junctions without pitting the wafer surface, introducing a layer of dopant to form a P/N junction in the front wafer surface, forming a first patterned conductive electrode over the dopant layer, and forming a second conductive electrode on the back surface of the wafer. In the preferred embodiment a sputtering operation is used to form the conductive electrodes.

4,062,371
Bolen, Lawrence A., inventor. *Walking Cane*. December 13, 1977.

This disclosure pertains to a walking cane, for use by the blind, having a portion of the shank thereof adapted with a solar cell. The current produced by the cell recharges a battery stored within the hollow interior portions of the cane. A lamp is selectively energized by operating a control switch. The lamp provides illumination warning others of the disabled condition of the user. A buzzer or other alerting device is selectively included in the electrical circuit which enables the user to test the successful illumination of the lamp.

4,062,698
Blakeslee, A. Eugene; Hovel, Harold John, inventors; International Business Machines Corporation, assignee. *Photoelectrical Converter*. December 13, 1977.

Photoelectrical conversion cells may be assembled on an electrically conducting heat sink and each may be electrically isolated therefrom by employing insulating substrate material between the photoresponsive region of each cell and the heat sink.

4,063,963
Bond, John W., Jr., inventor. *Terrestrial Photovoltaic Solar Cell Panel*. December 20, 1977.

Solar cells are interconnected by filaments stretched crosswise between the edges of a rectangular frame to form a gridwork, and thereby produce a lightweight inexpensive support that is not susceptible to damage from winds, snow, and ice. Additionally, the top of the cells have thin resistive wires mounted thereto for preventing snow and ice accumulation.

4,064,521
Carlson, David Emil, inventor; RCA Corporation, assignee. *Semiconductor Device Having a Body of Amorphous Silicon*. December 20, 1977.

An amorphous silicon material, fabricated by the process of a glow discharge in silane, is utilized as the body of semiconductor devices.

4,064,522
Shaw, Robert F.; Ghosh, Amal K., inventors; Exxon Research & Engineering Co., assignee. *High Efficiency Selenium Heterojunction Solar Cells*. December 20, 1977.

A photocell includes a metallic base electrode, a continuous, crystalline P-type semiconductive selenium layer less than about 50 microns thick, a thin tellurium layer interposed therebetween to metallurgically bond the base electrode to the selenium layer and to form an ohmic contact between the base electrode and the selenium layer, a thin N-type semiconductive cadmium selenide layer contiguous with the selenium layer and forming a photovoltaic heterojunction therebetween, a pellucid layer of at least one cadmium chalcogenide contiguous with the cadmium selenide layer and forming an ohmic contact therewith and a current collecting electrode on the cadmium chalcogenide layer. The sunlight conversion efficiency of the cell is at least about 3.0%. The efficiency can be further improved by doping the selenium layer to improve its conductivity and by providing an N-type layer of cadmium selenide and N+ cadmium oxide. This can be done by continuously varying the oxygen content of the N-type layer. It is further helpful if a counterelectrode in the form of a grid is added, which minimizes both the resistance between the grid members in the cadmium layer and the blockage of light by the grid.

1978

4,066,481
Manasevit, Harold M.; Simpson, William I., inventors; Rockwell International Corporation, assignee. *Metalorganic Chemical Vapor Deposition of IVA-VIA Compounds and Composite*. January 3, 1978.

A composite comprising a monocrystalline substrate and one or more layers of films of monocrystalline IVA-VIA compounds and/or alloys formed thereon by a chemical vapor deposition process. The composite is formed at a preferred temperature range of approximately 450°-650°C. The IVA-VIA layer(s) are produced by the pyrolysis of a gas mixture containing metalorganic compounds. Where single crystal metallic oxide substrates of rhombohedral structure, such as sapphire (α-Al_2O_3), or of cubic structure, such as magnesium aluminate (spinel), are used for the growth of monocrystalline lead-containing films such as $Pb_{1-x}Sn_xTe$, a nucleation layer of lead is preferably formed on the substrate prior to the pyrolysis of the mixed gaseous reactants. Using the present process, epitaxial monocrystalline IVA-VIA compounds and/or alloys can be grown on inorganic metal oxide substrates, such as cubic and rhombohedral oxides, on alkali halides and IIA fluorides, and on II-VI and III-V compounds. The compositions of the films can be varied without removing the composites from the deposition apparatus by changing the ratio of the reactant gases

and the reaction temperature. The conductivity type (n-type or p-type) of the films also can be controlled without removing the composites from the deposition apparatus by varying the reactant gas compositions and by incorporating a dopant into the reactant mixtures prior to pyrolysis.

4,066,527
Takagi, Toshinori; Morimoto, Kiyoshi; Utamura, Yukihiko, inventors; Futaba Denshi Kogyo K. K., assignee. *Method of Producing Semiconductor Device*. January 3, 1978.

A method of producing a semiconductor device comprising the step of forming a laminated element film on a substrate made of a material easy to cleave and easy to dissolve in various solvents such as water by successively depositing materials of the laminated element film on the substrate by what is called the ionized-cluster-deposition process so that crystalline film layers oriented by the crystal axis of the substrate material may be made to grow on the substrate, separating the laminated element film from the substrate by dissolving the substrate material in a solvent, and forming the semiconductor device by furnishing the separated laminated element film with suitable electrodes, etc.

4,067,764
Walker, Jack S.; Kittler, Wilfred C., inventors; Sierracin Corporation, assignee. *Method of Manufacture of Solar Cell Panel*. January 10, 1978.

There is described a solar cell panel consisting of an outer rigid transparent faceply of glass or plastic material to which are applied at least two layers of plastic such as polyvinyl butyral between which are positioned a plurality of solar cell wafers. A thin flexible film of polyethylene terephthalate forms the other outer surface of the panel. The panel is manufactured by laminating the materials together and allowing the margins of the plastic film to extend beyond the polyvinyl butyral layers so that the film can be brought into direct contact and sealed to a rigid base plate, forming a fully encapsulating structure. The assembled structure is then evacuated to withdraw air and to squeeze the layers together to promote adhesion. The evacuated laminated structure is then placed in an oven for applying heat and pressure to the laminated structure for permanent bonding. After cooling, excess film is trimmed from around the edges of the rigid face plate.

4,068,020
Reuschel, Konrad, inventor; Siemens Aktiengesellschaft, assignee. *Method of Depositing Elemental Amorphous Silicon*. January 10, 1978.

A smooth surfaced amorphous silicon layer useful in semiconductor technology is produced by pyrolytic deposition of elemental silicon onto a heated mandrel along with simultaneous pyrolytic deposition of at least one other element selected from Groups IV through VIII and which is non-semiconductive and does not function as a conductivity determining dopant.

4,069,812
O'Neill, Mark J., inventor; E-Systems, Inc., assignee. *Solar Concentrator and Energy Collection System*. January 24, 1978.

A curved prismatic, Fresnel-type lens primarily used for concentrating sunlight in a solar energy collector. The lens comprises a substantially smooth, convex outer surface and a plurality of prisms arranged side-by-side along a curve on the inner surface to direct incoming light to a common area. Each of the individual prisms has a front and back face joined by a bottom face. The front and back faces of the prisms are oriented such that the angle of incidence of the incoming light with the front face is equal to the angle of incidence of the outgoing light with the back face. Further, each of the prisms is arranged along the curve such that they do not obstruct light passing through any adjacent prism. The bottom face of each prism is over-extended beyond the path of the light passing through the prism to prevent loss of light due to blockage by the bottom face or the rounded point between the back face and bottom face. The improved lens is used in combination with a solar energy collector comprising the improved concentrator and a suitable energy receiver for converting incident sunlight into a useful energy output.

4,070,205
Rahilly, William P., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Aluminum Arsenide Eutectic Gallium Arsenide Solar Cell*. January 24, 1978.

An improved gallium arsenide solar cell is provided by forming a P+ layer on top of a wafer of plural vertical PN junction eutectic gallium arsenide crystal by liquid phase epitaxial growth of P doped GaAs followed by liquid phase epitaxial growth at Al_xAsGa_{1-x} on the surface of the vertical PN junction substrate. The deposited GaAs layer with P dopant and the Al_xAsGa_{1-x} layer forms horizontal P-N junctions with the N type vertical regions. An N+ region is formed on the solar cell backside by ion implantation of an N dopant followed by a pulse electron beam current of the implanted region.

4,070,206
Kressel, Henry; D'Aiello, Robert Vincent; Robinson, Paul Harvey, inventors; RCA Corporation, assignee. *Polycrystalline or Amorphous Semiconductor Photovoltaic Device Having Improved Collection Efficiency*. January 24, 1978.

A body of semiconductor material having a first surface and a second surface spaced from the first surface includes a first layer along the first surface, a second layer along the second surface, and a third layer between and contiguous to the first and second layers. The third layer is of a conductivity type opposite that of the first and second layers so as to form first and second P-N junctions respectively therebetween. The thickness of the third layer is at least twice the minority carrier diffusion length of the semiconductor material, so that carriers generated within the third layer have a high probability of being collected by one of the P-N junctions. The body includes means for electrically connecting the first and second P-N junctions and means for transferring the carriers collected at the first P-N junction to a portion of the first surface.

4,070,444
Ingle, William Martell, inventor; Motorola Inc., assignee. *Low Cost, High Volume Silicon Purification Process*. January 24, 1978.

Truly amorphous silicon having a low level of undesired impurities and therefore suitable for semiconductor applications, may be prepared by the present process. Impure silicon, for example, metallurgical grade silicon, is prepared at an elevated temperature, e.g., above 1400°C. The impure silicon and at least one binary silicon fluoride compound, e.g., silicon tetrafluoride, are chemically combined at the elevated temperature to form silicon difluoride gas. The silicon difluoride gas is polymerized. The silicon difluoride polymer is then thermally decomposed to produce the purified, amorphous silicon and binary silicon fluoride by-products. The binary silicon fluorides are recycled in the process to be chemically combined with the impure silicon. That step and the succeeding steps serve to reduce the level of unwanted impurities in the silicon produced by at least several orders of magnitude.

4,070,689
Coleman, Michael G.; Restrepo, Fabio, inventors; Motorola Inc., assignee. *Semiconductor Solar Energy Device*. January 24, 1978.

This disclosure relates to a semiconductor solar energy device which is of the PN-type and utilizes a dielectric anti-reflective coating on the side of the device that faces the sunlight. The fabrication techniques used in making this semiconductor device include the use of ion implantation to form doped or diffused regions in the device. One of the ion implanted regions located on the side of the device that is subjected to the sunlight is configured in order to permit metal ohmic contact to be made thereto without shorting through the doped region during sintering of the

metal contacts to the semiconductor substrate. The dielectric anti-reflective coating, in one embodiment, is a composite of silicon dioxide and silicon nitride layers. The device is designed to permit solder contacts to be made to the P and N regions thereof without possibility of shorting to semiconductor regions of opposite type conductivity.

4,072,541
Meulenberg, Andrew, Jr.; Reynolds, John Harvey, inventors; Communications Satellite Corporation, assignee. *Radiation Hardened P-I-N and N-I-P Solar Cells*. February 7, 1978.

A solar cell is constructed such that the losses resulting from radiation damage are reduced without sacrificing efficiency in the unirradiated cell. This is done by using a first conductivity type junction on the front of a high resistivity cell and a second, opposite conductivity type junction on the back of the cell. The two junctions are separated by an intrinsic region, and the cell potential, which is normally reduced by using high resistivity substrate material, is instead raised by using the second junction. The cell includes a reflective back surface and a nonreflective front surface to further enhance light absorption within the active cell volume. The reflective back surface is formed by polishing the substrate. The nonreflective front surface is a multi-pyramidal or V-grooved surface formed by preferential etching of the substrate material. The front electrode is a fine geometry grid deposited over the front surface of the cell. An anti-reflection coating may additionally be provided over the front surface of the cell to further promote the nonreflective characteristics of that surface. Further, a cover slide may be cemented to the front surface of the cell.

4,074,305
Johnston, Wilbur Dexter, Jr.; Shay, Joseph Leo, inventors; Bell Telephone Laboratories, Incorporated, assignee. *GaAs Layers as Contacts to Thin Film Semiconductor Layers*. February 14, 1978.

Electrical contact between a conducting substrate, e.g., graphite, and a polycrystalline semiconductor layer of, for example p-type indium phosphide in a semiconductor device is made through a p-type GaAs intermediary layer. The GaAs layer is deposited on the conducting substrate by conventional methods such as chemical vapor deposition. The indium phosphide layer can then be deposited on the GaAs by similar techniques. The specific resistance and blocking voltage of such an interface is typically below $2\Omega\text{-cm}^2$ and 50 millivolts respectively. The efficiency of a p-InP/nCdS solar cell containing the improved electrical contact is measurably increased.

4,075,034
Butler, David M., inventor. *Solar Converter*. February 21, 1978.

A solar energy converter for producing variable amplitude alternating current waveforms directly from solar energy including a photo-voltaic cell bank array, formed of a plurality of weighted photo-voltaic segments, a multi-sided, high speed, rotating, light concentrating, concave mirror and a servo means for tracking the sun. Rotation of the mirror past the weighted segments of the photo-voltaic bank produces instantaneous outputs which are proportional to the number of cells scanned in each segment. By suitable arrangement of the photo-voltaic segments, a simulated AC waveform is produced.

4,076,977
Tsunekawa, Tokuichi; Taguchi, Tetsuya, inventors; Canon Kabushiki Kaisha, assignee. *Light Measuring Circuit with Stray Capacitance Compensating Means*. February 28, 1978.

The present invention relates to a light measuring circuit consisting of an operational amplifier, a feed back path connected with said operational amplifier, a photovoltaic cell and a switching circuit for bringing the input terminals of said operational amplifier to the same potential at the time light measurement is commenced. By means of this switching circuit connected to the light measuring circuit the delayed response of the light measuring circuit due to the stray capacitance existing between the input terminal of the operational amplifier and ground is remarkably improved.

4,077,818
Chu, Ting L., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Process for Utilizing Low-Cost Graphite Substrates for Polycrystalline Solar Cells*. March 7, 1978.

Low-cost polycrystalline silicon solar cells supported on substrates are prepared by depositing successive layers of polycrystalline silicon containing appropriate dopants over supporting substrates of a member selected from the group consisting of metallurgical-grade polycrystalline silicon, graphite and steel coated with a diffusion barrier of silica, borosilicate, phosphosilicate, or mixtures thereof such that p-n junction devices are formed which effectively convert solar energy to electrical energy. To improve the conversion efficiency of the polycrystalline silicon solar cells, the crystallite size in the silicon is substantially increased by melting and solidifying a base layer of polycrystalline silicon before depositing the layers which form the p-n junction.

4,078,944
Mlavsky, Abraham I., inventor; Mobil Tyco Solar Energy Corporation, assignee. *Encapsulated Solar Cell Assembly*. March 14, 1978.

An encapsulated photovoltaic solar cell assembly comprising at least one solar cell mounted and hermetically sealed in a substantially rigid, elongated, tubular envelope which is transmissive to actinic radiation to which the photovoltaic solar cell is sensitive. The assembly can include an antireflection coating for reducing the reflection of solar radiation from the envelope as well as reflective coatings for uniformly distributing solar radiation over the light gathering surfaces of the cell.

4,078,945
Gonsiorawski, Ronald, inventor; Mobil Tyco Solar Energy Corporation, assignee. *Anti-Reflective Coating for Silicon Solar Cells*. March 14, 1978.

An anti-reflective coating is formed integrally with a silicon solar cell by treating the cell with an acidic solution comprising a mixture of HF and H_20_2.

4,080,221
Manelas, Arthur J., inventor. *Solar Cell Electric and Heating System*. March 21, 1978.

A system for converting solar energy into electric energy at reduced cost makes use of an array of light sensitive, voltage producing solar cells of the flat disc silicon type. To increase power, while using fewer costly cells, each cell of the array has a truncated conical shell mounted on legs at a spaced distance thereover, the shell having a mirror-like reflective inner surface. Thus, sunlight is received in the large end and reflected through the small end to the cell. A sealed, weather-tight enclosure for the array has fluid inlets and outlets for producing heat, the heat conductive shells absorbing and radiating heat.

4,081,289
Campbell, William Patrick, III inventor. *Solar Energy System*. March 28, 1978.

A system for extracting energy from the sun's rays including a bank of solar energy cells which generate electrical current when exposed to the rays of the sun, immersed in a bath of liquid formed to serve as a lens, concentrating the sun rays on the cells, and transmitting heat away from the cells.

4,081,290
Bachmann, Klaus Jürgen; Buehler, Ernest; Shay, Joseph Leo; Wagner, Sigurd, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Solar Cells and Photovoltaic Devices of InP/CdS*. March 28, 1978.

Heterodiodes showing excellent potential for use in solar cells and photoelectric devices consist of junctions of p-type indium phosphide and n-type cadmium sulfide. These heterojunctions can be formed either from single crystal or from polycrystalline semiconductor material. The former type junction when incorporated in a solar cell exhibits promise for applications such as in space vehicles. The latter type junction as used in a solar cell has potential for large scale power generation. A chemical vapor deposition process for producing polycrystalline p-type indium phosphide films for incorporation into such a power producing device is disclosed.

4,081,820
Chitre, Sanjeev R., inventor; Sensor Technology, Inc., assignee. *Complementary Photovoltaic Cell*. March 28, 1978.

This complementary photovoltaic cell has both an N^+/P^+ junction and a P+/N junction on the same epitaxial substrate, and so provides simultaneous photoresponsive outputs of both negative and positive polarity. A vertical photo-junction supplements the current output from the N^+/P^+ junction, and improves the efficiency of the cell. The N^+/P^+ junction by itself exhibits a high open circuit voltage.

4,082,568
Lindmayer, Joseph, inventor. *Solar Cell with Multiple-Metal Contacts*. April 4, 1978.

Solar cell having a contact formed from a titanium group element in contiguous relationship with the cell, a mixture of a titanium group element and a platinum group element overlying the titanium group layer, and a layer of a platinum group element overlying that layer. A body of silver or other contact metal is adhered to the platinum group layer. The three layers may be vapor deposited on the semiconductor body, while the silver layer is more advantageously applied by plating or electroplating.

4,082,569
Evans, John C., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Collector*. April 4, 1978.

A transparent, conductive collector layer containing conductive metal channels is formed as a layer on a photovoltaic substrate by coating a photovoltaic substrate with a conductive mixed metal layer; attaching a heat sink having portions protruding from one of its surfaces which define a continuous pattern in combination with recessed regions among said protruding portions to said substrate such that said protruding portions of said heat sink are in contact with the conductive layer of said substrate; and heating said substrate while simultaneously oxidizing the portions of the conductive layer exposed to a gaseous oxidizing substance forced into said recessed regions of said heat sink, thereby creating a transparent metal oxide layer on said substrate containing a continuous pattern of highly conductive metal channels in said layer.

4,082,570
House, Robert E.; Irvin, Robert A.; Kane, Daniel F., inventors; Semicon, Inc., assignee. *High Intensity Solar Energy Converter*. April 4, 1978.

A photovoltaic energy converter for converting incident radiant energy, such as solar energy, to electrical energy. The converter comprises a cell formed from a plurality of integrally interconnected p-n junction-containing semiconductor wafers. The wafers are stacked end-to-end in the cell so that the respective junctions in each wafer are parallel to each other. The efficiency and performance of the cell is improved, particularly upon exposure to concentrated sunlight, by imposing various conditions on the cell fabrication and design. Improvements result, for example, by selecting a high resistivity semiconductor as the starting material in the fabrication of the cell, controlling the diffusion process to optimize the junction gradient and minimize the thickness of the base region in each wafer, orienting the wafers in the cell so that they are illuminated at a small angle relative to the plane of the respective junctions therein, and treating the exposed surfaces of the wafer to reduce reflectivity and surface recombination velocities.

4,082,602
Chang, Kuang-Chou; Heller, Adam; Miller, Barry, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Photovoltaic Cell Manufacture*. April 4, 1978.

A quality control technique is based on the observation that trapping centers contribute to inefficient operation of junction devices. Devices are irradiated by a first radiation source of intensity sufficient to populate traps and a second radiation source of varying wavelength. Trapping centers are detected by a deviation from the expected photovoltaic output-incident wavelength relationship. Such "structure" is utilized as the basis for altering production conditions to minimize currents of such centers. While the procedure is of general applicability, it is particularly suitable as applied to photovoltaic cells.

4,082,947
Haywood, George Lewis; Haywood, Wesley Joseph, inventors; The George L. Haywood Co., assignee. *Solar Collector and Drive Circuitry Control Means*. April 4, 1978.

A control that will, when attached to a solar collector in a proper manner, allow said solar collector to track the sun as to azimuth and elevation automatically, without manual assistance, through the diurnal cycle without regard as to whether the sun is visible or not. Also controlling said collector at sunset to return to an easterly setting to await the following diurnal cycle.

4,083,097
Anagnostou, Evelyn; Forestieri, Americo F., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Making Encapsulated Solar Cell Modules*. April 11, 1978.

Electrical connections to solar cells in a module are made at the same time the cells are encapsulated for protection. The encapsulating material is embossed to facilitate the positioning of the cells during assembly.

4,084,024
Schumacher, Joseph C., inventor; J. C. Schumacher Co., assignee. *Process for the Production of Silicon of High Purity*. April 11, 1978.

A process is provided for the low cost, high volume production of polycrystalline high purity silicon by a vapor phase reduction of a halosilane, with hydrogen, the resulting polycrystalline silicon being particularly suited for use in the production of single crystal silicon for the manufacture of semiconductor devices, solar cells, and the like. The process of the invention involves the reaction of metallurgical grade silicon (of a purity of about 98%) with a halogen or hydrogen halide to form a halosilane intermediate; the purification of the halosilane and of hydrogen, the separate preheating of the purified halosilane and of the purified hydrogen to a temperature range above the chemical reaction temperature of the halosilane and the hydrogen; injection of the halosilane and the hydrogen into a continuous flow reduction tubular reactor wherein the feed materials are instantaneously mixed in a manner which causes a chemical reaction to be initiated followed by the nucleation and growth of solid high purity silicon particles as the reaction mass flows through the tubular reactor; introduction of the solid-gas reaction mass stream into a cyclone type separator wherein the high purity silicon particles are collected and separated from the gas stream and ejected from the bottom of the separator; emitting the gas stream from the top of the separator and conducting the gas stream to a condenser-scrubber

system wherein unreacted hydrogen is separated and then recycled to the hydrogen pre-heater for re-use, unreacted silicon halosilane is separated and recycled to the intermediate pre-heater for re-use, and reaction product hydrogen halide is separated and recycled to the silicon halosilane generator for re-use.

4,084,044
Heller, Adam; Miller, Barry; Robbins, Murray, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Liquid-Semiconductor Photocell Using Sintered Electrode*. April 11, 1978.

Liquid-semiconductor photocells have received attention recently for use in solar power devices. Alternatives to single crystal semiconductors have been sought to reduce the cost of the photocells. According to this invention, the semiconductor is made from a pressure sintered and vapor annealed semiconductor. The electrode is relatively inexpensive to make and the efficiency of the solar cell compares favorably to the efficiency of solar cells using single crystal electrodes.

4,084,172
Scranton, Robert A.; McGill, Thomas C., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Highly Electronegative $(SN)_x$ Contacts to Semiconductors*. April 11, 1978.

Polymeric sulfur nitride is a conductive metallic compound providing a highly electronegative contact for both n- and p-type semiconductor materials. Tests show the electronegativity to be higher than Au. Larger barriers are obtained for n-type semiconductors and smaller barriers, or Ohmics, for p-types.

4,084,985
Evans, John C., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method for Producing Solar Energy Panels by Automation*. April 18, 1978.

A solar cell panel is fabricated by photoetching a pattern of collector grid systems with appropriate interconnections and bus bar tabs into a glass or plastic sheet. These regions are then filled with a first, thin conductve metal film followed by a layer of a mixed metal oxide, such as $InAsO_x$ or $InSnO_x$. The multiplicity of solar cells are bonded between the protective sheet at the sites of the collector grid systems and a back electrode substrate by conductive metal filled epoxy to complete the fabrication of an integrated solar panel.

4,086,101
Jordan, John Francis; Lampkin, Curtis Magill, inventors; Photon Power, Inc., assignee. *Photovoltaic Cells*. April 25, 1978.

A method of making low cost photovoltaic cells on a large scale basis by means of a continuous process of coating sheet glass while the sheet glass moves in and has its under surface immersed in a tank of molten material, comprising forming the film of CdS microcrystals on the glass sheet, which has previously been coated with transparent SnO_x to a thickness of about 0.3 to 0.6 microns. A water solution of a cadmium salt, a sulphur compound, and an aluminum containing soluble compound is intermittenty sprayed on said glass while its exposed surface is maintained at a constant temperature in the range 500°F to 1100°F and while irradiating the surface with intense ultraviolet light so as to form a film of CdS microcrystals. This CdS film has Al impregnated within the stratum of the film adjacent to the $Sn0_x$, but only optionally has Al impregnated in the stratum of the CdS film adjacent to the exposed surface of the CdS film. After the spray process is completed, the temperature of the sheet of glass is brought to the range 450°C to 550°C, 525° being optimum. After heating, the glass is cooled to approximately room temperature and the exposed surface of the CdS is converted to Cu_xS, the x of Cu_xS being as close to 2 as possible, by dipping the coated glass in a solution comprising: a solvent, which may be water, a weak acid, such as tartaric acid, citric acid, or lactic acid; a copper containing compound; and, optionally, a quantity of $H_2Ce(SO_4)_4$ and NaCl, or some other chloride; or by electroplating to form a film of Cu_xS; or, by a combination of dipping and electroplating. The Cu_xS forming process proceeds by ion exchange, i.e., S from CdS combines with Cu to form Cu_xS. Cu is then applied over the Cu_xS, and the cell is cured at a temperature in the range 400°F to 500°F.

4,086,102
King, William J., inventor. *Inexpensive Solar Cell and Method Therefor*. April 25, 1978.

Solar cells are manufactured by a simplified method in which a single protective layer acts as an anti-reflection coating and an encapsulation. In cases where the junction is formed by ion implantation techniques, the same layer also serves as the implantation oxide. In addition, this multi-purpose layer may also serve as a mass analyzer, allowing the desired species of ions to reach the surface of the semiconductor but blocking the heavier undesired species. The necessary contacts may be formed prior to implantation, and the use of alloyed aluminum contacts with aluminum oxide passivation permits a simplified contacting procedure. A fully automatic contacting method and configuration for linear materials is also disclosed.

4,086,485
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *Solar-Radiation Collection Apparatus with Tracking Circuitry*. April 25, 1978.

The invention contemplates improved apparatus for collecting solar radiation and directionally concentrating the same upon utilization means such as a photovoltaic cell system. In the form described, arrayed collecting devices are mounted for individual tracking of maximum solar-energy response at each such cell system, utilizing time-shared access to a microprocessor, and correctional-drive signals uniquely appropriate to the orientation of each collecting device are supplied by the microprocessor on a time-shared basis for the respective components of orientation correction drive means for each collecting device. Since each collecting device is thus automatically correctively positioned for maximum output of its own utilization device, there is an avoidance of precision requirements (a) as to mounting the several collecting devices with respect to each other and (b) as to basic drives to anticipate relative aspect of the sun, as a function of the time of day, or the day of the year and whatever the earthbound location of the apparatus.

4,087,571
Kamins, Theodore I.; Manoliu, Juliana, inventors; Fairchild Camera and Instrument Corporation, assignee. *Controlled Temperature Polycrystalline Silicon Nucleation*. May 2, 1978.

The diffusivity of an impurity in a layer of polycrystalline silicon is controlled by forming the polycrystalline silicon on a thin nucleating layer of polycrystalline silicon possessing a maximum {110} texture.

4,087,960
Koichi, Oguchi, inventor; Kabushiki Kaisha Suwa Seikosha, assignee. *Solar Battery Wristwatch*. May 9, 1978.

A solar-battery wristwatch makes use of a flexible printed-circuit board for connecting the cells of the battery in series and for connecting said battery with a storage battery. The arrangement eliminates the need for connecting wires and extraneous supports in that the flexible printed-circuit board holds the solar battery against the dial plate of the watch.

4,088,116
Pastor, Jose, inventor. *Radiant Energy Collector*. May 9, 1978.

A radiant energy collector is described having a generally scroll-shaped configuration and exhibiting a hemispheric energy acceptance angle. Substantially all diffuse and direct radiant energy which is incident on a reflective surface of the collector is reflected toward an elongated energy conversion means. In one arrangement, the energy conversion means comprises a fluid container in which a transfer fluid is heated. In another arrangement, the energy conversion means comprises means for converting incident radiant energy into electrical energy.

4,088,121
Lapeyre, James M., inventor; The Laitram Corporation, assignee. *Solar Energy Concentrator*. May 9, 1978.

A solar energy concentrator having an array of horns each having converging reflecting surfaces which provide a multiple reflective path from a relatively wide entrance aperture exposed to incident solar energy and a smaller exit aperture from which intensified energy emanates. The energy received from the exit apertures of the horn array is of higher density than the incident energy density and can be used as heat or converted to electrical or other forms of energy for use.

4,088,508
Gravisse, Philippe Edouard, inventor. *Amplifying Device of Radiant Energy*. May 9, 1978.

A radiant energy amplifying device receiving energies from short wavelengths by a plurality of scintillating materials having high quantum yields operating in cascade which are distributed homogeneously in a matrix made of synthetic resinous material whose absorption threshold is at wavelength less than the absorption zone of the scintillating material located at the beginning of the cascade, wherein the scintillating materials are present in the matrix in a proportion varying according to the material from 2×10^{-3} to 10^{-7} mole/kg of resin, the highest concentration corresponding to the material being located at the beginning of the cascade.

4,089,576
Barchet, Reinhold J., inventor; General Electric Company, assignee. *Insulated Connection of Photovoltaic Devices*. May 16, 1978.

The electric terminals or leads of photovoltaic devices to be interconnected into an array are encased in the insulating layers of the devices. Guideholes pass through the devices and the terminals. Fasteners having an insulated head and shank with a conductive means on the shank are positioned so that the conductive means is in contact with the terminals. Screw and nail type fasteners are disclosed.

4,089,705
Rubin, Irwin, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Hexagon Solar Power Panel*. May 16, 1978.

A solar energy panel comprises a support upon which silicon cells are arrayed. The cells are wafer thin and of two geometrical types, both of the same area and electrical rating, namely hexagon cells and hourglass cells. The hourglass cells are composites of half hexagons. A near perfect nesting relationship of the cells achieves a high density packing whereby optimum energy production per panel area is achieved.

4,090,071
McCarter, Craig A., inventor; Hoffman Engineering Corporation, assignee. *Photometric Instrument with Thermoelectric Control of a Photovoltaic Semiconductor Detector*. May 16, 1978.

A highly accurate thermoelectrically controlled radiant energy detector achieving sufficient measurement stability to permit it to monitor the radiant energy output of a calibrated standard instrument such as a luminance/illuminance source, which is to generate a standard quantity of radiant energy to be used, e.g., in the field testing and calibration of photometric instruments. The radiant energy detector provides a highly stable and drift free photometric measurement using a silicon photovoltaic detector arranged to receive radiant energy upon a sensitive surface thereof and to emit an electrical output signal related to the magnitude of incident radiant energy. A thermally conductive member, such as a mounting block, carries the light detecting element, and temperature sensing means, such as the semiconductor junction of a transistor, is in thermal communication with the conductive member. Controllable heat emitting means, such as another transistor, also is in thermal communication with the conductive member and a feedback circuit responds to the temperature sensing means for controlling the heat emitting means to maintain the conductive member and the light detecting element carried thereby at a constant temperature elevated above ambient temperature, e.g., 40°C. The relationship between incident radiant energy and electrical output of the light detecting element remains substantially invariant, e.g., with a drift of approximately only 1% per year. Spectral response is stabilized and sensitivity is improved. Accordingly, the radiant energy detector and monitored radiant energy source allow highly accurate field or laboratory measurement and calibration to take place.

4,090,213
Maserjian, Joseph; Chern, Shy Shiun; Li, Seung P., inventors; California Institute of Technology, assignee. *Induced Junction Solar Cell and Method of Fabrication*. May 16, 1978.

An induced junction solar cell is fabricated on a p-type silicon substrate by first diffusing a grid of criss-crossed current collecting n^+ stripes, and thermally growing a thin SiO_2 film, and then, using silicon-rich chemical vapor deposition (CVD), producing a layer of SiO_2 having inherent defects, such as silicon interstices, which function as deep traps for spontaneous positive charges. Ion implantation increases the stable positive charge distribution for a greater inversion layer in the p-type silicon near the surface. After etching through the oxide, to parallel collecting stripes, a pattern of metal is produced consisting of a set of contact stripes over the exposed collecting stripes and a diamond shaped pattern which functions as a current collection bus. Then the reverse side is metallized.

4,090,359
Doellner, Oscar Leonard, inventor. *Radiant Energy Power Source for Jet Aircraft and Missiles*. May 23, 1978.

A radiant-energy-sensing power system applicable to aircraft having jet-type engines, vehicles having gas turbine engines, and missiles, comprising photovoltaic type cells mounted in the proximity of the combustion chamber of a jet engine and the aft end of a missile whereby the photovoltaic solar cells receive a portion of the radiant energy from the burning of the jet or missile fuel and convert same to electrical energy for use in the aircraft, missile, or vehicle.

4,090,577
Moore, Wallace H., inventor. *Solar Celled Hybrid Vehicle*. May 23, 1978.

A front wheel driven, gas powered vehicle is converted to include a rear differential connected for power input to a first and second electrical motor, or a single electric motor if desired. When first and second electrical motors are used they are connected in parallel, the power input thereto being brought across a current limiting series of resistors to protect and control the current level thereto. A switching circuit connects in various series and parallel combinations a plurality of batteries and concurrently switches the necessary current limiting resistance. Thus a control combination is provided including a manual selector for the desired forward and reverse directions and the low and high current ranges

which is further multiplied by the various resistances. In this configuration, the normally available gasoline power plant is retained in the vehicle and is augmented during periods of nonoptimal use by the above electric motor provisions. This electric power can be periodically replenished either by way of a charger or a set of solar panels placed on the roof of the vehicle.

4,092,446
Padovani, Francois A.; Miller, Michael Brant; Moore, James A.; Fowler, James H.; June, Malcolm Neville; Matthews, James D.; Morton, T. R.; Stotko, Norbert A.; Palmer, Lewis B., inventors; Texas Instruments Incorporated, assignee. *Process of Refining Impure Silicon to Produce Purified Electronic Grade Silicon*. May 30, 1978.

A balanced closed cycle silicon refinery has been developed for producing electronic silicon from industrial grade silicon. Impurities comprising approximately 1% of the industrial grade silicon are removed during the refinery process to produce the purified silicon, while only a relatively small percentage of make-up chemicals are added to the system. In the refinery, hydrogen chloride is reacted with the impure silicon in a halide reactor to provide trichlorosilane and silicon tetrachloride and hydrogen. The trichlorosilane and/or silicon tetrachloride are purified to remove the impurities, and then reacted with the hydrogen from the halide reactor in a fluidized bed reactor to produce the purified silicon and an effluent comprised of unreacted trichlorosilane, silicon tetrachloride, hydrogen, and the by-product hydrogen chloride. These materials are separated and the trichlorosilane and silicon tetrachloride and hydrogen are returned to the silicon reactor while the hydrogen chloride is returned to the halide reactor to be reacted with additional industrial grade silicon in a closed cycle process.

4,093,473
Lindmayer, Joseph, inventor. *Solar Panel with UV Absorber*. June 6, 1978.

A solar panel including photovoltaic cells encapsulated in a silicone resin containing an ultraviolet light absorber that will inhibit corrosion of metallic cell parts and resin delamination while having no substantial, adverse effect on curing of the resin.

4,094,704
Milnes, Arthur G., inventor. *Dual Electrically Insulated Solar Cells*. June 13, 1978.

Composite solar cells of improved efficiency comprise two cells of different characteristics arranged in optical series but electrically insulated from each other. Preferably, each cell is of larger crystal grain size than its substrate, which grain size is achieved by growing the cell semi-conductor on a molten intermediate rheotaxy layer of a suitable semi-conductor which solidifies at a temperature below the melting temperature of the solar cell semi-conductor. The substrate and the intermediate rheotaxy layer of the overlying cell are transparent to that fraction of sunlight which is utilized by the underlying cell. Various configurations of overlying and underlying cells are disclosed.

4,094,751
Nozik, Arthur J., inventor; Allied Chemical Corporation, assignee. *Photochemical Diodes*. June 13, 1978.

Photochemical diodes are provided which use light to drive both endoergic and exoergic chemical reactions such that optical energy is converted into chemical energy. The photochemical diodes are typically suspended in a bulk volume matrix of the constituent chemical reactants. The photochemical diodes, in the form of either Schottky-type diodes or p-n type diodes, are employed, for example, to convert water into hydrogen plus oxygen (or hydrogen peroxide); to convert hydrogen sulfide into hydrogen plus sulfur; and to photo-catalyze chemical reactions. The photochemical diodes of the invention comprise two portions, a first portion comprising an appropriately doped semiconductor material of a given conductivity and provided with an ohmic contact and a second portion comprising either metal(Schottky-type) or an appropriately doped semiconductor material of a conductivity type opposite to that of the first portion and provided with an ohmic contact (p-n type). The two portions are intimately joined together through the ohmic contact(s). Solar radiation is conveniently employed as a source of optical energy.

4,095,004
Fraas, Lewis M.; Bleha, William P., Jr., inventors; Hughes Aircraft Company, assignee. *Process for Low Temperature Stoichiometric Recrystallization of Compound Semiconductor Films*. June 13, 1978.

A new, useful and nonobvious process is disclosed wherein vapor phase controlled stoichiometry is employed to obtain compound semiconductor films having large crystallite textures. The process has been found to be particularly useful in the formation of compound semiconductor films where one of the components is a high vapor pressure element and the substrate material is amorphous.

4,095,006
Jordan, John Francis; Lampkin, Curtis Magill, inventors; Photon Power, Inc., assignee. *Cadmium Sulfide Film*. June 13, 1978.

A method of forming a cadmium sulfide film from a solution containing a cadmium salt and a sulfur containing compound comprising inclusion of a chlorine containing compound in the solution utilized to form the cadmium sulfide film.

4,095,217
Tani, Hirotsugu; Taguchi, Kyoji; Arita, Shigeru, inventors. *Combined Liquid Crystal Display and Photovoltaic Converter*. June 13, 1978.

By replacing the passive reflector in a liquid crystal display with a photovoltaic converter, the dual results of light reflection for display visibility and electrical energy generation for operation of the display and associated circuitry, such as electronic calculator circuitry, are achieved.

4,095,329
Ravi, Kramadhati Venkata, inventor; Mobil Tyco Solar Energy Corporation, assignee. *Manufacture of Semiconductor Ribbon and Solar Cells*. June 20, 1978.

A method is provided for producing solar cells employing slightly curved or nearly flat monocrystalline silicon ribbons. The ribbons are formed by cutting or slicing monocrystalline hollow tubes along their lengths, the tubes having been formed according to crystal growing processes disclosed in U.S. Pat. No. 3,591,348.

4,095,997
Griffiths, Kenneth F., inventor. *Combined Solar Cell and Hot Air Collector Apparatus*. June 20, 1978.

A solar collector having at least one solar cell, an air retaining plate located parallel to and immediately behind the unlit side of the cell. A plate is spaced from the back of the cell to permit passage of substantially all the air that is to be treated by the cell, the retaining plate being in communication with the portion of the collector through which the air is withdrawn.

4,097,308
Klein, William Richard; Kotila, Carl Leroy; Krams, Ira Leslie, inventors; Tideland Signal Corporation, assignee. *Glass Enclosed Solar Cell Panel*. June 27, 1978.

A solar panel for use in hostile environments. The panel includes top and bottom molded glass plates, each having a downwardly directed sidewall extending around their outer peripheries. The bottom plate is positioned beneath and within the sidewalls of the top plate thereby downwardly directing the opening to the compartment formed between the top and bottom plates. Recesses are molded in either the bottom of the top plate or in the top of the bottom plate for receiving solar cells whereby the thickness

of the compartment is minimized. The recesses are sized and shaped to conform to the size and shape of the solar cells. A passageway is provided from each recess to an adjacent recess for electrical connections between adjacent solar cells which are positioned in each of the recesses. Potting compound having an index of refraction similar to the index of refraction of glass fills the compartment. The thickness of the compartment is sufficient to allow the compound to withstand thermal cycling. Electrical connections to the solar cells sealably extend through the bottom plate.

4,097,309
Horne, William E., inventor; The Boeing Company, assignee. *Thermally Isolated Solar Cell Construction*. June 27, 1978.

Thermal isolation shields consisting of two glass slides separated by insulating standoffs are positioned upon the front radiation receiving surface of a solar cell and/or upon the back surface of the solar cell. One of the two glass plates is made from material selected to absorb and radiate electromagnetic wave energy with a wavelength above 5 microns to prevent overheating of the cell. The space between the two cover plates forms a thermal gap that is, if desired, bridged by a bimetallic strip. The strip is adhered to one of the plates and has a reverse bend to extend along the face surface of the opposed cover plate. The strip distorts under an increased temperature to break the bridge between the two plates and thereby isolates the solar cell from the thermal shield formed by the outer cover plate until there is a sufficient reduction in temperature at which the bimetallic strip reestablishes conductive contact between the cover plates. Each solar cell assembly in an array is adhered to a substrate by first bonding glass pads to the substrate and then heating the cell and glass pads to a temperature of about 400° while applying an electrical potential of the order of 400 volts with the glass being negative potential with respect to the cell. A hermetic bond is achieved without the use of adhesives.

4,097,310
Lindmayer, Joseph, inventor. *Method of Forming Silicon Solar Energy Cells*. June 27, 1978.

A method of forming a silicon solar energy cell, which comprises forming an electron generating junction on a single crystal silicon wafer and thereafter using a saw having a diamond blade to cut through the wafer and the junction formed therein.

4,099,199
Wittry, David Beryle, inventor; University of Southern California, assignee. *Photovoltaic Cell Employing a PbO-SnO Heterojunction*. July 4, 1978.

A photovoltaic cell that incorporates a PbO-SnO heterojunction of graded composition which, among other applications, can be utilized for the conversion of solar energy to electrical energy. A p-i-n junction is formed while PbO and SnO are simultaneously deposited on a substrate in a varying ratio that is either decreased or increased to form the compositions $Pb_{1-x}Sn_xO$ where x varies in the range of 0 to 1.

4,099,986
Diepers, Heinrich, inventor; Siemens Aktiengesellschaft, assignee. *Solar Cell Comprising Semiconductive Whiskers*. July 11, 1978.

A solar cell with semiconductor body consisting of single crystal semiconductor whiskers which are grown on a substrate surface permitting relatively inexpensive manufacture and high efficiency of the solar cell is disclosed.

4,100,051
Kilby, Jack S.; Lathrop, Jay W.; Porter, Wilbur A., inventors; Kilby, Jack S., assignee. *Light Energy Conversion*. July 11, 1978.

Solar energy conversion is provided by a structure formed of a plurality of photovoltaic sources. An electrolyte wets the sources. Upon exposure to light the photovoltaic sources cause a current to flow in the electrolyte, producing an electrochemical reaction. The products of this reaction are collected and stored. In a preferred embodiment the electrolyte is an aqueous solution of hydrogen iodide, and the hydrogen produced by the electrochemical reaction may be stored, burned as a fuel or used in a fuel cell to produce electrical energy.

4,100,427
Durand, Henri; Naaijer, Geert Jan, inventors; U.S. Philips Corporation, assignee. *Device for Converting Solar Energy*. July 11, 1978.

A device is described for converting solar energy into electric power for a load, which device is provided with photocells and electric accumulators. Switching means are provided which at least during starting of the load connect this load to the output terminals of the array of photocells so that during starting the current through the load is determined by the current supplied by the photocells. The device makes efficient use of the available solar radiation, is of simple design and is reliable.

4,101,341
Selders, Matthias Peter, inventor; Battelle Development Corporation, assignee. *CdSe-SnSe Photovoltaic Cell*. July 18, 1978.

The invention relates to a photovoltaic cell for converting solar energy into electrical power and which has, in sandwich construction, two different polycrystalline semiconductor layers in intimate contact and disposed on a metal or metal-coated substrate, the cell being provided with a light-transmissive or grating-shaped electrode on the side toward the light. The cell layers comprise the semiconducting selenides of cadmium and tin.

4,101,351
Shah, Pradeep L.; Fuller, Clyde R., inventors; Texas Instruments Incorporated, assignee. *Process for Fabricating Inexpensive High Performance Solar Cells using Doped Oxide Junction and Insitu Anti-Reflection Coatings*. July 18, 1978.

Silicon solar cells may be made from either "P" type substrates with "N" type dopants to form the geometries or with "N" type substrates and "P" type dopants forming the junction. This invention relates to the dopant species employed, the improved method of application and junction formation, formation of insitu anti-reflective coatings, and improved metallization processing for silicon solar cells. The invention does not affect preparation of the silicon substrate prior to diffusion steps, and is applicable both to planar solar cells and to vertical-multijunction cells. This invention discloses an alternate process of junction formation using arsenic as dopant. The process is uniquely different in the fact that it simplifies the number of process steps by using the doped oxide for junction formation, metallization mask and as an anti-reflection surface layer.

4,101,923
Gulko, Arnold G.; Steinberg, Jacob H., inventors. *Solar Cells*. July 18, 1978.

A solar cell is provided which comprises a layer of crystalline silicon doped with boron on at least one surface thereof and having the other surface doped with vanadium.

4,101,925
Kelley, Larry P.; Hardy, Craig A., inventors. *Centrifugal Forming Thin Films and Semiconductors and Semiconductor Devices*. July 18, 1978.

A method and apparatus for centrifugally forming thin semiconductor films or layers wherein centrifugal force is applied to a molten single-crystal forming material to overcome surface tension and evenly spread the material along a substrate surface substantially parallel to the axis of rotation. The material is thereafter cooled, uniformly or progressively from a seed single crystal, to form a thin layer or film of crystalline material. Desirably,

the films or layers will be substantially single crystals. The process and apparatus are useful in forming thin, semiconductor crystal layers useful, for example, in solar cells. Semiconductor devices according to the invention have a porous graphite substrate, a thin film or layer of silicon and a gridwork plated onto the silicon. The interface between the silicon grid graphite substrate is substantially free from silicon carbide.

4,102,764
Harvey, Francis J., II; Fey, Maurice G., inventors; Westinghouse Electric Corp., assignee. *High Purity Silicon Production by Arc Heater Reduction of Silicon Intermediates*. July 25, 1978.

A process for converting silicon intermediates to high purity silicon by an arc heater characterized by the thermal reduction of one of several potential purified silicon intermediate compounds using an arc heater as the reduction energy source and using hydrogen as the reductant.

4,102,765
Fey, Maurice G.; Harvey, Francis J., II; McDonald, Jack, inventors; Westinghouse Electric Corp., assignee. *Arc Heater Production of Silicon Involving Alkali or Alkaline-Earth Metals*. July 25, 1978.

A process for producing high purity silicon characterized by the employment of an electric arc heater into which a silicon halide is injected together with a metal reductant such as an alkali metal or an alkaline-earth metal which are reacted together by projecting them tangentially into a reaction chamber to cause the formation of liquid silicon and a gaseous metal halide salt which are separated in a suitable manner such as centrifugally or by condensation.

4,102,766
Fey, Maurice G., inventor; Westinghouse Electric Corp., assignee. *Process for Doping High Purity Silicon in an Arc Heater*. July 25, 1978.

A method for doping solar grade silicon characterized by the steps of feeding into an arc heated gas stream a quantity of a metal reductant such as an alkali metal or an alkaline-earth metal and also feeding into the stream a quantity of a silicon halide and of a corresponding halide of a doping agent such as arsenic to react with the metal reductant to produce reaction products including a salt of a metal reductant and a mixture of liquid silicon and doping agent, and separating the mixture from the salt of the metal reductant.

4,102,767
Mazelsky, Robert; Fey, Maurice G.; Harvey, Francis J., inventors; Westinghouse Electric Corp., assignee. *Arc Heater Method for the Production of Single Crystal Silicon*. July 25, 1978.

A method for the production of single crystal silicon characterized by the steps of feeding into an arc heater a quantity of uncontaminated silicon halide to react with hydrogen or a metal reductant, such as sodium, to produce reaction products including liquid silicon and a gaseous salt of the reductant, depositing the liquid silicon on a downwardly inclined surface, and attaching a single seed crystal of silicon to the liquid silicon and withdrawing the single seed crystal from the liquid silicon so as to propagate a large single crystal.

4,102,985
Harvey, Francis J., II, inventor; Westinghouse Electric Corp., assignee. *Arc Heater Production of Silicon Involving a Hydrogen Reduction*. July 25, 1978.

A process for the production of high purity silicon characterized by the employment of an electric arc heater in which a silicon halide is reacted with hydrogen to produce liquid silicon and gaseous co-products.

4,104,083
Hirano, Taizö, inventor; Japanese Government, assignee. *Solar Battery Package*. August 1, 1978.

A solar battery package having at least one solar cell substantially embedded in a block of fiber-reinforced thermosetting resin with a transparent flexible covering. The block as a portion, overlaying a light receiving area of the solar cell, which is transparent and has another portion which is either transparent or substantially opaque. A protective coating of fluorine-containing compound may be applied to the block to improve the weatherability of the solar battery package. A method of making the solar battery package is also disclosed.

4,104,084
Evans, John C., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cells Having Integral Collector Grids*. August 1, 1978.

A heterojunction or Schottky barrier photovoltaic device comprising a conductive base metal layer compatible with and coating predominately the exposed surface of the p-type substrate of the device such that a back surface field region is formed at the interface between the device and the base metal layer, a transparent, conductive mixed metal oxide layer in integral contact with the n-type layer of the heterojunction or Schottky barrier device having a metal alloy grid network of the same metal elements of the oxide constituents of the mixed metal oxide layer embedded in the mixed metal oxide layer, an insulating layer which prevents electrical contact between the conductive metal base layer and the transparent, conductive metal oxide layer, and a metal contact means covering the insulating layer and in intimate contact with the metal grid network embedded in the transparent, conductive oxide layer for conducting electrons generated by the photovoltaic process from the device.

4,104,091
Evans, John C., Jr.; Brandhorst, Henry W., Jr.; Mazaris, George A.; Scudder, Larry R., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Application of Semiconductor Diffusants to Solar Cells by Screen Printing*. August 1, 1978.

Diffusants are applied onto semiconductor solar cell substrates using screen printing techniques. The method is applicable to square and rectangular cells and can be used to apply dopants of opposite types to the front and back of the substrate. Then, simultaneous diffusion of both dopants can be performed with a single furnace pass.

4,104,420
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Photovoltaic Cell*. August 1, 1978.

A large area photovoltaic cell comprising a layer of multicrystalline cadmium sulfide, about 1 to 2 microns thick, formed by simultaneously spraying two suitably selected compounds on a uniformly heated plate of Nesa glass, thereafter forming a coating of of Cu_2S over the cadmium sulfide layer while the latter is heated, to form a photovoltaic heterojunction, applying thereover a layer of $CuSO_4$, and applying electrodes of Cu and Zn, respectively, to separated areas of the layer of $CuSO_4$, and heating the cell to form a cuprous oxide rectifying junction under the copper electrode by reaction of the Cu electrode with the $CuSO_4$, while diffusing the zinc through the body of the cell. The diffusion of the zinc provides a negative electrode coplanar with the positive copper electrode, eliminating any need for introducing mechanically complex provision for making a connection to the Nesa glass, while the use of a $CuSO_4$-Cu combination enables use of a layer of CdS only 1 to 2 microns thick, rather than the usual 20 microns, despite the fact that such thin layers tend to have pinholes, which in the prior art render the cells inoperative, but in the present teaching do not.

4,105,470
Skotheim, Terje A., inventor; The United States Government as represented by the United States Department of Energy, assignee. *Dye-Sensitized Schottky Barrier Solar Cells*. August 8, 1978.

A low-cost dye-sensitized Schottky barrier solar cell comprised of a substrate of semiconductor with an ohmic contact on one face, a sensitizing dye adsorbed onto the opposite face of the semiconductor, a transparent thin-film layer of a reducing agent over the dye, and a thin-film layer of metal over the reducing agent. The ohmic contact and metal layer constitute electrodes for connection to an external circuit and one or the other or both are made transparent to permit light to penetrate to the dye and be absorbed therein for generating electric current. The semiconductor material chosen to be the substrate is one having a wide bandgap and which therefore is transparent; the dye selected is one having a ground state within the bandgap of the semiconductor to generate carriers in the semiconductor, and a first excited state above the conduction band edge of the semiconductor to readily conduct electrons from the dye to the semiconductor; the reducing agent selected is one having a ground state above the ground state of the sensitizer to provide a plentiful source of electrons to the dye during current generation and thereby enhance the generation; and the metal for the thin-film layer of metal is selected to have a Fermi level in the vicinity of or above the ground state of the reducing agent to thereby amply supply electrons to the reducing agent.

4,105,471
Yerkes, John W.; Avery, James E., inventors; Arco Solar, Inc., assignee. *Solar Cell with Improved Printed Contact and Method of Making the Same*. August 8, 1978.

A silicon solar cell having a body of boron doped P-type silicon material with a shallow P/N junction formed therein through diffusion of phosphorous into one surface thereof. A contact pattern of conductive material is formed on the surface of the solar cell in which the P/N junction is formed. The pattern is formed by first depositing a metallic layer upon the entire surface of the body and then applying the contact pattern by printing upon the surface of the metal. The metal has a characteristic such that when heated in the presence of oxygen to an appropriate temperature to fire the conductive material, it oxidizes and forms an antireflective layer on the surface of the cell except in those areas where the printed contact pattern is disposed. In the areas of the printed contact pattern the metal forms an ohmic contact between the surface of the silicon and the printed contact pattern and provides a barrier to preclude the conductive contact pattern material from punching through the shallow P/N junction.

4,106,047
Lindmayer, Joseph, inventor. *Solar Cell with Discontinuous Junction*. August 8, 1978.

A silicon solar energy cell having a substantially constant voltage despite significant increases in illumination, which cell has a back surface junction that is discontinuous and has spaced, shorted portions formed therein.

4,106,482
Savage, Fred L.; Long, Alfred D., inventors. *Autonomic Solar Panel*. August 15, 1978.

An autonomic solar heat collecting system is provided. The heart of the system is a solar panel including a flat outer surface adapted to be exposed to the direction of the radiation of the sun. A flat or formed inner sheet is provided which is closely spaced from the outer surface section. Preferably, a flat, transparent plate is provided, which is spaced from, which covers, and is disposed outwardly from, the flat outer section, thereby forming an air-tight compartment between itself and the flat outer surface. Joining the inner and outer surfaces to one another at the top and at the bottom provides a hollow, fluid-tight cavity. Because the inner and outer surfaces are closely spaced from each other, the fluid is in the form of a thin fluid membrane. Means are provided for allowing entrance of a fluid into the cavity and means are provided for removal of the fluid from the other cavity. To provide most efficient control and heat removal, the collector should be made of two copper sheets, the outer of which is flat, separated about 0.016 inches apart with an enclosed volume of fluid not exceeding about 2.3 cubic inches/square foot of panel. Due to the small volume of fluid circulating through the solar panel, low power requirements are inherent to the system, and low voltage power is ample to activate the solar energy collecting system independent of any outside power source. Thus, an essential feature of the autonomic system is low wattage, low power pump means activated by a small predetermined temperature differential, and the means for providing power for the operation of the system is solar cells or wet or dry batteries.

4,106,951
Masi, James V., inventor; UCE, Inc., assignee. *Photovoltaic Semiconductor Device Using an Organic Material as an Active Layer*. August 15, 1978.

A photovoltaic semiconductor junction device which is particularly useful as a solar cell comprises a first layer of organic semiconductor material exhibiting one type of electronic conductivity and a second of inorganic semiconductor material having the same or opposite type conductivity. The first layer of organic semiconductor material has an energy bandgap relatively wider than that of the second layer of semiconductor material. The electron affinities of the first and second layers of semiconducting material may be equal, greater, or less than those of the other. The first layer of organic semiconductor material must either be doped to have a resistivity below 10^6 ohm-centimeters or be sufficiently thin to allow conduction. In devices employing n-type layers on p-type substrates, the conduction band energy level of the organic material is preferably at substantially the same energy level as the conduction band energy level of the narrower band gap semiconductor material. In devices employing p-type layers, the valence band energy level of the organic material is preferably at substantially the same energy level as the valence band energy level of the narrower bandgap inorganic semiconductor material.

4,106,952
Kravitz, Jerome H., inventor. *Solar Panel Unit*. August 15, 1978.

The elements of the solar panel are arranged generally in parallel planes that, starting from the top, include a transparent sheet, a plurality of converging lenses, a plurality of solar cells arranged in electrical series respectively aligned with the converging lenses, an electrically insulating support plate that together with the sides of the solar unit and the top sheet form a vacuum chamber for the lenses and solar cells to reduce heat transfer by convection and conduction upwardly from the solar cells, a thermopile, a heat sink plate receiving heat from the thermopile, heat transfer fins receiving heat from the heat sink plate, a serpentine conduit in heat exchange with the heat fins, thermal insulation, and a bottom plate that is connected to the side walls. Two side walls contain mating couplings for each of the conduit, thermopile, and photoelectric cells so that two adjacent panels may be interconnected with such couplings to provide fluid connection and electrical connection between the adjacent panels.

4,107,723
Kamath, G. Sanjiv, inventor; Hughes Aircraft Company, assignee. *High Bandgap Window Layer for GaAs Solar Cells and Fabrication Process Therefor*. August 15, 1978.

The specification describes a semiconductor solar cell and fabrication process therefor wherein a thin N-type gallium arsenide layer is deposited on a larger P-type substrate layer which is selected from the group of III-V ternary compounds consisting of aluminum phosphide antimonide, AlPSb, and aluminum indium phosphide, AlInP. P-type impurities are diffused from the substrate layer into a portion of the thin N-type gallium arsenide layer to form a P-type region therein which defines a PN junction in the thin gallium arsenide layer. Thus, the quantity of gallium arsenide

required to provide this PN photovoltaic junction layer in the cell is minimized, and the P-type substrate serves as a high bandgap window layer for the cell. Such high bandgap of this window material is especially well suited for efficiently transmitting the blue spectrum of sunlight to the PN junction, thus enhancing the power conversion efficiency of the solar cell.

4,108,405
Gibson, Preston H., inventor. *Light Assembly and Flasher Circuit*. August 22, 1978.

Generally speaking the present invention contemplates a kit-type railroad crossing signal device having four red, double lens lights attached to prewired arms, a module for flasher control, a battery box, an automatic controlled battery charger, switching control and, a metal conduit and clamps. A standard railroad signal bell can also be supplied.

4,108,540
Anderson, Raymond H.; Vanderwerf, Dennis F., inventors; Minnesota Mining and Manufacturing Company, assignee. *Refractor-Reflector Radiation Concentrator*. August 22, 1978.

A small-area focus solar concentrator comprising a linear echelon refractor and a linear echelon reflector. The increments of the refractor are crossed at approximately 90° to the increments of the reflector. The refractor and reflector cooperate to focus solar radiation incident on the front surface of the refractor to a small area focus in front of the refractor.

The refractor-reflector structure permits relatively low cost, high power concentrators using refractor-reflector matrices. Also, the refractor-reflector structure can be used to focus normal or non-normal incident radiation outside the path of the radiation to reduce or eliminate blockage of the radiation by an absorber located at the focus.

4,108,684
Zanio, Kenneth W.; Fraas, Lewis M., inventors; Hughes Aircraft Company, assignee. *Large Grain Thin Film Polycrystalline P-InP/N-CdS Solar Cell*. August 22, 1978.

A thin film solar cell having adjacent layers of P and N type polycrystalline semiconductor material which define a PN junction boundary, the improvement comprising a layer of n-type polycrystalline cadmium sulfide disposed on a chosen substrate material and having large grains with lateral grain boundaries on the order of about 20 micrometers or greater and a layer of polycrystalline P-type indium phosphide disposed on said layer of polycrystalline cadmium sulfide and having a thickness on the order of between 1.0 and 4.0 micrometers and further having large replicated grain boudaries with lateral dimensions and spacings approximately the same as the lateral dimensions and spacings of said large grains of cadmium sulfide, whereby the lateral grain dimensions in said cadmium sulfide and indium phosphide layers are maximized while the quantity of indium in said solar cell is minimized.

4,108,704
Horne, William E., inventor; The Boeing Company, assignee. *Method of Making an Array of Solar Cells*. August 22, 1978.

Thermal isolation shields consisting of two glass slides separated by insulating standoffs are positioned upon the front radiation receiving surface of a solar cell and/or upon the back surface of the solar cell. One of the two glass plates is made from material selected to absorb and radiate electromagnetic wave energy with a wavelength above 5 microns to prevent overheating of the cell. The space between the two cover plates forms a thermal gap that is, if desired, bridged by a bimetallic strip. The strip is adhered to one of the plates and has a reverse bend to extend along the face surface of the opposed cover plate. The strip distorts under an increased temperature to break the bridge between the two plates and thereby isolates the solar cell from the thermal shield formed by the outer cover plate until there is a sufficient reduction in temperature at which the bimetallic strip reestablishes conductive contact between the cover plates. Each solar cell assembly in an array is adhered to a substrate by first bonding glass pads to the substrate and then heating the cell and glass pads to a temperature of about 400° while applying an electrical potential of the order of 400 volts with the glass being negative potential with respect to the cell. A hermetic bond is achieved without the use of adhesives.

4,108,714
Keller, Wolfgang; Reuschel, Konrad, inventors; Siemens Aktiengesellschaft, assignee. *Process for Producing Plate-Shaped Silicon Bodies for Solar Cells*. August 22, 1978.

Molten silicon is controllably fed into a nip between spaced-apart rollers, converted into a wide ribbon of a desired thickness by passing through such nip and then solidified. The solidified silicon ribbon is then severed into plate-shaped bodies of desired dimension for use in the manufacture of solar cells.

4,109,271
Pankove, Jacques Isaac, inventor; RCA Corporation, assignee. *Amorphous Silicon-Amorphous Silicon Carbide Photovoltaic Device*. August 22, 1978.

A layer of amorphous silicon-carbide prepared by a glow discharge in a mixture of silane, hydrocarbon and doping gases is at the solar radiation incident surface of a photovoltaic device. The photovoltaic device includes first and second contiguous layers of amorphous silicon fabricated by a glow discharge in silane. The amorophous silicon carbide layer is contiguous to the second layer and opposite the first layer. The amorphous silicon carbide layer is substantially transparent to solar radiation and highly conductive, providing increased solar radiation collection efficiency and reduced internal resistance.

4,110,049
Younskevicius, Robert E., inventor; The United States of America as represented by the United States Department of Energy, assignee. *Sun Meter*. August 29, 1978.

A simple, inexpensive device for measuring the radiation energy of the sun impinging on the device. The measurement of the energy over an extended period of time is accomplished without moving parts or tracking mechanisms.

4,110,122
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *High-Intensity, Solid-State-Solar Cell Device*. August 29, 1978.

A semiconductor solar cell capable of converting incident radiation to electrical energy at high efficiency includes a plurality of series-connected unit solar cells formed on a common wafer of semiconductor material. The unit solar cells each include a semiconductor substrate of one conductivity type and a p-n junction formed in the substrate. The light-receiving surface of the cell may have an opaque member thereon, and incident light is directed onto the portion of that surface not covered by the opaque member. A variety of embodiments illustrates the invention.

4,110,123
Goetzberger, Adolf; Greubel, Waldemar, inventors; Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung e.V., assignee. *Apparatus for Converting Light Energy into Electrical Energy*. August 29, 1978.

An apparatus for the conversion of light energy into electrical energy, by which solar energy may be converted into electrical energy effectively and cheaply. The invention further relates to

fluorescent centers (light concentrators) which consist of thin layers of transparent solid or liquid materials with embedded fluorescent centers and which in conjunction with solar cells serve to convert solar energy into electrical energy.

4,110,628
Paull, Peter L.; Archer, Henry W., inventors; Texaco Development Corporation, assignee. *Solar Sea Power System*. August 29, 1978.

Described is an ocean thermal energy conversion system wherein floating, submerged and fixed drilling platforms installed offshore primarily for exploration and/or production of hydrocarbons serve also as working and supportive bases for means for producing electricity by the adiabatic expansion of hydrocarbon gases which are thereby cooled. The cooled gases are then heated by contact with the solar heated surface layers of water and thermally expand thereby actuating a turbine and an electricity producing generator. Pipelines usually installed for the transmission of gases and crude oil to the shore are used dually by running electric cables with them to bring the electricity produced by the system to on-shore consuming or storage facilities. The system also includes means for increasing the surface water temperature such as insulated pipes bringing heat-containing effluent streams from on-shore treating plants.

4,112,135
Heaps, Joseph D.; Tufte, Obert N., inventors; Honeywell, Inc., assignee. *Method for Dip-Coating Ceramic with Molten Silicon*. September 5, 1978.

It is desirable to coat large area, thin sheets of large-grain polycrystalline silicon on an inexpensive ceramic substrate for use in solar cell applications and the like. Such ceramic substrates as are used are chosen from those having thermal expansion coefficients similar to those of silicon. The ceramics meeting these requirements, for example mullite, alumina and zirconia, when brought into contact with molten silicon, however, are not wet by the silicon and no coating takes place. In this invention the method of coating includes the step of carbonizing the surface of such a substrate and then contacting the carbonized surface of the ceramic with the molten silicon, whereupon a large-grain silicon coating is produced wherever the ceramic is carbonized. In this way the ceramic of the type which is not wet by molten silicon can be successfully coated with silicon.

4,112,457
D'Aiello, Robert Vincent, inventor; RCA Corporation, assignee. *Photovoltaic Device Having an Extended PN Junction*. September 5, 1978.

A photovoltaic device having essentially only a body of semiconductor material having a first region of one conductivity type in contact with a second region of the opposite conductivity type, forming a portion of the device PN junction therebetween. A plurality of pocket regions of the same conductivity type as the first region extend into the second region thereby further defining a portion of the PN junction in the second region.

4,113,514
Pankove, Jacques Isaac; Lampert, Murray Alfred, inventors; RCA Corporation, assignee. *Method of Passivating a Semiconductor Device by Treatment with Atomic Hydrogen*. September 12, 1978.

A method of passivating a semiconductor device having at least one active component disposed therein comprises exposing the device to atomic hydrogen at a temperature lower than about 450°C.

4,113,531
Zanio, Kenneth W.; Fraas, Lewis M., inventors; Hughes Aircraft Company, assignee. *Process for Fabricating Polycrystalline InP-CdS Solar Cells*. September 12, 1978.

The specification describes a compound semiconductor solar cell and fabrication process therefor wherein both the P and N-type layers of the cell are polycrystalline semiconducting material and have large crystallites with grain boundaries of similar dimensions and spacings. These grain boundaries are spaced apart by a distance substantially greater than the optical absorption length, A, in one of the layers and by an amount sufficient to permit substantial numbers of photon-generated carriers in that one layer to cross the PN junction between the layers. Thus, substantial power is generated without the requirement for using expensive monocrystalline semiconductive materials.

4,113,532
Authier, Bernhard; Grisshammer, Rudolf; Köppl, Franz; Lang, Winfried; Sirtl, Erhard; Rath, Heinz-Jörg, inventors; Wacker-Chemitronic Gesellschaft fur Elektronik-Grundstoffe mbH, assignee. *Process for Producing Large-Size Substrate-Based Semiconductor Material Utilizing Vapor-Phase Deposition and Subsequent Resolidification*. September 12, 1978.

A process for producing large-size, substrate-based semiconductor material of silicon deposited on a substrate body from the gaseous phase, which comprises the steps of heating a substrate body by direct current passage to deposition temperature, contacting said body with a gaseous silicon-containing mixture to which a dopant has been added, until a deposit having a thickness from about 10 to 200 μm has been formed, subsquently melting 80 to 100% of the deposited silicon layer from the free surface downward, and resolidifying the molten silicon by adjustment of a temperature gradient from the substrate body upward. Large-sized plates obtained by cutting up the semiconductor material are used as solar cells.

4,115,149
Bell, Ronald L., inventor; Varian Associates, Inc., assignee. *Concentrator Arrangement for Photovoltaic Cell*. September 19, 1978.

A lens or mirror is employed to concentrate sunlight onto a photovoltaic cell. The cell employs a broad conductor around the periphery of its active surface, and narrow higher resistance conductor strips over the inner part of the surface. The cell and mirror are sized, positioned and shaped such that the image of the sun on the cell's surface is non-uniform, with a proportionately higher concentration of light falling near the periphery of the cell adjacent the peripheral conductors. Thus, the generated current is greater at the periphery, so that less energy is lost due to series resistance of the surface conductors, for more efficiency compared to a uniformly illuminated cell. The non-uniformity can conveniently be obtained by utilizing the natural spherical aberrations of a simple spherical mirror or lens. Also the cell can be positioned relatively close to the mirror outside the focal plane, so that the illuminated area on the cell is larger than the focused image of the sun in the focal plane. Thus, for given diameters of cell and mirror, the arrangement is more compact, and much less sensitive to inaccuracies in mirror curvature.

4,115,625
Reitz, Norman E., inventor; Sotec Corporation, assignee. *Sodium Thallium Type Crystal on Crystalline Layer*. September 19, 1978.

Relates to a composition of matter comprising a conductive sodium thallium type crystalline alloy substrate of LiZn, LiAl, LiGa, LiIn, NaTl or LiCd having crystalline silicon integrally overgrown thereon in an oriented crystal layer. Solar cells and semiconductors can be formed from the product.

4,115,633
Kasper, Horst Manfred; Tell, Benjamin; Wagner, Sigurd, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Electrochemical Device Comprising Ternary Ionic Conductors*. September 19, 1978.

Ionic conductivity in ternary chalcogenides of the form AB_xC_y where A is a metallic atom with atomic number no greater than 55 which has a +1 oxidation state, B is a group IIIA metallic atom and C is a group VIA atom, has been observed. This ionic conductivity makes the compounds useful as components in electrochemical cells, e.g., electrolytes and electrodes.

4,116,207
Dominguez, Ramon, inventor; Solarex Corporation, assignee. *Solar Panel with Mat Base Member*. September 26, 1978.

A solar panel including photovoltaic cells encapsulated in a silicone resin, in which the base member to which the silicone resin adheres is a glass mat polyester in laminate or molded form.

4,116,641
Ciszek, Theodore Frank, inventor; International Business Machines Corporation, assignee. *Apparatus for Pulling Crystal Ribbons from a Truncated Wedge Shaped Die*. September 26, 1978.

Method and apparatus for forming an elongated silicon crystalline body using a specially designed capillary die. The method and apparatus uses a higher melt meniscus in the central region of the growth front than at the edges of the front. The edges of the top surface of the die are not concentric with the ribbon cross-section.

4,116,717
Rahilly, William P., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Ion Implanted Eutectic Gallium Arsenide Solar Cell*. September 26, 1978.

An improved gallium arsenide solar cell is provided by ion implanting both the top and bottom of a plural vertical PN junction eutectic gallium arsenide cell body to obtain an electrical drift field, with multiple ion implants progressively larger in dose and progressively lower in implant energies to provide a P-type ion implanted top layer having a common connection to all P regions of the cell body and an N-type ion implanted bottom layer having a common connection to all N regions of the cell body. The implanted regions of the cell are pulsed electron beam annealed at room temperature.

4,116,718
Yerkes, John W.; Avery, James E., inventors; Atlantic Richfield Company, assignee. *Photovoltaic Array Including Light Diffuser*. September 26, 1978.

A photovoltaic array composed of a light transmitting member having a plurality of sides, at least one photovoltaic means carried by at least one of said sides, and a diffusive member covering a portion of said device.

4,118,249
Graven, Robert M.; Gorski, Anthony J.; Schertz, William W.; Graae, Johan E. A., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Modular Assembly of a Photovoltaic Solar Energy Receiver*. October 3, 1978.

There is provided a modular assembly of a solar energy concentrator having a photovoltaic energy receiver with passive cooling. Solar cell means are fixedly coupled to a radiant energy concentrator. Tension means bias a large area heat sink against the cell thereby allowing the cell to expand or contract with respect to the heat sink due to differential heat expansion.

4,118,548
Chang, Kuang-Chou; Heller, Adam; Miller, Barry, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Method of Operating a Liquid-Semiconductor Junction Photocell*. October 3, 1978.

Liquid-semiconductor photocells are described which produce a stable photocurrent output over extended periods of time by controllably removing material from the semiconductor surface in such a manner as to maintain the integrity of the junction characteristics. The removal may be either by photoetching or by chemical reaction with the electrolyte or with agents added to the electrolyte.

4,119,768
Bayard, Michel Lucien, inventor; Texas Instruments Incorporated, assignee. *Photovoltaic Battery*. October 10, 1978.

A photovoltaic battery in which a body of a photoactive material is disposed between first and second layers of ionically conductive material. The second layer is relatively high in ionic conductivity as compared to the first layer. An electric field oriented toward said second layer is induced through the photoactive body by virtue of the difference in chemical potential between the first and second layers of ionically conductive material. An electronically conductive body is disposed on the side of the first layer opposite from the photoactive body. The first layer in conjunction with the electronically conductive body acts as the positive electrode, the second layer acts as the negative electrode, and the photoactive body disposed therebetween acts as a solid electrolyte in the battery. When the photoactive body is exposed to visible light, it generates positive ions which are attracted to the negative electrode and electrons which are trapped by the electronically conductive body of the composite positive electrode. Charging of the battery thereby occurs as a result of the reaction between the photoactive body and light photons. During discharge of the battery, positive ions leave the negative electrode and enter the solid electrolyte comprising the photoactive body.

4,119,863
Kelly, Donald A., inventor. *Combined High Density Solar Panels and Vertical Wind Turbines*. October 10, 1978.

The combined high density solar panels and vertical wind turbines consist of multiple solar panels with closely spaced solar cells on both sides which are supported by an open framework and vertical posts. The adoption of an elevated, rooftop solar panel array, supported by vertical posts makes the basic structure attractive for the inclusion of multiple vertical wind turbines, as a supplementary power source. This combined natural power conversion arrangement is intended for mounting on the flat roofs of city buildings and other similar flat, limited area sites. Each solar panel is pivoted within the open framework to follow the sun's excursion relative to the earth, and the solar cells on the panel underside receive the solar energy by way of thin edge reflectors secured to both sides of the solar panels, for a high density exposure configuration. A washing spray provision is included for the panel array to keep the panels clean and operating at optimum efficiencies.

4,120,705
Shirland, Fred A., inventor; Westinghouse Electric Corp., assignee. *Vacuum Deposition Process for Fabricating a CdS-Cu_2S Heterojunction Solar Cell Device*. October 17, 1978.

A solar cell is comprised of (1) a Cu_2S thin film evaporated on a conductive substrate at an elevated temperature thereby growing a polycrystalline film of preferred orientation, and (2) an outer CdS layer grown epitaxially on the Cu_2S film.

4,120,743
Baghdadi, Aslan; Ellis, Ralph J., inventors; Motorola, Inc., assignee. *Crossed Grain Growth*. October 17, 1978.

A method of producing a sheet of semiconductor material directly usable for the production of solar cells is disclosed. The method comprises establishing a molten region at an edge of a sheet of semiconductor material, moving the molten region across the sheet to create a path of elongated crystal grains, establishing a molten zone along a portion of the path of the elongated crystal grains and parallel thereto, and causing the molten zone to travel in a direction transverse to the path of elongated crystal grains.

4,121,238
Bachmann, Klaus Jurgen; Schmidt, Paul Herman; Spencer, Edward Guerrant; Harsha, Karnamadakala Sreenivasaacharlu Sree, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Metal Oxide/Indium Phosphide Devices*. October 17, 1978.

Devices using a transparent conductive layer of indium oxide or indium tin oxide, and a layer of a direct gap semiconductor material have been found to operate as solar cells and as light emitting devices. Exemplary of such devices is an indium tin oxide/p-InP cell which shows a 12.5% solar power conversion efficiency and also emits a red colored light when biased.

Re. 29,812
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Photovoltaic Cell*. October 24, 1978.

A lagre area photovoltaic cell comprising a layer of multicrystalline cadmium sulfide, about 1 to 2 microns thick, formed by simultaneously spraying two suitably selected compounds on a uniformly heated plate of Nesa glass, thereafter forming a coating of Cu_2S by spraying two suitable compounds over the cadmium sulfide layer while the latter is heated, to form a photovoltaic heterojunction, applying thereover a layer of $CuSO_4$, and applying electrodes of Cu and Zn, respectively, to separated areas of the layer of $CuSO_4$, and heating the cell to form a cuprous oxide rectifying junction under the copper electrode by reaction of the Cu electrode with the $CuSO_4$, while diffusing the zinc through the body of the cell. The diffusion of the zinc provides a negative electrode coplanar with the positive copper electrode, eliminating any need for introducing mechanically complex provision for making a connection to the Nesa glass, while the use of a rectifying positive electrode enables use of a layer of CdS only 1 to 2 microns thick, rather than the usual 20 microns, despite the fact that such thin layers tend to have pinholes, which in the prior art render the cells inoperative but in the present teaching do not.

4,121,965
Leipold, Martin H., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Controlling Defect Orientation in Silicon Crystal Ribbon Growth*. October 24, 1978.

The orientation of twinning and other effects in silicon crystal ribbon growth is controlled by use of a starting seed crystal having a specific {110} crystallographic plane and <112> crystallographic growth direction.

4,122,214
Evans, John C., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Collector and Method for Producing Same*. October 24, 1978.

A transparent, conductive collector layer containing conductive metal channels is formed as a layer on a photovoltaic substrate by coating a photovoltaic substrate with a conductive mixed metal layer; attaching a heat sink having portions protruding from one of its surfaces which define a continuous pattern in combination with recessed regions among said protruding portions to said substrate such that said protruding portions of said heat sink are in contact with the conductive layer of said substrate; and heating said substrate while simultaneously oxidizing the portions of the conductive layer exposed to a gaseous oxidizing substance forced into said recessed regions of said heat sink, thereby creating a transparent metal oxide layer on said substrate containing a continuous pattern of highly conductive metal channels in said layer.

4,122,383
Von Roos, Oldwig H., inventor; The United States of America as represented by The Administrator of the National Aeronautics and Space Administration, assignee. *Method and Apparatus for Measuring Minority Carrier Lifetimes and Bulk Diffusion Length in P-N Junction Solar Cells*. October 24, 1978.

Carrier lifetimes and bulk diffusion length are qualitatively measured as a means for qualification of a P-N junction photovoltaic solar cell by alternately applying high frequency (blue) monochromatic light pulses and low-frequency (red) monochromatic light pulses to the cell while it is irradiated by light from a solar simulator, and synchronously displaying the derivative of the output voltage of the cell on an oscilloscope. This output voltage is a measure of the lifetimes of the minority carriers (holes) in the diffused N layer and majority carriers (electrons) in the bulk P material, and of the diffusion length of the bulk silicon. By connecting a reference cell in this manner with a test cell to be tested in reverse parallel, the display of a test cell that matches the reference cell will be a substantially zero output.

4,122,396
Grazier, James A.; Grazier, Leonard F., inventors. *Stable Solar Power Source for Portable Electrical Devices*. October 24, 1978.

The stable solar power source consists of solar cells for converting sunlight into electrical energy and a large capacitor for providing a current reserve to satisfy peak current demands and offset the effects of sunlight variations. The solar cells are mounted beneath a light transmitting thermal shield to minimize thermal induced cell output variations.

4,122,407
Van Vechten, James Alden, inventor; International Business Machines Corporation, assignee. *Heterostructure Junction Light Emitting or Responding or Modulating Devices*. October 24, 1978.

Practice of this disclosure reduces the concentration of intrinsic defects heretofore grown into semiconducting materials. Thereby, the operational lifetime is increased of heterostructure junction light emitting or responding or modulating devices which are fabricated in accordance with principles of the disclosure. Illustratively, the operational lifetime of a heterostructure junction laser device thus fabricated is extended. This improvement in operational lifetime of the device is attained by constraining growth e.g., liquid phase epitaxial growth, of the several layers of semiconducting materials which form such a device to proceed only upon unreconstructed surface layers. Illustratively, such an unreconstructed surface is any one of the set of (311) surfaces of a crystalline semiconductor having diamond, zinc-blend, or chalcopyrite structure. In particular, the operational lifetime of GaAlAs double heterostructure junction lasers is increased by constraining the liquid phase epitaxial growth to proceed only upon a (311B), i.e., an As terminated (311), surface so that respective interfaces between layers of the resultant devices are (311) crystal planes.

4,122,476
Hovel, Harold John; Woodall, Jerry MacPherson, inventors; International Business Machines Corporation, assignee. *Semiconductor Heterostructure*. October 24, 1978.

A technique for fabricating a semiconductor heterostructure by growth of a ternary semiconductor on a binary semiconductor substrate from a melt of the ternary semiconductor containing less than saturation of at least one common ingredient of both the binary and ternary semiconductors wherein in a single temperature step the binary semiconductor substrate is etched, a p-n junction with specific device characteristics is produced in

the binary semiconductor substrate by diffusion of a dopant from the melt and a region of the ternary semiconductor of precise conductivity type and thickness is grown by virtue of a change in the melt characteristics when the etched binary semiconductor enters the melt.

4,124,410
Kotval, Peshotan S.; Strock, Harold B., inventors; Union Carbide Corporation, assignee. *Silicon Solar Cells with Low-Cost Substrates*. November 7, 1978.

Epitaxial and diffusion-type planar diodes and solar cells utilize low-cost refined metallurgical silicon substrates having a substantially higher impurity content than conventional high-cost, high purity semiconductor grade silicon. The epitaxial type products have an n-on-p-on-p substrate configuration, while the diffusion-type products have pentavalent impurities diffused therein to form a p-n junction in the low cost silicon substrate. One embodiment employs a multigrained refined metallurgical silicon (RMS) prepared by precipitating essentially iron-free silicon platelets from a solution of metallurgical grade silicon in molten aluminum, melting said refined platelets, in contact with a silica slag and pulling silicon boules from a melt of said refined metallurgical silicon (RMS). By directionally solidifying the refined silicon-slag melt, a multigrained, directionally solidified refined metallurgical silicon (DS/RMS) is obtained, with boules being pulled from a melt thereof for use as said low-cost substrate. The DS/RMS may also be re-melted and directionally solidified a second time with the boules being pulled from said twice directionally-solidified material being a desirable, low-cost, single crystal material suitable for use as said substrate for planar diode and solar cell applications.

4,124,411
Meuleman, Johannes; Besselere, Jean-Pierre, inventors; U.S. Philips Corporation, assignee. *Method of Providing a Layer of Solid Material on a Substrate in which Liquid from which the Solid Material can be Formed, is Spread Over the Substrate Surface*. November 7, 1978.

A method of providing a layer of solid material, in particular semiconductor material, in which drops of a liquid from which the solid material is deposited, is dropped and spread on a flat surface which is given a rotating movement and also another periodic movement, changing the position of the plane of the substrate surface.

4,124,455
Lindmayer, Joseph, inventor. *Method of Making Solar Cell with Multiple-Metal Contacts*. November 7, 1978.

Solar cell having a contact formed from a titanium group element in contiguous relationship with the cell, a mixture of a titanium group element and a platinum group element overlying the titanium group layer, and a layer of a platinum group element overlying that layer. A body of silver or other contact metal is adhered to the platinum group layer. The three layers may be vapor deposited on the semiconductor body, while the silver layer is more advantageously applied by plating or electroplating.

4,124,464
Miyatani, Kazuo; Sato, Isao, inventors; RCA Corporation, assignee. *Grooved N-Type TiO_2 Semiconductor Anode for a Water Photolysis Apparatus*. November 7, 1978.

An n-type TiO_2 semiconductor anode for a water photolysis cell having one or more grooves exhibits increased oxygen evolution and greater photocurrent with minimal photon reflection losses.

Re. 29,833
Mlavsky, Abraham I., inventor; Mobil Tyco Solar Energy Corporation, assignee. *Tubular Solar Cell Devices*. November 14, 1978.

Tubular solar cells are provided which can be coupled together in series and parallel arrays to form an integrated structure. Solar energy concentrators are combined with the solar cells to maximize their power output. The solar cells may be cooled by circulating a heat exchange fluid through the interior of the solar cells and the heat captured by such fluid may be utilized, for example, to provide hot water for a heating system. The coolant circulating system of the solar cells also may be integrated with a solar thermal device so as to form a two-stage heating system, whereby the coolant is preheated as it cools the solar cells and then is heated further by the solar thermal device.

4,125,414
Tang, Ching W.; Marchetti, Alfred P.; Young, Ralph H., inventors; Eastman Kodak Company, assignee. *Organic Photovoltaic Elements*. November 14, 1978.

A photovoltaic element featuring a photoconductive composition comprising an electrically insulating binder, an organic dye, and an organic photoconductor is disclosed. The photovoltaic element has superior conversion efficiencies compared to other organic photovoltaic elements.

4,126,150
Bell, Alan E.; Williams, Brown F.; Carlson, David E., inventors; RCA Corporation, assignee. *Photovoltaic Device Having Increased Absorption Efficiency*. November 21, 1978.

A photovoltaic device has a body which includes a thin film active region and a layer substantially transparent to solar radiation. The thickness of the transparent layer is such that a first antireflection condition is present for solar radiation at a wavelength which is relatively highly absorbed by the material of the active region. Furthermore, the combined thickness of the transparent layer and active region are such that a second antireflection condition is present for solar radiation at a wavelength which is poorly absorbed by the material of the active region. As a result of the prevailing antireflection conditions the solar radiation absorption efficiency of the photovoltaic device is increased.

4,126,930
Moon, Ronald L., inventor; Varian Associates, Inc., assignee. *Magnesium Doping of AlGaAs*. November 28, 1978.

Aluminum gallium arsenide is used as a transparent, conducting contact layer on the exposed surface of a gallium arsenide photovoltaic cell. Increased conductivity for the high current generated when concentrated solar radiation strikes the cell, is provided by doping the AlGaAs layer with magnesium. During the formation of the layer, Mg diffuses into the gallium arsenide to form a p-type layer and a p-n junction.

4,127,424
Ullery, Lee R., Jr., inventor; Ses, Incorporated, assignee. *Photovoltaic Cell Array*. November 28, 1978.

In a photovoltaic cell which comprises: a substrate, a bottom electrode, a first layer of cadmium sulfide, a second layer of cuprous sulfide forming a barrier junction with said first layer and a top electrode, the improvement wherein said substrate is an insulative ceramic material and the bottom electrode is a conductive ceramic layer fused to said substrate. Said conductive layer is optionally coated with a metal having a high electrical conductivity.

4,127,425
Chambers, Robert R., inventor; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. November 28, 1978.

A thin, luminescent sheet having upper and lower large area surfaces separated by upstanding edge faces, said sheet being contoured in the vicinity of at least one of said edge faces so as to widen such edge face substantially, and at least one photovoltaic cell carried on and occupying a substantial portion of such widened edge face.

4,127,449
Heller, Adam; Miller, Barry, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Liquid-Semiconductor Junction Photocells*. November 28, 1978.

Liquid-semiconductor photocells using chalcogenide semiconductors have been advanced recently to the point where they compete favorably with silicon devices for solar power conversion. However, in common with silicon devices, the semiconductor needs to be a single crystal. This fact makes solar power impractically expensive. According to this invention, the chalcogenide semiconductor is made by anodizing cadmium or bismuth in a sulfide, selenide or telluride electrolyte. The anodized element, when operated photovoltaically in an electrolyte similar to the anodizing solution, produces useful power conversion and is relatively inexpensive.

4,127,738
Ghosh, Amal K.; Feng, Tom, inventors; Exxon Research & Engineering Co., assignee. *Photovoltaic Device Containing an Organic Layer*. November 28, 1978.

A photovoltaic device for the conversion of light (preferably in the visible spectrum) to electrical current consists of at least two electrodes (one of which must be substantially transparent to the light), each electrode being made of different materials and in which one electrode comprises an element that has a work function (generally expressed in electron volts) greater than that of aluminum (e.g., gold or silver) and the other electrode comprises an element that has a work function equal to or less than that of aluminum (e.g., aluminum or magnesium). Sandwiched between and in contact with the electrodes is a photoresponsive organic layer comprising at least one organic compound which, in general, has the capacity to sensitize or de-sensitize silver halides, titanium dioxide, zinc oxide, cadmium sulfide, selenium and polyvinyl carbazole (examples of the organic compounds are the cyanine dyes, especially the merocyanine dyes). The electrode comprising an element having a work function equal to or less than aluminum forms a Schottky barrier with the organic layer. Optionally, an insulating film is interposed between the Schottky barrier electrode and the organic layer.

4,128,680
Heaps, Joseph D., inventor; Honeywell, Inc., assignee. *Silicon Coated Ceramic Substrate with Improvements for Making Electrical Contact to the Interface Surface of the Silicon*. December 5, 1978.

When electrically insulating ceramic substrates are coated with silicon by any of a number of methods that bring the substrate into contact with molten silicon, electrical contact can only be made conveniently to the exposed surface of the silicon coating. This invention teaches an improvement for making electrical contact to the interface surface of the silicon. It was discovered that by providing narrow slits or small holes in the ceramic substrate that upon coating the substrate with molten silicon, molten silicon will wick through the slits or holes to the uncoated surface of the ceramic.

4,128,732
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *Solar Cell*. December 5, 1978.

An improved solar cell designed for optimum efficiency is comprised of a plurality of series connected unit solar cells formed from a common substrate of semiconductor material. Each unit solar cell has spaced elongate sidewalls, and a "dead space" area between adjoining sidewalls of adjacent units is made substantially smaller than an active, light receiving area, extending between the opposite sidewalls of each individual unit. In addition, the width of the active area is concisely limited to ensure that radiation incident on the active area is incident at a point which is spaced from the p-n junction of each unit by no more than a predetermined optimum distance. Reducing the "dead space" area while concisely limiting the width of the active area provides improved solar cell performance without requiring focusing lenses.

4,128,733
Fraas, Lewis M.; Zanio, Kenneth R.; Knechtli, Ronald C., inventors; Hughes Aircraft Company, assignee. *Multijunction Gallium Aluminum Arsenide-Gallium Arsenide-Germanium Solar Cell and Process for Fabricating Same*. December 5, 1978.

The specification describes a gallium aluminum arsenide-gallium arsenide-germanium solar cell and fabrication process therefor wherein the deposition of a layer of gallium aluminum arsenide establishes a first PN junction in the GaAs of one bandgap energy on one side of a gallium arsenide substrate, and the deposition of a layer of germanium establishes a second PN junction in Ge of a different bandgap energy on the other side of the GaAs substrate. The two PN junctions are responsive respectively to different wavelength ranges of solar energy to thus enhance the power output capability of a single wafer (substrate) solar cell. Utilization of the Group IV element germanium, as contrasted to compound semiconductors, simplifies the process control requirements relative to known prior art compound semiconductor processes, and germanium also provides a good crystal lattice match with gallium arsenide and thereby maximizes process yields. This latter feature also minimizes losses caused by the crystal defects associated with the interface between two semiconductors.

4,129,458
Kaplow, Roy; Frank, Robert I.; Goodrich, Joel L., inventors; Massachusetts Institute of Technology, assignee. *Solar-Cell Array*. December 12, 1978.

The invention contemplates a solar-cell construction wherein plural spaced elongate unit cells of an array are formed from a parallel-grooved single wafer of substrate material of a first conductivity type, with adjacent sidewalls of adjacent units at each inter-unit groove formation. In the transverse succession of such groove formations, the sidewalls of every other groove are formed with regions of a second conductivity type, so that at or near the radiation-exposure surface of each unit there is but one junction between first and second conductivity types. In one general form, all grooves go all the way between upper and lower wafer surfaces, thus defining discrete single-cell units; in another general form, every other groove ends close to but short of the upper surface, thus defining discrete twin-cell units. The units are series-connected by making ohmic connection between the second conductivity-type region of one unit and a first conductivity-type region of an adjacent unit. The construction lends itself to a relatively simple and economical method of manufacture, which is also described.

4,129,463
Cleland, John W.; Westbrook, Russell D.; Wood, Richard F.; Young, Rosa T., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Polycrystalline Silicon Semiconducting Material by Nuclear Transmutation Doping*. December 12, 1978.

A NTD semiconductor material comprising polycrystalline silicon having a mean grain size less than 1000 microns and containing phosphorus dispersed uniformly throughout the silicon rather than at the grain boundaries.

4,129,823
Van Der Pool, Kees; Rosinski, Louis S., Jr.; Belli, Johann B., inventors; Sensor Technology, Inc., assignee. *System for Determining the Current-Voltage Characteristics of a Photovoltaic Array*. December 12, 1978.

A nonlinear load circuit, consisting of a transistor and a resistor in series, is provided for the photovoltaic array under test. Base bias for the transistor is supplied via the source-to-drain path of a field effect transistor(FET). A ramp signal is fed to the gate of

the FET. As a result of the nonlinear relationship between the gate voltage and source-to-drain current of the FET, equal ramp steps result in a nonlinear effective load for the array under test. This produces a very gradual change in load impedance for each ramp step in the regions of high current output from the array ("current mode"), and relatively greater changes in load impedance for each ramp step at output levels of lower current and higher voltage from the array ("voltage mode"). Advantageously, the array is illuminated by a pulsed flash lamp. A photosensor detects the light level incident on the array, and comparison circuitry provides a "sample" pulse each time that the incident light level is at a selected value. This "sample" pulse gates a pair of sample and hold circuits that respectively sample the array output current and voltage under the load condition determined by the present ramp step. Consecutive like operatons facilitate measurement and plotting of the complete current-voltage curve.

4,130,445
Blieden, Harry R., inventor; Atlantic Richfield Company, assignee. *Light Collector*. December 19, 1978.

A luminescent photovoltaic array which employs a luminescent member carrying photovoltaic means on at least one of its sides, and conduit means in heat exchange contact with at least one side of said luminescent member, said conduit means being adapted to have a cooling fluid pass therethrough for cooling said luminescent member.

4,131,123
Della-Vedowa, Richard P.; Shahryar, Ishaq M., inventors; Solec International, Inc., assignee. *Solar Cell Module and Method of Making Same*. December 26, 1978.

Solar cell module and method of making same, characterized by a plurality of solar cell discs or wafers first disposed between opposite faces of an electrically insulating sheet of the same thickness as the wafers, and thence printed on both sides with electrical conducting material to provide a positive conducting face on one side of all wafers and integral solderless printed conductors between adjacent wafers and a negative grid on the other side of all wafers and integral solderless printed conductors between adjacent wafers. When the wafers are series connected, apertures are provided in the sheet through which the printing material extends to series connect adjacent wafers. The wafers may be secured within the sheet by securing same within apertures therein or elongated crystals may be disposed in a mold and electrically insulating material may be cast therearound to form a block which may then be sliced into modules.

4,131,485
Meinel, Aden B.; Meinel, Walter B., inventors; Motorola, Inc., assignee. *Solar Energy Collector and Concentrator*. December 26, 1978.

Modular structures for the collection, concentration and conversion of solar energy to another usable form such as electrical energy. The structures feature three conic section reflective surfaces, two of which focus in front of a receiver element and off the axis of the structure. The third reflective surface is utilized to redirect that energy which would otherwise miss the receiver element to improve overall efficiency.

4,131,486
Brandhorst, Henry W., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Back Wall Solar Cell*. December 26, 1978.

The application discloses a back-well cell, for example, a solar cell which comprises a first semiconductor material of one conductivity type with one face having the same conductivity type but more heavily doped to form a field region arranged to receive the radiant energy to be converted to electrical energy, and a layer of a second semiconductor material, preferably highly doped, of opposite conductivity type on the first semiconductor material adjacent the first semiconductor material at an interface remote from the heavily doped field region. Instead of the opposite conductivity layer, one may employ a metallic layer to form a Schottky diode. If the metallic Schottky diode layer is used, no additional back contact is needed. A contact such as a gridded contact, pervious to the radiant energy may be applied to the heavily doped field region of the more heavily doped, same conductivity material for its contact.

4,131,488
Lesk, Israel A.; Pryor, Robert A., inventors; Motorola, Inc., assignee. *Method of Semiconductor Solar Energy Device Fabrication*. December 26, 1978.

This disclosure relates to a semiconductor solar energy device which is of the PN-type and utilizes a dielectric anti-reflective coating on the side of the device that faces the sunlight. The fabrication techniques used in making this semiconductor device include the use of a rough or textured pyramid shaped silicon surface beneath the anti-reflective coating to increase solar cell efficiency. Also, ion implantation is used to form the PN junction in the device. The ion implanted region located on the side of the device that is subjected to the sunlight is configured in order to permit metal ohmic contact to be made thereto without shorting through the doped region during sintering of the metal contacts to the semiconductor substrate. The dielectric anti-reflective coating, in one embodiment, is a composite of silicon dioxide and silicon nitride layers. The device is designed to permit solder contacts to be made to the P and N regions thereof, without possibility of shorting to semiconductor regions of opposite type conductivity.

4,131,659
Authier, Bernhard; Griesshammer, Rudolf; Køppl, Franz; Lang, Winfried; Sirtl, Erhard; Rath, Heinz-Jörg, inventors; Wacker-Chemitronic Gesellschaft fur Elektronik-Grundstoffe mbH, assignee. *Process for Producing Large-Size, Self-Supporting Plates of Silicon*. December 26, 1978.

Process for producing large-size, self-supporting plates of silicon deposited from the gaseous phase on a substrate body, which comprises heating a graphite substrate to deposition temperature of silicon, which is deposited on the substrate from a gaseous compound to which a dopant has been added until a layer of about 200 to 650 μm has formed, subsequently melting 40-100% of this layer from the free surface downward, resolidifying the molten silicon by adjustment of a temperature gradient from the substrate body upward, and finally separating the silicon therefrom. The plates so formed are used primarily for making solar cells.

4,131,755
Keeling, Michael C.; Bailey, William L.; Coleman, Michael G.; Lesk, Israel A.; Pryor, Robert A., inventors; Motorola, Inc., assignee. *Interconnection for Photovoltaic Device Array*. December 26, 1978.

An interconnection system for interconnecting a plurality of photovoltaic devices. The photovoltaic devices each have a first and a second side and the interconnect system is located on the second side of the photovoltaic devices. A sheet of dielectric material and a sheet of electrically conductive material are bonded together and positioned so that the dielectric material is next to the photovoltaic devices. A plurality of patterns are formed in the sheet of electrically conductive material. The patterns each have angled tabs punched therein so that the angled tabs are punched through both the electrically conductive material and the dielectric material. When a photovoltaic device is positioned within a group of angled tabs, the angled tabs can be brought into contact with electrical contacts on the first side of the photovoltaic device. The group of angled tabs are electrically common to a part of the pattern which has an extended portion which extends beneath an adjacent photovoltaic device. Some of the dielectric material is removed from the extended portion so that this portion then makes contact with the second side of an adjacent photovoltaic device. The patterns can be formed in predetermined configurations to provide series or series-parallel interconnections

for photovoltaic devices within an array of photovoltaic devices. The interconnect system, in turn, provides for substantially all possible series, parallel, or series-parallel interconnections of a plurality of arrays.

4,131,827
Larrabee, Robert D., inventor; RCA Corporation, assignee. *Power Transfer Apparatus*. December 26, 1978.

A power transfer apparatus transfers electrical energy from a DC voltage source that may vary in potential, e.g., a solar cell array, to a load such as a DC motor connected to drive an AC motor-generator. A power transfer device couples the solar cells to the DC motor for driving the DC motor at a power level consistent with the power available from the array of solar cells. The AC motor is continuously connected to an AC line to be driven by conventional AC power. The DC motor, when operating, reduces the load on the AC motor and thereby reduces the AC power drawn or in some cases, causes the generator driven by the DC motor to return power to the AC line.

1979

4,131,984
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *Method of Making a High-Intensity Solid-State Solar Cell*. January 2, 1979.

A semiconductor solar cell capable of converting incident radiation to electrical energy at high efficiency includes a plurality of series-connected unit solar cells formed on a common wafer of semiconductor material. The unit solar cells each include a semiconductor substrate of one conductivity type and a p-n junction formed in the substrate. The light-receiving surface of the cell may have an opaque member thereon, and incident light may be directed onto the portion of that surface not covered by the opaque member. Various embodiments and methods illustrate the invention.

4,132,570
Caruso, Paul J.; Kurth, William T., inventors; Exxon Research & Engineering Co., assignee. *Structural Support for Solar Cell Array*. January 2, 1979.

A support for a solar cell array includes means for positioning the solar cells and limiting the relative movement of the cells. Integral rib stiffeners are provided as well as at least one integral junction box. The support further includes a perimeter skirt which may be used for connecting modules having the support to each other or to a mounting standard.

4,132,571
Cuomo, Jerome J.; DiStefano, Thomas H.; Rosenberg, Robert, inventors; International Business Machines Corporation, assignee. *Growth of Polycrystalline Semiconductor Film with Intermetallic Nucleating Layer*. January 2, 1979.

A method is disclosed for fabricating a thin elemental semiconductor, e.g., Si or Ge, film with columnar grains in a filamentary structure, by the use of an intermetallic compound incorporating the elemental semiconductor to form a nucleating layer for the growth of the semiconducting film. The semiconductor is grown from vapor phase by the technique of either vacuum evaporation or chemical vapor deposition, e.g., by decomposition of SiH_4. The semiconductor e.g., Si, is initially deposited onto a thin film of a specific metal, e.g., Pt or Ni, on any inert substrate, e.g., SiO_2 or Al_2O_3, which is held at a temperature, e.g., 900°C, above the eutectic point, i.e., 830°C, of an intermetallic compound and the metallic film, and below the eutectic point, i.e., 979°C, of another intermetallic compound and the semiconductor. Deposition of the semiconductor onto the metallic film produces a layer of liquid comprising the semiconductor and metal, which increases in thickness until the metallic layer is completely consumed. Additional deposition of the semiconductor produces a supersaturated liquid from which large crystallites of the intermetallic precipitate. With increasing deposition of semiconductor, the crystallites of intermetallic material continue to grow until they consume all of the metal in the liquid, at which point no liquid remains. Continuing deposition of semiconductor material results in the growth of filamentary crystallites of the semiconductor out of the intermetallic surface. The result is a columnar film of the semiconductor with a filamentary structure originating from the crystallites of intermetallic nucleating material.

4,132,999
Maillé, Jacques H. P.; Salaville, André, inventors; Societe Anonyme de Telecommunications, assignee. *Semiconductor Devices*. January 2, 1979.

A semiconductor device comprises a substrate made of an alloy having the formula $Cd_xHg_{1-x}Te$ where x is a non-zero number less than 1. The substrate has P type conductivity and a doping agent such as mercury is diffused into the substrate to form a region of N type conductivity therein. Before diffusion of the mercury into the substrate, a protective layer of cadmium telluride CdTe is applied to the surface of the substrate and the doping agent is diffused into the substrate through the protective layer. The device finds application as a photovoltaic detector of infrared radiation.

4,133,697
Mueller, Robert L.; Yasui, Robert K., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Array Strip and a Method for Forming the Same*. January 9, 1979.

Providing printed circuitry in a sandwiched relation with a pair of flexible layers of non-conductive material, depositing solder pads on the printed circuitry and storing the resulting substrate on a drum, withdrawing the substrate from the drum and incrementally advancing it along a linear path, serially transporting solderless solar cells into engagement with the pads and thereafter heating the pads for thus attaching the cells to the circuitry, cleaning excess flux from the solar cells, encapsulating the cells in a protective coating and thereafter spirally winding the resulting array on a drum.

4,133,698
Chiang, Shang-Yi; Carbajal, Bernard G., inventors; Texas Instruments Incorporated, assignee. *Tandem Junction Solar Cell*. January 9, 1979.

A solar cell having first and second closely spaced, parallel P-N junctions is fabricated, wherein the illuminated surface is totally free of metallization, i.e., the junction nearest the illuminated surface is not electrically connected, and thereby participates only indirectly in the collection of photo-generated carriers by providing a charge field to suppress the front surface recombination and to enhance collection at the back side junction. All metallization is on the back side, which preferably includes an interposed finger pattern of N^+ and P^+ zones.

4,133,699
Meulenberg, Andrew, Jr., inventor; Communications Satellite Corporation, assignee. *Shaped Edge Solar Cell Coverslide*. January 9, 1979.

A solar cell coverslide, oversize to protect the cell against damage from radiation, is modified to have an edge portion configured to bend light incident on said edge portion inwardly toward an underlying solar cell. An adhesive fillet may be formed between the undersurface of the overhanging portion of the coverslide and the top edge of the solar cell to facilitate further the transmission of light striking the configured edge portion into the solar cell.

4,134,387
Tornstrom, Eric, inventor; Mobil Tyco Solar Energy Corporation, assignee. *Solar Energy Concentrator*. January 16, 1979.

Low cost solar collectors are constructed by stretching a thin elongate, flexible reflective sheet (such as metallized polyethylene terephthalate film) over a frame so as to provide a ridged surface of desired geometric shape. In a preferred embodiment of the invention the frame comprises a plurality of rod-like members, with a supply reel on one end and a take-up reel on the other end. Extra reflective sheet material is stored on the supply reel so that when the sheet material in the concentrator degrades (after prolonged exposure to sun light), the degraded material can be rolled onto the take-up reel and fresh sheet material disposed in its place on the frame.

4,134,393
Stark, Virgil; Vayda, Alexandre; Rousset, Paul, inventors; Virgil Stark, assignee. *Solar Energy Collection*. January 16, 1979.

Apparatus and methods for concentrating and collecting solar energy are disclosed. In accordance with the invention, solar energy is concentrated by economical refringent lenses or lens systems including fluid lenses and/or Fresnel-type lenses. The lenses concentrate the solar energy preferably along lines in continuous linear foci or in discrete foci at an elongated collector comprising one or more fluid-carrying conduits and one or more fluids therein. In one embodiment, a plurality of photoelectric cells are located in or on the collector along the linear foci or at the discrete foci and operate at increased efficiency with heat being removed by the collector. A first fluid in the collector is heated by the concentrated solar energy and in a preferred embodiment is used to heat a second fluid contiguous to the first fluid, the first fluid having a boiling point exceeding that of the second fluid. In a preferred embodiment, the first fluid is carried in an inner conduit while the second fluid is carried by an outer conduit which encloses the inner conduit and first fluid. Thus, the two fluids can be heated to different temperatures by a single concentrating system and used for different purposes. Additionally, the invention provides for the storage of energy using two fluids of different boiling points. Also disclosed are methods and fixed and portable apparatus for distilling water containing salt or other substances by evaporation of the water and condesation of the water vapor wherein preferably the heat of condensation is recovered. The invention also provides for assemblies of individual systems to form larger systems. The present invention provides heat from solar energy at a cost competitive with heat produced from fuels.

4,135,235
Baker, Richard H., inventor; Exxon Research & Engineering Co., assignee. *Synthesizer Circuit for Generating Three-Tier Waveforms*. January 16, 1979.

A DC to AC converter capable of producing up to three-tier waveforms includes a first transistorized switching amplifier operable to a first condition, for charging a first capacitor to +2E volts, concurrent with applying +E volts to a first terminal, and connecting a DC supply of −E volts to the positive plate of, and in series circuit with, a second capacitor (previously charged to have a voltage drop thereacross of −2E volts), the series circuit being connected between a reference and second terminals, for applying −3E volts to the second terminal. The first switching amplifier is operable to a second condition for charging the second capacitor to −2E volts, concurrent with applying −E volts to the second terminal, and applying +E volts to the negative plate of the first capacitor, the positive plate of which is connected to the first terminal, for applying +3E volts to the first terminal. A second transistorized switching amplifier is operable to a first or second condition, for individually connecting the first and second terminals to an output terminal, respectively. A control circuit is used to operate the first and second switching amplifiers in various combinations of their respective first and second conditions, over a period of time, for producing a desired waveform at the output terminal. Two or more of the converters can be interconnected and driven by the control circuit for providing polyphase voltage waveforms.

4,135,290
Evans, John C., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method for Fabricating Solar Cells Having Integrated Collector Grids*. January 23, 1979.

A heterojunction or Schottky barrier photovoltaic device comprising a conductive base metal layer compatible with and coating predominately the exposed surface of the p-type substrate of the device such that a back surface field region is formed at the interface between the device and the base metal layer, a transparent, conductive mixed metal oxide layer in integral contact with the n-type layer of the heterojunction or Schottky barrier device having a metal alloy grid network of the same metal elements of the oxide constituents of the mixed metal oxide layer embedded in the mixed metal oxide layer, an insulating layer which prevents electrical contact between the conductive metal base layer and the transparent, conductive metal oxide layer, and a metal contact means covering the insulating layer and in intimate contact with the metal grid network embedded in the transparent, conductive oxide layer for conducting electrons generated by the photovoltaic process from the device.

4,135,537
Blieden, Harry R.; MacDonald, Roderick W., inventors; Atlantic Richfield Company, assignee. *Light Collector*. January 23, 1979.

A method and apparatus for recovering energy from light, such as sunlight, wherein a luminescent fluid is employed in conjunction with photovoltaic means, heat is recovered from the luminescent fluid, and electricity is recovered from the photovoltaic means.

4,135,950
Rittner, Edmund S., inventor; Communications Satellite Corporation, assignee. *Radiation Hardened Solar Cell*. January 23, 1979.

A radiation hardened junction solar cell is prepared by etching V-grooves in the surface of a semiconductor substrate. The overall thickness of the substrate and the depth of the V-grooves are chosen as functions of the diffusion length of the minority carriers in the substrate material at beginning of life and at end of life for a given design application. An opposite conductivity type layer is then formed over the V-grooved surface of the semiconductor substrate. The planar back surface of the solar cell is highly doped to convert it into a minority carrier reflecting region.

4,135,998
Gniewek, John J.; Reith, Timothy M.; Sullivan, Michael J.; White, James F., inventors; International Business Machines Corporation, assignee. *Method for Forming Pt-Si Schottky Barrier Contact*. January 23, 1979.

Use of a rare gas in combination with oxygen or nitrogen to sputter etch unreacted platinum after formation of a platinum silicide contact structure for the formation of a Schottky Barrier diode in a silicon semiconductor substrate.

4,136,436
Kilby, Jack S.; Lathrop, Jay W.; Porter, Wilbur A., inventors; Texas Instruments Incorporated, assignee. *Light Energy Conversion*. January 30, 1979.

A process for the manufacture of a light energy converter involves forming of a plurality of photovoltaic sources wherein first bodies of a first conductivity type semiconductor material each has a surface layer of a second conductivity type material and second bodies of said second conductivity type semiconductor material each has a surface layer of said first conductivity type material. The first and second bodies are intermingled in a one level layer in an insulating support. A conductive layer is applied to interconnect the first conductivity type material of all said first bodies with the second conductivity type material of all said second bodies. An electrolyte may wet such sources where, upon exposure

to light, the sources cause a current to flow in the electrolyte producing an electrochemical reaction. The products of this reaction where the electrolyte is a solution such as aqueous hydrogen iodide, and the hydrogen produced by the electrochemical reaction may be stored, burned as a fuel or used in a fuel cell to produce electrical energy.

4,137,095
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Constant Voltage Solar Cell and Method of Making Same*. January 30, 1979.

A silicon solar energy cell producing electricity at substantially constant voltage despite significant increases in illumination, in which the back surface junction of the cell is formed by alloying with gallium.

4,137,096
Maier, Henry B., inventor. *Low Cost System for Developing Solar Cells*. January 30, 1979.

Low cost solar cells are made by electrodeposition of a metallic coating on a conductive substrate, followed by cathodic conversion of the coating in a thiosulfate containing bath to form metallic sulfides. Electrical contacts are made to portions of the sulfide layer and the coated substrate is dried to a point sufficient to yield a photoresponsive device.

4,137,097
Kelly, Joseph E., inventor. *Solar Energy Assembly*. January 30, 1979.

A solar energy collector and heat exchanger assembly comprising a housing having a transparent top, a transparent wall within the housing parallel to the top to divide the housing into upper and lower chambers, the upper chamber having an air inlet and an air outlet, the lower chamber having a liquid inlet interconnected by a conduit to a liquid outlet, photo cells disposed in the lower chamber and adapted to provide heat to the conduit, and a reflector structure disposed in the lower chamber for directing sunlight to the photo cells and for reflecting sunlight to the upper chamber.

4,137,098
Field, Richard L., inventor; The United States of America as represented by the Secretary of the Navy, assignee. *Solar Energy Window*. January 30, 1979.

An energy absorbing venetian blind type device for generating electricity, providing heat, and serving as a sun shade. A plurality of slats covered with an array of photovoltaic cells are enclosed between two panes of glass of a window housing. A heat removal system using forced air cools the photovoltaic cells and collects heat for heating purposes elsewhere. The electricity generated by the photovoltaic cells is collected for immediate use or stored in storage batteries for later use.

4,137,123
Bailey, William L.; Coleman, Michael G.; Harris, Cynthia B.; Lesk, Israel A., inventors; Motorola, Inc., assignee. *Texture Etching of Silicon: Method*. January 30, 1979.

A surface etchant for silicon comprising an anisotropic etchant containing silicon is disclosed. The etchant provides a textured surface of randomly spaced and sized pyramids on a silicon surface. It is particularly useful in reducing the reflectivity of solar cell surfaces.

4,137,355
Heaps, Joseph D.; Tufte, Obert N., inventors; Honeywell, Inc., assignee. *Ceramic Coated with Molten Silicon*. January 30, 1979.

It is desirable to coat large area, thin sheets of large-grain polycrystalline silicon on an inexpensive ceramic substrate for use in solar cell applications and the like. Such ceramic substrates as are used are chosen from those having thermal expansion coefficients similar to those of silicon. The ceramics meeting these requirements, for example mulite, alumina and zirconia, when brought into contact with molten silicon, however, are not wet by the silicon and no coating takes place. In this invention the structure includes an interface layer comprising carbon on the surface of such a substrate to render the surface wettable by molten silicon. With this interface layer the ceramic of the type which is not wet by molten silicon can be successfully coated with silicon.

4,137,570
Baker, Richard H., inventor; Exxon Research & Engineering Co., assignee. *Waveform Synthesizer*. January 30, 1979.

A circuit for inverting a DC voltage to an AC voltage having a predetermined waveform, includes first and second level shifting stages for providing selectively at their respective output terminals a voltage having the level of the DC voltage, or about twice the level of the DC voltage. A first pair of transistorized switches are included for concurrently and selectively connecting the output terminal of one of the level shifters to one end of a load, and ground to the other end, respectively, for driving current through the load in a particular direction and obtaining a desired level and polarity of voltage thereacross, or the switches are operated to ground both ends of the load. In generatng a stepwise approximation of a symmetrical AC waveform, such as a sinewave, one level shifting stage is charging from the DC voltage supply while the other level shifting stage is discharging into the load, during each half-cycle of the AC voltage. A second pair of transistorized (or mechanical) switches are added for selectively connecting each one of the first pair of transistorized switches in parallel with a transistorized switch of each one of the first and second level shifting stages, respectively, for operating the waveform synthesizer at half-rated voltage, and twice-rated current. Also included is a control signal generator for operating the switches and level shifting stages in a manner providing in combination concurrent dynamic level shifting and pulse width modulation in synthesizing a desired AC waveform.

4,138,509
Ingle, William M.; Thompson, Stephen W., inventors; Motorola, Inc., assignee. *Silicon Purification Process*. February 6, 1979.

A process for producing semiconductor grade silicon. Metallurgical grade silicon, silicon dioxide, and silicon tetrafluoride are chemically combined at an elevated temperature to form silicon difluoride gas. The silicon difluoride gas is then polymerized, preferably in a two-step process. An initial small quantity of silicon difuoride polymers is formed at a first temperature. This initial polymerization removes most of the impurities that were present in the original metallurgical grade silicon and which were transported by the silicon difluoride gas. The bulk of the remaining silicon difluoride gas is then polymerized at a second, lower temperature. These polymers are substantially free from all impurities. The pure silicon difluoride polymers are then thermally decomposed at temperatures below 400°C to form binary silicon fluoride homologues. The homologues can be distilled for even higher purity, or can be used or stored as formed. The binary silicon fluoride homologues produce pure silicon and silicon tetrafluoride when heated to a temperature between 400°C and 950°C. The disproportionation of the homologues can be accomplished by chemical vapor deposition techniques onto heated substrates of silicon, metal, or quartz. This disproportionation will result in amorphous, polycrystalline, or monocrystalline silicon depending on the temperatures employed and on the substrate used for deposition.

4,139,399
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Solar Panel with Removable Cell Matrix, and Method of Making Same*. February 13, 1979.

A solar panel is formed with a frame defining channels adapted to receive and retain a solid body of resin therein. The body of resin forms a matrix that encapsulates photovoltaic cells. Part of the frame may be disassembled to permit the matrix to be inserted into or removed from the channels.

4,139,857
Takagi, Toshinori; Morimoto, Kiyoshi; Utamura, Yukihiko, inventors; Futaba Denshi Kogyo Kabushiki Kaisha, assignee. *Schottky Barrier Type Solid-State Element*. February 13, 1979.

A Schottky barrier type solid-state element and a method of producing the same, the Schottky barrier type solid-state element comprising a Schottky barrier type element portion consisting of a metallic board and a semiconductor film layer provided on the metallic board, the metallic board being formed of such a metal as can form a Schottky barrier between itself and the semiconductor film layer, and a semiconductor-side terminal electrode provided on the external surface of the semiconductor film layer so as to obtain an ohmic contact therewith, wherein at least the semiconductor film layer is formed by what is called the ionized-cluster-beam deposition process.

4,139,858
Pankove, Jacques I., inventor; RCA Corporation, assignee. *Solar Cell with a Gallium Nitride Electrode*. February 13, 1979.

A solar cell which comprises a body of silicon having a P-N junction therein with a transparent conducting N-type gallium nitride layer as an ohmic contact on the N-type side of the semiconductor exposed to solar radiation.

4,140,142
Dormidontov, Anatoly A.; Zykov, Evgeny M.; Litsenko, Tatyana A.; Nikitin, Boris A.; Polyakov, Vladimir I.; Strebkov, Dmitry S.; Unishkov, Vadim A.; Chernyshov, Vyacheslav V., inventors. *Semiconductor Photoelectric Generator*. February 20, 1979.

A semiconductor photoelectric generator, for converting radiation energy from a source, for example, the sun, into electric energy, comprises a matrix of photoelectric converters made of a semiconductor material. Each photoelectric converter is doped to form a P-N junction and an isotype junction. Current-collecting conductors are connected to a base region and to an alloy region. An operating surface of the semiconductor photoelectric generator is secured by a translucent adhesive layer to a coating exposed directly to radiation from a radiation source. The coating is composed of optical concentrators which focus the radiation energy in a focal spot and are disposed on the operating surface so that the absorption band of the focussed radiation in the focal spot is located in the base region and is spaced from the P-N junction by a distance not exceeding the diffusion length of the minority carriers in the base region.

4,140,544
Sill, Richard C., inventor; Atlantic Richfield Company, assignee. *Divergent Luminescent Collector for Photovoltaic Device*. February 20, 1979.

In the photovoltaic conversion of solar radiation to electrical energy, light energy passes through an upper or outer surface of a collector member where the light energy is absorbed and reradiated by luminescent materials in the collector. Internal light energy strikes the upper surface and a lower surface of the collector until it is emitted at an edge surface of the collector into a photovoltaic cell mounted on the edge surface. The upper and lower surfaces of the collector are divergent in one or more preselected directions. This divergence changes the internal angle of reflection and directs the light energy to the edge surface and photovoltaic cell thereby decreasing loss of useful energy from within the collector. Light emissive areas of the edge and lower surfaces not covered by a photovoltaic cell may also be covered by a reflective material. The reflective material may be a diffusive material.

4,140,545
Nagao, Hisao; Kawamura, Koichi, inventors; Sharp Kabushiki Kaisha, assignee. *Plural Solar Cell Arrangement Including Transparent Interconnectors*. February 20, 1979.

A plurality of solar cell elements are arranged on a supporting substrate. Each solar cell element has a light receiving surface, where electrodes are formed which are connected to the P-type region and the N-type region contained within the solar cell element, respectively. The electrodes formed on the light receiving surfaces of the plural solar cell elements are electrically connected to each other by light transmitting, electrically conductive wiring means formed on the light receiving surfaces, thereby developing electric energy.

4,140,610
Morimoto, Kiyoshi, inventor; Futaba Denshi Kogyo Kabushiki Kaisha, assignee. *Method of Producing a PN Junction Type Solar Battery*. February 20, 1979.

A PN junction type solar battery comprising a plurality of alternate P-type and N-type semiconductor layers provided in a laminated manner parallel to an incident-light-receiving plane, connection ears provided opposite each other and integrally connected to one end of each of the P-type and N-type semiconductor layers respectively, the connection ears being made of material of the same conduction type as the semiconductor layers respectively, and terminal electrodes mounted on the connection ears of the P-type and N-type semiconductor layers respectively so as to obtain ohmic contact therebetween.

A method of producing a PN junction type solar battery in which P-type and N-type semiconductor layers are formed on a substrate in a staggered manner relative to each other preferably by the ion-beam deposition method or the cluster-ion-beam deposition method.

4,141,020
Howard, James K.; Rosenberg, William D.; White, James F., inventors; International Business Machines Corporation, assignee. *Intermetallic Aluminum-Transition Metal Compound Schottky Contact*. February 20, 1979.

An aluminum-transition metal Schottky barrier contact, and methods of fabrication thereof are disclosed. In one preferred embodiment, the junction is comprised of an aluminum-tantalum intermetallic layer abutting a silicon substrate. Alternate embodiments utilize an intermetallic compound of a metal selected from the group of tantalum, zirconium, hafnium, niobium, titanium and nickel in combination with aluminum. The preferred embodiments can be fabricated by evaporation of a layer of a metal selected from the above mentioned group followed by evaporation of a layer of aluminum on a silicon substrate, after which an annealing step is utilized which creates the desired intermetallic compound in a layer abutting the silicon surface. Alternatively, the junction can be created by hot or cold sputtering of a preselected intermetallic compound of one of the metals with aluminium directly upon the silicon substrate, followed by deposition of a conductive layer such as aluminum. In the case of cold sputtering an annealing step is required to perfect the desired intermetallic compound structure; and in the case of hot sputtering an annealing step may be useful in perfecting the desired intermetallic structure, although it is not essential. The resulting devices are highly thermally stable with predictable barrier heights; and exhibit excellent electrical properties while they are capable of fabrication with good planarity.

4,141,764
Authier, Bernhard; Rath, Heinz J.; Schmidt, Dietrich; Hofer, Johann, inventors; Wacker Chemitronic Gesellschaft fur Elektronik-Grundstroffe mbH, assignee. *Process for the Manufacture of Silicon of Large Surface Area Bonded to a Substrate and Silicon-Bonded Substrates So Made*. February 27, 1979.

Process for the manufacture of silicon of large surface area bonded to a substrate, which comprises depositing silicon to a thickness of from 30 to 500 μm onto panel-shaped substrates of glassy carbon (glass-like carbon obtained by carbonizing a spatially cross-linked synthetic resin) that are heated by direct passage of an electric current to temperatures above the melting point of silicon, and thereafter cooling the silicon to a temperature below its melting point in the direction from its free surface toward the substrate. The invention also comprises the silicon panels so made which are especially useful in the manufacture of solar cells.

4,141,811
Yerkes, John W.; Avery, James E., inventors; Atlantic Richfield Company, assignee. *Plasma Etching Process for the Manufacture of Solar Cells*. February 27, 1979.

A process for manufacturing solar cells. Silicon wafers are assembled in a holding jig such as a diffusion boat in pairs with adjacent surfaces of each of the pairs in contact. The thus assembled wafers are subjected to a chemical vapor deposition diffusion step during which a phosphorous pentoxide glass layer is formed predominantly on the exposed surfaces and side edges of the wafers along with a PN junction thereunder. A small amount of the phosphorous pentoxide glass is also formed on the surfaces which are in contact with each other particularly at the outer edges thereof. The wafers are then reassembled in such a manner that the surfaces having the phosphorous pentoxide layer thereon are placed in contact with each other and again the wafers are placed in a holding jig. The thus assembled wafers are then placed in a plasma etching reactor for removal of the phosphorous pentoxide glass layer and the underlying PN junction from the side edges and the surfaces opposite the surfaces exposed during the previous diffusion step.

4,142,195
Carlson, David E.; Wronski, Christopher R.; Triano, Alfred R., Jr., inventors; RCA Corporation, assignee. *Schottky Barrier Semiconductor Device and Method of Making Same*. February 27, 1979.

A first layer of semiconductor device is of doped amorphous silicon prepared by a glow discharge in a mixture of silane and a doping gas. The first layer is on a substrate having good electrical properties. On the first layer and spaced from the substrate is a second layer of amorphous silicon prepared by a glow discharge in silane. On the second layer opposite the first layer is a metallic film forming a surface barrier junction therebetween, i.e. a Schottky barrier. The first layer is doped so as to make an ohmic contact with the substrate. Preferably the doping concentration of the first layer is graded so the dopant concentration is maximum at the interface of the first layer and the substrate. In a second embodiment of the Schottky barrier semiconductor device an intermediate layer is between and contiguous to both the first layer and the substrate. The intermediate layer facilitates in making ohmic contact between the amorphous silicon and the substrate. Annealing and heat treating steps are performed in the fabrication of the Schottky barrier device to increase device efficiency.

4,143,233
Kapany, Narinder S.; Hardy, Edgar E.; Orofino, Thomas A., inventors; Monsanto Research Corporation, assignee. *Solar Energy Collector*. March 6, 1979.

A solar energy collector is described which consists of either a photoelectric cell or a heat-absorbing material mounted within a hollow concentrator. The photoelectric cell has the form of a rod of a monocrystalline element or compound with a generally cylindrical junction spaced at a distance radially inwardly from the outer surface of the rod. The photoelectric cell is mounted within a hollow transparent trough shaped concentrator or body which contains a liquid, e.g. water, which can be made to flow in order to both cool the photoelectric cell, thereby improving its efficiency, and to promote transmission of solar energy to the photoelectric cell by total internal reflectance. The heat absorbing material can be a metal pipe through which liquid can be made to flow to remove heat absorbed by the pipe, and preferably the pipe will be coated black on the outside surface to promote the absorption of heat into the pipe, and/or the liquid in the hollow transparent trough-shaped body can be made to flow over heat absorbing material to recover heat energy.

4,143,234
Johnson, Gregory R.; Miles, Malcolm G.; Salyer, Ival O.; Hardy, Edgar E., inventors; Monsanto Company, assignee. *Solar Collector Using Total Internal Reflectance*. March 6, 1979.

A solar collector is constructed of a photoelectric cell mounted within a collector of the total internal reflectance type. The photoelectric cell has the form of a rod of a monocrystalline element or compound with a generally cylindrical junction spaced at a distance radially inwardly from the outer surface of the rod. The photoelectric cell is mounted within a trough shaped collector which is at least partially filled with a transparent solid wherein total internal reflectance of incident radiation increases the effectiveness of the collector.

4,143,235
Duisman, Jack A., inventor; Chevron Research Company, assignee. *Cadmium Sulfide Photovoltaic Cell and Method of Fabrication*. March 6, 1979.

A cadmium sulfide photovoltaic cell of improved efficiency comprising a barrier layer and cadmium sulfide-containing bilayer, the bilayer being formed by depositing at a first temperature an initial layer of cadmium sulfide in interfacial contact with the substrate and then depositing a subsequent layer of cadmium sulfide at a second temperature which is at least 20°C below the first temperature.

4,144,095
Mlavsky, Abraham I., inventor; Mobil Tyco Solar Energy Corporation, assignee. *Solar Energy Assembly*. March 13, 1979.

A solar energy assembly is disclosed comprising at least one hermetically sealed envelope in which a trough-shaped radiation collector having a reflective surface is disposed so as to receive incident solar radiation through the wall of said envelope. Radiation conversion means comprising at least one solar cell is positioned inside the trough to receive radiation concentrated by the collector. The collector and the radiation conversion means may be formed as a unit for joint positioning inside the envelope. Means may be provided for orienting the envelope toward the sun and a cooling fluid may be circulated through the envelope in order to maintain the temperature below a suitable level.

4,144,096
Wada, Shinji; Isobe, Yoshiyuki, inventors; Kabushiki Kaisha Suwa Seikosha, assignee. *Solar Battery and Method of Manufacture*. March 13, 1979.

A monolithic solar battery including a plurality of P-N junction unit solar cells mounted on a substrate is provided. Each unit solar cell is isolated electrically from an adjacent cell by a buffer region of a material having a different conductivity than the substrate. An active photovoltaic layer formed on the light receiving surface of each solar cell between two buffer regions overlaps one of the two buffers defining each cell. Wiring for electrically connecting the unit solar cells in series fashion and electrodes are provided on the upper or lower surfaces of the substrate.

4,144,097
Chambers, Robert R.; Wohlmut, Peter G., inventors; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. March 13, 1979.

A luminescent solar collector comprising a light transmitting member which carries at least one photovoltaic means, a luminescent member removably attached to the light transmitting member, and interface material between the two members assuring the transmission of light between said members. A method for increasing the efficiency of a luminescent photovoltaic device which contains a luminescent member of reduced efficiency comprising attaching to the low efficiency luminescent member a higher efficiency luminescent member with an interface material, the interface material assuring transmission of light from one luminescent member to the other.

4,144,139
Durkee, Lawrence F., inventor; Solarex Corporation, assignee. *Method of Plating by Means of Light*. March 13, 1979.

Plating electrical contacts onto one or more surfaces of a solar cell having an electrical junction therein is accomplished by immersing the cell in an electrolyte and exposing it to light so that platable ions in the electrolyte will be attracted to an oppositely charged surface of the cell.

4,146,407
Litsenko, Tatyana A.; Potapov, Valery N.; Strebkov, Dmitry S., inventors. *Solar Photoelectric Module*. March 27, 1979.

A solar photoelectric module is disclosed, wherein the solar energy concentrator also performs the function of a cooling means for the photovoltaic solar energy converter. With that object in view the concentrator is made as a hollow hermetically sealed vessel filled with a transparent heat transfer agent, while the photovoltaic solar energy converter is placed inside the hollow vessel.

4,146,408
Nelson, Richard B., inventor; Varian Associates, Inc., assignee. *Aspherical Solar Cell Concentrator*. March 27, 1979.

A light concentrator for use with photovoltaic cells has a novel aspherical shape to provide the desired distribution of energy over the surface of the cell. The cell is usually circular with a current-collecting bus electrode around the circumference of the active surface. To provide for minimum resistive losses due to the current generated in the cell and flowing to the bus, the light may be concentrated in a band just inside the bus with reduced or even zero energy density inside the band. This distribution is obtained by making the ray-deflecting surface of the concentrator as a figure of revolution whose generating line focuses incident rays arriving parallel to the axis of revolution onto a point removed from the axis. Thus, a point source at infinity is "focused" into a circle around the axis instead of the point focus of conventional optics. Solar light is "focused" into an annular ring. Since the concentrated light pattern is larger than the true image formed by conventional optics with the same focal length, for a given size of cell the focal length can be made shorter and hence the accurracy tolerance of the concentrator surface is greatly relaxed, providing a reduction of cost.

4,146,657
Gordon, Roy G., inventor. *Method of Depositing Electrically Conductive, Infrared Reflective, Transparent Coatings of Stannic Oxide*. March 27, 1979.

Electrically-conductive films of tin oxide are prepared by a novel process utilizing gaseous chemical compounds which react to form a tin-fluorine bond at a temperature which is (1) high enough so that the newly-created tin-fluorine bond-bearing molecule remains in the vapor phase; and (2) low enough so that oxidation of the molecule occurs only after the indicated re-arrangement. Films prepared by the process of the invention are characterized by surface resistances as low as 1 ohm per square when the film thickness is as thin as about a micron. These films are also characterized by extremely good reflectance of infrared radiation.

4,147,157
Zakhariya, Ramiz H., inventor. *Self-Supporting Active Solar Energy System*. April 3, 1979.

An active solar energy system comprising an array of solar collectors, a pumping device to circulate fluid therethrough and a storage tank to contain the heated fluid. The pump is driven by an electric motor and a solar-electric power transducer system energizes the motor, whereby the fluid is circulated through the collector system whenever sunlight is available. The heated fluid from the collector array, as well as the unheated fluid from the source are delivered to a mixing vessel from which the mixture fluid is delivered to a storage tank to meet demands.

4,147,560
Gochermann, Hans, inventor; Licentia Patent-Verwaltungs-GmbH, assignee. *Solar Cell Arrangement for Terrestrial Use*. April 3, 1979.

A solar cell generator for producing electrical energy for terrestrial use including a plurality of interconnected solar cells encased on all sides by a radiation resistant plastic material and a foil of a weather resistant material which adheres to the plastic material covering the outer surfaces of the casing.

4,147,561
Knight, John R., inventor. *Solar Energy Collector*. April 3, 1979.

This invention provides a solar energy collector including a Fresnel lens substantially fixed in orientation and position relative to the Earth, a receiver situated at a focal point of the said Fresnel lens, a mounting mechanism which constrains the receiver to move along the focal surface of the Fresnel lens, and orientation means for continually orientating the receiver so that the said receiver remains in a region of high intensity of radiation during periods of direct sunlight.

The solar energy collector according to the invention is particularly suitable for inclusion in building structures.

4,147,563
Narayan, Jagdish; Young, Rosa T., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Method for Forming P-N Junctions and Solar-Cells by Laser-Beam Processing*. April 3, 1979.

This invention is an improved method for preparing p-n junction devices, such as diodes and solar cells. High-quality junctions are prepared by effecting laser-duffusion of a selected dopant into silicon by means of laser pulses having a wavelength of from about 0.3 to 1.1 μm, an energy area density of from about 1.0 to 2.0 J/cm^2, and a duration of from about 20 to 60 nanoseconds. Initially, the dopant is deposited on the silicon as a superficial layer, preferably one having a thickness in the range of from about 50 to 100 Å. Depending on the application, the values for the above-mentioned pulse parameters are selected to produce melting of the silicon to depths in the range from about 1000 Å to 1 μm. The invention has been used to produce solar cells having a one-sun conversion efficiency of 10.6%, these cells having no antireflective coating or back-surface fields.

4,147,564
Magee, Thomas J.; Pettijohn, Richard R.; Stewart, Shelley A.; Thackray, Malcolm, inventors; SRI International, assignee. *Method of Controlled Surface Texturization of Crystalline Semiconductor Material*. April 3, 1979.

A method of forming a microscopically texturized surface on a crystalline semiconductor material is disclosed which method includes the use of a radioactive source for uniformly irradiating the surface. The radioactive source includes a plane surface having a uniform distribution of radioactive material thereon. In

one arrangement the radioactive source surface area is at least the size of the polished crystalline semiconductor surface to be texturized, and the radioactive source is positioned closely adjacent the polished surface for a predetermined time period for uniform irradiation of the same. If desired, the radioactive source and crystalline surface may be relatively movable during irradiation of the surface, in which case the source may be in the form of an elongated strip of sufficient length to extend beyond opposite edges of the polished surface area to be texturized. In any case, the large-surface area radioactive source produces a substantially uniform distribution of damage tracks in the crystalline surface, which surface then is anisotropically etched by use of a suitable etching solution. The damage tracks provide etching sites along which etching proceeds at a greater rate than in the undamaged area. Generally the surface to be texturized comprises the (100) orientation surface of a crystalline semiconductor material, such as silicon, at which surface etching preferentially proceeds for exposure of the (111) planes which intersect the surface with four-fold symmetry. With this method a controllable size distribution of tetrahedra may be formed over a large surface.

4,148,297
Sherman, Benjamin F., Jr., inventor. *Collector of Direct Dispersed and Reflected Waves*. April 10, 1979.

A collector of waves, such as of solar radiations entering from any direction, concentrates them upon a receiver that converts them to useful purposes. Moderate concentration factors are achieved without the necessity of tracking the sun. The reflective surface of the collector is a semicircular arc developed by rotation about an axis either in the plane of the arc passing through the center of curvature to form a hemisphere, or in the plane of the arc and tangent to one end to form a hemitoroid with a central cusp, or about some other axis; or some combination of these shapes. The device is compounded to provide an increased concentration factor. Means are taught for adapting the device to heat-collecting plates, heat pipes, or photovoltaic conversion devices (solar cells) of either disc, ribbon, or tube construction and for installing the device on surfaces of buildings with or without the capability of tracking the sun.

4,148,298
Sherman, Benjamin F., Jr., inventor. *Hemispherical Collector of Direct Dispersed and Reflected Waves*. April 10, 1979.

A collector of waves, such as of solar radiations entering from any direction, concentrates them upon a receiver that converts them to useful purposes. Moderate concentration factors are achieved without the necessity of tracking the sun. The reflective surface of the collector is a semicircular arc developed by rotation about an axis either in the plane of the arc passing through the center of curvature to form a hemisphere, or in the plane of the arc and tangent to one end to form a hemitoroid with a central cusp, or about some other axis; or some combination of these shapes. The device is compounded to provide an increased concentration factor. Means are taught for adapting the device to heat-collecting plates, heat pipes, or photovoltaic conversion devices (solar cells) of either disc, ribbon, or tube construction and for installing the device on surfaces of buildings with or without the capability of tracking the sun.

4,148,299
Sherman, Benjamin F., Jr., inventor. *Hemitoroidal Collector of Direct Dispersed and Reflected Waves*. April 10, 1979.

A collector of waves, such as of solar radiations entering from any direction, concentrates them upon a receiver that converts them to useful purposes. Moderate concentration factors are achieved without the necessity of tracking the sun. The reflective surface of the collector is a semicircular arc developed by rotation about an axis either in the plane of the arc passing through the center of curvature to form a hemisphere, or in the panel of the arc and tangent to one end to form a hemitoroid with a central cusp, or about some other axis; or some combination of these shapes. The device is compounded to provide an increased concentration factor. Means are taught for adapting the device to heat-collecting plates, heat pipes, or photovoltaic conversion devices (solar cells) of either disc, ribbon, or tube construction and for installing the device on surfaces of buildings with or without the capability of tracking the sun.

4,148,301
Cluff, C. Brent, inventor. *Water-Borne Rotating Solar Collecting and Storage Systems*. April 10, 1979.

A water-borne solar energy collecting and converting system employing an azimuth-tracking, floating platform equipped with reflectors and associated thermal collector tubes.

4,149,665
Costogue, Ernest N.; Downing, Roy G.; Middleton, Orwin; Mueller, Robert L.; Yasui, Robert K.; Cairo, Fred J.; Person, Jerry K., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Bonding Machine for Forming a Solar Array Strip*. April 17, 1979.

A machine for attaching solar cells to a flexible substrate having printed circuitry deposited thereon. The strip is fed through a first station in which solar cells are elevated into engagement with solder pads for the printed circuitry and thereafter heated by an infrared lamp, a second station at which flux and solder residue is removed, a third station at which electrical performance of the soldered cells is determined, a fourth station at which an encapsulating resin is deposited on the cells, a fifth station at which the encapsulated solar cells are examined for electrical performance and a final station at which the resulting array is wound on a takeup drum.

4,149,902
Mauer, Paul B.; Turechek, Gene D., inventors; Eastman Kodak Company, assignee. *Fluorescent Solar Energy Concentrator*. April 17, 1979.

Apparatus for concentrating radiant energy such as solar radiation, collected over a large area, to a smaller area for more efficient conversion of the radiant energy to a more useful form of energy. Fluorescent material in a thin film form is optically bonded by an adhesive or viscous, transparent medium to a massive slab of transparent material such as glass or plastic. Energy conversion devices, such as photovoltaic cells, are disposed around the edges of the slab.

4,149,903
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Hybrid Solar Energy Collecting Device*. April 17, 1979.

A hybrid solar energy collecting device adapted to generate an electrical current from sunlight and also to collect in an electrically insulating fluid thermal energy generated by such cells. The solar energy collecting device comprises a duct adapted for guiding the flow of an electrically insulating fluid such as air, and one or more photovoltaic cells mounted on an electrically insulated portion of the exterior surface of the duct. At least one of the photovoltaic cells has a heat sink which extends into the interior of the duct and is adapted to be contacted by the electrically insulating fluid.

Des. 251,663
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Solar Cell or Similar Article*. April 24, 1979.

The sole FIGURE is a top plan view of a solar cell or a similar article showing my new design . . . $\$=\pi$. The solar cell is of no substantial thickness and the rear is flat and plain.

4,151,005
Strebkov, Dmitry S.; Zadde, Vitaly V.; Unishkov, Vadim A.; Litsenko, Tatyana A.; Landsman, Arkady P., inventors. *Radiation Hardened Semiconductor Photovoltaic Generator*. April 24, 1979.

The semiconductor photovoltaic generator comprises one or several photovoltaic converters, each of which is provided with a rectifying barrier, which separates its base region from the inversion region, and with at least two current collector contacts, one of which being connected to the base region and the other being connected to the inversion region. The operating surface of the semiconductor photovoltaic generator is covered with a protection layer which receives the direct incident radiation and passes the photoactive part of the spectrum thereof to the operating surface of the semiconductor photovoltaic generator. The protection layer comprises elements transparent to the photoactive part of the incident radiation and intermediate metal layers to protect the photovoltaic converter material from the radiation effects which are liable to damage the semiconductor and lower the performance of the semiconductor photovoltaic generator.

4,151,058
Kaplan, Daniel; Velasco, Gonzalo, inventors; Thomson-CSF, assignee. *Method for Manufacturing a Layer of Amorphous Silicon Usable in an Electronic Device*. April 24, 1979.

A method aiming at imparting to the amorphous silicon properties which are compatible with the possibility of modifying by doping or field effect the position of the Fermi level in the volume of the amorphous silicon, a prime requirement for the operation of semiconductor devices. The method comprises a first step of depositing a layer of amorphous silicon onto a substrate under conditions ensuring the purity of the deposit obtained, then a second step wherein the deposit is subjected to a heat treatment consisting in maintaining the deposit in the atmosphere of a plasma containing atomic hydrogen for saturating the existing broken chemical bonds responsible for a parasitic electric conductivity.

4,152,174
Ludlow, Ogden R., inventor. *Photoelectric Cell Using an Improved Photoelectric Plate and Plate Array*. May 1, 1979.

A solar energy collector using rhombic photoelectric plates arranged in an array of connected plates and mounted in a housing can be positioned on a universal mount which is movable on a tracking servo using a position analyzer and a sun position sensor to direct the positioning of the solar collector housing. A lenticular surface on the cover of the housing can intensify the collection of solar energy within the individual photoelectric plates. A small portable tracking servo unit could be mounted on a camper or in another suitable location or the housing may be attached to a portable radio.

4,152,175
Burgess, Edward L.; Nasby, Robert D.; Schueler, Donald G., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Silicon Solar Cell Assembly*. May 1, 1979.

A silicon solar cell assembly comprising a large, thin silicon solar cell bonded to a metal mount for use when there exists a mismatch in the thermal expansivities of the device and the mount.

4,152,535
Deminet, Czeslaw; Horne, William E.; Oettel, Richard E., inventors; The Boeing Company, assignee. *Continuous Process for Fabricating Solar Cells and the Product Produced Thereby*. May 1, 1979.

The process comprises the following steps: (1) forming a glass sheet which defines a substrate layer for the solar cell product; (2) forming a diffusion barrier layer on at least one surface of the substrate; (3) forming a first electrically-conductive layer on the diffusion barrier, the first electrically-conductive layer being a first electrode in the solar cell product; (4) depositing small-grain polycrystalline silicon in a thin film, i.e., 10-100 micrometers, on the first electrode layer; (5) recrystallizing, typically by heating, the deposited polycrystalline silicon until it reforms into large-grain polycrystalline or single-crystal silicon; (6) forming a PN junction in the recrystallized silicon layer; and (7) forming a second electrically-conductive layer on the recrystallized silicon layer, the second electrically-conductive layer being a second electrode in the solar cell product. The solar cell product produced by the above process may be fabricated in large surface area configurations, suitable for terrestrial as well as extra-terrestrial use, at relatively low cost.

4,152,536
Ravi, K. V., inventor; Mobil Tyco Solar Energy Corporation, assignee. *Solar Cells*. May 1, 1979.

Disclosed are solar cells employing slightly curved or nearly flat monocrystalline silicon ribbons. The ribbons are formed by cutting or slicing monocrystalline hollow tubes along their lengths, the tubes having been formed according to crystal growing processes disclosed in U.S. Pat. No. 3,591, 348.

4,152,824
Gonsiorawski, Ronald, inventor; Mobil Tyco Solar Energy Corporation, assignee. *Manufacture of Solar Cells*. May 8, 1979.

The invention provides a method of producing solar cells having a composite shallow/deep junction device construction. The solar cells have grid-like contacts on their front energy-receiving sides, with each portion of each contact being coincident, i.e., aligned with, the deep junction regions while the shallow junction regions are exposed to incident radiation. The composite junction and contacts are formed by a novel method which employs conventional techniques, notably the use of doped oxide films as diffusion sources.

4,153,474
Rex, Dietrich, inventor; Erno Raumfahrttechnik GmbH, assignee. *Solar Energy Collector*. May 8, 1979.

A solar panel is constructed from plural parabolic-cylindrical mirrors arranged side by side, and each mirror has three functions. Its concave ground focusses solar energy, its convex rear carries a strip-like solar cell being thereby disposed close to the focal line of the adjacent mirror, while the rest of the rear surface and possibly also the ground surface dissipates thermal energy.

4,153,475
Hider, Ross B.; Hider, Ross J., inventors. *Three Dimensional Solar Panel Assembly*. May 8, 1979.

A plurality of solar cell panel units arranged in side by side, parallel, spaced relation with light directing devices positioned between each of the solar panels and on each of the outer side surfaces of the solar panels, so that light received from the side edges of the solar panels is redirected to the facing surfaces of each of the solar cell panels, thus allowing solar panel units to be packaged in stacked arrangement for compact presentation to the sun to maximize power output.

4,153,476
Shelpuk, Benjamin, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Double-Sided Solar Cell Package*. May 8, 1979.

In a solar cell array of terrestrial use, an improved double-sided solar cell package consisting of a photovoltaic cell having a metallized P-contact strip and an N-contact grid provided on opposite faces of the cell, a transparent tubular body forming an enclosure for the cell, a pedestal supporting the cell from within the enclosure comprising an electrical conductor connected with the P-contact strip provided for each face of the cell, and a reflector

having an elongated reflective surface disposed in substantially opposed relation with one face of the cell for redirecting light to impinge thereon whereby the cell is subjected to incident radiation at each of its opposite faces.

4,153,813
Blieden, Harry R.; Sill, Richard C., inventors; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. May 8, 1979.

A luminescent solar collector comprising at least one luminescent member having at least one photovoltaic means operably associated therewith, said luminescent member having a side which is to be exposed to incoming (incident) light, and a transparent member carried adjacent to the incident light side of the luminescent member, the outer exposed side of the transparent member having a roughened surface.

4,153,907
Kofron, Vernon K., inventor; Vactec, Incorporated, assignee. *Photovoltaic Cell with Junction-Free Essentially-Linear Connections to Its Contacts*. May 8, 1979.

Admixed glass frits and conductor-forming materials are applied directly to selected portions of the smooth-surface, doped areas of photovoltaic cells, and then are fired to form electrical contacts for those smooth-surface, doped areas. Those conductor-forming materials form electrical contacts that have essentially-linear, low resistance, electrical connections with those smooth-surface, doped areas and also provide exposed surfaces to which leads can be bonded; and those glass frits fuse to the smooth surfaces of the doped areas of those photovoltaic cells to provide sturdy mechanical bonds between those electrical contacts and those smooth-surface, doped areas. The admixtures of glass frits and of conductor-forming materials that are used in forming the electrical contacts for the smooth-surface, P-type doped areas on photovoltaic cells are P-type admixtures; and the admixtures of glass frits and of conductor-forming materials that are used in forming the electrical contacts for the smooth-surface, N-type doped areas on those devices are N-type admixtures.

4,154,625
Golovchenko, Jene A.; Venkatesan, Thirumalai N. C., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Annealing of Uncapped Compound Semiconductor Materials by Pulsed Energy Deposition*. May 15, 1979.

Damaged semiconductor materials are annealed using localized short term energy deposition. In a specific embodiment gallium arsenide damaged during ion implantation is annealed by exposure to short laser pulses.

4,154,998
Luft, Werner; Kennedy, Robert E.; Mesch, Hans G., inventors; TRW Inc., assignee. *Solar Array Fabrication Method and Apparatus Utilizing Induction Heating*. May 15, 1979.

A solar array having solar cells mounted on a substrate and electrically joined by rear connector elements on the substrate and front connector elements secured between the cells to the substrate is fabricated by placing the array components in assembled relation and utilizing induction heating to heat to their fusion temperatures a thermoplastic adhesive layer on the substrate and contacting fusible cladding on the solar cells and the connector elements while retaining the components in firm contact to effect adhesive bonding of the solar cells and front connector elements to the substrate and metallic bonding of the solar cells and connector elements to one another.

4,155,371
Wohlmut, Peter G.; Yerkes, John W., inventors; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. May 22, 1979.

A luminescent solar collector having a luminescent member with at least two types of photovoltaic cells, each type of cell operating efficiently for the generation of electricity over a wavelength range which is different from the efficient wavelength range of the other types of photovoltaic cells present on the luminescent member, each type of photovoltaic cell carrying intermediate to it and the luminescent member a filter means which allows only light within the efficient wavelength range for that type of photovoltaic cell to pass from the luminescent member into the photovoltaic cell.

4,155,781
Diepers, Heinrich, inventor; Siemens Aktiengesellschaft, assignee. *Method of Manufacturing Solar Cells, Utilizing Single-Crystal Whisker Growth*. May 22, 1979.

A solar cell with semiconductor body consisting of single-crystal semiconductor whiskers which are grown on a substrate surface permitting relatively inexpensive manufacture and high efficiency of the solar cell is disclosed.

4,155,785
Cuomo, Jerome J.; DiStefano, Thomas H.; Rosenberg, Robert, inventors; International Business Machines Corporation, assignee. *Process of Making a Radiation Responsive Device*. May 22, 1979.

The practice of this disclosure obtains a relatively high efficiency operation for a crystalline semiconductor solar cell containing various defects of the linear and planar types. Linear defects include screw dislocations as well as full and partial dislocations. Planar defects include twins, stacking faults, grain boundaries and surfaces. Such defects normally contain recombination centers at which electrons and holes generated in the semiconductor region recombine with loss to the external current of the charge carried thereby. Through application of the principles of this invention, especial dopant concentrations and conductivity regions are established in a finite region around the linear and planar defects so that electrons and holes which are generated in the semiconductor region by incident radiation are substantially collected for external current as consequence thereof.

4,156,309
Routh, Donald E.; Hollis, Ben R.; Feltner, William R., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Construction of a Multi-Cell Solar Array*. May 29, 1979.

The method of constructing a high voltage, low power, multi-cell solar array wherein a solar cell base region is formed in a substrate such as but not limited to that of silicon or on a substrate of sapphire, and then by the steps of application of a protective coating on the base, patterned etching of the coating and base to thereby form discrete base regions, forming a semi-conductive junction and upper active region in each base region defined by photolithography, and thus forming discrete cells which are interconnected by metallic electrodes.

4,156,310
Kamath, G. Sanjiv, inventor; Hughes Aircraft Company, assignee. *High Bandgap Window Layer for GaAs Solar Cells and Fabrication Process Therefor*. May 29, 1979.

The specification describes a semiconductor solar cell and fabrication process therefor wherein a thin N-type gallium arsenide layer is deposited on a larger P-type substrate layer which is selected from the group of III-V ternary compounds consisting of aluminum phosphide antimonide, AlPSb, and aluminum indium phosphide, AlInP. P-type impurities are diffused from the substrate layer into a portion of the thin N-type gallium arsenide layer to form a P-type region therein which defines a PN junction in the thin gallium arsenide layer. Thus, the quantity of gallium arsenide required to provide this PN photovoltaic junction layer in the cell is minimized, and the P-type substrate serves as a high bandgap window layer for the cell. Such high bandgap of this window material is especially well suited for efficiently transmitting the blue spectrum of sunlight to the PN junction, thus enhancing the power conversion efficiency of the solar cell.

4,156,622
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Tantalum Oxide Antireflective Coating and Method of Forming Same*. May 29, 1979.

A silicon solar energy cell having an antireflective coating on its light impinging surface. The coating consists essentially of a suboxide of tantalum having the generic formula Ta_2O_y, in which y is a number between about 2.5 and 4.8 on an atomic ratio basis.

4,158,577
Milnes, Arthur G., inventor. *High Output Solar Cells*. June 19, 1979.

A high output solar cell comprises a three-layer semiconductor compound article, the layers being doped in pn_1pn_2 order in the direction of light travel, the pn_1 junction being a homojunction and the n_1n_2 junction being a heterojunction. The doping of the layers is such that "valley-transferred" or "hot" electrons, so-called, are created in the p and n region secondary electron conduction bands and are transferred to the normal conduction band edge of the n_2 heterojunction material and ultimately to an ohmic contact.

4,158,591
Avery, James E.; Gay, Charles F., inventors; Atlantic Richfield Company, assignee. *Solar Cell Manufacture*. June 19, 1979.

A method for manufacturing solar cells wherein a plurality of wafers of a first conductivity type are assembled and thereafter doped with an active impurity of an opposite conductivity imparting type to establish a p-n junction. Thereafter front and back contacts are formed on the wafers by metallization, the back contact material being chosen so that it penetrates any p-n junctions present in the area of the back contact, if any, and thereby forms a low resistance ohmic contact through any such junction. Thereafter the contact containing wafers are coin stacked and plasma etched so that the edge faces of the coin stacked wafers have removed therefrom sufficient p-n junction to electrically isolate the front junction from the back junction or junctions.

4,158,717
Nelson, Norvell J., inventor; Varian Associates, Inc., assignee. *Silicon Nitride Film and Method of Deposition*. June 19, 1979.

A dense film of silicon nitride is deposited by a plasma discharge in a vapor of azidotrimethylsilane (AZS) $(CH_3)_3SiN_3$. AZS is less reactive and easier to handle than the previously used silane SiH_4. The resulting film is more stable chemically than the silicon nitride produced by other processes. It is useful for protective and anti-reflective coatings, for insulating, and for masking, particularly on semiconductive devices.

4,159,212
Yerkes, John W., inventor; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. June 26, 1979.

A luminescent solar collector containing at least one luminescent member having a pair of opposed surfaces and at least one photovoltaic means embedded in the luminescent member and extending essentially from one of said surfaces to the opposing surface of the luminescent member so that a portion of the photovoltaic means of a first conductivity is adjacent one of said surfaces while a portion of the same photovoltaic means that is of a second conductivity is adjacent the opposing surface.

4,159,354
Milnes, Arthur G.; Feucht, Donald L., inventors. *Method for Making Thin Film III-V Compound Semiconductors for Solar Cells Involving the Use of a Molten Intermediate Layer*. June 26, 1979.

Thin semiconductor films of compounds from groups III-V of the periodic table suitable for solar cells are formed on low cost substrates by forming on the substrate an intermediate film that is chemically related to but has a lower melting point than the desired semiconductor. The desired semiconductor film is then grown on this intermediate film while it is in a molten condition. The molten intermediate layer isolates the substrate from the desired semiconductor layer so that as that layer grows, large area crystals result. The intermediate film may be a semiconductor III-V compound or may be a group III metal alloy.

4,159,427
Wiedemann, Hans O., inventor; Messerschmitt-Boelkow-Blohm Gesellschaft Mit Beschraenkter Haftung, assignee. *Apparatus for Utilizing Natural Energies*. June 26, 1979.

This apparatus stores natural energies available on and/or under the surface of the world's oceans. Such energies include solar energy, wave energy, wind energy, as well as energy stored in the heat of the sea water. The energy extracting and storing equipment is installed on a floating vessel or raft. The energy storing equipment includes flywheel type rollers or cylinders driven by electric motors energized by electric generators which in turn receive their energy from the energy extracting equipment. The flywheel type rollers or cylinders include a supporting hollow cylinder having a relatively thin wall onto which there are wound fibers impregnated or embedded in a synthetic resin.

4,159,914
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Photovoltaic Cell*. July 3, 1979.

A photovoltaic cell having an electrically conductive substrate, which may be glass having a film of conductive tin oxide, a first layer containing a suitable semiconductor, which layer has a first component film with an amorphous structure and a second component film with an amorphous structure and a second component film with a polycrystalline structure; a second layer forming a hetrojunction with the first layer; and suitable electrodes where the heterojunction is formed from a solution containing copper, the amorphous film component is superposed above an electrically conductive substrate to resist permeation of the copper-containing material to shorting electrical contact with the substrate. The penetration resistant amorphous layer permits a variety of processes to be used in forming the heterojunction with even very thin layers (1-6μ thick) of underlying polycrystalline semiconductor materials. In some embodiments, the amorphous-like structure may be formed by the addition of aluminum or zirconium compounds to a solution of cadmium salts sprayed over a heated substrate.

4,160,045
Longshore, Randolph E., inventor; The United States of America as represented by the Secretary of the Army, assignee. *Method for Producing a Scabrous Photosensitive Surface*. July 3, 1979.

A layer of indium is deposited as small islands on a photosensitive material. The islands and the material not covered by the islands are bombarded with ions to cause sputtering of the islands and the material. When the islands have been sputtered away, the material has a surface consisting of cones and pyramids. Such a surface is more efficient at absorbing photons than is a smooth surface.

4,160,678
Jain, Faquir C.; Melehy, Mahmoud A., inventors. *Heterojunction Solar Cell*. July 10, 1979.

An improved efficiecy heterojunction solar cell comprises a narrow-gap collector (or base) region and a wide-gap window region. The latter includes an inner and an outer region of the same conductivity type but of different impurity concentrations. The higher impurity concentration outer window region receives the incident light radiation. The impurity concentration in the inner window region is less than that in the inner collector region, with which it forms a p-n junction.

4,160,816
Williams, Richard; Bloom, Allen, inventors; RCA Corporation, assignee. *Process for Storing Solar Energy in the Form of an Electrochemically Generated Compound*. July 10, 1979.

A process for storing energy from solar radiation whereby solar radiation is converted into electrical current which is supplied to an electrochemical cell in combination with water and carbon dioxide gas to produce formic acid as an electrochemical storage medium. The formic acid can be easily decomposed by catalysts known in the art into carbon dioxide and hydrogen gas which can be burned as fuel or used as a starting material in numerous commercial applications.

4,161,418
Morimoto, Kiyoshi; Utamura, Yukihiko; Takagi, Toshinori, inventors; Futaba Denshi Kogyo K. K., assignee. *Ionized-Cluster-Beam Deposition Process for Fabricating P-N Junction Semiconductor Layers*. July 17, 1979.

A p-n junction type solid-state element having at least a pair of p-n junction type semiconductor layers formed of a p-type semiconductor and an n-type semiconductor joined with each other and a method of producing the same, in which the p-type semiconductor and n-type semiconductor are formed and joined by forming at least one of the semiconductors using what is called the ionized-cluster-beam deposition process which evaporates a material to be deposited to form a vapor, injects the vapor into a vacuum region to form clusters of atoms, ionizes the clusters and electrically accelerates ionized clusters onto a substrate thereby forming a layer thereon.

4,161,657
Shaffer, Marlin R., Jr., inventor. *Hydrogen Supply and Utility Systems and Components Thereof*. July 17, 1979.

An energy system that is responsive to and converts radiant energy into direct current electricity at a pair of output connectors which are maintained at a potential difference. The hydrogen and oxygen-generating electrodes of an electrolysis cell are coupled to such terminals so that hydrogen and oxygen may be produced, with at least the former being stored under pressure. Valve or regulator means is supplied the hydrogen storage system such that, preferably, a constant volumetric output over a given time span is maintained for producing a useful result such as a continuous source of electrical energy. The valve means is regulated so that the gas pressure within the storage system is always maintained above a predetermined threshhold. Useful results are produced in the form of mechanical power, electrical power, the synthesizing of ammonia and other important products and results. Where a hydrogen engine is employed in the system, then the vapor output is preferably fed back to the electrolysis cells of the system so that the water needed in the cell is continuously replenished. The system is designed such that the radiant energy, though intermittent or irregular, will generate a regulated source of essentially uniform electrical or mechanical energy or other useful, continuous product or result, as desired.

4,162,174
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *Solar Cell Array*. July 24, 1979.

A semiconductor solar-cell array including a plurality of adjacent solar cell segments, each segment comprising a number of series-connected unit solar cells, and the series-connected unit solar cells from each segment being electrically connected in parallel with the series-connected unit solar cells from other segments. Concentrated solar radiation is focused on the upper surface of the solar-cell array wherein the periphery of the focused image is contained within the upper surface area. The series-parallel connection of the unit solar cells and solar cell segments provides maximum utilization of incident solar radiation to thereby increase solar cell output. In addition, the series-parallel connection scheme allows the array to operate effectively without imposing stringent requirements as to solar-tracking precision in order to maintain the focused image at a fixed location on the upper surface of the cell.

4,162,177
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Forming Solar Cell with Discontinuous Junction*. July 24, 1979.

A silicon solar energy cell having a substantially constant voltage despite significant increases in illumination, which cell has a back surface junction that is discontinuous and has spaced, shorted portions formed therein.

4,162,505
Hanak, Joseph J., inventor; RCA Corporation, assignee. *Inverted Amorphous Silicon Solar Cell Utilizing Cermet Layers*. July 24, 1979.

An amorphous silicon solar cell incorporating a transparent high work function metal cermet incident to solar radiation and a thick film cermet contacting the amorphous silicon opposite to said incident surface.

4,162,928
Shepard, Neal F., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Module*. July 31, 1979.

An improved solar cell module for use in terrestrial environments, characterized by an internally reflective plate having a planar surface of incidence and an opposed textured surface, a plurality of uniformly spaced silicon solar cells having the active surfaces thereof bonded to portions of the textured surface, and a layer of diffusely reflective matter applied to the textured surface in surrounding relation with the solar cells for reflecting solar energy to strike the surface of incidence at such angles as to be internally re-reflected and caused to progress toward the active surfaces of the solar cells, whereby concentration of incident flux on the solar cell is achieved without increased module depth.

4,163,194
Ross, Ronald G., inventor; California Institute of Technology, assignee. *Voltage-Current-Power Meter for Photovoltaic Solar Arrays*. July 31, 1979.

A meter is disclosed for measuring the voltage, current, and power (VIP) parameters of a photovoltaic solar array, or array module, under sunlight operating conditions utilizing a variable load connected across the array and controlled by a voltage regulator which responds to the difference between the output voltage of the array and a programmed test voltage from a source which generates a single ramp voltage for measuring and recording current as a function of voltage, repeated ramp voltages at a high rate for peak output measurements or a DC voltage for VIP measurements at selected points on the I-V characteristic curve of the array. The voltage signal from a current sensing element, such as a shunt resistor in series with the variable load, is compared with the output current of a reference solar cell to provide a normalizing signal to be added to the signal from the current-sensing element in order to provide a record of array current as a function of array voltage, i.e., for all load conditions from short circuit to open circuit. As the normalized current is thus measured, an analog multiplier multiplies the array voltage and renormalized current to provide a measurement of power. Switches are provided to selectively connect the power, P, current, I, or voltage, V, to a meter, directly or through a peak detector. At the same time any one of the parameters V, I, and P may be recorded as a function of any other parameter.

4,163,677
Carlson, David E.; Wronski, Christopher R., inventors; RCA Corporation, assignee. *Schottky Barrier Amorphous Silicon Solar Cell with Thin Doped Region Adjacent Metal Schottky Barrier*. August 7, 1979.

A Schottky barrier amorphous silicon solar cell incorporating a thin highly doped p-type region of hydrogenated amorphous silicon disposed between a Schottky barrier high work function metal and the intrinsic region of hydrogenated amorphous silicon wherein said high work function metal and said thin highly doped p-type region form a surface barrier junction with the intrinsic amorphous silicon layer. The thickness and concentration of p-type dopants in said p-type region are selected so that said p-type region is fully ionized by the Schottky barrier high work function metal. The thin highly doped p-type region has been found to increase the open circuit voltage and current of the photovoltaic device.

4,163,678
Bube, Kenneth R., inventor. *Solar Cell with Improved N-Region Contact and Method of Forming the Same*. August 7, 1979.

An improved solar cell, and method of forming the same, characterized by a semiconductor silicon wafer of P-type material having diffused therein a shallow N-type region, a sintered silver contact affixed to the surface of the N-type region at the outer surface thereof formulated from silver powder blended with silver metaphosphate for establishing a zone of increased carrier concentration, and an aluminum or silver/aluminum alloy contact affixed to the P-type wafer at the outer surface thereof opposite the N-type region.

4,163,987
Kamath, G. Sanjiv; Anderson, Carl L., inventors; Hughes Aircraft Company, assignee. *GaAs-GaAlAs Solar Cells*. August 7, 1979.

The specification describes an improved III-V compound solar cell stucture and fabrication process therefor wherein a P-type layer of gallium aluminum arsenide is epitaxially grown on an N-type gallium arsenide substrate to form a P-type region and a PN junction in the substrate. Controlled amounts of beryllium are introduced into both the epitaxial layer and the substrate, either during epitaxial growth or by using beryllium ion implantation techniques subsequent to the P-type epitaxial growth step. The homojunction-heterostructure device thus formed exhibits improved power conversion efficiencies in excess of 17%.

4,164,145
Aron, Milton, inventor; De Laval Turbine Inc., assignee. *Self-Powered Electrical Meter for Display of a Liquid-Level or the Like Measurement*. August 14, 1979.

The invention contemplates a sealed electrical-meter construction for measuring an electrical quantity such as an electrical resistance, and having particular application to the display of liquid-level where measured resistance is a function of observed liquid level. The meter construction provides a transparent side port at which a solar-cell assembly is exposed to external light, and the voltage output of the cell, after reduction to assure constant-voltage level is used to power the measuring circuit. Fiber-optics elements at the transparent side port convey light to the display face of the meter, so that even a flashlight at nighttime is sufficient to excite the solar-cell assembly and illuminate the display face.

4,164,431
Tang, Ching W., inventor; Eastman Kodak Company, assignee. *Multilayer Organic Photovoltaic Elements*. August 14, 1979.

A novel multilayer, organic composition, a photovoltaic element fabricated therefrom having enhanced conversion efficiencies, and their use to generate power, are disclosed. Compounds with generally planar polycyclic nuclei such as organic photoconductive dyes comprise the several layers of the composition.

4,164,432
Boling, Norman L., inventor; Owens-Illinois, Inc., assignee. *Luminescent Solar Collector Structure*. August 14, 1979.

Disclosed is a luminescent solar collector having a beveled edge meeting an extended face surface thereof at an angle of 40 to 50 degrees, ideally essentially 45 degrees, and physically attached and optically coupled to a relatively small area of said surface a photovoltaic cell adjacent to and parallel to said edge. Usually the beveled edge is a straight edge.

4,164,698
Kleeberg, Heinz, inventor; Triumph Werke Nurnberg, A. G., assignee. *Battery Charging Circuit*. August 14, 1979.

A circuit for use in charging a battery from a current source, such as a solar cell, includes a Zener diode, a current limiting resistor in series with the Zener diode, and a switch which shunts the resistor. In periods of high current output from the solar cell, the resistor is shunted allowing the Zener diode to limit the charging current to the battery in order to prevent damage thereto. In periods of low current output from the solar cell, the resistor limits the power consumption of the Zener diode to insure sufficient power delivery to the battery.

4,165,241
Yerkes, John W.; Avery, James E., inventors; Atlantic Richfield Company, assignee. *Solar Cell with Improved Printed Contact and Method of Making the Same*. August 21, 1979.

A silicon solar cell having a body of boron doped P-type silicon material with a shallow P/N junction formed therein through diffusion of phosphorous into one surface thereof. A contact pattern of conductive material is formed on the surface of the solar cell in which the P/N junction is formed. The pattern is formed by first depositing a metallic layer upon the entire surface of the body and then applying the contact pattern by printing upon the surface of the metal. The metal has a characteristic such that when heated in the presence of oxygen to an appropriate temperature to fire the conductive material, it oxidizes and forms an anti-reflective layer on the surface of the cell except in those areas where the printed contact pattern is disposed. In the areas of the printed contact pattern the metal forms an ohmic contact between the surface of the silicon and the printed contact pattern and provides a barrier to preclude the conductive contact pattern material from punching through the shallow P/N junction.

4,165,558
Armitage, William F., Jr.; Crisman, Everett E., inventors. *Fabrication of Photovoltaic Devices by Solid Phase Epitaxy*. August 28, 1979.

Fabrication of photovoltaic devices by solid phase epitaxy; devices produced by this method consisting of a semiconductor base and a semiconductor junction-forming epitaxial layer. The epitaxial layer grown by solid phase means from a metal-semiconductor alloy or from a sandwich structure of semiconductor/metal on the semiconductor base.

4,165,604
Matsumura, Osamu; Kato, Yutaka; Sekiguchi, Tsunetoshi; Namiki, Ryo, inventors; Citizen Watch Co., Ltd., assignee. *Solar Battery Timepiece*. August 28, 1979.

A solar battery timepiece has a structure of a module, a base plate on the module, a solar battery cell on the base plate, an insulating flexible sheet provided with a print wiring and interposed between the base plate and the solar battery cell, and a dial ring attached to the peripheral edge of the base plate whereby the solar battery timepiece may be made thin in thickness, small in size, simple in construction, shock resistant and reliable in operation.

4,166,880
Loferski, Joseph J.; Roessler, Barton, inventors; Solamat Incorporated, assignee. *Solar Energy Device*. September 4, 1979.

Selective absorber including a layer of semiconductor applied by arc plasma spraying over a metallic surface.

4,166,917
Dorfeld, William G.; Ortabasi, Ugur, inventors; Corning Glass Works, assignee. *Concentrating Solar Receiver*. September 4, 1979.

There has been provided a concentrating solar receiver of the type including a closed envelope having a window and reflective portions. A photocell is disposed at a focal zone for the reflector. Heat and/or electricity may be produced from received solar energy and the envelope is manufactured in the configuration of a specially formed bulb preferably having a thin wall glass structure.

4,166,918
Nostrand, Gerald E.; Hanak, Joseph J., inventors; RCA Corporation, assignee. *Method of Removing the Effects of Electrical Shorts and Shunts Created during the Fabrication Process of a Solar Cell*. September 4, 1979.

A method of removing the effects of electrical shorts and shunts created during the fabrication process and improving the performance of a solar cell with a thick film cermet electrode opposite to the incident surface by applying a reverse bias voltage of sufficient magnitude to burn out the electrical shorts and shunts but less than the break down voltage of the solar cell.

4,166,919
Carlson, David E., inventor; RCA Corporation, assignee. *Amorphous Silicon Solar Cell Allowing Infrared Transmission*. September 4, 1979.

An amorphous silicon solar cell with a layer of high index of refraction material or a series of layers having high and low indices of refraction material deposited upon a transparent substrate to reflect light of energies greater than the bandgap energy of the amorphous silicon back into the solar cell and transmit solar radiation having an energy less than the bandgap energy of the amorphous silicon.

4,167,015
Hanak, Joseph J., inventor; RCA Corporation, assignee. *Cermet Layer for Amorphous Silicon Solar Cells*. September 4, 1979.

A transparent high work function metal cermet forms a Schottky barrier in a Schottky barrier amorphous silicon solar cell and adheres well to the P^+ layer in a PIN amorphous silicon solar cell.

4,167,644
Kurth, William T.; Miles, Steven G., inventors; Exxon Research & Engineering Co., assignee. *Solar Cell Module*. September 11, 1979.

A solar cell module consisting of a solar cell panel and a frame therefor is disclosed. The solar cell panel is formed from a hard, light transparent sheet material which preferably is glass and has arrayed on the bottom surface of the glass a plurality of individual solar cells interconnected in the requisite series and/or parallel circuit arrangement. The cells are bonded permanently to the underside of the panel by suitable bonding means such as a silicon adhesive. The rear surface of the solar cells and glass is covered with a suitable material, preferably with a light transparent elastomer, to protect the cells from the elements, thereby preventing corrosion of the electrical contacts. The frame extends around the perimeter of the solar panel and has at least one top flange that is essentially coplanar with the solar panel for supporting engagement with a setting strip of resilient material. The setting strip has parts embracing the flange and the marginal edge of the solar cell panel.

4,167,805
Castel, Egil D., inventor; Photon Power, Inc., assignee. *Cuprous Sulfide Layer Formation for Photovoltaic Cell*. September 18, 1979.

An improved method for fabrication of a photovoltaic cell preferably of the CdS–Cu_xS type, having a copper electrode adjacent the Cu_xS. A portion of the CdS is converted to Cu_xS through ion exchange wherein the CdS is immersed in a first solution of cuprous ions and a second solution of cupric ions to produce a non-stoichiometric Cu_xS. A layer of metallic copper is applied by conventional techniques, such as vacuum deposition, and the photovoltaic cell heat treated to affect formation of the CdS–Cu_xS heterojunction. Metallic copper diffusing through the CdS and Cu_xS from the electrode is captured by the non-stoichiometric Cu_xS whereby the Cu_xS is substantially stoichiometric in the completed photovoltaic cell.

4,168,124
Pizzi, Gilbert, inventor; Centre National d'Etudes Spaciales, assignee. *Method and Device for Measuring The Solar Energy Received at a Particular Place*. September 18, 1979.

The invention provides a method and apparatus for measuring and recording the amount of solar energy falling at a place over a given period of time, comprising means for producing a frequency signal representative of the energy falling at the place, the provision of the frequency signal being controlled in response to the level of solar energy falling exceeding a morning threshold and falling below an evening threshold, and the frequency signal being applied to a counter, preferably fitted with print-out means, whereby the counter may record the total energy falling between the morning and evening thresholds.

4,169,738
Luque, Antonio, inventor. *Double-Sided Solar Cell with Self-Refrigerating Concentrator*. October 2, 1979.

A planar solar cell photovoltaically active on both sides is positioned in a solar concentrator capable of simultaneously illuminating both sides of the cell. The cell is immersed in a transparent liquid that enhances solar energy concentration and aids in removing undesirable heat from the cell. The solar cell, having two photovoltaically active sides, can be constituted by an n^+pn^+ structure or by an n^+pp^+ structure. Electrically conductive metal grids serving as cathode and anode connections are formed on both sides of the cell. The grid apertures advantageously allow the light to enter into the appropriate semiconductor regions. In the case of an n^+pn^+ structure, window means in the n^+ layers are provided to permit electrical contact between the anode grids and the p region. Solar cells with complementary dopings, for example p^+np^+, are also possible.

4,169,739
Lindmayer, Joseph, inventor; Semix, Incorporated, assignee. *Method of Making Silicon-Impregnated Foraminous Sheet by Partial Immersion and Capillary Action*. October 2, 1979.

A foraminous sheet of carrier substrate is contacted, by full or partial immersion, with a bath of molten silicon to form a sheet of material in which the foramina are filled with silicon and at least one surface of the sheet is coated with silicon. The coated sheet is suitable for use in forming a photovoltaic cell.

4,169,740
Kalbitzer, Siegfried; Müller, Gerhard; Spear, Walter E.; Le Comber, Peter G., inventors; Max-Planck-Gesellschaft zur Forderung der Wissenschafter, assignee. *Method of Doping a Body of Amorphous Semiconductor Material by Ion Implantation*. October 2, 1979.

To provide for effective doping and obtain substantial conductivity change in amorphous semiconductor material, typically silicon, a body of said material is raised to a temperature above about 20°C and below the recrystallization temperature for example in the range of between 100°C, preferably above 200°–250°C and

below about 450°C during the ion implantation. The doping ions are, for example for silicon, of groups III and V of the periodic system, particularly boron and phosphorus. Semiconductor junctions can be made by this process by selectively doping spatially limited regions of the semiconductor body to thereby produce semiconductor components by doping with ions of different characteristics, for example of different conductivity type.

4,169,970
Opiela, Michael L.; Zelazny, Stanley D., inventors. *Memorial Audio Reproduction System*. October 2, 1979.

An audio reproduction system is provided for use in conjunction with a tombstone for the repeated playback, upon activation, of a prerecorded message. The system comprises a housing which is secured within the tombstone. A prerecorded message on an endless magnetic tape is operatively mounted within a tape playback device which in turn is contained within the interior of the housing. A Hall effect switch wholly contained within the housing activates, upon closure, a time module to operatively connect a self-contained source of electrical power to the tape playback device for the predetermined period of time. A solar cell is also operatively coupled with the electrical power source to supplement the same.

4,170,507
Keeling, Michael C.; Doss, Dwight E., inventors; Motorola, Inc., assignee. *Method for Encapsulating a Solar Cell Array*. October 9, 1979.

An enclosure for a solar cell array and a method of fabricating a solar cell module. The array is enclosed between a metal back plate and a cover glass. The edges of the enclosure are sealed by a pliable sealant material and a spring loaded bezel that is riveted or welded in place. The interior of the enclosure is filled with a potting material which surrounds and cushions the solar cell array. During the module fabrication a fixture supports the enclosure parts and provides a temporary edge seal to facilitate the potting procedure. Controlled flexure of the enclosure back plate and controlled spacing of the cover glass ensure a compressive loading of the potting material which eliminates possible delamination of the potting material in its subsequent usage.

4,170,667
Rodgers, Michael A., inventor; Motorola, Inc., assignee. *Process for Manufacturing Pure Polycrystalline Silicon*. October 9, 1979.

A process for the production of high purity polycrystalline silicon from a mixture of silicon tetrachloride and trichlorosilane. Such a mixture can be used for the rapid deposition of polycrystalline silicon while, at the same time, producing an excess of trichlorosilane in exhaust gases from the reaction. The process permits the modification of the reactor design for the economical and energy conscious production of polycrystalline silicon.

4,171,003
Forrat, Francis, inventor; Commissariat a l'Energie Atomique, assignee. *Solar Energy to Electrical Energy Converter*. October 16, 1979.

Solar radiation is collected and directed through transparent material for the optical conversion of solar radiation to infrared radiation onto a rod-shaped multijunction semi-conductor photovoltaic cell. This is achieved by means of a focusing structure of linear form having a focal line and a plate of transparent converting material. The plate is placed in the vicinity of the focal line and performs the double function of light guide and optical converter. The semiconductor rod is placed along one of the longitudinal edges of the plate.

4,171,235
Fraas, Lewis M.; Zanio, Kenneth R.; Knechtli, Ronald C., inventors; Hughes Aircraft Company, assignee. *Process for Fabricating Heterojunction Structures Utilizing a Double Chamber Vacuum Deposition System*. October 16, 1979.

The specification describes a gallium aluminum arsenide-gallium arsenide-germanium solar cell and fabrication process therefor wherein the deposition of a layer of gallium aluminum arsenide establishes a first PN junction in the GaAs of one bandgap energy on one side of a gallium arsenide substrate, and the deposition of a layer of germanium establishes a second PN junction in Ge of a different bandgap energy on the other side of the GaAs substrate. The two PN junctions are responsive respectively to different wavelength ranges of solar energy to thus enhance the power output capability of a single wafer(substrate) solar cell. Utilization of the Group IV element germanium, as contrasted to compound semiconductors, simplifies the process control requirements relative to known prior art compound semiconductor processes, and germanium also provides a good crystal lattice match with gallium arsenide and thereby maximizes process yields. This latter feature also minimizes losses caused by the crystal defects associated with the interface between two semiconductors.

4,171,989
Pryor, Robert A., inventor; Motorola, Inc., assignee. *Contact for Solar Cells*. October 23, 1979.

An improved solar energy device has a body of semiconductor material of a first conductivity type with a region of a second conductivity type formed in the body and extending to its surface. A current collection metallization pattern is disposed on the second conductivity type region, with at least three distinct and identifiable current accumulation points connected to the metallization pattern adjacent to the periphery of the second conductivity type region. External electrical connection is made to extract available electrical power from the device at the current accumulation points. The periphery of the device is free of other electrically equivalent external electrical connection areas. These features allow a substantial increase in device efficiency.

4,171,991
Lindmayer, Joseph, inventor; Semix, Incorporated, assignee. *Method of Forming Silicon Impregnated Foraminous Sheet by Immersion*. October 23, 1979.

A foraminous sheet of carrier substrate is formed by immersing the sheet in a bath of molten silicon. After cooling, the coated sheet is suitable for use in making a photovoltaic cell.

4,171,997
Irmler, Horst, inventor; Brown, Boveri & Cie, A. G., assignee. *Method of Producing Polycrystalline Silicon Components, Particularly Solar Elements*. October 23, 1979.

A method of producing semiconductor components, particularly solar elements, in which a P- or N-semiconductor chip is subjected to an oxidation step prior to formation of the device PN junction, such that the external surface and internal grain boundaries of the wafer are covered by a passivating oxide layer. Thereafter, the oxide layer on at least a portion of the semiconductor chip is removed, and at least one PN junction is formed in the chip.

4,172,739
Tassen, Devon, inventor; Solar Homes, Inc., assignee. *Sun Tracker with Dual Axis Support for Diurnal Movement and Seasonal Adjustment*. October 30, 1979.

A sun tracker including a dual axis support for following diurnal movement of the sun and a drive mechanism for providing motive force about a first axis of the support. Accurate movement of the tracker about a second support axis is caused by a system of cables and a cooperating cable engaging arcuate surface shaped to produce the necessary movement about the second axis to maintain the tracker in appropriate orientation with the sun throughout the day. Seasonal adjustment is effected by adjusting the cable lengths.

4,172,740
Campbell, William Patrick, III, inventor. *Solar Energy System*. October 30, 1979.

A system for extracting energy from the sun's rays including a bank of solar energy cells which generate electrical current when exposed to the rays of the sun, immersed in a bath of liquid formed to serve as a lens, concentrating the sun rays on the cells, and transmitting heat away from the cells. The cells are shaped so as to cause a trapping effect of radiation incident thereon. The improved solar converting unit additionally includes a method for preheating the interior thereof. The converting unit is preferably equipped with light gathering and focusing means thereby providing coherent optically output.

4,172,925
Chen, Schoen-Nan; Russak, Michael A.; Witzke, Horst; Reichman, Joseph; Deb, Satyendra K., inventors; Refac Electronics Corporation, Grumman Aerospace Corporation, assignee. *Photoelectrochemical Cell*. October 30, 1979.

Photoelectrochemical cell structures and methods of fabrication are disclosed which provide for easily manufactured efficient conversion devices. The structures incorporate one or more chambers for the electrolyte, and utilize semiconductor photoelectrodes. In the plural chamber structure, the semiconductor may be opaque, and need not necessarily be a thin film. Specific dopants for the semiconductor provide for decreased dark current and increased open circuit voltage. Post deposition treatment is disclosed for the semiconductor to provide an increased shorting current. Increased sputtering wattage is provided to increase the short circuit current available from the cell. An electrolyte composition is described having improved performance at high light intensity.

In a multi-chamber embodiment, the electrode placement causes the photoactive site to be at an end of the chamber removed from the irradiation window, thereby permitting the use of non-transparent photoelectrodes.

A third embodiment is disclosed including two photoelectrodes, in combination with a properly selected electrolyte, to provide response to two different portions of the spectrum at an increased operating efficiency. A method and apparatus is disclosed for utilizing a photoelectrochemical cell of the type provided in a dual role, both for electrical conversion of impinging radiation and for heat utilization resulting therefrom.

Finally, A multi-chamber, multi-electrolyte structure is disclosed providing electrical charge storage after termination of radiation.

4,173,213
Kelly, Donald A., inventor. *Solar Power System, with High Concentration, Linear Reflective Solar Panels*. November 6, 1979.

The solar power system with high concentration linear reflective solar panels of the linear parabolic type is intended to increase the electrical power output from conventional silicon solar cells, and heat water for steam power.

Circular parabolic reflectors have been used for this purpose but they are not as flexible in application as the linear parabolic reflectors (L.P.R.'s).

The solar power system may be arranged as an all electric type using continuous lines of silicon solar cells located at the apex or focal zone of the parabola, or may be designed as a dual solar conversion system with both solar photoelectric means and a water heating steam means, as an indirect or secondary power source.

The key feature of the system is the geometric configuration of the linear parabolic reflectors (L.P.R.'s), with an unusually high reflective concentration ratio of 10:1 minimum, plus boosters, and the connection of these pivoted linear panels to a common oscillating linkage and timing unit for full sun following capability to maintain optimum direct solar exposure each day.

4,173,229
Halfon, Leon, inventor. *Therapeutic Adornments Utilizing Solar Cells*. November 6, 1979.

A therapeutic adornment or jewelry object incorporating a solar cell operable to generate a beneficial electrical current flow through the body of a person wearing same. The solar cell is mounted in a housing effective to electrically insulate the cell itself from a person's body while permitting the transmission of sunlight to the cell's active energy collecting surface. The cell has positive and negative electrical output terminals across which a voltage is generated by the energy collected. The adornment is arranged to mount the cell on a person's body with its active surface exposed to the sun and its terminals electrically connected to spaced apart points on the person's body, whereby a flow of electricity is generated through the person's body between these spaced apart body points. The adornment is illustrated in the forms of a bracelet and necklace.

4,173,494
Johnson, Elwin L.; Kilby, Jack S.; Lathrop, Jay W.; McFerren, John S.; Myers, David J., inventors; Jack S. Kilby, assignee. *Glass Support Light Energy Converter*. November 6, 1979.

Semiconductor particles are distributed in a single level layer orientation in a glass sheet with portions of each particle exposed at both surfaces of the sheet. A metal layer on one surface of the sheet is in ohmic contact with the body of each particle and forms a common electrode.

4,173,495
Rapp, Charles F.; Boling, Norman L., inventors; Owens-Illinois, Inc., assignee. *Solar Collector Structures Containing Thin Film Polysiloxane, and Solar Cells*. November 6, 1979.

Disclosed is a composite collector and concentrator structure comprising a laminate having a self-supporting layer of solid light transmitting material of extended area in one plane in optical contact with a relatively thin layer of a silicone resin derived from a trifunctional silane containing at least one species of luminescent material which absorbs electromagnetic radiation and emits electromagnetic radiation of a longer wavelength. Use with photovoltaic solar cells is also disclosed.

4,173,496
Chiang, Shang-Yi; Carbajal, Bernard G., inventors; Texas Instruments Incorporated, assignee. *Integrated Solar Cell Array*. November 6, 1979.

An integrated, monolithic array of solar cells wherein isolation between cells permits series interconnection of the cells to provide an output voltage for the array equal to the sum of the voltages of the unit cells. Although normal PN junction isolation is ineffective when exposed to light, the present structure includes a form of junction isolation that is effective when exposed to light, or to other radiation. For example, a band of heavily doped P-type silicon, formed by thermomigration of aluminum through an N-type wafer, provides such isolation.

4,173,497
Schmidt, Ferenc J.; Betz, Jacob F., inventors; Ametek, Inc., assignee. *Amorphous Lead Dioxide Photovoltaic Generator*. November 6, 1979.

Photovoltaic generator, comprised of photovoltaic amorphous lead dioxide with an oxygen to lead ratio in the range of 1.66 to 1.99, and having rectifying and ohmic junctions therewith. Said lead dioxide may be formed by electrodeposition on substrates, such as copper, nickel, stainless steel, carbon, brass, stannic oxide, indium oxide, and gold plated copper or brass, and generally provides an ohmic junction with the substrate. A rectifying photovoltaic junction of the Schottky barrier type is formed by

overcoating the lead oxide with one or more of an evaporated, sputtered or ion plated film of copper, aluminum, Inconel™, nickel, gold, platinum, palladium, nickel oxide, titanium, titanium oxide, and copper oxide.

Re. 30,147
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Method of Coating a Glass Ribbon on a Liquid Float Bath*. November 13, 1979.

A method of making low cost solar cells on a large scale basis by means of a continuous process of fabricating float glass and coating the float glass, in sequence, with tin oxide, cadmium sulphide, and copper sulphide, while the glass floats atop tanks of molten material in a furnace of proper temperature for each step of the process, the application of the coatings, in a preferred embodiment, being accomplished by depositing materials which form the coatings on contact with heated surfaces at such slow rates and, in the case of spray application, via drops of such uniformity that the float glass may (1) remain at uniform temperatures by virtue of the superior thermal conductivity of the molten material and retain those temperatures despite the abstraction of heat from the glass by evaporation of liquids and/or formation of crystalline layers, and (2) be substantially free of temperature gradients along the surface of the sheet glass.

4,173,820
Mueller, Robert I.; Yasui, Robert K., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method for Forming a Solar Array Strip*. November 13, 1979.

A method for forming a solar array strip including the steps of depositing solder pads on printed circuitry deposited on flexible substrate storing the resulting substrate on a drum, withdrawing the substrate from the drum and incrementally advancing it along a linear path, serially transporting solderless solar cells into engagement with the pads and thereafter heating the pads for thus attaching the cells to the printed circuitry, cleaning excess flux from the solar cells, encapsulating the cells in a protective coating and thereafter spirally winding the resulting array on a drum.

4,174,234
Lindmayer, Joseph, inventor; Semix, Incorporated, assignee. *Silicon-Impregnated Foraminous Sheet*. November 13, 1979.

A foraminous sheet of carrier substrate is contacted, by full or partial immersion, with a bath of molten silicon to form a sheet of material in which the foramina are filled with silicon and at least one surface of the sheet is coated with silicon. The coated sheet is suitable for use in forming a photovoltaic cell.

4,174,561
House, Robert E.; Irvin, Robert A.; Kane, Daniel F., inventors; Semicon, Inc., assignee. *Method of Fabricating High Intensity Solar Energy Converter*. November 20, 1979.

A photovoltaic energy converter for converting incident radiant energy, such as solar energy, to electrical energy. The converter comprises a cell formed from a plurality of integrally interconnected p-n junction-containing semiconductor wafers. The wafers are stacked end-to-end in the cell so that the respective junctions in each wafer are parallel to each other. The efficiency and performance of the cell is improved, particularly upon exposure to concentrated sunlight, by imposing various conditions on the cell fabrication and design. Improvements result, for example, by selecting a high resistivity semiconductor as the starting material in the fabrication of the cell, controlling the diffusion process to optimize the junction gradient and minimize the thickness of the base region in each wafer, orienting the wafers in the cell so that they are illuminated at a small angle relative to the plane of the respective junctions therein, and treating the exposed surfaces of the wafer to reduce reflectivity and surface recombination velocities.

4,174,978
Lidorenko, Nikolai S.; Evdokimov, Vladimir M.; Zadde, Vitaly V.; Kozlov, Alexandr I.; Ryabikov, Stanislav V.; Potapov, Valery N.; Strebkov, Dmitry S.; Surianinova, Tatiana I.; Chubrikov, Boris A.; Zatravina, Valentina V.; Korlev, Boris V.; Kulikov, Viktor F.; Zhuravleva, Larisa L.; Unishkov, Vadim A.; Dormidontov, Anatoly A.; Moiseev, Viktor I.; Kudeshova, Ljubov P., inventors. *Semiconductor Photovoltaic Generator and Method of Fabricating Thereof*. November 20, 1979.

A semiconductor photovoltaic generator is proposed which comprises a plurality of photovoltaic converters interconnected in series along their opposite surfaces by current-collecting contacts to form a monolithic structure. Every photovoltaic converter is provided with a p-n junction between the base and inverse regions. The photo-active face of the generator is made as a staircase-type structure. The area of every step is inversely proportional to the intensity of incident radiation and the width of the step is about equal to, or smaller than, the diffusion distance of minority carriers in the base region.

4,175,249
Gruber, Robert P., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Self-Reconfiguring Solar Cell System*. November 20, 1979.

A self-reconfiguring solar cell array wherein some of the cells are switched so that they can be either in series or in shunt within the array. This feature of series or parallel switching of cells allows the array to match the load to achieve maximum power transfer. Automatic control is used to determine the conditions for maximum power operation and to switch the array into the appropriate configuration necessary to transfer maximum power to the load.

4,175,610
Zauhar, Helmut; Authier, Bernhard; Luptovits, Roland; Schmidhammer, Leonhard, inventors; Wacker-Chemitronic Gesellschaft fur Elektronik-Grundstoffe mbH, assignee. *Process and Apparatus for the Semicontinuous Production of Silicon Moldings*. November 27, 1979.

The invention relates to a process and apparatus for manufacturing silicon castings or moldings, having a columnar structure of single-crystal regions of crystal with a preferential crystallographic orientation, and which can be manufactured cheaply and in large numbers in a semi-continuous mode of production. Liquid silicon is cast in a casting station, under an inert gas and preferably under reduced pressure, preferably in graphite molds which are exposed to a temperature gradient of 200° to 1,000°C. After cooling, the silicon is withdrawn automatically via a transport chamber connected to the casting station into special cooling stations, while the casting station is reloaded with an empty mold for repeating the process. The silicon blocks which have preferably been produced by this procedure are used as basic material for inexpensive solar cells having efficiencies of more than 10%, after they have been sawn into individual small wafers and have been doped and lead-bonded.

4,175,980
Davis, Robert R.; Sill, Richard C.; Yerkes, John W., inventors; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. November 27, 1979.

A luminescent solar collector comprising at least one luminescent member which has at least one photovoltaic means operably associated therewith, the luminescent member having a side which is to be esentially oriented toward the sun when in operation, and an optically transparent member on the sun-facing side of the luminescent member, the transparent member being spaced from the sun-side to provide space between the luminescent member and the transparent member, the transparent member being essentially coextensive with the luminescent member.

4,175,981
Loutfy, Rafik O.; McIntyre, Lloyd F.; Sharp, James H., inventors; Xerox Corporation, assignee. *Photovoltaic Cell Comprising Metal-Free Phthalocyanine*. November 27, 1979.

A photovoltaic cell wherein the photoactive layer comprises a thin layer of metal-free phthalocyanine dispersed in a binder. The electrical output is greatly in excess of that obtained from prior art organic semiconductor photovoltaic cells of the same surface area.

4,175,982
Loutfy, Rafik O.; Hsiao, Cheng-Kuo; Sharp, James H., inventors; Xerox Corporation, assignee. *Photovoltaic Cell*. November 27, 1979.

A photovoltaic cell having an improved barrier electrode comprising indium or tin. The cell utilizes metal-free phthalocyanine dispersed in an electrically insulated binder as the photoactive layer in contact with an ohmic electrode.

4,176,370
Koguchi, Nobuyuki; Masumoto, Katashi, inventors; National Research Institute for Metals, assignee. *Photovoltaic Converter*. November 27, 1979.

A photovoltaic converter, useful for example as a photodetector or solar cell, comprising a main unit consisting of a p-n heterojunction of a p- or n-type magnetic semiconductor MCr_2X_4 in which M is Zn, Cd or Hg and X is O, S, Se or Te and an n- or p-type semiconductor $M'In_2S_4$ in which M' is Zn, Cd or Hg and which has an optical absorption edge at a shorter wavelength than the optical absorption edge of the MCr_2X_4; a first electrode ohmically fixed to the surface of the MCr_2X_4; and a second electrode fixed ohmically to the surface of the $M'In_2S_4$ and allowing light to reach the surface of $M'In_2S_4$. With a decrease in temperature, the photovoltaic converter has the long wavelength edge of its spectral photovoltaic response shifted to a longer wavelength contrary to known photovoltaic converters.

4,177,083
Kennedy, William S., inventor; Acurex Corporation, assignee. *Photovoltaic Concentrator*. December 4, 1979.

A photovoltaic concentrator utilizes as an airtight enclosure a fused glass structure similar to an automotive sealed-beam headlamp. One of the halves is aluminized to provide a reflector for the impinging sunlight and for focusing it on a photocell carried within the enclosure. The foregoing structure because of developed mass production techniques is low cost and in addition the airtight rugged enclosure protects the fragile reflective surface and photocell.

4,177,093
Feng, Tom; Ghosh, Amal K., inventors; Exxon Research & Engineering Co., assignee. *Method of Fabricating Conducting Oxide-Silicon Solar Cells Utilizing Electron Beam Sublimation and Deposition of the Oxide*. December 4, 1979.

In preparing tin oxide and indium tin oxide-silicon heterojunction solar cells by electron beam sublimation of the oxide and subsequent deposition thereof on the silicon, the engineering efficiency of the resultant cell is enhanced by depositing the oxide at a predetermined favorable angle of incidence. Typically the angle of incidence is between 40° and 70° and preferably between 55° and 65° when the oxide is tin oxide and between 40° and 70° when the oxide deposited is indium tin oxide.

4,177,473
Ovshinsky, Stanford R., inventor; Energy Conversion Devices, Inc., assignee. *Amorphous Semiconductor Member and Method of Making the Same*. December 4, 1979.

An amorphous semiconductor member includes an amorphous semiconductor material which is formed in a solid amorphous host matrix having structural configurations which have local rather than long-range order and electronic configurations which have an energy gap and a large electrical activation energy, and, added to the amorphous host matrix, a modifier material having orbitals which interact with the amorphous host matrix and form electronic states in the energy gap which modify substantially the electronic configurations of the amorphous host matrix for reducing substantially the activation energy thereof and, hence, increasing substantially the electrical conductivity of the semiconductor member substantially at room temperature and above. The amount of addition of the modifier material controls the range of electrical conductivity, and can be greater than dopant amounts usually used for doping semiconductors. The amorphous host matrix is normally of intrinsic-like conduction and the modifier material added thereto changes the same to extrinsic-like conduction. In one form of the invention, a primarily lone-pair amorphous semiconductor material having orbitals is utilized wheren the orbitals of the modifier material interact with the orbitals of the amorphous host matrix and form the electronic states in the energy gap. In another form, a primarily tetrahedral bonding amorphous semiconductor material is utilized wherein the orbitals of the modifier material, added primarily in a non-substitutional manner, interact with the amorphous host matrix and form the electronic states in the energy gap. In a further form, an amorphous semiconductor material containing boron is utilized wherein the orbitals of the modifier material interact with the amorphous host matrix and form the electronic states in the energy gap.

4,177,795
Schultz, Robert T., inventor. *Triggering Device Responsive to Energy Flow and Controlled Solar Heating System Incorporating the Device*. December 11, 1979.

A device, and controlled solar heating system incorporating the device, for providing an electrical control signal responsive to the rate of flow of species of radiant energy through an area. The device includes means for providing an electrical input signal responsive to the rate of flow of the species of radiant energy, such as solar energy, and an electrical circuit for receiving the input signal and for providing a control signal in response to the input signal. Solar cells may provide the input signal to a Schmidt Trigger Circuit set to provide two control signals at predetermined rates of solar energy flow through an area. The device, incorporated into a solar heating system, may be used to control the circulation of fluid through solar heating panels.

4,178,175
Narita, Kiichi; Mori, Takasuke; Ito, Takamichi, inventors; Kobe Steel, Ltd., assignee. *Method for Agitating a Bath of Melted Metal for Treating the Same*. December 11, 1979.

A method of agitating a bath of melted metal for treating the same by blowing gas into a columnar body of such melted metal disposed in the bath to cause the apparent specific gravity of the columnar body to be reduced and to thereby be hydrostatically lifted, and returning the lifted portion of the melted metal to the bath by pouring the same with a splashing effect onto the free surface of the bath, in a manner to continuously change the pouring position on the free surface of the bath, thereby causing improved agitation of the bath, and especially improved contact and mixing of the melted metal and a treating agent generally floating on the free surface of the bath.

4,178,395
Jordan, John F.; Singh, Vijay P., inventors; Photon Power, Inc., assignee. *Methods for Improving Solar Cell Open Circuit Voltage*. December 11, 1979.

A method for producing a solar cell having an increased open circuit voltage. A layer of cadmium sulfide (CdS) produced by a chemical spray technique and having residual chlorides is exposed to a flow of hydrogen sulfide (H_2S) heated to a temperature of 400°-600°C. The residual chlorides are reduced and any remaining $CdCl_2$ is converted to CdS. A heterojunction

is formed over the CdS and electrodes are formed. Application of chromium as the positive electrode results in a further increase in the open circuit voltage available from the H_2S-treated solar cell.

4,178,415
Ovshinsky, Stanford R.; Sapru, Krishna, inventors; Energy Conversion Devices, Inc., assignee. *Modified Amorphous Semiconductors and Method of Making the Same*. December 11, 1979.

An amorphous semiconductor film includes an amorphous semiconductor host matrix, such as silicon or silicon and oxygen, and a modifier material comprising an alkali metal, such as lithium, incorporated therein by codeposition of the same. The modifier material incorporated in the amorphous host matrix controls the electrical conductivity of the film and other phenomena associated therewith.

4,179,308
Olsen, Gregory H.; Ettenberg, Michael, inventors; RCA Corporation, assignee. *Low Cost High Efficiency Gallium Arsenide Homojunction Solar Cell Incorporating a Layer of Indium Gallium Phosphide*. December 18, 1979.

A new low cost high efficiency gallium arsenide homojunction solar cell incorporating a passivating surface layer of indium gallium phosphide. The thickness of the indium gallium phosphide layer is selected so that it is transmissive to photons having wavelengths shorter than its bandgap energy.

4,179,318
Kaplow, Roy; Frank, Robert I.; Goodrich, Joel L., inventors; Massachusetts Institute of Technology, assignee. *Method of Making a Solar-Cell Array*. December 18, 1979.

The invention contemplates a method of making a solar-cell construction wherein plural spaced elongate unit cells of an array are formed from a parallel-grooved single wafer of substrate material of a first conductivity type, with adjacent sidewalls of adjacent units at each inter-unit groove formation. In the transverse succession of such groove formations, the sidewalls of every other groove are formed with regions of a second conductivity type, so that at or near the radiation-exposure surface of each unit there is but one junction between first and second conductivity types. In one general form, all grooves go all the way between upper and lower wafer surfaces, thus defining discrete single-cell units; in another general form, every other groove ends close to but short of the upper surface, thus defining discrete twin-cell units. The units are series-connected by making ohmic connection between the second conductivity-type region of one unit and a first conductivity-type region of an adjacent unit. The construction lends itself to a relatively simple and economical manufacture.

4,179,612
Smith, Peter D., inventor. *Radiation Tracking Control*. December 18, 1979.

A control system for radiation tracking apparatus comprises: (a) photo sensors to receive incident radiation, (b) edge means to intercept radiation directed toward each sensor so that primary and secondary locations on each sensor respectively receive and do not receive incident radiation, the sensors controlling tracking movement of the apparatus, (c) the sensors being electrically energized and having electrical outputs which vary a function of radiation interception by the sensors, and there being means responsive to said outputs to control said tracking movement, and (d) there being control means connected with the sensors and responsive to increases and decreases in the intensity of said radiation to respectively decrease and increase electrical energization of the sensors.

4,179,627
Reitz, Ronald P., inventor; Tom Swift Enterprises, Inc., assignee. *Electrical Apparatus*. December 18, 1979.

An electrical apparatus for use as a capacitor, solar cell, switching device, wave-shaper and the like. The apparatus comprises a first electrode, a first dielectric positioned proximate one side of the first electrode, a second electrode positioned proximate the first dielectric, a second dielectric positioned proximate one side of the second electrode, a third electrode positioned proximate the second dielectric and generally facing said one side of the second electrode, a third dielectric positioned proximate the non-facing side of the third electrode, a fourth electrode positioned proximate the third dielectric, means for connecting the first and fourth electrodes to a control circuit whereby an electrical potential is established between the first and fourth electrodes, and means for connecting the second and third electrodes to an external circuit whereby upon operation of the external circuit the second and third electrodes are connected in circuit.

4,179,633
Kelly, Donald A., inventor. *Magnetic Wheel Drive*. December 18, 1979.

The permanent magnet wheel drive consists of two basic magnetic components, one large driven flat wheel containing a uniform series of identical magnet segments, and a second magnetic driving means comprising multiple oscillating magnetic couples of opposite identical magnet segments.

The magnetic mechanism simulates the action of a clock escapement mechanism in that the oscillating magnet couples uniformly oscillate between the wheel magnet segments to induce continuous wheel rotation.

All of the multiple oscillating magnet couples are oscillated by a motor(s) driven eccentric through a suitable gear reduction unit. The small D. C. motor(s) are powered by multiple arrays of silicon solar photovoltaic cells at some convenient rooftop location.

4,179,702
Lamorte, Michael F., inventor; Research Triangle Institute, assignee. *Cascade Solar Cells*. December 18, 1979.

A monolithic cascade cell for converting incident radiation, particularly solar radiation, into electrical energy at a high efficiency with at least three layers of semiconductive Group III-IV material. The top layer is doped into p and n regions with a homojunction therebetween and has a bandgap such that photons above a predetermined energy interact with the semi-conductive material to produce a potential across the homojunction and current flow and photons below that energy pass through the first layer to a second similar layer having a lower bandgap so that some of the radiation passing through the first layer produces a potential across a homojunction in the second layer to improve the overall energy conversion efficiency of the cell. The first and second layers are separated by at least a third layer of a Group III-V material, similarly doped into p and n regions with a tunnel junction formed therebetween to provide a low voltage electrical connection between the first and second layers. In one embodiment, the first and second layers are connected in series to be additive so that current flow takes place between contacts associated with the first and second layers. In another embodiment, the first and second layers are connected in opposition with a third terminal connected to the third layer which, in this case, need not be a tunnel junction. Alternatively, the two layers may be light producing devices such as light emitting diodes (LEDs), emitting light at different wavelengths, or photodiodes, detecting light of different wavelengths, or one layer can be a light producing device such as an LED while the other layer is a light receiving device such as a photodiode, again operating at different wavelengths.

4,180,414
Diamond, Ronald M.; Ling, Ku S.; Winterer, Allen G., inventors; Optical Coating Laboratory, Inc., assignee. *Concentrator Solar Cell Array Module*. December 25, 1979.

A concentrator solar cell array module having a metallic heat sink with a planar mounting surface. A semiconductor spacer is provided. The semiconductor spacer is provided with a layer of insulating material in the form of silicon oxide. The silicon oxide surface is secured to the mounting surface of the heat sink by a thermally conductive adhesive. A semiconductor solar cell is provided. Solder is utilized for securing the solar cell to the spacer. A glass cover is secured to the solar cell by an adhesive. The glass cover is provided with a textured surface to cause diffusion of the light impinging upon the solar cell.

4,180,618
Alpha, James W.; Dumbaugh, William H., Jr., inventors; Corning Glass Works, assignee. *Thin Silicon Film Electronic Device*. December 25, 1979.

The present invention is related to the fabrication of electronic devices wherein a thin film of silicon is deposited upon a substrate. More particularly, the invention is directed to such devices wherein the substrate therefor is an alkaline earth metal aluminosilicate glass consisting essentially, by weight, of about 55-75% SiO_2, 5-25% Al_2O_3, and at least one alkaline earth metal oxide selected from the group consisting of 9-15% CaO, 14-20% SrO, 18-26% BaO, and mixtures thereof in a total amount equivalent on a molar basis to 9-15% CaO.

4,180,625
Wagner, Sigurd, inventor; Bell Telephone Laboratories, Incorporated, assignee. *Semiconductor Liquid Junction Photocell Using a $CuInS_2$ Electrode*. December 25, 1979.

Liquid-semiconductor photocells have received much attention recently as candidates for use in solar power conversion devices. A semiconductor liquid junction photovoltaic cell having a photoactive electrode made from CuInS2 and a liquid electrolyte containing a redox couple consisting of $S_2=/S=$ anions has been found to produce a stable photocurrent output.

1980

4,181,538
Narayan, Jagdish; White, Clark W.; Young, Rosa T., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Method for Making Defect-Free Zone by Laser-Annealing of Doped Silicon*. January 1, 1980.

This invention is a method for improving the electrical properties of silicon semiconductor material. The method comprises irradiating a selected surface layer of the semiconductor material with high-power laser pulses characterized by a special combination of wavelength, energy level, and duration. The combination effects melting of the layer without degrading electrical properties, such as minority-carrier diffusion length. The method is applicable to improving the electrical properties of n- and p-type silicon which is to be doped to form an electrical junction therein. Another important application of the method is the virtually complete removal of doping-induced defects from ion-implanted or diffusion-doped silicon substrates.

4,181,755
Liu, Shing-Geag; Duigon, Ferdinand C., inventors; RCA Corporation, assignee. *Thin Film Pattern Generation by an Inverse Self-Lifting Technique*. January 1, 1980.

A method of pattern generating a circuit film and adjacent barrier film on a substrate. A continuous layer of circuit film is applied to the substrate surface, and a photoresist pattern is delineated on the circuit film such that the photoresist remains on the circuit film pattern area. The area of circuit film not covered by photoresist is then removed, exposing the substrate surface. While retaining the photoresist which covers the circuit film pattern, the entire substrate surface is coated with the barrier film. The remaining photoresist is then removed, causing the barrier film which covers it to lift off, thereby exposing the circuit film pattern.

4,182,960
Reuyl, John S., inventor. *Integrated Residential and Automotive Energy System*. January 8, 1980.

An integrated system including a residence and an automobile utilizes environmental energy, such as solar energy, as the primary energy source and the automobile provides a backup or supplementary source of energy for this system. An exemplary system has photovoltaic and thermal collectors associated with the residence for collecting radiant solar energy and converting a portion thereof to electricity and to heat, and residential energy storage means for storing energy generated within the integrated energy system; hybrid electric drive means associated with the automobile in this exemplary system includes batteries for storing electrical energy generated within the integrated energy system, an electrically energized motor to propel the automobile, and a liquid-fueled combustion engine for driving an associated electrical generator to function as a backup or supplementary source of energy for both the residence and the automobile. Interface umbilicals interconnect the residence and the automobile to enable energy to be selectively transferred from the residence to the automobile, and from the automobile to the residence, under the control of suitable sensing and control circuits.

4,183,628
Laesser, Claude; Viennet, René; Saurer, Eric, inventors; Ebauches S.A., assignee. *Electronic Watch and Display Device for Such Watch*. January 15, 1980.

An electro-optic display device having a partially transparent display cell and a semi-transparent mirror located behind said cell and arranged to transmit light waves within a first wave length band and to reflect light waves within a second wave length band. An electro-optic component is located behind the semi-transparent mirror and operates in a third wave length band which overlaps at least partially the first wave length band. The electro-optical component may be a plurality of photo cells used for recharging an acumulator for the display device and/or a light source transmitted across a light plate of frosted or clear glass to illuminate the display cell. The display cell is illuminated by either the reflected light waves or the light waves emitted from the light source.

4,184,111
Turner, Gary B., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Driver for Solar Cell I-V Characteristic Plots*. January 15, 1980.

A bipolar voltage ramp generator applies a linear voltage through a resistor to a solar cell for plotting its current versus voltage (I-V) characteristic between short circuit and open circuit conditions, with automatic stops at the end points. The resistor serves the multiple purpose of providing a current sensing resistor, setting the full-scale current value, and providing a load line with a slope approximately equal to one, such that it will pass through the origin and the approximate center of the I-V curve with about equal distance from that center to each of the end points.

4,184,482
Cohen, Eli, inventor. *Solar Energy Collecting System*. January 22, 1980.

A solar energy collecting system is disclosed, especially adapted for suspended installation from overhead support members at a roof or other enclosure which includes energy-transmissible portions for enabling the solar energy to be rendered incident on the system. The system comprises a flexible, relatively thin sheet, which includes a solar energy-reflecting surface. Frame means are provided, which are securable to a plurality of parallel spaced,

strip-like zones on the sheet, the frame means being adapted to form the sheet at the said zones into parabolic arcs, with the reflective surface residing on the concave side of such arcs. The frame means are adapted to maintain the sheet in a taut condition between the spaced parabolically-arced zones, thereby maintaining the sheet in the configuration of a line-generated parabolic surface. Energy conversion means are disposed along the line of foci of the surface, for receiving reflected solar energy and converting same into a further utilizable energy form. Support means are provided for the frame means and energy conversion means, for disposing the system to receive incident solar energy onto the concave parabolic surface; and means are provided for rotating the frame means together with the parabolic surface about the line of foci, to at least partially track the incident solar radiation.

4,184,894
Lindmayer, Joseph; Wrigley, Charles Y., inventors; Solarex Corporation, assignee. *Integrated Photovoltaic Generator*. January 22, 1980.

Disclosed is an integrated photovoltaic generator containing a plurality of photovoltaic cells, the generator capable of producing a voltage greater than that generated by a single photovoltaic cell of comparable chemical composition. The gnerator comprises a wafer of semiconductor material having two major surfaces, at least one of the major surfaces including a plurality of discrete areas containing an impurity of one type of conductivity, at least the portion of the remainder of the wafer contiguous to the areas containing an impurity of an opposite conductivity type, and electrical conductor means between at least one area and the portion of the wafer containing the impurity of the opposite conductivity type.

4,184,895
Oster, Eugene A., Jr., inventor; Owens-Illinois, Inc., assignee. *Structure for Conversion of Solar Radiation to Electricity and Heat*. January 22, 1980.

Disclosed is a structure which in one apparatus converts a part of incident solar energy to electrical energy by the use of photocells mounted on a luminescent solar collector of tubular design while another portion of such incident energy is converted to thermal energy.

4,184,903
Dillard, Paul A.; Fritz, Walter M.; Lott, Dan R., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Fabricating a Photovoltaic Module of a Substantially Transparent Construction*. January 22, 1980.

A method characterized by the steps of positioning a plurality of uniformly dimensioned photovoltaic cells in registered relation with a plurality of openings formed in a planar tool for affording access to the P contact surface of each of the cells, connecting the N contact surface of alternate cells to the P contact surface of the cells interposed therebetween, removing therefrom residue of solder flux, applying to the N contact surfaces of the cells a transparent adhesive, placing a common transparent cover plate in engaged relation with the adhesive, placing a film over the circular openings for hermetically sealing the openings, and establishing a vacuum between the film and the cover plate for thus simultaneously forcing the cells into vacuum bonded relation with the cover plate.

4,186,033
Boling, Norman L.; Rapp, Charles F., inventors; Owens-Illinois, Inc., assignee. *Structure for Conversion of Solar Radiation to Electricity and Heat*. January 29, 1980.

Disclosed is a modified flat plate thermal collector, modified to substitute for one of its insulating flat light conducting members a flat luminescent solar collector plate coupled to a photocell and having a thin layer containing a luminescent species responsive to solar radiation, to provide a structure for producing both electrical and thermal energy, wherein said thin layer is protected from the ambient atmosphere and wherein the thin layer is out of contact with said photocell.

4,187,123
Diggs, Richard E., inventor. *Directionally Controlled Array of Solar Power Units*. February 5, 1980.

A directionally controlled array of solar power units includes a supporting frame having conduits for flow of hot and cold water to each of the units supported on the frame, and each unit includes a solar cell which directly converts solar energy into electrical energy, the solar energy being concentrated on the cells by lenses. The solar cells are electrically connected for desired use of the electrical energy produced thereby, and the hot and cold water conduits are connected with the cells for flow of cold water in heat exchange relationship with the cells to cool the cells and heat the water and the hot water is available for work. Thermocouples and controls are connected with the units for moving the units to keep them pointed at the sun to thus utilize maximum energy therefrom throughout daylight hours.

4,187,124
Muller, Jean-Claude; Ponpon, Jean-Pierre; Kurek, Joseph; Siffert, Paul, inventors; Agence Nationale de Valorisation de la Recherche (ANVAR), assignee. *Process for Doping Semiconductors*. February 5, 1980.

A process and apparatus for doping a substrate by ion implantation or discharge. The process comprises the steps of maintaining an electric discharge in an evacuated enclosure containing a gaseous compound of a dopant for creating ions of said dopant; extracting and accelerating a beam of said ions from said atmosphere toward said substrate under a voltage selected for achieving a predetermined doping profile; and circulating said substrate transversely to said beam.

4,187,126
Radd, Fred J.; Oertle, Don H.; McKinney, Charles N., inventors; Conoco, Inc., assignee. *Growth-Orientation of Crystals by Raster Scanning Electron Beam*. February 5, 1980.

A method of grain-orienting the crystal structure of a layer of semiconductor material by application of a raster scanning electron beam to a layer of polycrystalline semiconductor material which has been previously formed on a substrate, such as by sputter-plasma film deposition. The method comprises electron beam lithography computer-applied to the crystal growth and orientation of a polycrystalline thin sheet of silicon or other semiconductor material.

4,188,238
Boling, Norman L., inventor; Owens-Illinois, Inc., assignee. *Generation of Electrical Energy from Sunlight, and Apparatus*. February 12, 1980.

Disclosed is a process and apparatus for concentrating sunlight optically and impinging the concentrated light on at least one luminescent solar collector coupled to a first photocell, passing residual concentrated sunlight to at least one other luminescent solar collector in one embodiment, coupled to a different photocell, and finally passing the remaining concentrated sunlight directly to a still different photocell.

4,188,239
Boling, Norman L., inventor; Owens-Illinois, Inc., assignee. *Luminescent Solar Collector Structure*. February 12, 1980.

Disclosed is a luminescent solar collector optically coupled to a photovoltaic cell and in confronting relationship thereto a diffusing layer of a particulate phosphorescent material deposited on and backed by a mirror.

4,189,881
Hawley, Wilbur W., inventor; Atlantic Richfield Company, assignee. *Photovoltaic Roof Construction*. February 26, 1980.

In a batten-seam roof construction employing at least one photovoltaic cell module, the electrical conduits employed with the at least one photovoltaic cell module are disposed primarily under the battens of the roof.

4,190,321
Dorer, Gary L., inventor; Minnesota Mining and Manufacturing Company, assignee. *Microstructured Transmission and Reflectance Modifying Coating*. February 26, 1980.

Single layer coatings that render a surface more light transmitting and less light reflecting without an attendant increase in diffuse scattering are produced by depositing a thin metal film on the surface, totally converting the thin metallic film to either an oxide and/or hydroxide microstructured layer by chemical or a combination of chemical and electrochemical methods. Uniform optical properties are exhibited over large angles of incidence and an extremely broad range of wavelengths.

4,190,465
Boling, Norman L., inventor; Owens-Illinois, Inc., assignee. *Luminescent Solar Collector Structure*. February 26, 1980.

Disclosed is a luminescent solar collector comprising a relatively thick layer with a photocell coupled to a face surface thereof and at least one thin luminescent layer optically coupled to said thick layer, said thick layer having an index of refraction at least 0.04 more than each of said luminescent layers and being at least 10 times as thick as the sum of all other layers of said collector.

4,190,852
Warner, Raymond M., Jr., inventor. *Photovoltaic Semiconductor Device and Method of Making Same*. February 26, 1980.

A photovoltaic semiconductor device which is a horizontal multijunction series-array solar battery with a monocrystalline body and having elongate zones of aluminum doped silicon passed entirely through N-type silicon layers by Thermomigration process to connect together epitaxially grown buried P layers. Masked elongate N diffusion zones which are parallel and substantially contiguous to each elongated P zone penetrates at least through the lowest P layer thereby forming an inactive pn junction. A thin shallow layer of P-type material is diffused across the top N-type layer. Topologically continuous photovoltaic junctions exist in each cell of the photovoltaic semiconductor device between the shallow layer of P-type material, the buried layer or layers of P-type material, the elongate zone of aluminum doped silicon, and the N-type silicon thereby forming active pn junctions. Metallic strips, at the other pn junctions formed by the thermomigrated aluminum which are inactive, electrically connect the cells together. A method is disclosed for manufacturing the photovoltaic semiconductor device.

4,191,164
Kelly, Donald A., inventor. *Dual Conversion Steam and Electric Solar Power System*. March 4, 1980.

The dual conversion, steam and electric solar power system is aimed at attaining an optimum cost/effective balance between arrays of direct electric conversion solar cells and an indirect steam-to-electric solar power system. The concentration panels for the system consist of the previously disclosed four quadrant, two dimensional type of concentration panel with higher side concave extensions to provide concentration ratios up to 35:1. A continuous flash boiler pipe serves as the base conversion means, with a box-form array of solar cells mounted at the cold water entrance end of the pipe(s). The entering cold water dissipates heat from the solar cells while pre-heating the water for the subsequent section of the flash boiler pipe exposed section. The solar panel width to focal zone width is between 22:1 and 28:1.

4,191,593
Cacheux, Jean A., inventor; Centre National d'Etudes Spatiales, assignee. *Double Heterojunction Solar Cells*. March 4, 1980.

Photovoltaic cell comprising two heterojunctions between three component semiconductors $Ga_{1-x}Al_xAs$ with x varying from 0 to 0.9, GaAs, and Ge which have respective bandgaps of 0.66, 1.43, and 2.4 eV, lattice constants matching at 0.07% and expansion coefficients matching at 1.7%. The cell is mounted in a cell device comprising a parallelepipedal unit, a Frensel lens, a tapering cavity within said unit, partially filled up with a lens shaped antireflecting transparent material and a radiator, said device forming a sunlight concentrator.

4,191,594
Stark, Virgil; Vayda, Alexandre; Rousset, Paul, inventors; Virgil Stark, assignee. *Solar Energy Conversion*. March 4, 1980.

Apparatus and methods for concentrating and collecting solar energy are disclosed. In accordance with the invention, solar energy is concentrated by economical refringent lenses or lens systems including fluid lenses and/or Fresnel-type lenses. The lenses concentrate the solar energy preferably along lines in continuous linear foci or in discrete foci at an elongated collector comprising one or more fluid-carrying conduits and one or more fluids therein. In one embodiment, a plurality of photoelectric cells are located in or on the collector along the linear foci or at the discrete foci and operate at increased efficiency with heat being removed by the collector. A first fluid in the collector is heated by the concentrated solar energy and in a preferred embodiment is used to heat a second fluid contiguous to the first fluid, the first fluid having a boiling point exceeding that of the second fluid. In a preferred embodiment, the first fluid is carried in an inner conduit while the second fluid is carried by an outer conduit which encloses the inner conduit and first fluid. Thus, the two fluids can be heated to different temperatures by a single concentrating system and used for different purposes.

4,191,794
Shirland, Fred A.; Biter, William J., inventors; Westinghouse Electric Corp., assignee. *Integrated Solar Cell Array*. March 4, 1980.

An integrated array of solar cells, each cell having a positive and a negative electrode, is disclosed. A first grid comprising a plurality of non-interescting electrically conductive members is affixed to an insulating substrate. Each single individual member of this grid forms the negative electrode of an individual cell of the array. Overlying and affixed to the negative electrodes and the surface of the substrate between these electrodes is a semiconductor layer of a first conductivity type. Isolated (i.e., non-touching or non-abutting) semiconductor regions of a second conductivity type form a plurality of PN junctions with the semiconductor layer. These P-N junctions are the active areas of the individual cells of the array. Each of the isolated semiconductor regions of the second conductivity type is solely coupled to an individual member of another grid whose members form the positive electrodes of the individual cells. Electrical interconnection is made through a non-active region of the semiconductor layer to couple the cells comprising the array in series circuit relationship.

4,192,720
Bucker, Edward R.; Amick, James A., inventors; Exxon Research & Engineering Co., assignee. *Electrodeposition Process for Forming Amorphous Silicon*. March 11, 1980.

A method for electroplating amorphous silicon from a non-aqueous solution containing a silicon solute wherein a heat treatment is requisite to producing stable coatings of photoconductive amorphous silicon.

4,192,721
Fawcett, William R.; Baranski, Andrzej S., inventors. *Method for Producing a Smooth Coherent Film of a Metal Chalconide*. March 11, 1980.

Smooth coherent films of metal chalconides are electroplated onto a cathode from an electroplating bath comprising a solution of a metal salt and elemental chalcogen at elevated temperature and low current density.

4,193,081
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *Means for Effecting Cooling Within Elements for a Solar Cell Array*. March 11, 1980.

A solar cell array, comprised of a plurality of series-connected unit solar cells, formed from a common substrate, is cooled by providing cooling passages between adjacent sidewalls of adjoining unit cells through which a heat transfer medium is transmitted. Transmission of the heat transfer medium through the passages effectively cools the solar cell array as the cooling surfaces provided by the sidewalls of the cooling passages are much larger than the light-receiving surfaces of the cells. Enhanced cooling effectiveness can be accomplished by providing additional cooling passages along the lower surfaces of the unit cells.

4,193,819
Wohlmut, Peter G., inventor; Atlantic Richfield Company, assignee. *Luminescent Photovoltaic Solar Collector*. March 18, 1980.

A photovoltaic device composed of a luminescent sheet having a pair of flat, opposed semicircularly shaped sides connected by a thin edge face having a curved, semicylindrically shaped section and a straight section and at least one photovoltaic cell carried on the straight section of said thin edge face.

4,193,820
Thomas, Ronald, inventor; Organisation Europeenne de Recherches Spatiales, assignee. *Interconnection Device for Solar Cells*. March 18, 1980.

An interconnection device for solar cells is described comprising two flat strips intended to be welded to two adjacent solar cells and a hinge element linking the two flat strips, said hinge element having two branches each connected by its free end to one of the flat strips and the said hinge element extending longitudinally between the two adjacent solar cells. The hinge element may be covered with an insulating material. In a particular embodiment the branches of the hinge element are linked by a linking element.

4,193,821
Feng, Tom; Ghosh, Amal K., inventors; Exxon Research & Engineering Co., assignee. *Fabrication of Heterojunction Solar Cells by Improved Tin Oxide Deposition on Insulating Layer*. March 18, 1980.

Highly efficient tin oxide-silicon heterojunction solar cells are prepared by heating a silicon substrate, having an insulating layer thereon, to provide a substrate temperature in the range of about 300°C to about 400°C and thereafter spraying the so-heated substrate with a solution of tin tetrachloride in an organic ester boiling below about 250°C. Preferably the insulating layer is a naturally grown silicon oxide layer.

4,193,974
Kotval, Peshotan S.; Strock, Harold B., inventors; Union Carbide Corporation, assignee. *Process for Producing Refined Metallurgical Silicon Ribbon*. March 18, 1980.

Silicon platelets essentially free of iron are precipitated from a solution of metallurgical grade silicon in molten aluminum and are melted in contact with silica slag to produce a refined metallurgical silicon. The silicon-slag melt is solidified in a unidirectional manner so as to directionally solidify said silicon. A directionally solidified refined metallurgical silicon (DS/RMS) ribbon is pulled from a melt of the thus-refined silicon. This DS/RMS ribbon is a low-cost product having a substantially higher impurity content level than in conventional high purity semiconductor grade silicon while, at the same time, being useful for solar cell applications.

4,194,212
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Semicrystalline Silicon Article and Method of Making Same*. March 18, 1980.

A semicrystalline silicon solar energy cell formed from individual grains of silicon having portions thereof at the light-receiving surface of the cell. An electrical junction is formed at said light-receiving surface and extends across and below that surface and into and between the boundaries of adjoining grains to an extent such that the total junction area substantially exceeds the product of the linear dimensions of the wafer surface but does not extend completely around the boundaries of the silicon grains or to the opposed surface of the wafer.

4,196,041
Baghdadi, Aslan; Gurtler, Richard W., inventors; Motorola, Inc., assignee. *Self-Seeding Conversion of Polycrystalline Silicon Sheets to Macrocrystalline by Zone Melting*. April 1, 1980.

A polycrystalline semiconductor sheet may be converted to a monocrystalline or macrocrystalline semiconductor sheet through use of a geometric restriction in the sheet. The process requires formation of a region of the sheet having a small width compared to the width of the remainder of the sheet. A molten zone is formed in the small width region of the sheet. At least a portion of the molten zone is allowed to solidify into a single crystal or crystals of large size of the semiconductor material coextensive with the small width of the region at the portion of the molten zone so solidified. The molten zone is then moved from the small width region of the sheet into the remainder of the sheet. The sheet is allowed to solidify successively as the molten zone passes along it. As a result, the macrocrystal formed in the narrow width region of the sheet propagates into the remainder of the sheet through which the molten zone passes. This process allows formation of high modified semiconductor material without requiring use of a seed crystal.

4,196,438
Carlson, David E., inventor; RCA Corporation, assignee. *Article and Device Having an Amorphous Silicon Containing a Halogen and Method of Fabrication*. April 1, 1980.

An amorphous silicon capable of the formation of a semiconductor junction. The amorphous silicon can be fabricated by a glow discharge in a gas atmosphere including hydrogen and a deposition gas. The deposition gas has therein the elements silicon and a halogen selected from the group consisting of chlorine, bromine and iodine.

4,197,141
Bozler, Carl O.; Fan, John C. C., inventors; Massachusetts Institute of Technology, assignee. *Method for Passivating Imperfections in Semiconductor Materials*. April 8, 1980.

A method of passivating imperfections, such as grain boundaries and/or dislocations, in semiconductor materials is disclosed which comprises selectively passing electrical current along the imperfections by employing the semiconductor material as an electrode in an electrolytic cell.

4,197,142
Bolton, James R.; Janzen, Abram F., inventors; Canadian Patents & Development Ltd., assignee. *Photochemical Device for Conversion of Visible Light to Electricity*. April 8, 1980.

A photochemical device for conversion of visible light to electricity comprising one or more monolayers of dye material such as chlorophyll, an electron acceptor monolayer of saturated fatty acid between suitable electrode layers, all formed or mounted on a suitable substrate sheet.

4,198,246
Wu, Chung P., inventor; RCA Corporation, assignee. *Pulsed Laser Irradiation for Reducing Resistivity of a Doped Polycrystalline Silicon Film*. April 15, 1980.

A method of reducing the resistivity of a doped polycrystalline silicon film deposited on a substrate comprises the step of irradiating the film with a laser pulse having an energy density of less than about 1.5 joules per square centimeter.

4,198,262
Gay, Charles F., inventor; Atlantic Richfield Company, assignee. *Solar Cell Manufacture*. April 15, 1980.

A method for manufacturing solar cells from a silicon wafer having a p-n junction therein and front and back contacts thereon, the improvement comprising washing said wafer with a buffered hydrofluoric acid solution having a pH of from about 3.5 to about 6.5 and containing from about 2 to about 10 weight percent hydrofluoric acid based on the total weight of the solution.

4,199,376
Sill, Richard C., inventor; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. April 22, 1980.

A luminescent sheet having two essentially parallel opposed large area surfaces separated by one or more thin edge faces, the sheet being penetrated by one or more tapered, asymmetrically disposed cavities extending from one such surface at least partially through such sheet toward the opposite surface and a corresponding number of photovoltaic cells positioned on such opposite surface in respective concentric alignment with such cavities so that light internally reflected from the convergent side walls of such cavities toward such opposite surface is concentrated onto such cells.

4,199,377
Corwin, Rudolph E.; Riemer, Dietrich E., inventors; The Boeing Company, assignee. *Solar Cell*. April 22, 1980.

A solar cell including a dielectric isolation member to electrically isolate an active region of the cell from the unfinished edge thereof and to protect the p-n junction from surface contaminants. The isolation member is fabricated on top of a semiconductor wafer before diffusion.

4,199,383
Wittry, David B., inventor; University of Southern California, assignee. *Method of Making a Photovoltaic Cell Employing a PbO-SnO Heterojunction*. April 22, 1980.

A photovoltaic cell that incorporates a PbO-SnO heterojunction of graded composition which, among other applications, can be utilized for the conversion of solar energy to electrical energy. A p-i-n junction is formed while PbO and SnO are simultaneously deposited on a substrate in a varying ratio that is either decreased or increased to form the compositions $Pb_{1-x}Sn_xO$ where x varies in the range of 0 to 1.

4,199,397
Gurtler, Richard W., inventor; Motorola, Inc., assignee. *Spontaneous Growth of Large Crystal Semiconductor Material by Controlled Melt Perturbation*. April 22, 1980.

A polycrystalline semiconductor sheet may be converted to a macrocrystalline or monocrystalline semiconductor sheet through use of a controlled melt perturbation in the sheet. The process is initiated by formation of a small melt area generally in the center of the sheet of polycrystalline material and then by controlled sweeping motions a molten zone is ultimately formed across the entire width of the sheet. As the molten zone is allowed to solidify, crystals of large size are formed and, with proper control of this crystal, can grow across the entire width of the polycrystalline sheet, or at least crystals of sufficiently large size for production of semiconductor activity may be produced. Following formation of macrocrystalline material across the width of the sheet the perturbation may be continued throughout the process to sweep any dislocations or crystal boundaries to the edge of the sheet where they may be trimmed from the remainder of the material as desired. This process allows formation of a highly modified macrocrystalline semiconductor material without requiring use of a seed crystal.

4,199,894
Fischer, Artur, inventor. *Toy Model Kit Including a Solar Collector*. April 29, 1980.

A solar collector, particularly as a power source for a toy model assembled from structural elements of a kit, has a supporting member, at least one solar cell mounted on the supporting member, mechanical connecting elements arranged on the supporting member for mechanically connecting the latter with another structural element of the toy model, and electrical connecting elements also arranged on the supporting member for electrically connecting the solar cell with other solar cells. The electrical connecting elements may connect the solar cells with one another in parallel and/or in series. The supporting member may be platelike. The electrical connecting elements may be arranged on two opposite side faces of the supporting member and may include two pairs of plugs and/or sockets.

4,200,472
Chappell, Terry I.; White, Richard M., inventors; The Regents of the University of California, assignee. *Solar Power System and High Efficiency Photovoltaic Cells Used Therein*. April 29, 1980.

A solar power system including a movable platform for tracking the sun, a radiation concentrator, and a plurality of photovoltaic cell modules positioned on the platform for receiving concentrated solar radiation. The module includes a heat dissipation housing which supports a silicon cell across an open end of the housing. A heat transfer block physically engages the silicon cell and a metallic sponge and wick is attached to the heat transfer block and depends therefrom into the housing. The housing is partially filled with liquid to facilitate heat removal. The silicon cells are processed by preferential etching to form V grooves which define a plurality of diode elements having generally trapezoidal cross-sections. The elements may be serially interconnected by metallization on the V groove surfaces. The physical configurations of the elements and the use of antireflective coatings on surfaces of the elements result in high efficiency cells.

4,200,473
Carlson, David E., inventor; RCA Corporation, assignee. *Amorphous Silicon Schottky Barrier Solar Cells Incorporating a Thin Insulating Layer and a Thin Doped Layer*. April 29, 1980.

Amorphous silicon Schottky barrier solar cells which incorprate a thin insulating layer and a thin doped layer adjacent to the junction forming metal layer exhibit increased open circuit voltages compared to standard rectifying junction metal devices, i.e., Schottky barrier devices, and rectifying junction metal insulating silicon devices, i.e., MIS devices.

4,200,833
Wilkerson, Alan W., inventor. *Power Maximization Circuit*. April 29, 1980.

A power maximization circuit periodically samples the output power of a power supply to regulate output voltage or current toward that resulting in maximum output power. Power increasing variations in voltage or current are continued until maximum power is reached and exceeded, at which time the direction of variation is reversed until operation becomes stabiized at maximum power conditions. The circuit includes a sampling means for periodically sampling the output power. The sampling means is connected to a comparison means providing an output signal, the condition of which is indicative of whether the power at any given sampling period is greater or less than the previous sampling period. Means are provided for detecting on a coincidence basis, the condition of the comparison means output signal and for altering the magnitude of the current or voltage of the power supply toward that which obtains maximum power.

4,200,904
Doan, Duc, inventor. *Solar Powered Street Lighting System*. April 29, 1980.

A solar powered street lighting system that is totally independent of any external power supply. Solar panels are connected in such a manner to charge a maintenance-free storage battery with sufficient capacity to light street lights and/or traffic signals. An auxillary generator may also be provided having a wind driven vane for also charging the battery if sufficient sun light is not available.

4,201,622
Salama, Amal M., inventor; The United States of America as represented by The Administrator of the National Aeronautics and Space Administration, assignee. *Method of Mitigating Titanium Impurities Effects in P-Type Silicon Material for Solar Cells*. May 6, 1980.

Microstructural evaluation tests performed on Cu-doped, Ti-doped, and Cu/Ti doped p-type silicon single crystal wafers, before and after the solar cell fabrication, and evaluation of both dark forward and reverse I-V characteristic records for the solar cells produced from the corresponding silicon wafers, show that Cu mitigates the unfavorable effects of Ti, and thus provdes for higher conversion efficiency, thereby providing an economical way to reduce the deleterious effects of titanium, one of the impurities present in metallurgical grade silicon material.

4,201,798
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Applying an Antireflective Coating to a Solar Cell*. May 6, 1980.

A tantalum oxide antireflective coating is applied to a surface of a solar energy cell by depositing a layer of a suboxide of tantalum on the surface and then oxidizing the layer to an oxide approaching Ta_2O_5.

4,202,004
Andersen, David C., inventor. *Energy Conversion Unit*. May 6, 1980.

A crystal of a semiconductor material has an electrically conducting loom assembly embedded therein, whereby the crystal and loom assembly define a unit which converts light or other electromagnetic radiation into an electrical current for flow to an external electrical circuit. The loom assembly has a plurality of electrodes coated with another semiconductor material so that the semiconductor materials define a plurality of n-p junctions within the crystal. Radiation absorbed by the crystal will liberate electrons which will flow across the junctions and along electrical paths formed in the loom assembly to conductor means which can be connected to an external electrical circuit. The loom assembly comprises a plurality of very small loom units comprised of pairs of spaced electrodes, one of the electrodes of each loom unit having a coating of a semiconductor material in contact with the semiconductor material of the crystal. The loom assembly can be made by laser cut tooling and the crystal can be grown on the loom assembly. The crystal can be mounted in any suitable manner to receive solar energy, such as in optical alignment with a lens system or at the focus of a curved mirror.

4,202,704
Hodgson, Rodney T.; Hovel, Harold J.; Woodall, Jerry M., inventors; International Business Machines Corporation, assignee. *Optical Energy Conversion*. May 13, 1980.

Enhanced efficiency can be achieved in the construction of semiconductor optical energy conversion devices such as solar cells by providing a translucent frequency shifting supporting member with appropriate doping such as $Al_2O_3:Cr^{+3}$(Ruby) that is capable of shifting the wavelength of incident light energy in the direction of greatest efficiency of the semiconductor device. The efficiency can be further enhanced by providing a crystal perfection accomodation region between the active region of the device and the light frequency shifting substrate.

4,203,646
Desso, Jerome A.; Ritchie, Leon T.; Yeager, Marvin L., inventors; AMP Incorporated, assignee. *Clip for Electrically Connecting Planar Elements Such as Solar Cells, and the Like, in Series*. May 20, 1980.

A clip is disclosed for interconnecting planar elements, such as solar cells, and the like, in series. The cells are connected by the clip to electrically interconnect a top circuit of one element to a bottom circuit of an adjacent element. The clips are manufactured from stock which includes a metallic strip with at least one insulating web secured along one surface covering approximately half the area thereof. At least two cantilever beams are stamped from the strip extending toward each end of the clip and lying spaced above a portion of the clip. The first arm presents an insulated surface to an uninsulated portion of the clip while the second arm presents an uninsulated surface to an insulation portion of the clip.

4,203,785
Hawrylo, Frank Z., inventor; RCA Corporation, assignee. *Method of Epitaxially Depositing Cadmium Sulfide*. May 20, 1980.

A single crystal layer of either cadmium sulfide or an alloy of cadmium sulfide and indium phosphide is epitaxially deposited on a substrate of cadmium sulfide by liquid phase epitaxy using indium as the solvent.

4,204,147
Larrabee, Robert D., inventor; RCA Corporation, assignee. *Power Transfer Apparatus*. May 20, 1980.

A power transfer apparatus includes an impedance matching system coupled between a variable voltage source, e.g., a solar cell array, and a load. A parameter of the load indicative of the power being delivered to the load is sensed and the control signal thereby derived is employed to adjust the impedance matching system. The adjustment is such as to maximize the value of the parameter.

4,204,216
Heeger, Alan J.; MacDiarmid, Alan G.; Chiang, Chwan K.; Gau, Shek-Chung, inventors; University Patents, Inc., assignee. *Electrically Conducting Doped Polyacetylene Film Exhibiting N-Type Electrical Conductivity and Method of Preparing Same*. May 20, 1980.

Electrically conducting organic polymeric film material exhibiting a preselected room temperature n-type electrical conductivity ranging from that characteristic of semiconductor behavior to that characteristic of metallic behavior, is prepared by controlled electron donor doping of a polycrystalline film of polyacetylene with a metal dopant whose Pauling electronegativity value is no greater

than 1.6. Preferred metal dopants are the alkali metals. The procedure may be employed in preparing polyacetylene film with a p-n junction formed by two adjacent portions of the film respectively provided with p-type and n-type electrical conductivities.

4,204,881
McGrew, Stephen P., inventor. *Solar Power System*. May 27, 1980.

A system for generating electrical power from sunlight, comprising a focussing diffraction grating or other focussing, spectrally dispersive means and a photocell array. The diffraction grating focuses sunlight into a spectrally dispersed band. The photocell array is composed of cells with different spectral sensitivities, located in positions in the dispersed band corresponding to the cell spectral sensitivities so that the net conversion efficiency of sunlight to electricity exceeds the conversion eficiency attainable with nondispersive collectors and single material photocells. Alternate embodiments of the invention provide sun tracking means, reflective or transmissive diffraction gratings, flat or curved diffraction grating surfaces, on- or off-axis focus, and optical coatings on the photocell surfaces.

4,204,933
Barlow, William A.; Rhodes, Maurice; Sherliker, Francis R.; Williams, Edward W., inventors; Imperial Chemical Industries Limited, assignee. *Electrocoating Process for Producing a Semiconducting Film*. May 27, 1980.

Application of heat preferentially to one surface of a film of a semiconducting sulphide, sulphoselenide, selenide or telluride to establish a temperature differential between the surfaces of the film improves the electrical and photochemical properties of the film. The film may be employed in solar cells. Preferably the film is prepared by electrophoresis of a colloidal suspension of the semiconductor in an aqueous medium.

4,205,265
Staebler, David L., inventor; RCA Corporation, assignee. *Laser Beam Apparatus and Method for Analyzing Solar Cells*. May 27, 1980.

A laser beam apparatus and method for analyzing, inter alia, the current versus voltage curve at the point of illumination on a solar cell and the open circuit voltage of a solar cell. The apparatus incorporates a lock-in amplifier, and a laser beam light chopper which permits the measurement of the AC current of the solar cell at an applied DC voltage at the position on the solar cell where the cell is illuminated and a feedback scheme which permits the direct scanning measurements of the open circuit voltage. The accuracy of the measurement is a function of the intensity and wavelength of the laser light with respect to the intensity and wavelength distribution of sunlight and the percentage the dark current is at the open circuit voltage to the short circuit current of the solar cell.

Re. 30,292
Dominguez, Ramon, inventor; Solarex Corporation, assignee. *Solar Panel with Mat Base Member*. June 3, 1980.

A solar panel including photovoltaic cell encapsulated in a silicone resin, in which the base member to which the silicone resin adheres is a glass mat polyester in laminate or molded form.

4,205,657
Kelly, Donald A., inventor. *Convertible Modular Tri-Mode Solar Conversion System*. June 3, 1980.

The convertible, modular tri-mode solar conversion system provides two primary heating modes, both hot water and hot air for winter time operation, with conversion to one secondary mode for electric power generation and air-conditioning during summertime operation. The tri-mode solar conversion system utilizes linear parabolic concentrators for converting solar energy to hot water/steam, hot air, and heat engine/electric power generation for nearly all year round operation with improved overall cost-effectiveness. Wintertime hot water is provided within a conventional focal piping line with hot air produced through a thin plastic duct which is concentric to the focal piping. The thin plastic duct is supported by thin, spirally wound wire coils with uniformly located, radial struts fastened to both the focal piping and the wire coils. Summertime air conditioning and electric power are provided from both the focal piping steam and the hot air flow by way of a simple Rankine cycle heat engine loop.

4,206,002
Sabnis, Anant G.; Butera, Richard A.; Meiksin, Zvi H.; Narasimhan, K. S. V. L., inventors; University of Pittsburgh, assignee. *Graded Band Gap Multi-Junction Solar Energy Cell*. June 3, 1980.

The specification discloses a solar cell having a graded band gap and a plurality of alternately active and inactive p-n junctions. The cell has a gradually changing monocrystalline structure of IIIA-VA compounds. The graded band gaps of the cell are the result of the gradually changing chemical composition of the cell's monocrystalline structure. The junctions are produced by conventional doping techniques.

4,207,119
Tyan, Yuan-Sheng, inventor; Eastman Kodak Company, assignee. *Polycrystalline Thin Film CdS/CdTe Photovoltaic Cell*. June 10, 1980.

A photovoltaic cell and a process of making and using it are disclosed wherein extremely thin semiconductor layers are provided through the use of polycrystalline CdS and CdTe. The cell has conversion efficiencies as high as 6% or more when exposed to AM2 light.

4,209,346
King, Roger A., inventor. *Solar Energy Recharger*. June 24, 1980.

A portable power supply including a rechargeable battery, an array of solar cells, a heat sink thermally engaging the cells and the batteries for transmission from the former to the latter, and a cover pivotal between a first position in which it protects the solar cells and a second position in which it supports the unit with the cells in optimum orientation for insulation.

4,209,347
Klein, Norman S., inventor; RCA Corporation, assignee. *Mounting for Solar Cell*. June 24, 1980.

A mounting for a silicon solar cell comprises a layer of molybdenum on the back surface of the cell and a molybdenum wire along the peripheral edge of the radiation receiving surface of the cell. An electrode formed with an aperture aligned with the radiation receiving surface abuts and is secured along the border of the aperture to the wire and a heat sink is in conductive contact with the molybdenum layer. The coefficients of expansion of the molybdenum and silicon are similar and this protects the relatively brittle cell from damage when its temperature is changed.

4,209,735
Yoshida, Yoshisaburo, inventor; Sharp Kabushiki Kaisha, assignee. *Solar Battery Powered Electronic Calculator*. June 24, 1980.

A solar battery panel is installed on an electronic calculator through an arrangement formed on a rear casing of the electronic calculator or on a glass substrate supporting a display unit, a semiconductor chip, and wiring leads. The solar battery panel is exposed to light through a window formed on the rear casing or a rear casing over the glass substrate. A wallet is provided for protecting and supporting the electronic calculator. The solar battery panel is exposed to the outside through a window in the wallet even when the wallet is surrounding the electronic calculator.

4,210,121
Stark, Virgil, inventor. *Solar Energy Collection*. July 1, 1980.

Apparatus and methods for concentrating and collecting solar energy and for lowering the cost and increasing the efficiency of solar energy systems are disclosed. Solar energy is concentrated by economical refringent lenses or lens systems including fluid lenses and/or Fresnel-type lenses. The lenses concentrate the solar energy preferably along lines in continuous linear foci or in discrete foci at an elongated collector comprising one or more fluid-carrying conduits and one or more fluids thierein. In one embodiment, a plurality of photovoltaic cells is located in or on the collector along the linear foci or at the discrete foci and operates at increased efficiency with heat being removed by the collector. Heating at the photoelectric cells is reduced by utilizing a fluid lens in which the lens fluid and lens plates absorb heat-producing infrared rays which otherwise would be converted to heat at the cells while permitting the electricity-producing luminous rays to pass to the cells with little absorption by the lens fluid and plates. A first fluid in the collector is heated by the concentrated solar energy and in a disclosed embodiment is used to heat a second fluid contiguous to the first fluid, the first fluid having a boiling point exceeding that of the second fluid. The first fluid is carried in an inner conduit while the second fluid is carried by an outer conduit which encloses the inner conduit and first fluid. Thus, the two fluids can be heated to different temperatures by a single concentrating system and used for different purposes. Energy is stored using two fluids of different boiling points. Also disclosed are methods and fixed and portable aparatus for distilling liquids including water containing salt or other substances by evaporation of the water and condensation of the water vapor wherein preferably the heat of condensation is recovered and heat in the condensate and brine is also preferably recovered. The invention also provides for assemblies of individual systems and subsystems to form larger and/or composite systems.

4,210,462
Tourneux, Michel, inventor; U.S. Philips Corporation, assignee. *Generator Panel Having Solar Cells Incorporated in a Laminated Assembly*. July 1, 1980.

A photovoltaic generator panel comprising a plurality of solar cells incorporated in a laminated assembly, each of the external faces of which is formed of a glass plate. The laminated assembly comprises an inset plate formed of a transparent synthetic resin stable at elevated temperatures and provided with a recess for each solar cell. Optionally, an inset film preferably formed of the same transparent synthetic resin can be positioned between the inset plate and one or both glass plates. Assembly of these several lamellar elements is effected by the use of a transparent adhesive polymerized at a temperature below 70°C.

4,210,463
Escher, William J. D., inventor. *Multimode Solar Energy Collector and Process*. July 1, 1980.

A solar energy collector providing both concentrating-tracking functions and non-concentrating diffuse absorption functions in a single unit. The solar energy collector and process may provide both a higher temperature heat transfer fluid and a lower temperature heat transfer fluid for utilization in various processes, such as environmental conditioning, which may advantageously utilize thermal energy of two different temperatures. The solar energy thermal collector and process of this invention provides a high temperature thermal output in combination with a simplified tracking capability.

4,211,581
Vasilinina, Olga V.; Kidyashev, Jury K.; Potapov, Valery N.; Ryabikov, Stanislav V.; Stepanov, Anatoly M.; Strebkov, Dmitry S., inventors. *Solar Photoelectric Conversion Apparatus with Cooling Means*. July 8, 1980.

A solar photoelectric conversion apparatus comprises a light converter immersed in a transparent liquid heat carrier which occupies the lower part of the cavity of a hollow hermetically sealed reservoir. The apparatus also includes a solar radiation concentrator inserted in a beam of a solar radiation incident on an active surface of the light converter. During operation of the apparatus, vapors of the heat carrier condense on the inner walls of the reservoir and return by gravity to the liquid in the lower portion of the cavity, thereby cooling the liquid and the light converter immersed therein by "thermal siphon" action.

4,212,932
Calgari, Seba; Sirtori, Vittorio; Bellobono, Ignazio R., inventors; Societa' Nazionale Industria Applicationi Viscosa s.p.a. (Snia Viscosa), assignee. *Device for the Direct Conversion of Radiant Energy to Electrical Energy*. July 15, 1980.

A cell for the direct conversion of radiant energy to electrical energy for carrying the process is characterized in that it comprises two layer-like zones each comprising a transparent material and at least one photochromic compound, electrical conduction means between said two zones, and two electrodes. The two layer-like zones may be constituted by different portions of a same layer. The photochromic compounds used are preferably spiro-2H-pyranes and the electrodes are metals having a standard oxidation potential higher than–2.5V or their oxides or photoactive semi-conductors.

4,213,798
Williams, Richard; Arie, Yehuda, inventors; RCA Corporation, assignee. *Tellurium Schottky Barrier Contact for Amorphous Silicon Solar Cells*. July 22, 1980.

A Schottky barrier amorphous silicon solar cell incorporates a tellurium layer as the Schottky barrier.

4,213,801
Johnston, Wilbur D., Jr., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Ohmic Contact of N-GaAs to Electrical Conductive Substrates by Controlled Growth of N-GaAs Polycrystalline Layers*. July 22, 1980.

Thin layers of polycrystalline n-type GaAs have been deposited on a conducting substrate such as graphite. These contacted GaAs layers exhibit desirable properties for device applications, i.e., adequate cohesion between the GaAs and the substrate, good electrical contact to the conducting substrate, and good nucleation of the GaAs on the substrate yielding pinhole free or near pinhole free GaAs layers composed of large grains. These properties are obtained by first depositing a very thin coating, a coating with a nominal thickness between 1000 Å and 250 Å, of a Group IV element, Ge, Si, or Sn, onto the conducting substrate and then depositing the GaAs over this thin layer.

4,214,916
Felsher, Hal C.; Pollak, Fred H.; Bradley, Arthur, inventors. *Thin Film Photovoltaic Converter and Method of Preparing Same*. July 29, 1980.

The photovoltaic converter of the present invention comprises a thin film consisting essentially of a lattice of stacked carbon chains comprising alternating single and double bonds deposited on the surface of an electrode transparent to sunlight. The carbon lattice is prepared in situ by depositing and exposing a plastic film comprising a highly oriented polymer system to heat or other types of radiation for controlled degradation. The exposed source of the degraded film is then covered with a vapor-deposited coating of aluminum, and is finally compressed with a metal electrode cover. Illumination directed onto the film induces an electromotive force at the interface of the degraded polymer and the transparent electrode, which constitutes a "Schottky barrier." A

particular feature is the addition of the preformed polymer coating before degradation of electron-attracting molecules which serve as conductive bridges between the carbon layers in the residue.

4,214,920
Amick, James A.; Milewski, John V.; Wright, Franklin J., inventors; Exxon Research & Engineering Co., assignee. *Method for Producing Solar Cell-Grade Silicon from Rice Hulls*. July 29, 1980.

The present invention relates to the production of high purity solar grade silicon from common rice hulls. A unique process for material purification and reduction includes leaching the rice hulls in acid followed by treatment with high purity water, coking the acid-cleaned hulls in a non-oxidizing ambient, compensating the carbon or silica content of the coked hulls to obtain a desired carbon to silica ratio and reducing the silica to produce high purity silicon.

4,215,185
Williams, Richard, inventor; RCA Corporation, assignee. *Liquid Junction Schottky Barrier Solar Cell*. July 29, 1980.

A mixture of ceric ions (Ce^{+4}) and cerous ions (Ce^{+3}) in an aqueous electrolyte solution forms a Schottky barrier at the interface between an active region of silicon and the electrolyte solution. The barrier height obtained for hydrogenated amorphous silicon using the Ce^{+4}/Ce^{+3} redox couple is about 1.7 eV.

4,217,147
Ziemba, Georg, inventor. *Facility for Generating Technically Useable Energy by Conversion of Solar Energy*. August 12, 1980.

A facility for generating technically useable energy by converting solar energy in which a single large concave mirror is disposed in a depression in the ground and has supported thereabove a supporting structure, on a support arm of which an elongated energy collector is provided extending from the theoretical focal point for rays on the axis to the periphery of the spherical mirror, said supporting structure supporting the energy collector for rotation about the center of the mirror to follow the changing position of the sun. Also disclosed is a method for making such a mirror.

4,217,148
Carlson, David E., inventor; RCA Corporation, assignee. *Compensated Amorphous Silicon Solar Cell*. August 12, 1980.

An amorphous silicon solar cell incorporates a region of intrinsic hydrogenated amorphous silicon fabricated by a glow discharge wherein said intrinsic region is compensated by P-type dopants in an amount sufficient to reduce the space charge density of said region under illumination to about zero.

4,217,374
Ovshinsky, Stanford R.; Izu, Masatsugu, inventors; Energy Conversion Devices, Inc., assignee. *Amorphous Semiconductors Equivalent to Crystalline Semiconductors*. August 12, 1980.

A method of making an amorphous semiconductor film or the like having desirable photoconductive and/or other properties comprises forming an amorphous semiconductor film, preferably by vaporizing silicon or the like in an evacuated space and condensing the same on a substrate in such space, and preferably at the same time, introducing at least two or three compensating or altering agents into the film, like activated hydrogen and fluorine, in amounts which substantially reduce or eliminate the localized states in the energy gap thereof so that greatly increased diffusion lengths for solar cell applications is obtained and dopants can be effectively added to produce p or n amorphous semiconductor films so that the films function like similar crystalline materials.

4,217,633
Evans, John C., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell System Having Alternating Current Output*. August 12, 1980.

A monolithic multijunction solar cell is modified by fabricating an integrated circuit inverter on the back of the cell to produce a device capable of generating an alternating current output. In another embodiment, integrated circuit power conditioning electronics is incorporated in a module containing a solar cell power supply.

4,219,368
David, Gérard R., inventor; U.S. Philips Corporation, assignee. *Semiconductor Device Having a Number of Series-Arranged Photosensitive Cells*. August 26, 1980.

A semiconductor device having a number of series-arranged photosensitive cells which are provided on a common substrate of a first conductivity type and which are separated by grooves extending down to the substrate. The cells consist of first regions of a first conductivity type which form planar photosensitive junctions with second regions of the second conductivity type. According to the invention, a highly doped layer of the second conductivity type is present between the substrate and the second region and each photosensitive cell is provided, along at least a part of its circumference, with a highly doped semiconductor zone of the second conductivity type which extends along the wall of the groove down to the highly doped layer and is separated from the adjacent cell by the substrate.

4,219,448
Ross, Bernd, inventor. *Screenable Contact Structure and Method for Semiconductor Devices*. August 26, 1980.

An ink composition for deposition upon the surface of a semiconductor device to provide a contact area for connection to external circuitry is disclosed, the composition comprising an ink system containing a metal powder, a binder and vehicle, and a metal frit. The ink is screened onto the semiconductor surface in the desired pattern and is heated to a temperature sufficient to cause the metal frit to become liquid. The metal frit dissolves some of the metal powder and densifies the structure by transporting the dissolved metal powder in a liquid sintering process. The sintering process typically may be carried out in any type of atmosphere. A small amount of dopant or semiconductor material may be added to the ink systems to achieve particular results if desired.

4,219,830
Gibbons, James F., inventor. *Semiconductor Solar Cell*. August 26, 1980.

There is described a semiconductor solar cell of improved efficiency. The cell has a built-in electric field which extends from the surface of the cell to the interior to keep minority carriers away from the surface whereby recombination at the surface is reduced. Interior contacts are provided whereby current flow along the surface of the device to contacts is avoided to reduce surface resistance and recombination.

4,219,926
Bloch, Joseph T.; Hanger, Randolph T.; Nichols, Frank W., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method and Apparatus for Fabricating Improved Solar Cell Modules*. September 2, 1980.

The invention is embodied in a method and apparatus for fabricating an inproved solar cell module. The apparatus includes a supply drum for feeding a flexible strip having deposited thereon etched electrical circuitry, a supply drum for feeding into overlying engagement with the flexible strip a flexible tape having a pair of exposed tacky surfaces, and a plurality of rams for receiving

and depositing a plurality of solar cells in side-by-side relation on an exposed tacky surface of the tape in electrical contacting engagement with the etched circuitry.

4,222,371
Heath, George F., inventor. *Solar Energy Collector*. September 16, 1980.

A solar energy collector that includes a number of elongated, hollow, metallic, tubular members of such transverse cross section that when disposed side-by-side they define a number of spaced longitudinal apertures through which solar energy rays are directed by lens systems into a number of elongate cavities having dark or black surfaces. The hollow members have the ends so connected to one another that water or other fluid flowing to the collector sequentially traverses the longitudinal passages in the tubular members prior to discharging from the collector. During the flow through the passages heat is transferred to the water or other fluid flowng therethrough from the heated cavities. The solar rays directed by the lens system into the cavities may, if desired, be used to activate photoelectric cells, and the light be transformed directly into electricity.

4,223,174
Moeller, Douglas E., inventor; Sun Trac Corporation, assignee. *Sun-Tracking Solar Energy Conversion System*. September 16, 1980.

A number of solar energy converter assemblies are carried by a support frame which is mounted for independent rotation about a horizontal and a vertical axis. Sensors detect the position of the sun; and control circuitry positions the support frame in elevation and azimuth so that the converter assemblies track and face the sun whenever the sun incident energy is greater than a threshold level of about 25 percent of normal. Each converter assembly includes a solar cell and a multiangular conical concentrator shell for collecting, concentrating and directing incident solar energy onto the solar cell. The converter assemblies, the support frame and its mount, and the drive mechanism for the support frame are all located within a transparent stationary housing or enclosure, which provides complete environmental protection for all elements mounted within the enclosure.

4,223,214
Dorian, Mark E.; Nelson, David H., inventors; American Solar Systems, Inc., assignee. *Solar Tracking Device*. September 16, 1980.

An improved solar tracking arrangement is provided for directing a solar energy collector to face the sun. An electrical control mechanism is provided to detect misalignment of the collector as the sun traverses in relative movement across the sky. When the misalignment exceeds an adjustable limit of tolerance, the tracking system moves the collector to an orientation slightly in advance of the current position of the sun by an amount equal to the limit of tolerance. A threshold light level is required to activate the tracking system, and differential photosensors are employed, the composite signals of which compensate for variations in ambient light level so that the amount of surrounding illumination of the environment does not effect the preset limit of tolerance. The tracking system includes east and west limit switches, which reorient the collector to an eastward facing direction at the end of each day. A high temperature cut off is provided to direct the collector away from the sun when the operating temperature of the collector exceeds a predetermined limit of safety. For self-contained operation, photovoltaic cells are mounted on the collector to provide electricity for the tracking system.

4,224,081
Kawamura, Koichi; Honda, Junichi; Hisatomi, Junichirou; Shigemasa, Junichiro, inventors; Sharp Kabushiki Kaisha, assignee. *Solar Cell Sealed by Glass Laminations*. September 23, 1980.

One or more solar cells are sandwiched by a pair of glass laminations substantially transparent to (i.e., essentially transmissive of) the impinging light, thereby avoiding output drop which may occur due to temperature increase by passing of the impinging light therethrough. A thermoplastic or thermosetting type filler, for example, polyvinylbutyral or a silicone resin is used to fill the cavity surrounded by the glass laminations for accommodating the solar cells therein, while serving as an embedding and potting compound to provide resilient environmental protection for the solar cells. Any room temperature vulcanizing type filler may be used.

4,224,082
Jacobson, J. Merritt, inventor; Independent Power Company, Inc., assignee. *Multi-Functional Solar Collector Pole*. September 23, 1980.

A plurality of solar collectors including at least a solar energy to electrical energy transducer and a solar energy to heat transducer positioned on a single pole. The electrical energy transducer comprises a plurality of solar cells arranged with their faces parallel to the longitudinal axis of the pole and pointed in a plurality of directions. A reflector is positioned to the north of the pole and the cells which reflects sunlight to the northerly facing cells. The heat transducer comprises tubing helically arranged about the pole encased in a transparent ambient air screen. A reflector is attached to the north side of the ambient air screen. The wires from the solar cells and the pipes connected to the helical tubing run down through the center of the pole. A wind energy to electrical energy transducer may also be positioned at the top of the pole.

4,224,084
Pankove, Jacques I., inventor; RCA Corporation, assignee. *Method and Structure for Passivating a Semiconductor Device*. September 23, 1980.

A method of passivating a silicon semiconductor device having at least one active component disposed in a crystalline region thereof comprises the steps of bombarding a surface of the crystalline region with ions to convert a part of the region adjacent the surface into an amorphous layer of graded crystallinity, and then exposing the amorphous layer of atomic hydrogen, whereby an integral layer of hydrogenated amorphous silicon is formed adjacent the crystalline region.

4,224,355
Lampkin, Curtis M.; Roderick, Guy A.; Locke, Peter, inventors; Photon Power, Inc., assignee. *Method for Quality Film Formation*. September 23, 1980.

Methods and apparatus are provided for forming films of materials which are component layers of solar energy conversion devices, e.g. photovoltaic cells and heat collector panels. A selected substrate, generally glass, is heated while being sprayed with solutions which react on the heated surface to form a particular film. Films of SnO_x and CdS are particularly produced. According to the present invention, a thermal energy input gradient is provided to approximate the energy loss gradient during the spray process. Radiative heaters provide a rapid resupply of energy to the substrate and, in some instances, directly to the film forming surface. Temperature detectors, such as thermocouples, monitor substrate temperature to provide the radiative energy input needed for substantial temperature uniformity.

4,225,367
Anglerot, Didier, inventor; Rhone-Poulenc Industries, assignee. *Production of Thin Layers of Polycrystalline Silicon on a Liquid Layer Containing a Reducing Agent*. September 30, 1980.

Thin layers of polycrystalline silicon are formed atop a metal substrate, by reducing a gaseous silicon containing compound with metallic zinc, in liquid state, and in the presence of at least one other metal which is also in liquid state, same being either tin, lead, gold, silver, antimony and/or bismuth. The reaction is conducted under conditions such that the zinc compound product of reduction is also in gaseous state.

4,225,408
Barlow, William A.; Rhodes, Maurice; Sherliker, Francis R.; Williams, Edward W., inventors; Imperial Chemical Industries Limited, assignee. *Process for Electrolytically Preparing a Semiconducting Film on a Flexible Substrate*. September 30, 1980.

Electrophoresis of a colloidal suspension of a semiconducting sulphide, sulphoselenide, selenide or telluride in an aqueous medium produces a thin pin-hole-free film on a surface of a substrate. The film may be employed in solar cells.

Re. 30,412
Raychaudhuri, Pranab K., inventor; Eastman Kodak Company, assignee. *CdTe Barrier Type Photovoltaic Cells with Enhanced Open-Circuit Voltage, and Process of Manufacture*. October 7, 1980.

A cadmium telluride photovoltaic cell is produced with increased conversion efficiency arising from enhanced open-circuit voltage. Such voltage is achieved by altering the surface of the crystalline cadmium telluride that contacts the barrier metal by heating the cadmium telluride in the presence of oxygen prior to depositing the barrier metal.

4,226,017
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method for Making A Semiconductor Device*. October 7, 1980.

A method for use in making semiconductor type electrical devices such as solar cells. In the method, a wafer of semiconductor material having two major surfaces is provided, the wafer being doped with an impurity of one conductivity type. A layer of a metal-containing compositions such as aluminum, is placed on one of the major surfaces of the wafer, and the wafer is then heated in the presence of an impurity of the opposite conductivity type to a temperature such that a high-low junction is formed by the metal at one major surface while the impurity of the opposite conductivity type diffuses or penetrates the other major surface to form a p-n junction thereat.

4,226,256
Hawley, Wilbur W., inventor; Atlantic Richfield Company, assignee. *Solar Panel Assembly and Support Pad*. October 7, 1980.

A solar panel assembly comprising at least one solar panel, supoport means for carrying said panel, and at least one support pad having a base plate, upstanding longitudinal sides, and spaced apart flange means for connection to said support means, said upstanding sides and opposed flange means defining an interior volume for receiving and holding weighting material.

4,226,643
Carlson, David E., inventor; RCA Corporation, assignee. *Method of Enhancing the Electronic Properties of an Undoped and/or N-Type Hydrogenated Amorphous Silicon Film*. October 7, 1980.

The dark conductivity and photoconductivity of an N-type and/or undoped hydrogenated amorphous silicon layer fabricated by an AC or DC proximity glow discharge in silane can be increased through the incorporation of argon in an amount from 10 to about 90 percent by volume of the glow discharge atmosphere which contains a silicon-hydrogen containing compound in an amount of from about 90 to about 10 volume percent.

4,227,291
Schumacher, John C., inventor; J.C. Schumacher Co., assignee. *Energy Efficient Process for Continuous Production of Thin Semiconductor Films on Metallic Substrates*. October 14, 1980.

An energy efficient process is disclosed for the continuous production of semiconductor matrices formed from depositing doped siiicon or germanium films on metallic sheet substrates. The energy released from such deposition can then be used to regenerate the anode material used in the deposition.

4,227,298
Keeling, Michael C.; Bailey, William L.; Coleman, Michael G.; Lesk, Israel A.; Pryor, Robert A., inventors; Motorola, Inc., assignee. *Method for Interconnecting Photovoltaic Devices*. October 14, 1980.

An interconnection system for interconnecting a plurality of photovoltaic devices. The photovoltaic devices each have a first and a second side and the interconnect system is located on the second side of the photovoltaic devices. A sheet of dielectric material and a sheet of electrically conductive material are bonded together and positioned so that the dielectric material is next to the photovoltaic devices. A plurality of patterns are formed in the sheet of electrically conductive material. The patterns each have angled tabs punched therein so that the angled tabs are punched through both the electrically conductive material and the dielectric material. When a photovoltaic device is positioned within a group of angled tabs, the angled tabs can be brought into contact with electrical contacts on the first side of the photovoltaic device. The group of angled tabs are electrically common to a part of the pattern which has an extended portion which extends beneath an adjacent photovoltaic device. Some of the dielectric material is removed from the extended portion so that this portion then makes contact with the second side of an adjacent photovoltaic device. The patterns can be formed in predetermined configurations to provide series or series-parallel interconnections for photovoltaic devices within an array of photovoltaic devices. The interconnect system, in turn, provides for substantially all possible series, parallel, or series-parallel interconnections of a plurality of arrays.

4,227,327
Thompson, Marion E., inventor. *Solar Sign Assembly*. October 14, 1980.

A display assembly is provided including a base, d.c. motor mounted completely within the base, a solar cell operatively mounted to the base, and a sign member rotated by the motor. A sleeve is provided on an elongated shaft connected to the sign member, and that sleeve slips over the motor shaft to provide an interference fit, but not a press fit. The sign has sufficient cross-sectional area to provide enough air-resistance so that, in combination with the interference fit between the shafts, the sign will turn at an appropriate speed for easy reading even though the motor shaft is turning much more quickly.

4,227,939
Zewail, Ahmed H; Batchelder, J. Samuel, inventors; California Institute of Technology, assignee. *Luminescent Solar Energy Concentrator Devices*. October 14, 1980.

Increased light output is achieved from solar energy concentrator light piping device by rendering the top surface of the device concave, and/or forming the device into a close-packing hexagonal shape and/or curving and applying a mirror coating to the output edge of the device.

4,227,940
Ling, Ku Sun; Khemthong, Seksan, inventors; Optical Coating Laboratory, Inc., assignee. *Solar Cell for Use in Concentrator*. October 14, 1980.

Solar cell for use in a concentrator having a body formed essentially of silicon doped with a P-type impurity and having a base resistivity ranging from 0.5 to 1.5 ohm-centimeter and having back and front side planar surfaces. A layer of aluminum is formed on the back side surface and is alloyed into the silicon body to form a P-plus layer extending through the back side surface. An N^+ layer is formed in the silicon body and extends through the front side surface. A multi-layer metal contact structure is secured by the backside and makes a P-type contact. A multi-layer metal contact structure is carried by the front side surface and makes an N-type contact. The multi-layer contact structure carried by the front side surface is formed into a grid line pattern with the grid

line pattern being characterized by first and second common bus bars extending substantially through 360° on said surface and being spaced at different distances from the center of the front side surfaces.

4,227,941
Bozler, Carl O.; Chapman, Ralph L.; Fan, John C. C.; McClelland, Robert W., inventors; Massachusetts Institute of Technology, assignee. *Shallow-Homojunction Solar Cells*. October 14, 1980.

Improvements in shallow-homojunction solar cells based upon a plurality of layers of a direct gap semiconductor material such as GaAs, as well as their fabrication, are disclosed. The shallow-homojunction solar cells have a $n^+/p/p^+$ structure in which the n^+ top layer is limited to a thickness which permits significant carrier generation to occur in a lower semiconductor layer. An anodic antireflection coating is applied over the n^+ top layer, and a particularly preferred method for applying the antireflection coating is by anodization. These solar cells can be grown on relatively inexpensive substrates, if desired, such as silicon or germanium.

4,227,942
Hall, Robert N., inventor; General Electric Company, assignee. *Photovoltaic Semiconductor Devices and Methods of Making Same*. October 14, 1980.

A solar cell which has high efficiency and which can be fabricated at low cost is described. The cell includes a semiconductor wafer with a front radiation-receiving surface which is entirely open and free of current conducting grids and also includes an array of interconnection paths which carry photocurrent from the front surface through the cell to metal electrodes on the rear surface of the cell.

4,227,943
Cohen, Marshall J.; Harris, James S., Jr., inventors; Rockwell International Corporation, assignee. *Schottky Barrier Solar Cell*. October 14, 1980.

A solar cell is constructed by coating an n-type conductivity semiconductor with a thin layer of bromine doped, polymeric sulfur-nitride, $(SNBr_{0.4})_x$. Metal deposits are provided on both materials for making electrical contact to the cell. In a preferred embodiment, the semiconductor is silicon. In a second preferred embodiment, the semiconductor is GaAs on an n^+-type conductivity GaAs substrate.

4,228,315
Napoli, Louis S., inventor; RCA Corporation, assignee. *Solar Cell Grid Patterns*. October 14, 1980.

A grid pattern for a solar cell of the type including a base layer of one conductivity type and an emitter layer of opposite conductivity type. The solar cell may have a square face and in this case the grid pattern is in the form of four symmetrical sub-patterns, each in a different quadrant of the square. Each such sub-pattern comprises a set of nested V shaped grid conductors, the apices of which lie on a common diagonal of the square and the ends of which connect to a common bus conductor at the peripheral edge of the square. Within each quadrant, the sub-pattern comprises a symmetrical pattern relative to a diagonal of the square. The pattern reduces the effect of line and sheet resistance and thereby permits more of the photon induced charge carriers to be collected and also permits a relatively large part of the cell face area to be available for the reception of photons.

4,228,570
Chamberlin, Rhodes R.; Bigham, Herbert L., inventors; Photon Power, Inc., assignee. *Electroding Preparation Apparatus*. October 21, 1980.

An apparatus is provided for forming a large area photovoltaic cell into a plurality of photovoltaic cells on a common substrate and preparing the individual cells for an overlying layer of conductive material. A tool bit is urged against the polycrystalline materials forming the heterojunction to remove a preselected pattern and expose a layer of conductive material, tin oxide, on a supporting glass substrate. Tool bit pressure causes fracturing of the crystals to produce defined edges along the tool bit furrow. An electrical arc is produced to vaporize a portion of the exposed tin oxide to electrically isolate the individual photovoltaic cells. Applicator pens coat the edges of the polycrystalline material with preselected insulating films. Finally, a buffer wheel abrades a preselected metal onto the remaining exposed surface of the tin oxide to obtain an improved metallurgical and/or electrical contact between the tin oxide and the subsequent conductor layer. Indexing mechanisms are provided for positioning the large area cell relative to the various tools for providing a plurality of preparatory passes along the large area cell.

4,228,789
Kay, James C., inventor. *Solar Energy Collector*. October 21, 1980.

A solar energy collector is provided with a transparent, corrugated cover. An internal system of curved mirrors concentrates the radiant energy toward a thermally insulated chamber which houses either a set of heat exchanger tubes with a heat exchange fluid flowing through them or a photovoltaic device for converting thermal energy to electricity.

4,229,231
Witt, August F.; Raman, Ramaswamy V., inventors; Massachusetts Institute of Technology, assignee. *Method of Forming a Laminated Ribbon Structure*. October 21, 1980.

A method of forming, by melt-spinning techniques, a laminated ribbon structure consisting, for example, of a semiconductor disposed on a metal ribbon substrate. The substrate may be 10-100 μm thick and the semiconductor may be 10-100 μm thick, for example; typically the ribbon width is about one millimeter to several centimeters.

4,229,233
Hansen, Thomas A.; Johnson, Claude, Jr.; Wilbarg, Robert R., inventors; International Business Machines Corporation, assignee. *Method for Fabricating Non-Reflective Semiconductor Surfaces by Anisotropic Reactive Ion Etching*. October 21, 1980.

A differential reactive ion etching process significantly reduces the reflectivity of silicon. The process takes place in a reactive ion etching tool, typically a diode-configured system employing ambient gases which react with the silicon.

4,230,508
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Making Semicrystalline Silicon Article*. October 28, 1980.

A semicrystalline silicon solar energy cell formed from individual grains of silicon having portions thereof at the light-receiving surface of the cell. An electrical junction is formed at said light-receiving surface and extends across and below that surface and into and between the boundaries of adjoining grains to an extent such that the total junction area substantially exceeds the product of the linear dimensions of the wafer surface but does not extend completely around the boundaries of the silicon grains or to the opposed surface of the wafer.

4,231,807
Keeling, Michael C.; Doss, Dwight E., inventors; Motorola, Inc., assignee. *Enclosure for a Solar Cell Array*. November 4, 1980.

An enclosed solar cell array. The array is enclosed between a metal back plate and a cover glass. The edges of the enclosure are sealed by a pliable sealant material and a spring loaded bezel that is riveted or welded in place. The interior of the enclosure is filled with a potting material which surrounds and cushions

the solar cell array. During the module fabrication a fixture supports the enclosure parts and provides a temporary edge seal to facilitate the potting procedure. Controlled flexure of the enclosure back plate and controlled spacing of the cover glass ensure a compressive loading of the potting material which eliminates possible delamination of the potting material in its subsequent usage.

4,231,808
Tabei, Masatoshi; Kawaziri, Kazuhiro; Nakajima, Yosuke, inventors; Fuji Photo Film Co., Ltd., assignee. *Thin Film Photovoltaic Cell and a Method of Manufacturing the Same*. November 4, 1980.

An improved type of thin film photovoltaic cell can be produced by forming a thin layer of n-type CdTe up to 2 micron thick on a conductive support, heat-treating the CdTe layer at 80° to 210°C for 20 to 180 minutes, and providing on the free surface of the heat-treated CdTe layer a transparent electrode.

4,233,085
Roderick, Guy A.; Locke, Peter, inventors; Photon Power, Inc., assignee. *Solar Panel Module*. November 11, 1980.

A solar panel module is provided, wherein a plurality of solar panel units are electrically interconnected and supported within a low cost frame assembly, which may conveniently be formed from wood products. Each solar panel unit is provided with extending conductors for electrical connections with adjacent solar panels. Each solar panel unit is formed in a back-wall configuration where solar radiation is incident on a transparent vitreous substrate. The panel surface opposite the substrate is sealed, preferably with a bituminous material, to minimize permeation of the solar panel by environmental elements. The sealing material cooperates with the frame to provide an insulated exposed surface. In one embodiment, the completed module is formed to external dimensions generally standard in the building industry for easy installation.

4,233,338
Ricard, Jean; Excoffon, Charles, inventors; Produits Chimiques Ugine Kuhlmann, assignee. *Processes for Deposition of Thin Films of Crystalline Silicon on Graphite*. November 11, 1980.

Processes for the continuous deposition of crystalline silicon on graphite substrates, the silicon being undoped or N- or P-doped and the substrates being useful for photovoltaic cells and other electronic devices, the processes comprising placing crystalline silicon in at least one crucible having a capillary port with a vertical axis in its lower part; bringing the silicon to its melting point; bringing a graphite substrate into contact with the pendant drop formed at the lower mouth of the capillary; moving the substrate at a selected speed in a constant predetermined direction; and removing the substrate coated with the crystalline substance at chosen time intervals.

4,233,613
Morimoto, Kiyoshi, inventor; Futaba Denshi Kegyo K.K., assignee. *Compound Semiconductor Wafer*. November 11, 1980.

A compound semiconductor wafer having a substrate of a IV-group element semiconductor of a predetermined conductivity type, an epitaxial layer formed by epitaxially growing on the substrate a compound semiconductor having the same conductivity type as the substrate by an ion beam deposition process or a cluster ion beam deposition process, and a compound semiconductor layer of a conductivity type opposite to that of the epitaxial layer and formed on the epitaxial layer so as to form a PN junction with the epitaxial layer.

4,233,961
Kelly, Donald A., inventor. *Suspended, Hot-Box Solar Collectors*. November 18, 1980.

The suspended, hot box solar collector is designed to provide approximately double area solar insolation on to a closed, truncated triangular structure which is double-glazed and insulated to collect and store solar heat energy for hot air space heating. Direct solar radiation is collected through sloped front, bottom and top double-glazed windows, with reflected solar rays received through the same windows by means of fixed, highly reflective surfaces of about the same corresponding total surface area. Solar radiation collection in three planes, both direct and reflected, will produce very high temperatures with the storage of a portion of this heat energy within thermal storage compartments within the unit. The suspended, hot box unit is designed for both winter-time space heating and summer-time photovoltaic/electric power generation, for both back yard and flat roof-top installations.

4,234,351
Deminet, Czeslaw; Oettel, Richard E., inventors; The Boeing Company, assignee. *Process for Fabricating Glass-Encapsulated Solar Cell Arrays and the Product Produced Thereby*. November 18, 1980.

The process includes the steps of (1) forming a pattern of indentations and adjacent boundary ridges in a base layer of glass which is heated to a temperature where it is formable but not flowing, (2) depositing electrically conducting first connecting elements on the upper surface of the base glass layer, with each first connecting element extending from an indentation to a point on an adjacent ridge, (3) positioning a solar cell into each indentation in the base glass layer in such a manner that the lower surface of the solar cell comes in electrical contact with one end of a first connecting element, (4) depositing electrically conducting second connecting elements which extend between the end of the first connecting elements on a ridge to the top surface of a solar cell in an adjacent indentation, and (5) forming a top glass layer which is in intimate contact with the product of steps 1-4. The product produced thereby is an array of glass-encapsulated solar cells which are electrically connected together by means of the first and second connecting elements but are otherwise physically isolated from each other by the glass-encapsulation.

4,234,352
Swanson, Richard M., inventor; Electric Power Research Institute, Inc., assignee. *Thermophotovoltaic Converter and Cell for Use Therein*. November 18, 1980.

Disclosed is a thermophotovoltaic converter which includes a parabolic cone radiation concentrator portion and a processor portion including a radiator which absorbs concentrated radiation and generates incandescent radiation. A photovoltaic cell in close proximity to the radiator receives the incandescent radiation and generates an electrical voltage. The cell includes an intrinsic or lightly doped silicon substrate having a top surface for receiving radiation and a bottom surface having a plurality of diffused N and P conductivity regions arranged in rows. A titanium-silver layer overlays the bottom surface and conductively interconnects regions of one conductivity type and provides a reflective surface to photons which pass through the substrate.

4,234,353
Donaghey, Lee F., inventor; Chevron Research Company, assignee. *Process for Preparing Photovoltaic Cells Having Increased Adhesion of the Semi-Conducting Layer and Produced Thereby to the Conducting Layer*. November 18, 1980.

Improved adhesion of the semi-conducting layer to the conducting layer in a thin film photovoltaic cell is obtained by incorporating a minor amount of the element or elements of the conducting layer in the semi-conducting layer.

4,234,354
Lidorenko, Nikolai S.; Litsenko, Tatyana A.; Potapov, Valery N.; Ryabikov, Stanislav V.; Strebkov, Dmitry S., inventors. *Solar Power Unit*. November 18, 1980.

The hereinproposed solar power unit comprises a solar energy collector made up of mirror facets and a solar energy receiver. A sun-light-sensitive surface of the receiver is exposed to a radiation flux reflected by the collector. Each facet of the collector is

hermetically enclosed in a radiation-transparent convex shell filled with a reducing agent. The shells have a radius of curvature of 20 to 200 mm.

4,234,947
Matsumoto, Masataka, inventor; Citizen Watch Co., Ltd., assignee. *Solar Battery Powered Timepiece*. November 18, 1980.

A solar battery powered electronic timepiece of the type wherein a watch glass and a base plate supporting a solar battery are secured in an annular recess in a watch case. The base plate is positioned on a bottom surface of the recess and secured in position by a resilient packing which is preferably made from a resin material. The packing extends around the base plate and has a portion which overlines the the outer periphery of the base plate and on which is positioned the watch glass. Another portion of the packing extends between the outer periphery of the watch glass and a side wall of the recess to secure the watch glass in position. A structure of this type is particularly suitable for securing a base plate of a material such as epoxy resin to which fastening legs cannot easily be attached.

4,235,221
Murphy, Gerald G., inventor. *Solar Energy System and Apparatus*. November 25, 1980.

The present invention relates to solar energy collection and distribution systems and more particularly to such systems wherein the solar energy collecting elements, arrays or sections are disposed over or floated on a body of water while having associated control, distribution and auxillary means largely disposed or contained on a land mass adjacent or nearby the body of water. The collecting elements or sections may also be supported on frames, structures or platforms slightly above the surface of the body of water to clear wave or tidal action and the like.

The invention also relates to associated means and apparatus for energy collection, conversion, conservation and distribution with which to economically and efficiently implement the purposes of the invention and extend its utility over a broad area.

4,235,643
Amick, James A., inventor; Exxon Research & Engineering Co., assignee. *Solar Cell Module*. November 25, 1980.

A solar cell module is provided having a plurality of circular solar cells arrayed on a support structure in which at least the land areas between the cells have facets with light reflecting surfaces. An optical cover medium couples the facets and the cells. Importantly the angular relationship of the facet surfaces is such that light impinging thereon will be reflected upwardly into the optical medium and then internally reflected downwardly toward an active cell area thereby effectively increasing the output of the module.

4,235,644
Needes, Christopher R. S., inventor; E. I. Du Pont de Nemours and Company, assignee. *Thick Film Silver Metallizations for Silicon Solar Cells*. November 25, 1980.

Thick film conductor compositions containing silver powder and lead bismuthate glass frit powder and an organic vehicle/solvent system are presented for use as grid metallizations to the n-type layers of n- on p-silicon solar cells.

4,235,651
Kamath, G. Sanjiv; Anderson, Carl L., inventors; Hughes Aircraft Company, assignee. *Fabrication of GaAs-GaAlAs Solar Cells*. November 25, 1980.

The specification describes an improved III-V compound solar cell structure and fabrication process therefor wherein a P-type layer of gallium aluminum arsenide is epitaxially grown on an N-type gallium arsenide substrate to form a P-type region and a PN junction in the substrate. Controlled amounts of beryllium are introduced into both the epitaxial layer and the substrate, either during epitaxial growth or by using beryllium ion implantation techniques subsequent to the P-type epitaxial growth step. The homojunction-heterostructure device thus formed exhibits improved power conversion efficiencies in excess of 17%.

4,235,662
Reitz, Norman E., inventor; Sotec Corporation, assignee. *Layer of Crystalline Silicon Having (111) Orientation on (111) Surface of Lithium Aluminum*. November 25, 1980.

Low strain heteroepitaxy of (111) silicon on (111) lithium aluminum between the reconstructed 7×7 surface of (111) silicon and a 6×6 array of aluminum atoms on the surface of the (111) lithium aluminum. The 7×7 reconstructed (111) silicon surface contains 36 silicon atoms and 13 vacancies for every 49 surface sites. The 36 silicon atoms on an area averaged basis match the 36 aluminum atoms in the 6×6 aluminum diamond structure (zero vacancies) present at the (111) surface of lithium aluminum to within about 1%.

4,235,955
Sammells, Anthony F.; Ang, Peter G. P., inventors; Institute of Gas Technology, assignee. *Solid State Photoelectrochemical Cell*. November 25, 1980.

A solid state photoelectrochemical cell providing in-situ electrochemical energy storage having a homogeneous solid electrolyte matrix and associated ionic conductors with a central electrolyte separator portion providing ionic conductance and an oxidant portion on one side and a reductant portion on the other side each having redox couples in fixed lattice positions and possessing ionic and electronic conductivity. At least one photosensitive photoelectrode is in ionic communication with the oxidant and/or reductant portion(s) whereby electrons or electron holes are transmitted to that portion while the photoelectrode is illuminated causing oxidation or reduction of the redox couple. The apparatus and process provide conversion of solar to electrical energy using a solid state photoelectrochemical cell.

4,236,937
Wihl, Manfred G., inventor; Solarex Corporation, assignee. *Solar Collector Device*. December 2, 1980.

A solar collector device such as a solar receiver or solar panel, the device including a substrate comprising a base member having a major surface including a plurality of generally planar platform areas, each platform area being in a different plane than adjacent platform areas, and at least one photovoltaic cell mounted on each of the platform areas, a portion of each of the cells extending beyond the platform area upon which it is mounted. The collector device tends to maximize the utilization of light received by the device.

4,236,938
Brody, Philip S., inventor; The United States of America as represented by the Secretary of the Army, assignee. *Efficient High Voltage Photovoltaic Cells*. December 2, 1980.

A photovoltaic cell comprised of a plurality of single crystal, remanently polarized, ferroelectric layers in a stack with electrodes affixed to each end. Additionally, electrodes are disposed between adjacent layers or conductive or semi-conductive regions are formed at and near the interfaces between layers by chemical reduction or doping. The cell has a higher conversion efficiency than ferroelectric cells heretofore known.

4,237,150
Wiesmann, Harold J., inventor; The United States of America as represented by the United States Department of Energy, assignee. *Method of Producing Hydrogenated Amorphous Silicon Film*. December 2, 1980.

This invention relates to hydrogenated amorphous silicon produced by thermally decomposing silane (SiH_4) or other gases comprising H and Si, from a tungsten or carbon foil heated to a temperature of about 1400°-1600°C, in a vacuum of about 10^{-6} to 10^{-4} torr, to form a gaseous mixture of atomic hydrogen and atomic silicon, and depositing said gaseous mixture onto a substrate independent of and outside said source of thermal decomposition, to form hydrogenated amorphous silicon. The presence of an ammonia atmosphere in the vacuum chamber enhances the photoconductivity of the hydrogenated amorphous silicon film.

4,237,151
Strongin, Myron; Ghosh, Arup K.; Wiesmann, Harold J.; Rock, Edward B.; Lutz, Harry A., III, inventors; The United States of America as represented by the United States Department of Energy, assignee. *Thermal Decomposition of Silane to Form Hydrogenated Amorphous Si Film*. December 2, 1980.

This invention relates to hydrogenated amorphous silicon produced by thermally decomposing silane (SiH_4) or other gases comprising H and Si, at elevated temperatures of about 1700°-2300°C, and preferably in a vacuum of about 10^{-8} to 10^{-4} torr, to form a gaseous mixture of atomic hydrogen and atomic silicon, and depositing said gaseous mixture onto a substrate outside said source of thermal decomposition to form hydrogenated amorphous silicon.

4,237,332
Winston, Roland, inventor; The United States of America as represented by the United States Department of Energy, assignee. *Nonimaging Radiant Energy Direction Device*. December 2, 1980.

A radiant energy nonimaging light direction device is provided. The device includes an energy transducer and a reflective wall whose contour is particularly determined with respect to the geometrical vector flux of a field associated with the transducer.

4,238,246
Genequand, Pierre; Stark, Virgil, inventors; North American Utility Construction Corp., assignee. *Solar Energy System with Composite Concentrating Lenses*. December 9, 1980.

In order to improve the efficiency of a solar energy system utilizing a Fresnel lens for concentrating solar rays on a conduit system or the like, only the central portion of a Fresnel lens, otherwise of large width, is utilized and slide assemblies, each containing a plurality of slats with a reflective coating and disposed at an angle such as to reflect solar energy to the same focal point as the Fresnel lens, are disposed on each side of the lens thereby effectively increasing the aperture of the lens and increasing efficiency of concentration.

4,238,247
Oster, Eugene A., Jr., inventor; Owens-Illinois, Inc., assignee. *Structure for Conversion of Solar Radiation to Electricity and Heat*. December 9, 1980.

Disclosed is a structure which in one apparatus converts a part of incident solar energy to electrical energy by the use of photocells mounted on a luminescent solar collector of tubular design while another portion of such incident energy is converted to thermal energy.

4,238,436
Hill, Lawrence R.; Garbis, Dennis; Heller, Robert, inventors; General Instrument Corporation, assignee. *Method of Obtaining Polycrystalline Silicon*. December 9, 1980.

Polycrystalline silicon is obtained by providing a silicon wafer having disposed over at least one face thereof a base coating of oxide, nitride or oxynitride composition, forming a substantially pinhole-free and scratch-free layer of carbon on said base coating over at least the face, forming on the face of the carbon layer a layer of polycrystalline silicon, and removing the silicon layer from the protective coating. Any of the carbon layer adhering to the silicon layer is easily removable to provide the silicon layer separate from the substrate. The wafer/coating unit is reusable in the procedure. The wafer/coating/carbon layer unit comprises a workpiece useful in the practice of the invention.

4,239,553
Barnett, Allen M.; Masi, James V.; Hall, Robert B., inventors; University of Delaware, assignee. *Thin Film Photovoltaic Cells Having Increased Durability and Operating Life and Method for Making Same*. December 16, 1980.

A solar cell having a copper-bearing absorber is provided with a composite transparent encapsulating layer specifically designed to prevent oxidation of the copper sulfide. In a preferred embodiment, the absorber is a layer of copper sulfide and the composite layer comprises a thin layer of copper oxide formed on the copper sulfide and a layer of encapsulating glass formed on the oxide. It is anticipated that such devices when exposed to normal operating conditions of various terrestrial applications, can be maintained at energy conversion efficiences greater than one-half the original conversion efficiency for periods as long as thirty years.

4,239,554
Yamazaki, Shunpei, inventor. *Semiconductor Photoelectric Conversion Device*. December 16, 1980.

A semiconductor photoelectric conversion device employing a semiconductor layer which has at least one inter-semiconductor heterojunction. The semiconductor layer is composed of at least a first non-single-crystal semiconductor region having a first energy gap and a third non-single-crystal semiconductor region serving as the heterojunction formed to extend between the first and second semiconductor regions and having an energy gap continuously changing from the first energy gap on the side of the first semiconductor region to the second energy gap on the side of the second semiconductor region. The semiconductor layer is doped with a recombination center neutralizer and a conductive material. The non-single-crystal semiconductor layer doped with the conductive material is formed on a substrate by a low pressure chemical vapor deposition or glow discharge method. Then, the non-single-crystal semiconductor layer is exposed to a hydrogen gas or a mixture thereof with a small amount of halogen so that the non-single-crystal semiconductor layer is doped with hydrogen or halogen as a recombination center neutralizer, whereby to obtain the semiconductor photoelectric conversion device.

4,239,555
Scharlack, Ronald S.; Tornstrom, Eric, inventors; Mobil Tyco Solar Energy Corporation, assignee. *Encapsulated Solar Cell Array*. December 16, 1980.

Solar cell array and method for manufacturing same wherein the individual cells of the array are sandwiched and held resiliently captive between and electrically isolated from a transparent protective front cover and a protective rear substrate by an encapsulating transparent silicone elastomer cast in situ in the interstices between the cover, the cells, and the substrate, the elastomer being introduced, while fluid, into the sandwich through the same terminals used for the electrical connection of the array to its electrical load.

4,239,583
Hatch, Arthur E.; Yates, Douglas A., inventors; Mobil Tyco Solar Energy Corporation, assignee. *Method and Apparatus for Crystal Growth Control*. December 16, 1980.

A system for and method of growing a crystalline body of a selected material is described, whereby the body grown is of a selected cross-sectional shape. The system and method are used in accordance with known capillary die techniques and further includes observing opposite edge portions of the growing body, preferably just above the meniscus (of melt material from which the body is being pulled). The cross-sectional size of the growing crystalline body can be controlled by determining when horizontal shifts occur in the edge portions relative to each other as well as the same predetermined reference position.

4,239,585
Köhl, Franz, inventor; Wacker-Chemitronic Gesellschaft für Elektronik-Grundstoffe mbH, assignee. *Process for the Production of High Purity Silicon Monocrystals Having a low Oxygen Content*. December 16, 1980.

The invention provides a process according to which the oxygen content in crucible-drawn silicon crystals can be lowered and kept substantially constant throughout the length of the rod. This is achieved in that, after applying the seed crystal to the melt pool, the silicon rod being drawn from the melt pool is initally rotated at a speed from 3 to 6 rev/min and this rotational speed is preferably increased to higher values during the drawing process.

4,239,734
Ciszek, Theodore F., inventor; International Business Machines Corporation, assignee. *Method and Apparatus for Forming Silicon Crystalline Bodies*. December 16, 1980.

Apparatus for forming an elongated silicon crystalline body using a specially designed capillary die. The apparatus uses a higher melt meniscus in the central region of the growth front than at the edges of the front. The edges of the top surface of the die are not concentric with the ribbon cross-section.

4,239,809
Lampkin, Curtis M.; Roderick, Guy A.; Nikodem, Robert B., inventors; Photon Power, Inc., assignee. *Method for Quality Film Formation*. December 16, 1980.

Methods and apparatus are provided for forming films of materials which are component layers of solar energy conversion devices, e.g. photovoltaic cells and heat collector panels. A selected substrate is heated while being sprayed with solutions which react on the heated surface to form a particular film. Films of SnO_x and CdS are particularly produced. According to the present invention, the spray is projected at an angle to control upstream flow and confine film formation to the substrate panel portions most suitable for forming the selected film. Various waste products are removed to minimize defects in the resulting film. Baffles are located to shield the substrate surface at selected areas and preclude the spray from impacting on the shielded areas.

4,239,810
Alameddine, Oussama; Briska, Marian; Thiel, Klaus P., inventors; International Business Machines Corporation, assignee. *Method of Making Silicon Photovoltaic Cells*. December 16, 1980.

A method of making silicon solar cells and other silicon photovoltaic cells. The method includes the steps of forming a silicon element having a metallic electrode coating on one surface of the element, applying to the other surface of the element a coating containing aluminum and silicon and heating the coated element at a temperature below the eutectic temperature of aluminum-siicon to form an antireflective coating of a fine matrix of silicon pyramids doped with aluminum. The matrix formed on the surface of the silicon has an overlying aluminum coating. A portion of the aluminum coating is removed to expose the matrix for use as a photovoltaic cell.

4,240,842
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Solar Cell Having Contacts and Antireflective Coating*. December 23, 1980.

A photovoltaic cell is formed by applying electrical contact material through an antireflective coating on the light receiving surface of the cell by flame, arc or plasma spraying. The cell so formed has a metal contact spaced portions of which are in electrical contact with the light-receiving surface of the cell.

4,240,882
Ang, Peter G. P.; Sammells, Anthony F., inventors; Institute of Gas Technology, assignee. *Gas Fixation Solar Cell Using Gas Diffusion Semiconductor Electrode*. December 23, 1980.

A gas diffusion semiconductor electrode and solar cell and a process for gaseous fixation, such as nitrogen photoreduction, CO_2 photoreduction and fuel gas photo-oxidation. The gas diffusion photosensitive electrode has a central electrolyte-porous matrix with an activated semiconductor material on one side adapted to be in contact with an electrolyte and a hydrophobic gas diffusion region on the opposite side adapted to be in contact with a supply of molecular gas.

4,241,108
Tracy, Chester E.; Kern, Werner; Vibronek, Robert D., inventors; RCA Corporation, assignee. *Sprayable Titanium Composition*. December 23, 1980.

The addition of 2-ethyl-1-hexanol to an organometallic titanium compound dissolved in a diluent and optionally containing a lower aliphatic alcohol spreading modifier, produces a solution that can be sprayed onto a substrate and cured to form an antireflection titanium oxide coating having a refractive index of from about 2.0 to 2.2.

4,241,493
Andrulitis, William B.; Miles, Steven G.; Kurth, William T., inventors. *Method of Fabricating Solar Cell Modules*. December 30, 1980.

The solar cell module of this invention is fabricated by placing an array of solar cells in a suitable mold having a bottom surface, an entry port and an exit port. A light transparent superstrate effectively serves as the top for the mold and is placed over the array of solar cells in the mold. The superstrate is spaced from the array such that the superstrate does not come in contact with the top surface of any of the cells or interconnectors of the solar cell array. Clamp means are provided to hold the superstrate in position while encapsulant is pumped into the mold under pressure through the inlet port in an amount sufficient to fill the mold. Thereafter the assembly can be placed in an oven and heated for a time sufficient to cure the encapsulant and bond the materials to each other.

4,242,147
DeToia, Vincent D., inventor. *Device for Converting Waste Nuclear Energy to Electricity*. December 30, 1980.

A device for converting waste nuclear energy to electricity comprising a shielded casing housing, a plurality of holders of radioactive materials surrounded by tubes of phosphorescent material to convert the radiation to electricity in adjacent photocells such as photoelectric or photovoltaic cells. The walls of the casing have mirrored top and bottom surfaces. Shade-type control means adjustably cover the photocells so as to regulate the amount of electricity produced.

4,242,374
Sansregret, Joseph L., inventor; Exxon Research & Engineering Co., assignee. *Process for Thin Film Deposition of Metal and Mixed Metal Chalcogenides Displaying Semi-Conductor Properties*. December 30, 1980.

A low cost chemical spray deposition of metal and mixed metal chalcogenides is accomplished by spray depositing an oxide film from a mixture of a salt of the metal in solution with a water soluble hydrocarbon and water solvent. This oxide film is subjected to a heat treatment in the presence of a chalcogenide gas to induce an ion exchange process transforming the metal oxide or mixed metal oxide into the chalcogenide films of the present invention. The deposition process is used to provide efficient selective absorbing surfaces for a solar thermal energy converter. The process may further be employed to produce a thin film photovoltaic device for converting light energy into electricity.

4,242,580
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *Solar-Radiation Collection Apparatus*. December 30, 1980.

The invention contemplates improved apparatus for use in a self-tracking optical system for directing highly concentrated solar radiation upon utilization means such as a photovoltaic cell, wherein the full image of the sun covers the exposure surface substantially only when the axis of the optical system is aligned with the sun. Certain structural features associated with the optical system in the vincinity of cell support effectively enlarge the margin of off-axis misalignment within which self-tracking is achievable. At the same time, certain aspects of these features inherently prevent thermal losses which would otherwise be attributable to convection currents of air in the region of heat concentration.

4,242,696
Diguet, Daniel; David, Gérard A.; Aubril, Pierre, inventors; U.S. Philips Corporation, assignee. *Method of Forming a Contact on the Surface of a Semiconductor Body by Serigraphy and Body Obtained by Means of this Method*. December 30, 1980.

A method of forming a contact on the surface of a semiconductor by a serigraphy treatment in which a doped conductive paste is provided in a first deposition, and then a second deposition containing no dopant is provided at least partly on the first deposition. Devices made in accordance with the invention are particularly suited for use as photovoltaic converters for solar radiation.

1981

4,243,432
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Solar Cell Array*. January 6, 1981.

An array of photovoltaic cells in a back wall-type configuration supported by a rigid transparent vitreous substrate, such as glass, for admitting incident radiation to the cells. A plurality of cells are interconnected into a desired electrical configuration by one or more layers of electrically conducting materials which overlie substantially the entire heterojunction of each cell to minimize the internal resistance of the cell and may conveniently protect the heterojunction from degrading environmental conditions. The conducting layer interconnects an exposed electrode region of one cell with the heterojunction forming material of the adjacent cell while remaining insulated from any intervening cell structure. In one embodiment, the uppermost conducting layer is lead, which seals the underlying materials from atmospheric constituents, such as oxygen and water vapor, while remaining relatively inert to such constituents.

4,243,471
Ciszek, Theodore F.; Schwuttke, Guenter H., inventors; International Business Machines Corporation, assignee. *Method for Directional Solidification of Silicon*. January 6, 1981.

A method for growing silicon crystalline material by the directional solidification method without cracking the growth container. The container material must have an average thermal expansion coefficient of between about 3.0 to $4.3 \times 10^{-6} °C^{-1}$ between about 20° and 650°C. The molten silicon is provided in the container and solidified sequentially from the enclosed regions to the open region of the container to form the crack-free silicon crystalline material.

4,243,928
Nazimek, Kenneth, inventor; Exxon Research & Engineering Co., assignee. *Voltage Regulator for Variant Light Intensity Photovoltaic Recharging of Secondary Batteries*. January 6, 1981.

A simplified voltage regulator circuit permits varient light intensity photovoltaic recharging of secondary batteries. The regulator circuit electronically shunts serially connected regions of a photovoltaic recharger array to avoid overcharging during periods of high light intensity or full battery charge conditions. The regulator circuitry provides minimal series resistance to the photovoltaic array and requires nominal driving power. The photovoltaic array and the regulator circuitry may comprise discrete components or may share a common substrate body.

4,244,750
Chenevas-Paule, André; Melnick, Igor; Vieux-Rochaz, Line, inventors; Commissariat a l'Energie Atomique, assignee. *Photovoltaic Generator*. January 13, 1981.

A basic photovoltaic stack is constituted by a semiconducting layer interposed between a layer forming an ohmic contact and a layer forming a Schottky contact. A second photovoltaic stack having the same structure as the basic stack is formed on this latter and includes one of the layers forming an ohmic or Schottky contact. The layer or layers forming an ohmic contact are connected together so as to constitute a first output terminal of the photovoltaic generator. The layer or layers forming a Schottky contact are connected together so as to constitute a second output terminal of the generator.

4,245,386
Kausche, Helmold; Mayer, Gerhard; Stein, Karl-Ulrich, inventors; Siemens Aktiengesellschaft, assignee. *Method of Manufacturing a Solar Cell Battery*. January 20, 1981.

Solar cells are constructed as a plurality of spaced strips formed along the length of synthetic foils. They are connected in series along their entire length in a simple manner. Therefore, the connections are formed by means of vapor-deposited metal layers and the solar cells lying next to one another are connected in series by means of vapor-deposited metal layers, whereby these vapor-deposited metal layers respectively connect the upper semiconductor layer or, respectively, a Schottky contact metal layer, as the case may be, of one solar cell with the lower metal layer of the neighboring solar cell. Sections of any desired length may be cut off from the elongated battery by cutting transversely to the length thereof. The series-connected sections thus formed may be employed without re-wiring.

4,246,042
Knasel, Thomas M.; Houghton, Alexander J., inventors; Science Applications, Inc., assignee. *Fixed Solar Energy Concentrator*. January 20, 1981.

An apparatus for the concentration of solar energy upon a fixed array of solar cells. A transparent material is overlayed upon the cell array, and a diffuse reflective coating is applied to the surface area of the transparent medium in between cells. Radiant light, which reflects through the transparent layer and does not fall directly incident to a cell surface is reflected by the coating layer in an approximate cosine pattern. Thereafter, such light undergoes internal reflection and rediffusion until subsequently it either strikes a solar cell surface or is lost through the upper surface of the transparent material.

4,246,043
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Yttrium Oxide Antireflective Coating for Solar Cells*. January 20, 1981.

Yttrium oxide is used as an antireflective coating for photovoltaic cells.

4,246,050
Moon, Ronald L., inventor; Varian Associates, Inc., assignee. *Lattice Constant Grading in the $Al_yGa_{1-y}As_{1-x}Sb_x$ Alloy System*. January 20, 1981.

Liquid phase epitaxy is employed to grow a lattice matched layer of GaAsSb on GaAs substrates through the compositional intermediary of the III-V alloy system AlGaAsSb which acts as a grading layer. The Al constituent reaches a peak atomic concentration of about 6% within the first 2.5 μm of the transition layer, then decreases smoothly to about 1% to obtain a lattice constant of 5.74 A. In the same interval the equilibrium concentration of Sb smoothly increases from 0 to about 9 atomic percent to form a surface on which a GaAsSb layer having the desired energy bandgap of 1.1 eV for one junction of an optimized dual junction photovoltaic device. The liquid phase epitaxy is accomplished with a step cooling procedure whereby dislocation defects are more uniformly distributed over the surface of the growing layer.

4,247,528
Dosaj, Vishu D.; Hunt, Lee P., inventors; Dow Corning Corporation, assignee. *Method for Producing Solar-Cell-Grade Silicon*. January 27, 1981.

Silica is reduced in a direct arc reactor by activated carbon or carbon black having relatively low boron (B) and phosphorous (P) contents to produce silicon having similarly low B and P contents and suitable for use in photovoltaic cells for converting solar energy directly to electrical energy.

Re. 30,504
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Photovoltaic Cell*. February 3, 1981.

A photovoltaic cell having an electrically conductive substrate, which may be glass having a film of conductive tin oxide; a first layer containing a suitable semiconductor, which layer has a first component film with an amorphous structure and a second component film with a polycrystalline structure; a second layer forming a heterojunction with the first layer; and suitable electrodes where the heterojunction is formed from a solution containing copper, the amorphous film component is superposed above an electrically conductive substrate to resist permeation of the copper-containing material to shorting electrical contact with the substrate. The penetration resistant amorphous layer permits a variety of processes to be used in forming the heterojunction with even very thin layers (1-6μ thick) of underlying polycrystalline semiconductor materials. In some embodiments, the amorphous-like structure may be formed by the addition of aluminum or zirconium compounds to a solution of cadmium salts sprayed over a heated substrate.

4,248,643
Peters, Melville F., inventor; Walter Todd Peters, Margot Elizabeth Peters, Albert F. Kronman, Arthur H. Steller, Grace B. Steller, assignee. *Solar Energy Conversion Panel*. February 3, 1981.

A solar energy conversion panel is provided by means of which solar energy is recovered as converted electrical energy and also thermal energy. An array of solar energy collectors direct solar energy received from the sun upon photovoltaic cells within the collectors. The photovoltaic cells convert a portion of this energy into electrical energy. The balance of the solar energy is recovered as thermal energy which is carried from the panel by a circulating fluid. Specific shapes and arrangements of energy collectors are disclosed by means of which the energy recovered may be maximized. A means for protecting the panel from wind damage is also disclosed.

4,248,675
Bozler, Carl O.; Chapman, Ralph L.; Fan, John C. C.; McClelland, Robert W., inventors; Massachusetts Institute of Technology, assignee. *Method of Forming Electrical Contact and Antireflection Layer on Solar Cells*. February 3, 1981.

A method of applying an electrical contact and an anodic reflection coating to an n^+ layer of a direct gap semiconductor device, comprising applying an anodizable metal contact to the n^+ layer and thereafter anodizing the n^+ layer whereby its thickness is reduced and an antireflection layer is formed thereover.

4,249,516
Stark, Virgil, inventor; North American Utility Construction Corp., assignee. *Solar Energy Collection*. February 10, 1981.

Apparatus and methods for concentrating and collecting solar energy and for lowering the cost and increasing the efficiency of solar energy systems are disclosed. Solar energy is concentrated by economical refringent lenses or lens systems including fluid lenses and/or Fresnel-type lenses. The lenses concentrate the solar energy preferably along lines in continuous linear foci or in discrete foci at an elongated collector comprising one or more fluid-carrying conduits and one or more fluids therein. According to one aspect of the invention, lower reflectors are disposed below a central reflector and positioned to reflect and preferably concentrate solar energy toward the central reflector. The central reflector reflects and preferably concentrates the solar energy from the reflectors towards the collector means, also disposed below the central reflector. A lens, preferably a fluid lens, is disposed in the path of reflected solar energy between the lower reflectors and the collector. The lens(es) is positioned in the path between the lower reflectors and the central reflector and/or in the path between the central reflector and the collector, the reflected solar energy being focused in or on the collector by the lens or central reflector. The central reflector, the lower reflectors, the lens and the collector may be movable to track the sun seasonally and preferably also daily (hourly).

4,249,957
Koliwad, Krishna M.; Daud, Taher, inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Copper Doped Polycrystalline Silicon Solar Cell*. February 10, 1981.

Photovoltaic cells having improved performance are fabricated from polycrystalline silicon containing copper segregated at the grain boundaries.

4,249,958
Baudin, Pol; Leger, Lucien; Collignon, Pierre, inventors; BFG Glassgroup, assignee. *Panel Comprising at Least One Photo-Voltaic Cell and Method of Manufacturing Same*. February 10, 1981.

In order to reduce or prevent absorption of water in the adhesive of a panel comprising at least one photovoltaic cell located between a transparent sheet and a second sheet bonded together using an adhesive material, the invention provides that another material is applied at least in part between the sheets to form a moisture barrier which surrounds the cell(s) and the adhesive. The preferred adhesive material is polyvinyl butyral, and the preferred barrier forming material is selected from neoprene based adhesives, polysulphide adhesives and polyvinylidene chloride. When the latter is used a second barrier forming material such as polysulphide adhesive is preferably interposed between the adhesive and the polyvinylidene chloride.

4,249,959
Jebens, Robert W., inventor; RCA Corporation, assignee. *Solar Cell Construction*. February 10, 1981.

A plurality of like solar cell generators, each in the form of a segment of a circle, are spaced in a circular array on a face of a disc of insulating base material. They are formed by cutting a plurality of diagonal slits through a solar cell disc on the base material. A metallized grid structure is on the active cell face of each generator and an electrode in the form of a like circular segment juxtaposed with each generator is connected between the generator, on a side opposite the grid structure, and the base layer disc. The electrode has a terminal portion extending beyond the generator region. The slits electrically isolate the cells from each other.

4,250,148
Cota, Marlo E.; Gurtler, Richard W., inventors; Motorola, Inc., assignee. *Apparatus and Method for Producing Polycrystalline Ribbon*. February 10, 1981.

A method for the substantially continuous growth of polycrystalline silicon ribbon. The polycrystalline silicon is chemically vapor deposited on elongated foils which move slowly through a resistance heated furnace chamber. Vapor sealing entrance and exit ports are provided which allow the continuous transfer of the foils and polycrystalline ribbon between the chamber and the ambient. The foils are positioned within the chamber so as to mask the chamber walls and to restrict the deposition to the foils. All deposition of polycrystalline silicon takes place on one side of each of the foil pieces; deposition on the edges or backs of the foils is prevented by the positioning of the foils relative to each other. Adhesion of the foils to each other is prevented by insuring that all foils are in relative motion. The process is highly efficient and cost effective because it employs efficient resistance heating, because the only surfaces which the reactant gases can contact are hot and are regions of desired deposition, and because the length of the reaction zone can be made long enough to obtain an optimum amount of gas reaction.

4,251,284
Oster, Eugene A., Jr., inventor; Owens-Illinois, Inc., assignee. *Tubular Luminescent Solar Collector-Photocell Structure*. February 17, 1981.

Disclosed is a tubular luminescent solar collector structure containing semiconductor photocells bonded to the surface thereof along the length of said tube.

4,251,285
Yoldas, Bulent E.; Yoldas, Lubomyra A., inventors; Westinghouse Electric Corp., assignee. *Diffusion of Dopant from Optical Coating and Single Step Formation of PN Junction in Silicon Solar Cell and Coating Thereon*. February 17, 1981.

The PN juncture in a silicon chip and an oxide coating on its surface are simultaneously formed from clear solution derived from titanium alkoxides, water, alcohol, a suitable acid, and a P or N dopant compound by partial hydrolysis and polymerization. The solution is applied to the surface of a silicon chip. The chip is then heated which converts the solution to a solid oxide coating which meets the antireflective optical film requirements and induces the migration of the dopants into the chip, forming a PN junction in the chip. The method also provides deep and uniform junction formation or diffusion without resulting in excessive carrier concentration.

4,251,286
Barnett, Allen M., inventor; The University of Delaware, assignee. *Thin Film Photovoltaic Cells Having Blocking Layers*. February 17, 1981.

Electrical path failures in thin film photovoltaic cells are avoided by disposing at least one blocking layer in the cell to prevent undesired electrical contact which might otherwise occur between the transparent and opaque electrical contacts as well as between one of the contacts and the semiconductor which is remote from it.

4,251,287
Dalal, Vikram L., inventor; The University of Delaware, assignee. *Amorphous Semiconductor Solar Cell*. February 17, 1981.

A solar cell comprising a back electrical contact, amorphous silicon semiconductor base and junction layers and a top electrical contact includes in its manufacture the step of heat treating the physical junction between the base layer and junction layer to diffuse the dopant species at the physical junction into the base layer.

4,251,288
Yerkes, John W., inventor; Atlantic Richfield Company, assignee. *Photovoltaic Device with Specially Arranged Luminescent Collector and Cell*. February 17, 1981.

A photovoltaic device for collecting solar radiation and converting it to electrical energy has a luminescent collector shaped in a way that maintains collecting area efficiency while allowing the photovoltaic cell to be entirely shadowed or protected from the direct rays of solar energy. The shape of the luminescent collector is also especially suited to air cooling and to placement of insulation between the collector surface and the cell. The collector has a first extension which receives and absorbs the light energy and at least one side extension which extends away from the sun collecting part of the collector. The side extension or extensions conduct the collected light energy to the protected cell or cells. For example, the luminescent collector may have an inverted U-shape or L-shape. A photovoltaic cell is coupled to the side extension, preferably at the end surface of the side extension. Each cell is placed entirely away from surfaces directly heated by the rays of the sun and is entirely shadowed from radiant heating by a part of the photovoltaic device. The underside of the collector may be shaped to form a channel. The channel may be used for air cooling, thermal insulation, or a combination of air cooling and thermal insulation of the sun-receiving part of the collector. The upper outer surface of the collector may be protected by a protective radiation transmissive cover. Light emissive areas of the edge and lower surfaces of the collector not covered by photovoltaic cells may also be covered by a reflective material.

4,251,289
Moustakas, Theodore D.; Friedman, Robert A.; Wronski, Christopher R., inventors; Exxon Research & Engineering Co., assignee. *Gradient Doping in Amorphous Silicon*. February 17, 1981.

An amorphous silicon semiconductor having a gradient doping profile is produced by thermo-electrically diffusing an ionizable deposit material such as antimony or aluminum, for example, into the amorphous silicon layer. Embodied in a photovoltaic device, the gradient doping profile increases the width of the depletion or barrier region and concurrently ensures an ohmic contact between amorphous silicon and current carrying electrodes.

4,251,327
Grenon, Lawrence A., inventor; Motorola, Inc., assignee. *Electroplating Method*. February 17, 1981.

A method for electroplating a metallic layer onto the surface of a photovoltaic device absent any external electrical contacts to the surface. The photovoltaic device is placed in an electrolytic plating bath where it is illuminated with electromagnetic radiation to which the device is photovoltaically responsive. Plating from the electrolytic bath results from current flow generated in the device itself.

4,251,679
Zwan, Bryan J., inventor; E-Cel Corporation, assignee. *Electromagnetic Radiation Transducer*. February 17, 1981.

Electromagnetic radiation is converted to usable power in the form of electrical current by means of a plurality of transducing cavities having a wall structure that is inclined inwardly to receive impinging radiation and includes potential barrier strips each having different conduction electron densities which are also different from the conduction electron density of the material constituting the wall structure of each cavity; each potential barrier strip extends from the mouth of the cavity to the base thereof and, at the mouth, is connected to a conductor having a preselected conduction electron density whereby radiation impinging on a cavity will induce current flow which will be rectified across the potential barriers; the cavities are connected in parallel so that current can be delivered to a load connected across the conductors.

4,252,573
Boer, Karl W.; Freedman, Norman S.; Hadley, Henry C., Jr.; Phillips, James; Ruiz-Urbieta, Manuel, inventors; University of Delaware, assignee. *Collector Grid for CdS/CuS Photovoltaic Cells*. February 24, 1981.

By increasing the line spacing and the width of the grid wires of cadmium sulfide/copper sulfide photovoltaic cells, an easier to manufacture, low cost cell having a higher conversion efficiency is obtained. Seven to eight grid wires per inch have been found to be particularly desirable in achieving these end results.

4,252,861
Heaps, J. Don; Zook, J. David, inventors; Honeywell, Inc., assignee. *Growth Technique for Silicon-On-Ceramic*. February 24, 1981.

The present invention is an improvement to the method of growing silicon films on a substrate by bringing the substrate in contact with molten silicon. The improved growth technique may be classified as an asymmetric mode of growth of silicon on the substrate and is characterized by the substrate being maintained at a higher temperature than the solidification of silicon in the area of the substrate where the silicon layer-growth is taking place, that is in the area of the liquid-solid interface. The higher temperature of the substrate causes the liquid-solid interface to be tilted to be nearly parallel to the substrate surface but inclined at a reentrant angle, so that the leading edge of the crystallization front is away from the substrate. This provides several advantages including increased growth speed, a nonhomogeneous doping of the silicon layer, that is an impurity concentration gradient and results in a high-low junction at the back surface and gives the back surface field effect.

4,252,865
Gilbert, Laurence R.; Messier, Russell F.; Roy, Rustum, inventors; National Patent Development Corporation, assignee. *Highly Solar-Energy Absorbing Device and Method of Making the Same*. February 24, 1981.

The invention contemplates a highly solar-energy absorbing device wherein the surface exposed to incident solar energy is a particularly characterized roughness of an amorphous semiconductor material, the particular characterization being that of an array of outwardly projecting structural elements of relatively high aspect ratio and at effective lateral spacings which are or include those in the order of magnitude of wavelengths within the solar-energy spectrum.

4,253,880
Bellugue, Jacques, inventor; U.S. Philips Corporation, assignee. *Device for the Conversion of Solar Energy into Electrical Energy*. March 3, 1981.

A device is described for the conversion of solar energy into electrical energy with the aid of a photovoltaic cell. A central lens forms a round radiation spot on the radiation-sensitive area of the cell, while a toric mirror arranged round the lens forms an annular radiation spot. Thus, it is ensured that the entire area of the cell remains illuminated, independent of the movement of the sun relative to the cell. Owing to the selected intensity distribution in the radiation spots a satisfactory efficiency of the cell can be maintained even at a high concentration of the solar energy.

4,253,881
Hezel, Rudolf, inventor. *Solar Cells Composed of Semiconductive Materials*. March 3, 1981.

A solar cell is composed of a semiconductive material having an active zone in which charge carriers are produced by photons which strike and penetrate into the solar cell. The cell is comprised of a semiconductive body having an electrically insulating laminate with metal contacts therein positioned on the semiconductor body in the active zone thereof. The insulating laminate is composed of a double layer of insulating material, with the layer in direct contact with the semiconductive surface being composed of SiO_2 which is either natural or is produced at temperatures below 800°C and the layer superimposed above the SiO_2 layer being composed of a different insulating material, such as plasma-produced Si_3N_4. In certain embodiments of the invention, a whole-area pn-junction is provided parallel to the semiconductive surface. The solar cells of the invention exhibit a higher degree of efficiency due to a higher fixed interface charged density, and low surface recombination velocity, an increased UV sensitivity, improved surface protection and passivation and improved antireflection characteristics relative to prior art solar cell devices.

4,253,882
Dalal, Vikram L., inventor; University of Delaware, assignee. *Multiple Gap Photovoltaic Device*. March 3, 1981.

A multiple gap photovoltaic device having a transparent electrical contact adjacent a first cell which in turn is adjacent a second cell on an opaque electrical contact, includes utilizing an amorphous semiconductor as the first cell and a crystalline semiconductor as the second cell.

4,253,919
Hall, Dale E.; Clark, William D. K., inventors; The International Nickel Company, Inc., assignee. *Electrodeposition of Cadmium-Selenium Semiconducting Photoelectrodes from an Acid Citrate Bath*. March 3, 1981.

A process for electrodepositing cadmium and selenium onto a material suitable for use as a photoelectrode in a photovoltaic cell. The plating electrolyte, in one embodiment, consists essentially of an acid citrate bath including hydrated citric acid, hydrated sodium citrate, hydrated cadmium chloride and selenious acid. The deposit may be subsequently heat treated.

4,254,093
Faria, Sixdeniel; Chiola, Vincent, inventors; GTE Products Corporation, assignee. *Solar Energy Grade Cadmium Sulfide*. March 3, 1981.

A composition consisting essentially of discrete particles of cadmium sulfide that are relatively free of anionic, cationic and volatile impurities has an average particle size of from about 8 to about 25 micrometers and a bulk density of from about 1.7 to about 1.9 grams per cubic centimeter and has superior properties for use in solar energy applications. The composition is prepared by forming a finely-divided impure cadmium sulfide by chemical precipitation, heating the resulting precipitate to an intermediate temperature in a flow of an inert gas, heating the material at an elevated temperature in a flowing sulfide atmosphere selected from hydrogen sulfide and carbon disulfide and cooling the heated material in a sulfide atmosphere to about the intermediate temperature and cooling to ambient temperature in an inert gas.

4,254,426
Pankove, Jacques I., inventor; RCA Corporation, assignee. *Method and Structure for Passivating Semiconductor Material*. March 3, 1981.

A structure for passivating semiconductor material comprises a substrate of crystalline semiconductor material, a relatively thin film of carbon disposed on a surface of the crystalline material, and a layer of hydrogenated amorphous silicon deposited on the carbon film.

4,254,429
Yamazaki, Shunpei, inventor. *Hetero Junction Semiconductor Device*. March 3, 1981.

A hetero junction semiconductor device having at least one inter-semiconductor hetero junction, which has at least a first non-single-crystal semiconductor region having a first energy gap, a second non-single-crystal semiconductor region having a second energy gap different from the first energy gap and a third non-single-crystal semiconductor region serving as the hetero junction formed to extend between the first and second semiconductor regions and having an energy gap continuously changing from the first energy gap on the side of the first semiconductor region to the second energy gap on the side of the second semiconductor region, and in which the first, second and third semiconductor regions are doped with recombination center neutralizers.

4,254,546
Ullery, Lee R., Jr., inventor; SES, Incorporated, assignee. *Photovoltaic Cell Array*. March 10, 1981.

In a photovoltaic cell which comprises: a substrate, a bottom electrode, a first layer of cadmium sulfide, a second layer of cuprous sulfide forming a barrier junction with said first layer and a top electrode, the improvement wherein said substrate is an insulative ceramic material and the bottom electrode is a conductive ceramic layer fused to said substrate. Said conductive layer is optionally coated with a metal having a high electrical conductivity.

4,255,206
Endler, Wolfgang; Zschauer, Karl-Heinz, inventors; Siemens Aktiengesellschaft, assignee. *Method for Manufacturing a Semiconductor Structure*. March 10, 1981.

A method for manufacturing a semiconductor structure, especially for optoelectronic components, in which, at least one layer of a further semiconductor compound is deposited epitaxially on a substrate of a semiconductor compound. The surface of the substrate is provided with a multiplicity of bevelled structures of the further semiconductor compound. Prior to deposition, the surface of the substrate is provided with a multiplicity of mesas in a predetermined distribution, from each of which a bevelled structure is then generated. The plane and fault-free crystal surface of the bevels is preserved when further layers are deposited. The method is especially well suited for the manufacture of optoelectronic and microwave components.

4,255,208
Deutscher, Siegfried G.; Grunbaum, Enrique, inventors; Ramot University Authority for Applied Research and Industrial Development Ltd., assignee. *Method of Producing Monocrystalline Semiconductor Films Utilizing an Intermediate Water Dissolvable Salt Layer*. March 10, 1981.

A method is described for producing semiconductor films, particularly monocrystalline silicon and germanium films, characterized by the steps of: epitaxially growing on a substrate, such as silicon or sapphire, a layer of dissolvable material, such as sodium fluoride, sodium chloride, or silver; epitaxially growing on the dissolvable layer a layer of the semiconductor; and dissolving the dissolvable layer, thereby separating the semiconductor from the substrate. The substrate may thus be reused as a matrix for growing many such films. Also a plurality of semiconductor layers may be epitaxially grown on a common substrate, each separated by a dissolvable layer, all the latter layers being dissolved at one time to produce a plurality of the semiconductor films.

4,255,211
Fraas, Lewis M., inventor; Chevron Research Company, assignee. *Multilayer Photovoltaic Solar Cell with Semiconductor Layer at Shorting Junction Interface*. March 10, 1981.

A new high efficiency, multijunction photovoltaic solar cell for use with a concentration lens. This cell comprises an elemental single crystal substrate without an internal light sensitive junction, upon which are two or more successive homogenous layers of semiconductor materials, each layer containing within it a light sensitive p/n junction of a similiar polarity, each layer having essentially the same lattice constant as the single crystal substrate, each layer having a shorting junction contact with the layer immediately above and below it, each successive layer adsorbing light energy at a shorter wavelength, and each layer being of sufficient thickness and appropriate composition to develop essentially the same current as the other layers. At the junction, between the successive layers of the multilayer cell, a thin pseudo transparent low bandgap semiconductor layer is provided at the shorting junction interface. The outer surfaces of the top layer and the substrate are provided with electrical contacts for distribution of the electric current. The top contact comprises a layer of a transparent conductive material with electrical connections and the whole structure is completed with an antireflection coating over the top.

4,255,212
Chappell, Terry I.; White, Richard M., inventors; The Regents of the University of California, assignee. *Method of Fabricating Photovoltaic Cells*. March 10, 1981.

A solar power system including a movable platform for tracking the sun, a radiation concentrator, and a plurality of photovoltaic cell modules positioned on the platform for receiving concentrated solar radiation. The module includes a heat dissipation housing which supports a silicon cell across an open end of the housing. A heat transfer block physically engages the silicon cell and a metallic sponge and wick is attached to the heat transfer block and depends therefrom into the housing. The housing is partially filled with liquid to facilitate heat removal. The silicon cells are processed by preferential etching to form V grooves which define a plurality of diode elements having generally trapezoidal cross-sections. The elements may be serially interconnected by metallization on the V groove surfaces. The physical configurations of the elements and the use of antireflective coatings on surfaces of the elements result in high efficiency cells.

4,255,501
Osa, Tetsuo; Fujihira, Masamichi, inventors; President of Tohoku University, assignee. *Internally Reflective, Dye Sensitized, Wet-Type Photocell*. March 10, 1981.

An internally reflective, dye sensitized, wet-type photocell suitably adaptable as a photosensitive element or a solar cell, comprising anodes and cathodes immersed in an electrolyte solution containing a reduction-oxidation agent and dye sensitizers. Each of the anodes is provided with a light inlet end adapted for the introduction of light into the interior thereof, and a surface layer portion of an n-type semiconductive substance so that light introduced through the light inlet end to the interior of the anode is reflected a plurality of times so as to absorb the energy of the light to generate a voltage. Thus, since the dye sensitizing effect is efficiently utilized, the photocell enables the conversion efficiency of photo energy to electric energy to improve sufficiently for practical uses.

4,256,513
Yoshida, Manabu; Fukuchi, Jun; Takayanagi, Shigetoshi, inventors; Matsushita Electric Industrial Co., Ltd., assignee. *Photoelectric Conversion Device*. March 17, 1981.

A photoelectric conversion device such as a solar cell in which electrodes formed from a conductive paste make ohmic contact

with the surfaces of impurity diffused layers respectively formed in a semiconductor substrate. The conductive paste contains ultrafine particles of silver and gold as its principal solid components. The conductive paste further contains, as its additional principal solid components, ultrafine particles of a metal having a eutectic temperature lower than that of silver when alloyed with the semiconductor and a powdery glass material not containing any lead oxide glass component. The electrodes provided by the conductive paste exhibit excellent electrical properties when the conductive paste is subjected to firing treatment at a temperature of about 600°C. Thus, when, for example, the semiconductor substrate is of n-type silicon and a p^+-type diffused layer is formed in one of its major surfaces to form a p^+/n junction of relatively small depth, the electrode making ohmic contact with the p^+-type diffused layer does not penetrate through the p^+/n junction and has a low contact resistance. The photoelectric conversion device such as the solar cell thus obtained can operate with a higher conversion efficiency than hitherto and can be manufactured at a lower cost than hitherto.

4,256,544
Kazacos, Maria S.; Miller, Barry, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Method of Making Metai-Chalcogenide Photosensitive Devices*. March 17, 1981.

We have found that a photoactive metal selenide film, such as CdSe, may be formed by cathodic eletrodeposition from a selenosulfite ($SeSO_3^{2-}$) solution without the need for a subsequent heat treating step which, it is hypothesized, was required by the simultaneous deposition of elemental selenium.

4,256,681
Lindmayer, Joseph, inventor; Semix Incorporated, assignee. *Method of Producing Semicrystalline Silicon*. March 17, 1981.

A method of producing semicrystalline silicon by heating the silicon to a molten state and gradually cooling the silicon to mitigate disruptions in the silicon continuum and promote semicrystalline growth. The product formed is a silicon body, which may be sliced into wafers having highly ordered grains of a mean diameter of at least about 1 mm.

4,257,676
Greubel, Waldemar; Quella, Ferdinand, inventors; Siemens Aktiengesellschaft, assignee. *Device for Collecting Light*. March 24, 1981.

A light-collecting device in the form of, for example, a rectangularly-shaped body having a so-called "fluorescent plate" with at least one light-exit window is comprised of a solid carrier material having an index of refraction greater than one, such as a polar, water-containing amorphous material based on a polysilicate or a polyphosphate and containing organic or inorganic fluorescent particles therein, which have finite dipole moments with different values in the basic and the excited state, with the fluorescent particles being substantially uniformly distributed throughout the carrier material. In embodiments where the fluorescent particles are organic, an amphiphilic additive, such as a soap, is colloidally dissolved in the carrier material in such a manner that the fluorescent particles are each surrounded by a colloid particle. The disclosed device is useful as a solar collector, an optical indicia transmitter or an image brightener for passive displays.

4,257,821
Kelly, Franklin G.; Bashin, Saul; Kennedy, Robert E., inventors; TRW Inc., assignee. *Universal Solar Cell/Conductor Junction Element and Solar Panel Embodying Same*. March 24, 1981.

A solar electric power generating panel (solar panel) includes one or more universal electrical junction elements of approximately the same size and shape as conventional solar cells mounted along with the cells on a solar array substrate at any selected cell position or positions of the cell array. Each junction element has terminals which may be electrically connected to interconnects of the solar cells and electrical conductors such as lead wires of the cell array in such a way as to condition the element to serve as a series string termination with or without blocking diodes, an electrical voltage tap with or without blocking diodes or a mounting for cell shunting diodes. Automatic assembly tooling may be utilized to assemble and electrically connect the solar cells, conductors, and junction elements into a completed solar array.

4,258,647
Pohl, Dieter W.; Scheel, Hansjoerg, inventors; International Business Machines Corporation, assignee. *Apparatus for Manufacturing Multilayered Semiconductor Elements by Means of Liquid-Phase Epitaxy*. March 31, 1981.

In a crucible or reactor for making multi-layered semiconductor devices by means of liquid-phase epitaxy, different supersaturated solutions are brought into contact with semiconductor substrates for short times. Transport of the solutions occurs by alternating acceleration. Either gravity alternates with centrifugal force, or a positive rotational acceleration alternates with a negative one. Chambers within the reactor are interconnected by channels so that the alternating forces acting upon the solutions cause these to flow in a preferred direction without mixing with each other.

4,259,122
Purwin, Paul E.; Shaw, Robert F., inventors; Exxon Research & Engineering Co., assignee. *Selenium Photovoltaic Device*. March 31, 1981.

A high efficiency selenium photovoltaic solar cell comprises a transparent base: a pellucid layer of conductive oxide; a layer of polycrystalline selenium forming a heterojunction to the underlying oxide; a thin layer of tellurium interposed between the oxide and selenium layers providing a metallurgical bond therebetween; a layer of high work function metal forming an ohmic contact to the selenium layer. A process of optimizing the optical and electrical characteristic of each component of the solar cell results in increased sunlight engineering efficiencies in excess of about 3.5%.

4,260,219
Greubel, Waldemar; Quella, Ferdinand, inventors; Siemens Aktiengesellschaft, assignee. *Device for Collecting Light and Method of Manufacturing Such Device*. April 7, 1981.

A light-collecting device in the form of, for example, a rectangularly-shaped body having a so-called "fluorescent plate" with at least one light-exit window is comprised of a solid polymerized synthetic carrier material, such as a polyacrylate, a polymethacrylate, polystyrene or copolymer of a methacrylate and a styrene, containing fluorescing particles therin which have finite dipole moments with different values in the basic and in the excited state and containing an amphiphilic additive, such as an ionoic or non-ionoic or polymeric soap, with such amphiphilic additive being colloidally dissolved in the synthetic carrier in such a manner that the fluorescing particles are each surrounded by one of the colloid particles and an environment with an orientation polarization is attained whereby the environment can reorientate so quickly that it achieves its thermodynamic equilibrium substantially completely during the existence of the excited state in the fluorescing particles and tends to suppress the disruptive self-absorption of a light within the fluorescent plate. Such self-absorption originates from a partial overlap of the emission spectrum with the absorption spectrum of the fluorescing particles. In certain embodiments of the invention, an additional polar solvent for the fluorescing particles is also enclosed in the colloid particles. The amphiphilic additive and/or polar solvents can be admixed in the synthetic carrier material and the so-attained system can be cast into a desired body form. The disclosed device is useful as a solar collector, an optical indicia transmitter of an image brightener for passive displays.

4,260,427
Fulop, Gabor F.; Betz, Jacob F.; Meyers, Peter V.; Doty, Mitchell E., inventors; Ametek, Inc., assignee. *CdTe Schottky Barrier Photovoltaic Cell*. April 7, 1981.

Photovoltaic cell comprises thin film cadmium telluride in ohmic contact with a smooth conductive substrate, preferably comprising a cadmium surface, through a cadmium-rich layer at the interface with the substrate, the cell further including a rectifying barrier layer. Preferably, the film is electrodeposited on the substrate surface with specific materials and process conditions. Preferably also, the film or cell is subsequently treated to enhance its barrier layer interface function.

4,260,428
Roy, Pradip K., inventor; SES, Incorporated, assignee. *Photovoltaic Cell*. April 7, 1981.

A photovoltaic cell having improved stability and lifetime comprising a cadmium sulfide film, an overlying copper sulfide film and deposited on the coopper sulfide film, a film selected from the group consisting of a film of chromium, a film of chromium having deposited thereon a film of copper, a film of copper having deposited thereon a film of chromium and a film of an admixture of chromium and copper. A method for making such a photovoltaic cell is also disclosed.

4,260,429
Moyer, Richard L., inventor; SES, Incorporated, assignee. *Electrode for Photovoltaic Cell*. April 7, 1981.

In a photovoltaic cell which comprises a first electrode, a first layer of cadmium sulfide, a second layer of cuprous sulfide forming a barrier junction with said first layer, and a second electrode, the improvement wherein said second electrode is formed by coating a conducting metal wire with a solid polymer containing electrically conductive particles, and attaching the coated wire to the cuprous sulfide layer by the application of moderate heat and/or pressure.

4,261,802
Fulop, Gabor F.; Betz, Jacob F.; Meyers, Peter V.; Doty, Mitchell E., inventors; Ametek, Inc., assignee. *Method of Making a Photovoltaic Cell*. April 14, 1981.

Photovoltaic cell comprises thin film cadmium telluride in ohmic contact with a smooth conductive substrate, preferably comprising a cadmium surface, through a cadmium-rich layer at the interface with the substrate, the cell further including a rectifying barrier layer. Preferably, the film is electrodeposited on the substrate surface with specific materials and process conditions. Preferably also, the film or cell is subsequently treated to enhance its barrier layer interface function.

4,262,161
Carey, James E., inventor; Shell Oil Company, assignee. *Covered Solar Cell Assembly*. April 14, 1981.

A covered solar cell having improved light reception characteristic comprises a layer of a semiconductor material, an electrical contact, a transparent cover plate and a transparent film interposed between the cover plate and the layer of semiconductor material wherein the transparent film contains a block copolymer having at least two monoalkenyl arene polymer end blocks A and at least one polymer mid block B selected from the group consisting of substantially completely hydrogenated conjugated diene polymer blocks, ethylene-propylene polymer blocks and ethylenebutene polymer blocks. Also disclosed and claimed are novel methods for making the covered solar cell.

4,262,206
Viehmann, Walter, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Fluorescent Radiation Converter*. April 14, 1981.

A fluorescent radiation converter having a substantially undoped optically transparent substrate and a waveshifter coating deposited on at least one portion of the substrate for absorption of radiation and conversion thereof to fluorescent radiation. Such coating is formed of substantially 1000 grams/liter of a solvent, 70 to 200 grams/liter of an organic polymer, and 0.2 to 25 grams/liter of at least one organic fluorescent dye. The incoming incident radiation impinges on said coating and enters therein. Radiation is absorbed by the fluorescent dye and is re-emitted as a longer wave-length radiation. This radiation is trapped within the substrate and is totally internally reflected by two boundary surfaces towards ends of the converter. Emitted radiation leaves said ends to be detected.

Re. 30,584
Russell, Charles R., inventor; Owens-Illinois, assignee. *Optical Concentrator and Cooling System for Photovoltaic Cells*. April 21, 1981.

An optical concentrator and cooling system in which a photovoltaic cell array is immersed in a liquid inside an elongated tube having a curved transparent wall for incident radiation, said liquid having a refractive index suitable for concentrating the incident radiation onto the photovoltaic cell array.

4,262,411
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Method of Making a Solar Cell Array*. April 21, 1981.

A method of producing an array of photovoltaic cells responsive to incident radiation by forming heterojunction-forming material layers over a transparent substrate panel having a transparent electrically conductive coating and thereafter removing selected portions of the materials to form a plurality of cells on a common substrate. The cells are then electrically interconnected by depositing electrcally conducting materials over substantially the entire panel and removing only those portions of the deposited materials required to form series electrical connections.

4,263,064
Clawson, Arthur R.; Lum, Wing Y.; McWilliams, Gerald E., inventors; The United States of America as represented by the Secretary of the Navy, assignee. *Method of Liquid Phase Epitaxial Growth*. April 21, 1981.

An improved method of liquid phase epitaxial growth of III-V compound on an InP substrate by growing the epitaxial layer in an atmosphere of H_2 with 10^{-5} to 10^{-4} mole fraction PH_3.

4,264,124
Greubel, Waldemar; Quella, Ferdinand, inventors; Siemens Aktiengesellschaft, assignee. *Device for Collecting Light and Method of Manufacturing Such Device*. April 28, 1981.

A light-collecting device in the form of, for example, a rectangularly-shaped body having a so-called "fluorescent plate" with at least one light-exit window is comprised of a solid polymerized synthetic carrier material, such as a polyacrylate, a polymethacrylate, a polystyrene or copolymers thereof, containing fluorescing particles therein which have finite dipole moments with different values in the basic and in the excited state and containing a polar organic additive, such as a high-boiling polar solvent, for example, an aliphatic or aromatic alcohol, a nitrile or an ionogenic or non-ionogenic soap, with the fluorescing particles and additive being substantially uniformly distributed throughout such carrier material. The additive creates an environment with an orientating polarization about the fluorescent particles whereby the environment can re-orientate so quickly that it achieves its thermodynamic equilibrium substantially completely during the existence of the excited state in the fluorescing particles and tends to suppress the disruptive self-absorption of light within the fluorescent plate. Such self-absorption originates from a partial

overlap of the emission spectrum with the absorption spectrum of the fluorescing particles. The additive can be dissolved in the synthetic carrier material or can be chemically linked therewith and the so-attained system can be injection moulded, extruded or cast into a desired body form. The disclosed device is useful as a solar collector, an optical indicia transmitter or an image brightener for passive displays.

4,264,962
Kodaira, Hitoshi, inventor; Beam Engineering Kabushiki Kaisha, assignee. *Small-Sized Electronic Calculator*. April 28, 1981.

A small-sized electronic calculator, which comprises a power source in the form of a solar battery having a film of polycrystalline photoconductive material, such as selenium. The solar battery is connected for angular movement to the calculator body by suitable connection means, such as a hinge and a foldable metal spring. The calculator body includes a display section of liquid crystal elements. The solar battery may include an overvoltage preventing circuit and a reset switch. The output of the solar battery may be converted to a digital value to indicate the luminescent by the display section.

4,265,422
Van Leeuwen, Matthew J., inventor; Atlantic Richfield Company, assignee. *Pole Mounting Solar Panel Assembly*. May 5, 1981.

A single pole mounting solar panel assembly comprising at least one solar panel and upper and lower brackets fixed to the panel and to the pole, the upper bracket having a first flange means for mating with the pole and a first base plate fixed to the panel, the lower bracket means having a second flange means fixed to and encompassing a substantial portion of the circumference of the pole and a plane surface which extends out to the panel, the width of the plane surface varying from about the width of the pole to the width of the panel, the flange means for the lower bracket having upstanding side means extending longitudinally of the plane surface for about the full length of the plane surface, the side means and plane surface terminating at a second base plate fixed to the panel.

4,265,933
Jordan, John P.; Lampkin, Curtis, inventors; Photon Power, Inc., assignee. *Photovoltaic Cell*. May 5, 1981.

A large area photovoltaic cell comprising a layer of polycrystalline cadmium sulfide, about 1 or 2 microns thick, formed by simultaneously spraying two suitably selected compounds on a uniformly heated plate of Mesa glass and irradiating the layer of polycrystalline cadmium sulfide with intense ultra-violet light during the spraying.

4,266,178
Asakawa, Tatsushi, inventor; Kabushiki Kaisha Suwa Seikosha, assignee. *Charge Control Circuit*. May 5, 1981.

A charge control circuit for regulating the current applied to a secondary battery utilized as a power supply in an electronic instrument is provided. The secondary battery is adapted to be charged to a predetermined voltage level in response to a charging current being applied thereto. A charging current is produced by a charging device, such as a solar battery. Voltage regulating circuitry is disposed intermediate the charging device and the secondary battery for detecting the voltage level of the secondary battery and, in response thereto, selectively regulating the application of the charging current to the voltage supply.

4,266,984
Wronski, Christopher R.; Myers, Bruce P., inventors; Exxon Research & Engineering Co., assignee. *Enhanced Open Circuit Voltage in Amorphous Silicon Photovoltaic Devices*. May 12, 1981.

An amorphous silicon photovoltaic device having enhanced photovoltage and increased longevity is produced by treatment of a barrier forming region of the amorphous silicon in the presence of a partial pressure of sulfur dioxide.

4,267,003
Mesch, Hans G.; Debenham, Colin H.; Yasui, Robert K., inventors; TRW, Inc., assignee. *Automatic Solar Cell Glassing Machine and Method*. May 12, 1981.

Solar cells are glassed mechanically to form solar cell stacks, each having a protective coverslide adhesively bonded to the active face of a solar cell, by relative movement of assembly fixtures past a solar cell dispenser which places a solar cell on each fixture, a following adhesive dispenser which applies adhesive to the active face of each cell, and a final coverslide dispenser which applies a coverslide to each cell to form an adhesively bonded cell stack. The preferred adhesive is a liquid adhesive which is applied to a central region only of each active cell face, then spreads over the entire cell face by capillary flow following application of the cell coverslide, and is finally cured by relative movement of the cell stack through an oven or the like.

4,267,398
Rothwarf, Allen, inventor; University of Delaware, assignee. *Thin Film Photovoltaic Cells*. May 12, 1981.

A solar cell has as its transparent electrical contact a grid made from a non-noble metal by providing a layer of copper oxide between the transparent electrical contact and the absorber-generator.

4,268,347
Stephens, Richard B., inventor; Exxon Research & Engineering Co., assignee. *Low Reflectivity Surface Formed by Particle Track Etching*. May 19, 1981.

Low reflectivity surfaces are formed by particle track etching of a dielectric material such that the horizontal scale of surface texture is less than the wavelength of incident radiation and the depth of texture is equal to or greater than said wavelength. As a consequence, the reflection coefficient is thereby reduced by a factor of at least two, and light is more efficiently transmitted into the material. For solar cells encapsulated in transparent material, efficiency of absorption of solar radiation may be improved by at least about two times per etched surface, or to less than about 2% for the air/transparent material interface and to less than about 15% for the transparent material/solar cell interface.

4,268,709
Boling, Norman L., inventor; Owens-Illinois, Inc., assignee. *Generation of Electrical Energy from Sunlight, and Apparatus*. May 19, 1981.

Disclosed is concentrating sunlight optically and impinging the concentrated light on at least one luminescent solar collector coupled to a first photocell, passing residual concentrated sunlight to at least one other luminescent solar collector in one embodiment, coupled to a different photocell and finally passing the remaining concentrated sunlight directly to a still different photocell.

4,268,711
Gurev, Harold S., inventor; Optical Coating Laboratory, Inc., assignee. *Method and Apparatus for Forming Films from Vapors Using A Contained Plasma Source*. May 19, 1981.

Method for forming mixed oxide and/or nitride films upon the surface of an article by the use of a partially confined plasma-activated source. The plasma-activated source has a cavity in which an RF field is formed within the cavity to create a gas plasma in the cavity as gas is introduced into the cavity. The gas plasma is caused to exit from the cavity to impinge upon the surface of the article to be coated. At least one of the constituents of the film is selected as a compound vapor and is chemically reacted with at least one other constituent by utilization of the

gas plasma to form the thin film on the surface of the article while the article is maintained at a low temperature. A chemical reaction takes place within the cavity itself and/or alternatively at the surface to be coated for the formation of the films.

4,269,168
Johnson, Steven A., inventor. *Focusing Reflector Solar Energy Collector Apparatus and Method*. May 26, 1981.

A solar energy collector apparatus and method, the apparatus including an open-top shell-like structure with a reflective optical system in the shell structure for directing solar energy toward a solar energy absorber apparatus inside the shell structure. The shell structure is mounted upon a hollow axle for rotation about its longitudinal axis and may be mounted for vertical movement to follow north-south changes in the apparent seasonal position of the sun. The solar energy absorber apparatus is nonrotatably mounted inside the shell structure in fluid communication with heat transfer conduits that pass through the hollow axle thereby avoiding rotatable couplings in the conduits. Photovoltaic apparatus for converting at least a portion of the solar spectrum to electrical energy may also be included in the shell structure. This combination of features provides higher solar efficiencies and higher temperatures in the heat transfer fluid. The method includes tracking the sun with the solar energy collector apparatus thereby maximizing the amount of solar energy collected while eliminating coupling failures in the heat transfer conduits.

4,270,018
Gibbons, James F., inventor. *Amorphous Solar Cells*. May 26, 1981.

A solar cell having single crystal or polycrystalline n-type and p-type layers separated by an amorphous layer.

4,270,972
Crouse, Allen G., inventor; Rockwell International Corporation, assignee. *Method for Controlled Doping Semiconductor Material with Highly Volatile Dopant*. June 2, 1981.

In conjunction with the use of a float-zone crystal grower for doping silicon, a holder for temporarily storing pellets of solid dopant is disposed outside the housing of the crystal grower. A rotatable cylinder in the holder is provided with a plurality of chambers into which charges of varying amounts of dopant may be stored. A separate charge of dopant is propelled by inert gas under pressure into the melt zone of a silicon rod in the crystal grower upon the occurrence of a specified event such as passage of time or translation of the silicon rod. The apparatus and method are particularly applicable to doping with a highly volatile dopant such as indium.

4,271,328
Hamakawa, Yoshihiro; Okamoto, Hiroaki; Nitta. Yoshiteru; Adachi, Toshio, inventors; Yoshihiro Hamakawa, assignee. *Photovoltaic Device*. June 2, 1981.

A photovoltaic device including a plurality of amorphous silicon unit cells each having a p-i-n structure layered in succession on a substrate made of stainless steel. A transparent electrically conductive layer, for withdrawing a photoelectromotive force in cooperation with the electrically conductive substrate, is formed on the uppermost unit cell, so that rays of light may be incident upon the photovoltaic device from the uppermost unit cell. Preferably, the thickness of the unit cells closer to the light incidence surface is selected to be less than the thickness of the unit cells farther from the light incident surface. Each of the unit cells is structured such that the n type, i type and p type layers are disposed in the above described order from the light incidence surface in terms of the impurity type.

4,272,641
Hanak, Joseph J., inventor; RCA Corporation, assignee. *Tandem Junction Amorphous Silicon Solar Cells*. June 9, 1981.

An amorphous silicon solar cell has an active body with two or a series of layers of hydrogenated amorphous silicon arranged in a tandem stacked configuration with one optical path and electrically interconnected by a tunnel junction. The layers of hydrogenated amorphous silicon arranged in tandem configuration can have the same bandgap or differing bandgaps.

4,273,421
Gurtler, Richard W., inventor; Motorola, Inc., assignee. *Semiconductor Lifetime Measurement Method*. June 16, 1981.

A method for the measurement of minority carrier lifetime in semiconductor wafers, sheets and ribbons by purely optical means. The method does not require electrical or MOS contacts to the wafer, nor does it require any specific processing to facilitate measurement. The technique is non-destructive, and is applicable to any semiconductor wafer, with or without surfcace dielectric films (e.g., SiO_2, Si_3N_4, Ta_2O_5) as long as it has no metal films. This technique is fast, accurate, and of reasonable high resolution, so that it may be applied to evaluate the effects of specific process steps (e.g., ribbon growth, diffusion, oxidation, ion implantation, dielectric deposition, annealing) in real time and hence serve as a production control technique as well as a research tool. By utilizing reasonable equipment sophistication, this technique should enable the measurement of lifetime over a wide range of values, covering the scale from high-speed bipolar devices and integrated circuits ($\sim 10^{-9}$s) to power transistors and solar cells ($\sim 10^{-3}$s).

4,273,594
Heller, Adam; Leamy, Harry J.; Miller, Barry; Nelson, Ronald J.; Parkinson, Bruce A., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Gallium Arsenide Devices Having Reduced Surface Recombination Velocity*. June 16, 1981.

Semiconductor devices using chemically treated n-type GaAs have greatly reduced surface recombination velocities. A preferred embodiment uses fractional monolayers of ruthenium on the GaAs surface.

4,273,608
Kerlin, Allen L., inventor. *Method of Forming a Sheet of Single Crystal Semiconductor Material*. June 16, 1981.

Apparatus for forming thin layers of material such as single crystalline silicon includes a container having a generally cylindrical interior surface. The container is rotatably mounted and movable through a heater. In forming the layer of material, the material is heated in the container to a temperature above the material melting point. The container is rotated whereby the liquid material adheres to the interior surface of the container by centrifugal force. The container is slowly cooled beginning at one end thereof whereby the layer of material solidifies.

4,273,950
Chitre, Sanjiv R., inventor; Photowatt International, Inc., assignee. *Solar Cell and Fabrication Thereof Using Microwaves*. June 16, 1981.

Solar cells are fabricated by spraying a dopant coating onto a semiconductor wafer and heating the surface of the wafer using unipolar microwaves. The resultant controlled heating drives dopant atoms from the coating into the wafer to produce a shallow junction at a selectable depth. Advantageously, metallic conductors are predeposited atop the dopant coating and then sintered to the semiconductor by the same unipolar microwave field concurrently with dopant drive-in. Efficient solar cells can be made with this process using polycrystalline silicon, since with unipolar microwave surface heating the grain boundaries do not become so deeply doped as to short circuit the junctions formed in the individual grains. Unipolar microwave heating also may be used to anneal ion implanted semiconductor devices.

4,274,044
Barre, Claude, inventor; U.S. Philips Corporation, assignee. *DC-DC Converter for Charging a Battery by Means of a Solar Cell*. June 16, 1981.

A DC-DC converter is described of the blocking oscillator type, for charging a battery from a solar cell. The use of a field effect transistor enables the oscillation to be started by the voltage from a single solar cell, even if the battery is fully exhausted. The overall efficiency of the circuit is improved by the use of the base-emitter junction of the switching transistor of the converter as rectifying element for the battery charging current.

4,274,890
Varon, Jacques J., inventor; U.S. Philips Corporation, assignee. *Method for the Epitaxial Manufacture of a Semiconductor Device Having a Multi-Layer Structure*. June 23, 1981.

A method is provided of manufacturing, on a substrate of a binary compound, layers of ternary or quaternary compounds in which epitaxial intermediate layers separate the substrate from the end layer, wherein the relative increase of the dimensions of the crystal lattices in the successive epitaxial intermediate layers increases.

4,275,525
Geisler, Diether; Eckert, Joachim, inventors; Beiersdorf AG, assignee. *Housing with Motor and Solar Cell*. June 30, 1981.

The present invention relates to a housing for a solar cell driven motor suitable for use in model toys. The housing typically has an inclined surface to which the solar cells may be applied. The housing may be used to energize a toy mill, radar tower, conveyor, or lever conductor.

4,276,137
Hovel, Harold J.; Woodall, Jerry M., inventors; International Business Machines Corporation, assignee. *Control of Surface Recombination Loss in Solar Cells*. June 30, 1981.

Surface recombination in solar cells that is produced by band bending at the surface of the semiconductor which is in turn caused by defect states which pin the Fermi level at the surface, may be improved by applying a surface layer which may be a plasma oxide that has been hydrogen annealed and this layer may also be useful as an antireflecting coating.

4,278,473
Borden, Peter G., inventor; Varian Associates, Inc., assignee. *Monolithic Series-Connected Solar Cell*. July 14, 1981.

A monolithic series-connected solar cell comprises a series of cells each having a mesa-like structure which is electrically interconnected from the top of each cell to a contact ledge formed in the base region of the adjoining cell. The individual cells are supported on an insulating substrate. The monolithic series-connected solar cell is fabricated from a fully formed single junction solar cell by forming a series of breaks down to an insulating substrate, forming a contact ledge in the base region on one side of the mesa defined by each break, applying a layer of insulating material along the opposite side of each mesa and forming a conductive lead between the top region of individual cells and the contact ledge of the adjoining cell.

4,278,474
Blakeslee, A. Eugene; Mitchell, Kim W., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Device for Conversion of Electromagnetic Radiation into Electrical Current*. July 14, 1981.

Electromagnetic energy may be converted directly into electrical energy by a device comprising a sandwich of at least two semiconductor portions, each portion having a p-n junction with a characteristic energy gap, and the portions lattice matched to one another by an intervening superlattice structure. This superlattice acts to block propagation into the next deposited portion of those dislocation defects which can form due to lattice mismatch between adjacent portions.

4,278,704
Williams, Brown F., inventor; RCA Corporation, assignee. *Method for Forming an Electrical Contact to a Solar Cell*. July 14, 1981.

A method of forming an electrical contact to a shallow junction silicon semiconductor device such as a solar cell comprises evaporating a sufficient amount of a metal which upon heating will form a silicide with the silicon to a predetermined depth and thereafter oxidizing the surface of the silicon so as to form a shallower junction in the unoxidized portions of said silicon. The portion of the silicon device which has formed the silicide does not oxidize and forms an electrical contact to the silicon. In addition, the metal silicide can have additional metal plated thereto to lower the sheet resistivity and resistance of the electrical contact.

4,278,829
Powell, Roger A., inventor. *Solar Energy Conversion Apparatus*. July 14, 1981.

Apparatus is disclosed for converting solar energy to more useful forms, i.e., thermal and electrical energy. Such apparatus includes a photoelectric transducer (e.g., an array of photovoltaic cells), means for concentrating solar energy on the transducer, and means for circulating a liquid between the transducer and the solar energy concentrator. The spectral properties of the liquid are such that the liquid functions as a bandpass filter, transmitting solar energy to which the transducer is responsive and absorbing solar energy to which the transducer is non-responsive. The transmitted solar energy is converted to electrical energy by the transducer, and the absorbed solar energy is converted to heat by the liquid. Preferably, the liquid is circulated through a container which, in the vicinity of the transducer, is constructed so as to provide optical gain to the system and to integrate incident solar energy for the purpose of eliminating "hot spots" which could overheat, and thereby damage, the transducer.

4,278,830
Stirn, Richard J.; Yeh, Yea-Chuan M., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Schottky Barrier Solar Cell*. July 14, 1981.

A Schottky barrier solar cell consists of a thin substrate of low cost material with at least the top surface of the substrate being electrically conductive. A thin layer of heavily doped n-type polycrystalline germanium, with crystalline sizes in the submicron range, is deposited on the substrate. But first a passivation layer may be deposited on the substrate to prevent migration of impurities into the polycrystalline germanium on a substrate of low-cost conductive material. Then the polycrystalline germanium is recrystallized to increase the crystal sizes in the germanium layer to not less than 5 microns, and preferably considerably more. It serves as a base layer on which a thin layer of gallium arsenide is vapor-epitaxially grown to a selected thickness. Then, a thermally-grown oxide layer of a thickness of several tens of angstroms is formed on the gallium arsenide layer. A metal layer, of not more than about 100 angstroms thick, is deposited on the oxide layer, and a grid electrode is deposited to be in electrical contact with the top surface of the metal layer. An antireflection coating may be deposited on the exposed top surface of the metal layer. In another embodiment, the recrystallized germanium layer serves as the substrate for a Schottky barrier solar cell with more than one active semiconductor layer. The techniques of forming an oxide layer are also applicable in forming an oxide layer between a metal layer and a semiconductor material which together form a Schottky barrier junction in any solar cell.

4,278,831
Riemer, Dietrich E.; Corwin, Rudolph E., inventors; The Boeing Company, assignee. *Process for Fabricating Solar Cells and the Product Produced Thereby*. July 14, 1981.

An electrically conductive, anti-reflective coating is formed on a base layer of prepared silicon in such a manner as to form a good ohmic contact therewith. If doped, the coating can serve as an impurity source during a following diffusion step, in which a PN junction is formed in the silicon. Undoped coatings may be used when the PN junction has previously been formed in the silicon. Thick film electrical contacts are then formed by screen printing on the top surface of the anti-reflective coating and then fired at high temperature, i.e. 500°–1000°C. The material comprising the coating is such that it acts as a barrier to the diffusion of the metal forming the electrical contacts into the silicon base layer during the firing of the thick film contacts. Since the coating is electrically conductive, a conductive path between the contacts and the silicon is established.

4,280,853
Palazzetti, Mario; Ponti, Cesare; Tenci, Pier L., inventors; Centro Ricerche Fiat S.p.A., assignee. *Solar Energy Conversion Unit*. July 28, 1981.

A solar energy converter is provided in the form of a unit for assembly together with other similar units to build up a solar-energy conversion installation. Each unit includes a fixed support structure, a mounting element articulated on the support structure, and an optical concentrator carried by the mounting element. The optical concentrator consists of a plurality of coplanar, spherical lenses, the centers of which are located at the vertices of a polygon. The center of the polygon lies on a line extending perpendicularly to the plane of the lenses through the point of articulation of the mounting element on the support structure. Each unit further includes a plurality of converter modules located at the foci of respective ones of the spherical lenses and carried by respective connecting legs which extend from the mounting element. Each converter module includes a photovoltaic cell and means for transferring the heat dissipated in the photovoltaic cell to a liquid.

4,281,053
Tang, Ching W., inventor; Eastman Kodak Company, assignee. *Multilayer Organic Photovoltaic Elements*. July 28, 1981.

A photoconductive laminate and its use are disclosed, the laminate comprising two layers of compounds, each layer being a single phase and at least one of the compounds having a generally planar polycyclic nucleus.

4,281,208
Kuwano, Yukinori; Imai, Terutoyo; Umetani, Masakazu, inventors; Sanyo Electric Co., Ltd., assignee. *Photovoltaic Device and Method of Manufacturing Thereof*. July 28, 1981.

A photovoltaic device comprises a light transmissive insulating substrate, on which a plurality of isolated transparent electrodes are formed. An amorphous silicon layer of a PIN structure, for example, is formed on the substrate continuously and in common to the respective transparent electrodes. Aluminum electrodes are formed on the surface of the amorphous silicon layer so as to correspond to the respective transparent electrodes. The transparent electrodes and the aluminum electrodes are electrically connected to the adjacent opponent electrodes to withdraw in a series fashion photovoltaic power generated at the respective photoelectric conversion regions.

4,281,278
Bilsky, Herbert W.; Callen, Patrick J., inventors; RCA Corporation, assignee. *Redundant Battery Protection System*. July 28, 1981.

A satellite power system in which solar cells provide power to a load during sunlight hours and also charge, through regulators, rechargeable batteries which provide power during dark periods. In order to prevent the batteries from being overcharged by solar cell current bypassing the regulators (through the load connection) each battery is protected by a redundant protection system including a pair of diodes and switch means normally connecting one of the diodes between the battery and the load. If the one diode fails or shorts, the switch means connects the other diode between the battery and the load; the voltage across the one diode and current therethrough are sensed to determine if the diode has failed.

4,281,369
Batte, Christopher L., inventor. *Method and Apparatus for Solar Power Lighting*. July 28, 1981.

Solar powered and/or augmented lighting systems embodied within conventional hollow light pole configuration incorporating a solar power lamp cell. A plurality of solar cells are disposed in an array about an upstanding light pole of conventional design of the type having a hollow interior and laterally extending lighting elements. The lighting element itself is provided in a configuration incorporating a solar cell atop a storage battery atop a light source, such as a bulb, operable from said light power system. The lighting cell is selectively powered by either a storage battery system operable in conjunction with the solar panel array and/or the solar power network incorporated therein. A network of electrical storage cells is disposed within the hollow configuration of the light pole and supported upon an elevator system for facilitating access thereto. In this manner, the overall consumption of energy from conventional power lines may be reduced and/or eliminated. The commercial lines may remain connected to said light poles for augmented power during periods of low solar energization and for purposes of original solar collector orientation.

4,283,589
Kaplow, Roy; Frank, Robert I., inventors; Massachusetts Institute of Technology, assignee. *High-Intensity, Solid-State Solar Cell*. August 11, 1981.

A semiconductor solar cell capable of converting incident radiation to electrical energy at high efficiency includes a plurality of series-connected unit solar cells formed from a common wafer of semiconductor material. The unit solar cells each include a semiconductor substrate of one conductivity type and a p-n junction formed in the substrate. The light-receiving surface of the cell may have an opaque member thereon, and incident light is directed onto the portion of that surface not covered by the opaque member. A variety of embodiments illustrates the invention.

4,283,590
Bilger, Gerhard; Hewig, Gert; Pfisterer, Fritz; Schock, Hans-Werner, inventors; Werner H. Bloss, assignee. *Method for Production of Solar Cells and Solar Cells Produced Thereby*. August 11, 1981.

A method for the production of solar cells with a thin-layer PN heterojunction, having a cadmium sulfide layer vapor deposited on an electrically conductive support and a cuprous sulfide layer chemically produced on the cadmium sulfide layer, and having an electrically conductive grid in contact with the cuprous sulfide layer, wherein the two layers and the conductive support are formed into one structural part, and the conductive grid is formed into a second structural part including a covering glass member, and the two structural parts are adhesively joined to form a closed encapsulated cell.

4,283,591
Böer, Karl W., inventor; SES, Incorporated, assignee. *Photovoltaic Cell*. August 11, 1981.

A process for improving the stability of a cadmium chalcogenide/copper chalcogenide photovoltaic cell is disclosed. The improvement comprises positioning a layer of a polymer composition containing electrically conductive particles between the

copper chalcogenide layer and the metal electrode such that the metal electrode does not make physical contact with the copper chalcogenide layer.

4,285,762
Moustakas, Theodore D., inventor; Exxon Research & Engineering Co., assignee. *Plasma Etching of Amorphous Silicon (SE-35)*. August 25, 1981.

Amorphous silicon is selectively etched by concurrently exposing the silicon to an ionized plasma containing hydrogen and heating the silicon to a temperature of between about 150°C to about 350°C. In one embodiment the selective etching technique is utilized to texture the surface of the amorphous silicon reducing the reflectivity thereof to less than about 5%.

4,287,382
French, Hollis E., inventor; Exxon Research & Engineering Co., assignee. *Solar Cell Assembly and Fabrication of Solar Cell Panels Utilizing Same*. September 1, 1981.

An assembly comprising a plurality of solar cells arrayed on and adhesively bonded to a sheet of non-woven heat-actuatable fabric is provided which offers significant advantages in the fabrication of solar cell panels, particularly fabrication of panels by vacuum lamination techniques.

4,287,383
Peterson, Terry M., inventor; Chevron Research Company, assignee. *Cadmium Sulfide Photovoltaic Cell of Improved Efficiency*. September 1, 1981.

Cadmium sulfide photovoltaic cells of improved efficiency comprising transparent metal conducting electrode layer, first cadmium semi-conductor layer, short-barrier layer, second cadmium sulfide semi-conductor layer, barrier layer and collecting metal electrode layer.

4,287,473
Sawyer, David E., inventor; The United States of America as represented by the United States Department of Energy, assignee. *Nondestructive Method for Detecting Defects in Photodetector and Solar Cell Devices*. September 1, 1981.

The invention described herein is a method for locating semiconductor device defects and for measuring the internal resistance of such devices by making use of the intrinsic distributed resistance nature of the devices. The method provides for forward-biasing a solar cell or other device while it is scanning with an optical spot. The forward-biasing is achieved with either an illuminator light source or an external current source.

4,287,485
Hsieh, Jaw J., inventor; Massachusetts Institute of Technology, assignee. *GaInAsP/InP Double-Heterostructure Lasers*. September 1, 1981.

Double-heterostructure (DH) diode lasers based upon very thin epitaxial layers of $Ga_xIn_{1-x}As_yP_{1-y}$ grown on and lattice-matched to oriented InP substrates are disclosed. A preferred method for fabricating such lasers involves the successive growth, on an InP substrate, of an InP buffer layer, the GaInAsP active layer and an InP top barrier layer using liquid phase epitaxy techniques to grow these layers from supercooled solutions. Stripe geometry lasers can be fabricated from these materials which emit in the 1.1-1.3 μm range and are capable of cw operation for extended periods at room temperature.

4,287,848
Leibenzeder, Siegfried; Heindl, Christine, inventors; Siemens Aktiengesellschaft, assignee. *Apparatus for the Manufacture of Epitaxial $Ga_{1-x}Al_xAs$:Si Film*. September 8, 1981.

Apparatus for manufacturing epitaxial $Ga_{1-x}Al_xAs$:Si films via liquid-phase epitaxy, using a boat in a quartz tube. The Ga, which is contained in a graphite boat, open at the long side, is baked out first. The Ga-melt is allowed to run onto GaAs substrate wafers, on which Si is deposited, and to be drawn into the gap between the GaAs-substrate wafers and the plane graphite surfaces. The thin Ga-melt formed above the GaAs substrate wafers is then brought into contact with the melted Al and is allowed to cool.

4,289,112
Roseen, Rutger A., inventor; Studsvik Energiteknik AB, assignee. *Heat Storing Solar Collector Device*. September 15, 1981.

A solar collector device is placed on a floating insulating lid of a reservoir containing a heat storing liquid. The solar collector device comprises lens means which concentrate incident solar radiation to focal points or focal lines rear or at the lid, and the lid has apertures through which the focus portions of the radiation beams pass with snug clearance. Transparent evaporation preventing diaphragms seal the appertures. Electricity generating semi-transparent solar cells may be arranged in the apertures, whereby incident solar radiation partly produces electricity, partly heats the liquid, and whereby the liquid cools the cells. In the case the lens means comprise axially elongated lenses in parallel with the lid and the apertures are slots, aligned with the lens axes, the lid is rotatable whereby to maintain the lens axes, the slots and the sun radiation in one and the same plane during day time.

4,289,118
Stark, Virgil, inventor; North American Utility Construction Corp., assignee. *Solar Energy System with Pivoting Lens and Collector and Conduit System Therefor*. September 15, 1981.

A system in which solar energy is concentrated by an elongated lens in an elongated focus and collected in an elongated collector is disclosed. The lens is supported above the collector for pivotal movement with respect to the conduit about a first axis thereof to track the sun with the conduit remaining stationary. The collector further includes a container having an elongated solar energy transmitting aperture facing the lens along and adjacent to which the conduit extends, the container and lens being interconnected for pivotal movement with respect to the conduit about the first axis to maintain the aperture facing the lens with the conduit remaining stationary while the interconnected lens and container are pivoted. In one embodiment, the interconnected lens, container and conduit are also pivoted about a second axis transverse to the first axis. One embodiment of a conduit system includes an inner metal conduit having darkened outer surfaces to absorb solar energy and transmit heat to a fluid in the metal conduit. The metal conduit is enclosed by an enclosure and a dead space is provided around the inner metal conduit. In one embodiment, photovoltaic cells are installed in an inner transparent conduit in which the elongated focus of a Fresnel lens is located. The inner conduit is enclosed by an outer transparent conduit of at least about 3 times larger diameter and a fluid is circulated in the outer conduit which will substantially transmit therethrough the luminous solar energy while absorbing substantial amounts of the infrared solar energy.

4,289,571
Jewett, David N., inventor; Energy Materials Corporation, assignee. *Method and Apparatus for Producing Crystalline Ribbons*. September 15, 1981.

A method and associated apparatus are disclosed for the continuous formation of single crystal silicon ribbons. A seed crystal is placed on the surface of a pool of molten silicon and pulled at a slight angle above the horizontal over the edge of a meniscus attachment member at a rate commensurate with the rate of growth of the ribbon. The formation of the ribbon is controlled in part by a submerged stabilizer disposed under the molten silicon below the advancing edge of the ribbon at the surface of the silicon. A thermal impedance is provided below the surface of the molten silicon to provide stability in the formation of the

ribbon and to provide the proper temperature gradients conducive to the efficient formation of the ribbon from the molten material.

4,289,602
Sansregret, Joseph L., inventor; Exxon Research & Engineering Co., assignee. *Electrochemical Oxidation of Amorphous Silicon*. September 15, 1981.

The invention teaches an electrochemical process for electrolysis growth of an oxide layer on hydrogenated amorphous silicon. Embodied in a photovoltaic device, the oxide layer increases the open circuit voltage of the device and enhances the longevity of the photovoltaic characteristics of the device.

4,289,920
Hovel, Harold J., inventor; International Business Machines Corporation, assignee. *Multiple Bandgap Solar Cell on Transparent Substrate*. September 15, 1981.

The disclosure provides a highly efficient, e.g., up to 40% efficiency, solar cell for solar energy concentrator use. Two solar cell layers comprised of different semiconductor materials are grown upon a transparent, insulating substrate. A metal layer covering the bottom serves to reflect light back through the structure, and can serve as a wrap-around electrical contact to both materials. As an example, a structure of Si and GaAlAs is produced on a substrate from the group consisting of Al_2O_3, Spinel, Quartz, and BeO.

4,290,411
Russell, George F., inventor. *Solar Energy Collector Sun-Tracking Apparatus and Method*. September 22, 1981.

A solar energy collector is mounted for adjustable azimuth rotation about a vertical axis and adjustable elevation tilting about a horizontal axis for pointing toward the sun. The collector is driven for rotation about the vertical axis and for tilting about the horizontal axis by drive mechanism controlled by the angle of incidence of the sun's rays to the collector when the insolation is above a predetermined intensity. When the insolation is below such predetermined value, the drive mechanism is controlled by a stored computerized program. Control responsive to the sun's rays is effected by at least one light sensitive photoelectric cell. Preferably one pair of cells is arranged in a horizontal axis and another pair is arranged in a plane perpendicular to such horizontal axis. The photoelectric cells are buried in shield tubes to shield the cells from stray light. However, the outer end of the tubes are canted to increase the field from which direct rays from the sun will activate the photoelectric cells. Switching between control responsive to sun's rays and control by a computerized program is affected by a light level sensitive photoelectric cell. Further, the collector rotating and tilting drive mechanism is responsive to a stored computerized program that will effect return of the collector from a terminal position at sunset to an initial position for reactivation at sunrise of the following day.

4,291,191
Dahlberg, Reinhard, inventor; Licentia Patent-Verwaltungs GmbH, assignee. *Solar Cell Arrangement*. September 22, 1981.

A solar cell arrangement comprises a first plate or disc of light transmissive material, one side of the first plate or disc having a structure of light transmissive elevations tapering parabolically and cut off parallel to the surface of the plate or disc at the level of their focal points or lines, the structure having a layer of at least partially light transmissive electrically conductive material on the surface of the elevations and a second plate or disc of semiconductor or metallically conducting material, the plate or discs being assembled together to provide photovoltaic and electrical contacts between the said cut off surfaces, of one plate or disc and the surface of the other plate or disc such that light passing through the first plate is concentrated at the contacts.

4,291,318
Sansregret, Joseph L., inventor; Exxon Research & Engineering Co., assignee. *Amorphous Silicon MIS Device*. September 22, 1981.

The present invention relates to an amorphous silicon MIS device having an insulating oxide formed by the chemical oxidation of the silicon surface. A process comprising etchng the silicon surface followed by a treatment of the etched surface in a sulfur based oxidant forms a controlled thickness oxide layer, useful in modifying the junction forming characteristics of the semiconductor and additionally stabilizing the semiconductor properties of the photoconductive amorphous silicon.

4,291,323
Bachmann, Klaus J., inventor; Bell Telephone Laboratories, Incorporated, assignee. *Indium Phosphide Arsenide Based Devices*. September 22, 1981.

Devices based on $InAs_{1-x}P_x$ where $0.85 \leqslant x < 1$ show advantageous properties. An exemplary device is a rectifying diode formed from indium tin oxide deposited on the subject $InAs_{1-x}P_x$.

4,292,092
Hanak, Joseph J., inventor; RCA Corporation, assignee. *Laser Processing Technique for Fabricating Series-Connected and Tandem Junction Series-Connected Solar Cells into a Solar Battery*. September 29, 1981.

A method of fabricating series-connected and tandem junction series-connected solar cells into a solar battery with laser scribing.

4,292,093
Ownby, Gary W.; White, Clark W.; Zehner, David M., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Method Using Laser Irradiation for the Production of Atomically Clean Crystalline Silicon and Germanium Surfaces*. September 29, 1981.

This invention relates to a new method for removing surface impurities from crystalline silicon or germanium articles, such as off-the-shelf p- or n-type wafers to be doped for use as junction devices. The principal contaminants on such wafers are oxygen and carbon. The new method comprises laser-irradiating the contaminated surface in a non-reactive atmosphere, using one or more of Q-switched laser pulses whose parameters are selected to effect melting of the surface without substantial vaporization thereof. In a typical application, a plurality of pulses is used to convert a surface region of an off-the-shelf silicon wafer to an automatically clean region. This can be accomplished in a system at a pressure below 10^{-8} Torr, using Q-switched ruby-laser pulses having an energy density in the range of from 60 to 190 MW/cm^2.

4,292,342
Sarma, Kalluri R.; Rice, M. John, Jr.; Lesk, I. Arnold, inventors; Motorola, Inc., assignee. *High Pressure Plasma Deposition of Silicon*. September 29, 1981.

Polycrystalline silicon is deposited on the interior surface of a shaped container. The silicon is deposited by reacting hydrogen and a silicon bearing gas in the presence of a high pressure plasma. The silicon body is separated from the shaped container by utilizing thermal expansion shear stress.

4,292,343
Plaettner, Rolf; Kruehler, Wolfgang; Grabmaier, Josef, inventors; Siemens Aktiengesellschaft, assignee. *Method of Manufacturing Semiconductor Bodies Composed of Amorphous Silicon*. September 29, 1981.

Semiconductor bodies comprised of amorphous silicon are produced by sequentially depositing a plurality of amorphous silicon layers on a heat-resistant substrate by glow discharge in a silicon halide atmosphere at low pressures and low substrate temperatures, with each layer being hydrogenated with atomic hydrogen

before deposition of the next subsequent layer. The semiconductor bodies thus produced are useful as basic or raw materials for fabricating solar cells.

4,292,461
Hovel, Harold J., inventor; International Business Machines Corporation, assignee. *Amorphous-Crystalline Tandem Solar Cell*. September 29, 1981.

A high efficiency tandem solar cell may be fabricated wherein a layer of transparent conducting material is placed over a crystalline substrate and under an amorphous region. Light incident on the upper surface has higher energy photons absorbed in the higher bandgap amorphous material and lower energy photons pass through the transparent conductor to a point of absorption in the lower energy gap crystalline material.

4,292,959
Coburn, John F., Jr., inventor; Exxon Research & Engineering Co., assignee. *Solar Energy Collection System*. October 6, 1981.

A system is provided for the collection of electromagnetic radiation and the transmission of that radiation to a point of utilization in the form of light. Basically, the system employs a first solar concentrator for the collection and concentration of solar radiation. Optically coupled to the first solar concentrator is at least one additional solar concentrator for further concentrating the collected solar radiation for efficient coupling with a light pipe. Thus, the light pipe directs the collected and concentrated light to a point of utilization. Preferably, the solar concentrators are planar fluorescent solar concentrators having different fluorescent materials in each concentrator.

4,293,732
Rancourt, James D.; Seddon, Richard I., inventors; Optical Coating Laboratory, Inc., assignee. *Silicon Solar Cell and 350 Nanometer Cut-On Filter for Use Therein*. October 6, 1981.

Solar cell construction having a body formed essentially of silicon and having a surface with a photovoltaic junction applied thereon. An anti-reflection coating is formed on the surface. A transparent protective cover is provided. A cut-on filter is carried by the cover for reflecting solar energy below approximately 350 nanometers. A layer of substantially transparent cement is used for securing the protective cover to the body so that it overlies the junction and the anti-reflection coating. The cut-on filter includes a stack of high and low index layers for reflecting solar energy in the ultraviolet region of 350 nanometers and below, and also may include at least one additional layer of material of absorbing ultraviolet energy below 350 nanometers which passes through the high and low index layers above it.

4,293,808
Varadi, Peter F.; Dominguez, Ramon, inventors; Solarex Corporation, assignee. *Battery Charging Device Employing Solar Cells*. October 6, 1981.

A device utilizing solar energy cells to charge a battery or a plurality of batteries. An array of solar cells is disposed on a container having lid and tray parts. The parts are electrically interconnected to the solar cell array so that in container closed position the circuit including the solar cell array and the battery is closed to effect charging of the battery, and in container open position the circuit including the solar cell array and the battery is open with no flow of solar cell electrical output to the battery.

4,294,602
Horne, William E., inventor; The Boeing Company, assignee. *Electro-Optically Assisted Bonding*. October 13, 1981.

A method of bonding a cover glass to a semiconductor substrate having conductors thereon. The cover glass and the semiconductor substrate are placed in a relatively high voltage field and heated to induce ion drift in the glass and improved conductivity in the substrate. Additional localized heating softens the cover glass in the vicinity of the conductors permitting the cover glass to flow around the conductors and to be drawn into contact and bonded with the substrate.

4,294,811
Aulich, Hubert; Grabmaier, Josef, inventors; Siemens Aktiengesellschaft, assignee. *Process for Manufacturing Si Useful for Semiconductor Components from Quartz Sand*. October 13, 1981.

Relatively pure Si (having less than about 1 ppm of detrimental impurities therein) is obtained from ordinary quartz sand by uniformly admixing such sand with suitable glass-forming materials, such as boron oxide and alkali-metal carbonates or oxides, melting such admixture to form a glass, annealing the glass so as to obtain a phase separation comprised of an SiO_2-rich phase and an impurity-rich phase, extracting the impurity-rich phase via strong acid, such as nitric acid, washing and drying the remaining glass and reducing such glass with carbon-containing compounds, such as graphite, sucrose, statch, etc., in an electric arc. The so-obtained relatively pure silicon is suitable for fabrication into semiconductor components, such as solar cells.

4,295,002
Chappell, Terry I.; Woodall, Jerry M., inventors; International Business Machines Corporation, assignee. *Heterojunction V-Groove Multijunction Solar Cell*. October 13, 1981.

A solar cell is disclosed with V-grooves which are series connected, but electrically isolated, indirect bandgap solar cells which are responsive to different light frequencies on both sides of a semi-insulating optically transparent substrate. The device has a very high conversion efficiency of approximately 40% and high open circuit voltage and low series resistance. An exemplary structure in accordance with this disclosure has a series of silicon V-groove cells on one side and another series of GaAlAs V-groove cells on the other side. The cells are of generally trapezoidal cross-section. The difference between the characteristics of the Si Cell and the GaAlAs cell is matched by control of the number of V-grooves.

4,296,188
Hodes, Gary; Cahen, David; Manassen, Joost, inventors; Yeda Research and Development Company Ltd., assignee. *Cd(Se,Te) Alloy Photovoltaic Materials*. October 20, 1981.

A photovoltaic system comprising a Cd(Se,Te) alloy junction forming material. A process of preparing a thin layer of the alloy by electrodeposition and by application of a slurry of the alloy to a substrate which is then annealed at an elevated temperature. The junction forming material finds particular application in photoelectrochemical cell systems, particularly those containing $S/S^=$ electrolytes. Electrodes formed of the inventive materials exhibit increased efficiency and improved stability.

4,296,270
Köhler, Kranz, inventor; Messerschmitt-Bölkow-Blohm GmbH, assignee. *Array of Solar Cells*. October 20, 1981.

An arrangement or array of solar cells comprises a plurality of cells each having contacting connectors which establish an electrically conducting connection between the individual solar cells. Each solar cell has a connector which projects slightly from the edge thereof and is of a selected profile or shape such that the contacting connectors of adjacent cells may be overlapped and connected to each other for electrical connection in an arrangement in which they do not come in contact with each other adjacent the solar cells.

4,296,731
Cluff, C. Brent, inventor. *Tracking Booster and Multiple Mirror Concentrator Floating Collector*. October 27, 1981.

A water-borne tracking solar energy collecting and converting system employing booster and multiple mirror concentrator collectors for concentrating sunlight on photovoltaic cells and/or flat plate collectors.

4,297,391
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Applying Electrical Contacts to a Photovoltaic Cell*. October 27, 1981.

A method of forming an electrical contact on the surface of a photovoltaic cell in which particles of electrically conductive material are formed at a temperature in excess of the alloying temperature of the material and silicon, and thereafter spraying, e.g., flame spraying, arc spraying, or plasma spraying, the particles to one or both major surfaces of the cell so that the particles alloy with the silicon and adhere to the surface of the cell.

4,297,521
Johnson, Steven A., inventor. *Focusing Cover Solar Energy Collector Apparatus*. October 27, 1981.

A solar energy collector apparatus and method, the apparatus including an open-top shell structure configured with either an enclosed or lattice configuration and having a Fresnel lens system covering the open top of the shell structure. A mirror system and solar energy absorber apparatus are placed inside the shell structure. The shell structure is mounted upon a hollow axle for rotation about its longitudinal axis. The shell structure is also mounted for vertical movement of one end of the longitudinal axis to adapt the shell structure for following north-south changes in the sun's seasonal position. The hollow axle supports the solar energy absorber apparatus nonrotatably inside the shell structure and in fluid communication with insulated heat transfer conduits that pass nonrotatably through the hollow axle. A photovoltaic apparatus may be included in the shell structure for converting at least a portion of the solar flux to electrical energy while the heat transfer conduits supply any necessary cooling to the photovoltaic apparatus. This combination of features provides higher solar efficiencies and higher temperatures in the heat transfer fluid. The method includes tracking the sun with the solar energy collector apparatus thereby maximizing the amount of solar energy collected while eliminating twisting and thereby coupling failures in the heat transfer conduits.

4,297,717
Li, Chou H., inventor. *Semiconductor Device*. October 27, 1981.

A method of making hybrid solar cell comprising eutectically forming a vertical multi-junction solar cell having vertical photovoltaic junctions in the form of Schottky barriers and/or PN junctions and comprising a plurality of vertically elongated bodies of a first semiconductor material and a plurality of similarly elongated metal bodies which contact the semiconductor material bodies and space them from each other. All the bodies terminate at a common termination surface. The method also includes providing a horizontal solar cell comprising a layer of a second semiconductor layer deposited on the common, horizontal termination surface. The horizontal semiconductor layer has photovoltaic junctions either located at the common termination surface, or separating it into two horizontal sublayers, or both. The vertical and horizontal solar cells are so electrically interconnected that the output voltage of the hybrid cell is the sum of the output voltages of the two cells making it up. The material of the horizontal layer has a band gap different from that of the vertical semiconductor material bodies, and the solar cell with the wider band gap semiconductor material faces the sun. Structures of hybrid solar cells are also disclosed.

4,298,410
Nakajima, Koichiro; Watanabe, Masaharu, inventors; Tokyo Shibaura Denki Kabushiki Kaisha, assignee. *Method for Growing a Liquid Phase Epitaxial Layer on a Semiconductor Substrate*. November 3, 1981.

A method for selectively growing a liquid phase epitaxial layer on a semiconductor substrate comprises a first step of supplying a liquid phase epitaxial solution in a chamber of an upper body and supplying a semiconductor substrate on which is selectively coated an insulating layer in a recess in an under body, the upper surface of which constituting the bottom of said chamber; a second step of heating said semiconductor substrate and said solution to a predetermined temperature and sliding said upper body and said under body relative to each other so as to position said chamber above said recess, thereby effecting contact between said solution and said semiconductor substrate; a third step of effecting said sliding again so as to separate said recess and said chamber so that said solution remains on the regions of said semiconductor substrate surface on which said insulating layer is not coated; and a fourth step of cooling said solution and said semiconductor substrate at a constant cooling rate so as to grow a liquid phase epitaxial layer.

4,298,423
Lindmayer, Joseph, inventor; Semix Incorporated, assignee. *Method of Purifying Silicon*. November 3, 1981.

A method of purifying silicon, in which the silicon is heated to a molten state, contacted with a gas inert to silicon to remove impurities, and thereafter cooled to a solid state.

4,298,587
Kapur, Vijay K., inventor; Atlantic Richfield Company, assignee. *Silicon Purification*. November 3, 1981.

A method for purifying silicon which employs an electrolytic step using a metal fluoride electrolysis to generate silicon fluoride followed by a chemical reaction step which produces elemental silicon in a highly pure form.

4,298,802
Quella, Ferdinand; Pape, Heinz, inventors; Siemens Aktiengesellschaft, assignee. *Method and Device for Collecting Light Utilizing a Light Trap*. November 3, 1981.

A method and a device for collecting light characterized by a body which acts as a light trap, contains at least two different groups of fluorescent particles with each group having an absorption range and light emitting range which are different from the other groups, and has at least one light decoupling window to emit the fluorescent light therefrom.

4,299,648
Ciszek, Theodore F.; Schwuttke, Guenter H., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Method and Apparatus for Drawing Monocrystalline Ribbon from a Melt*. November 10, 1981.

A method and apparatus for drawing a monocrystalline ribbon or web from a melt comprising utilizing a shaping die including at least two elements spaced one from the other, each having a portion thereof located below the level of the melt and another portion located above the level of the melt a distance sufficient to form a raised meniscus of melt about the corresponding element.

4,301,321
Bartels, Frederick T. C., inventor; Spectrolab, assignee. *Two-Axis Focusing Energy Concentrator*. November 17, 1981.

A focusing multi-point high-concentrator optical system is disclosed. The system is useful for concentrating energy such as solar radiation for use in solar energy conversion systems. The configuration of the optical system incorporates thin metallized

Fresnel reflector elements applied to panels formed into focusing surfaces having a common axis. The Fresnel elements are oriented axially to the axis of the focusing surfaces. The optical configuration produces a substantially rectangular focal zone centered over each panel. For a plurality of panels of a given width, there will be a plurality of focal zones, each separated by a distance equivalent to the panel width. At least one energy absorber is maintained substantially at each focal zone and may comprise a photovoltaic cell, thermal absorber, etc. and combinations thereof.

4,301,322
Amick, James A., inventor; Exxon Research & Engineering Co., assignee. *Solar Cell with Corrugated Bus*. November 17, 1981.

The invention teaches an improved bus for current collection in photovoltaic solar cells. The bus is prefabricated from a highly conductive metal and is corrugated to compensate for differences in thermal coefficients of expansion between the bus and the solar cell body.

4,301,323
Schink, Norbert, inventor; Siemens Aktiengesellschaft, assignee. *Lead-Doped Silicon with Enhanced Semiconductor Properties*. November 17, 1981.

Silicon having semiconductor properties, adapted for use as an optoelectronic component, in particular solar cells, has its optoelectronic properties improved by adding to the silicon an agent, preferably lead, which increases the carrier lifetime.

4,301,409
Miller, Emmett L.; Shumka, Alex; Gauthier, Michael K., inventors; California Institute of Technology, assignee. *Solar Cell Anomaly Detection Method and Apparatus*. November 17, 1981.

A method is provided for detecting cracks and other imperfections in a solar cell, which includes scanning a narrow light beam back and forth across the cell in a raster pattern, while monitoring the electrical output of the cell to find locations where the electrical output varies significantly. The electrical output can be monitored on a television type screen containing a raster pattern with each point on the screen corresponding to a point on the solar cell surface, and with the brightness of each point on the screen corresponding to the electrical output from the cell which was produced when the light beam was at the corresponding point on the cell. The technique can be utilized to scan a large array of interconnected solar cells to determine which ones are defective.

4,301,592
Lin, Hung Chang, inventor. *Method of Fabricating Semiconductor Junction Device Employing Separate Metallization*. November 24, 1981.

A method of fabricating a p-n junction device such as solar cells using metal contacts for p regions and n region heat-treated at two different temperatures. A metal with low work functions is heated first to a high temperature for making ohmic contact to a p-type semiconductor substrate, and then at low temperature for contacting the n-type region. A metal with high work function is heated first to a high temperature for contacting an n-type semiconductor substrate and then at low temperature for contacting the p-type region.

4,303,463
Cook, Melvin S., inventor. *Method of Peeling Thin Films Using Directional Heat Flow*. December 1, 1981.

A method is disclosed for peeling thin layers of crystal from the substrates on which they have been grown. A thin layer of single-crystal material is grown on a single-crystal substrate having a lower melting point temperature than the layer. The layer and substrate are then brought to the melting point temperature of the substrate material, and the layer is contacted to a hot object so that heat flows through the layer to the substrate for liquifying the substrate material contiguous to the layer. The layer is peeled from the substrate where such liquification has occurred.

4,304,607
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Photovoltaic Cell*. December 8, 1981.

A photovoltaic cell having an elctrically conductive substrate, which may be glass having a film of conductive tin oxide; a first layer containing a suitable semiconductor, which layer has a first component film with an amorphous structure and a second component film with a polycrystalline structure; a second layer forming a heterojunction with the first layer; and suitable electrodes where the heterojunction is formed from a solution containing copper, the amorphous film component is superposed above an electrically conductive substrate to resist permeation of the copper-containing material to shorting electrical contact with the substrate. The penetration resistant amorphous layer permits a variety of processes to be used in forming the heterojunction with even very thin layers (1-6μ thick) of underlying polycrystalline semiconductor materials. In some embodiments, the amorphous-like structure may be formed by the addition of aluminum or zirconium compounds to a solution of cadmium salts sprayed over a heated substrate.

4,304,763
Dietl, Josef; Wohlschläger, Michael, inventors; Consortium fur Elektrochemische Industrie GmbH, assignee. *Process for Purifying Metallurgical-Grade Silicon*. December 8, 1981.

A process is provided for purifying metallurgical-grade silicon for the manufacture of solar cells, wherein the acid treatment of the silicon, known per se, is combined with vacuum evaporation. This may be optionally combined with slag extraction and directional solidification.

4,304,955
Meckler, Gershon, inventor; Energy Integrated Systems, Inc., assignee. *Solar Energy Collector*. December 8, 1981.

A solar energy collector is disclosed. The collector includes a photo-voltaic cell, a reflector for directing solar energy from the sun to the photo-voltaic cell, a mount for the reflector, vacuum means and positioning means for the reflector. The vacuum means separates the photo-voltaic cell and the reflector from the atmosphere to prevent conduction and convection heat losses therefrom and corrosion of the reflector. The mounting means supports the reflector within the vacuum means for rotation about an axis along which the photo-voltaic cell extends. The positioning means is operable to produce a magnetic field which attracts a ferromagnetic portion of the reflector, and to rotate the magnetic field about the axis to cause rotation of the reflector and maximizing the amount of solar energy directed to the photo-voltaic cell.

4,305,776
Grabmaier, Josef, inventor; Siemens Aktiengesellschaft, assignee. *Method for Producing Disc or Band-Shaped Si Crystals with Columnar Structure for Solar Cells*. December 15, 1981.

Si-crystals with columnar structures are produced by contacting a silicon melt with a melt-resistant carrier body having periodically spaced crystallization-seed centers on a surface thereof facing the melt, establishing a controlled temperature gradient at the interface between the carrier body surface and the melt so that crystallization of the melt onto the seed centers occurs and then removing the body with the adhering crystal layer from the melt. In a preferred embodiment, an elongated traveling web having a select hole pattern therein functioning as the seed centers is utilized as a carrier body.

4,306,183
Wright, Maurice J., inventor; Lucas Industries Limited, assignee. *Voltage Regulation Circuit for a Solar Cell Charging System*. December 15, 1981.

A voltage regulation circuit includes an active integrator circuit which generates an output signal representing the time integral of the error between the voltage across a load and a reference voltage. The integrator circuit output is connected to a series of voltage comparators (each having hysteresis), each of which controls one of a series of separate switch elements each controlling a proportion of the total current flow from a source to the load.

4,307,680
Haigh, John; Faktor, Marc M.; Moss, Rodney H., inventors; London Post Office, assignee. *Growth of Semiconductor Compounds*. December 29, 1981.

Semiconductor compounds which are alloys of group III-V compounds are grown by a liquid phase epitaxy method which includes heating growth apparatus in a reducing atmosphere while maintaining a solvent for the compound, a source of the group III-V compound and another element of the alloy separate from each other. After heating to reduce oxides, the element is added to the solvent, the source is brought into contact with the solvent and the resulting solution is brought into contact with a substrate to effect growth of the compound. Apparatus for carrying out the method is also described.

4,307,681
Lampkin, Curtis M.; Roderick, Guy A.; Locke, Peter, inventors; Photon Power, Inc., assignee. *Apparatus for Quality Film Formation*. December 29, 1981.

Methods and apparatus are provided for forming films of materials which are component layers of solar energy conversion devices, e.g. photovoltaic cells and heat collector panels. A selected substrate, generally glass, is heated while being sprayed with solutions which react on the heated surface to form a particular film. Films of SnO_x and CdS are particularly produced. According to the present invention, a thermal energy input gradient is provided to apoproximate the energy loss gradient during the spray process. Radiative heaters provide a rapid resupply of energy to the substrate and, in some instances, directly to the film forming surface. Temperature detectors, such as thermocouples, monitor substrate temperature to provide the radiative energy input needed for substantial temperature uniformity.

4,308,245
Dietl, Josef; Holm, Claus, inventors; Heliotronic Forschungs- und Entwicklungsgesellschaft fur Solarzellen-Grundstoffe mbH, assignee. *Method of Purifying Metallurgical-Grade Silicon*. December 29, 1981.

A method of purifying metallurgical-grade silicon for the production of silicon solar cells is provided, in which metallurgical-grade silicon is dissolved in aluminum and brought into contact with an aluminum sulphide extraction melt. Thereafter, the silicon is crystallized out and separated off by cooling the melt to a minimum temperature of 600°C. The aluminum melt remaining can then be recharged with silicon, heated, brought into contact with the extraction melt, so that additional silicon can be crystallized out.

1982

4,309,225
Fan, John C. C.; Zieger, Herbert J., inventors; Massachusetts Institute of Technology, assignee. *Method of Crystallizing Amorphous Material with a Moving Energy Beam*. January 5, 1982.

An improved method for crystallizing amorphous material with a moving beam of energy is disclosed. In this method, the energy beam is scanned in a manner to provide controlled, continuous motion of the crystallization front.

4,309,239
Rodot née Fumeton, Huquette, inventor; Agence Nationale de Valorisation de la Recherche, assignee. *Method and Means for Manufacturing Mono-Crystalline Silicon in Tape Form*. January 5, 1982.

This invention relates to a process for manufacturing monocrystalline silicon. According to this process, the fused zone is formed on a cylinder of polycrystalline silicon and a film is "drawn" by means of a seed-plate. The fused zone is obtained by resorting to heating means, notably one or several electron guns whose beam is situated in a plane. By means of this process, monocrystalline silicon is manufactured in the form of tape.

4,309,241
Garavaglia, Paul M.; Gutsche, Henry W., inventors; Monsanto Company, assignee. *Gas Curtain Continuous Chemical Vapor Deposition Production of Semiconductor Bodies*. January 5, 1982.

Apparatus and process for producing electronic-grade semiconductor bodies are disclosed wherein continuously-pulled slim rod, which can be formed in situ from the reaction of a seed crystal and a molten semiconductor material source, is pulled into and through a chemical vapor deposition chamber, having a gas curtain along the inner wall, the slim rod surface being preheated before entry into the deposition chamber where it is simultaneously exposed to focused heating and thermally decomposable gaseous compounds in order to provide suitable surface reaction conditions on the slim rod for the decomposition of the gaseous compounds which results in deposition growth upon the surface of the rod. Single crystal semiconductor bodies are produced according to the process by avoiding poly-growth conditions through the in situ continuously pulled virgin slim rod, preheating of the slim rod for entry into the chemical vapor deposition chamber wherein the rod is simultaneously heated or maintained at reaction temperature conditions while being exposed or contacted with elected thermally decomposable gaseous compounds and continuously drawn through the chemical vapor deposition chamber reaction zone resulting in an enlarged single crystal semiconductor body which is withdrawn continuously from the chemical vapor deposition chamber.

4,309,460
Singh, Shobha; Van Uitert, LeGrand G.; Zydzik, George J., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Process for Producing Gold Films*. January 5, 1982.

A process is described for producing devices and articles with gold films made by gold evaporation in which certain fluoride compounds are used to insure good adhesion of the gold film to the substrate. The process is particularly applicable to the production of gold films on non-metallic surfaces such as ceramic and glass surfaces. This procedure not only insures better adhesion of the gold film to the surface, but also permits greater processing variations without adversely affecting film adhesion.

4,310,211
Bunnell, Edward D.; Sotolongo, Thomas J., inventors; AMP Incorporated, assignee. *High Current Contact System for Solar Modules*. January 12, 1982.

A high current connector system is disclosed for use with photovoltaic modules of the type employed by the solar energy industry. The connector provides quick and positive means of connecting an array of solar cells in a module to a common bus and with a harness connector. The connector is configured to protect against inadvertent electrical shock during mating or unmating of the connector. The connector plug member has a two stage assembly which in the first stage allows for free passage for a conductor through the plug housing and in the second assembly stage provides an environmentally sealed condition for the plug with the seal also serving as a strain relief for the conductor.

4,310,405
Heller, Adam, inventor; Bell Telephone Laboratories, Incorporated, assignee. *Device for the Photoelectrochemical Generation of Hydrogen at P-Type Semiconductor Electrodes*. January 12, 1982.

A device having a p-type electrode comprising InP or Si and an electrolyte comprising a redox couple and a hydrogen catalyst evolves hydrogen at the p-type electrode when illuminated.

4,310,987
Chieffo, Joseph M., inventor. *Amusement Device*. January 19, 1982.

A rolling amusement device powered by light falling on solar cells wherein the solar cells constantly face the light source.

4,311,728
Sansregret, Joseph L., inventor; Exxon Research & Engineering Co., assignee. *Method for Depositing Photoconductive Zinc Tin Phosphide*. January 19, 1982.

Invention teaches a combined chemical vapor deposition/thermal ion exchange method for producing photoconductive thin films of zinc tin phosphide. A layer of tin oxide is converted to zinc tin phosphide by annealing in the presence of gaseous phosphine and zinc metal vapor or zinc chloride vapor. The thin film zinc tin phosphide taught by the present invention is amenable to use in large area applications such as solar cells and the like.

4,311,869
Kurth, William T.; Andrulitis, William B., inventors; Exxon Research & Engineering Co., assignee. *Solar Cell Modules*. January 19, 1982.

Solar cell modules having light scattering surfaces at least in the land areas between a plurality of arrayed solar cells and optically coupled to the cells by means of an internally reflective plate having a planar surface of incidence and an opposed textured surface provide increased module output. Insolation impinging on the light scattering surfaces is diffused upwardly through the optical coupling medium and then downwardly toward a solar cell, thereby increasing the output of the module.

4,311,870
Salama, Amal M., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Efficiency of Silicon Solar Cells Containing Chromium*. January 19, 1982.

Efficiency of silicon solar cells containing about 10^{15} atoms/cm^3 of chromium is improved about 26% by thermal annealing of the silicon wafer at a temperature of 200°C to form chromium precipitates having a diameter of less than 1 Angstrom. Further improvement in efficiency is achieved by scribing laser lines onto the back surface of the wafer at a spacing of at least 0.5 mm and at a depth of less than 13 micrometers to preferentially precipitate chromium near the back surface and away from the junction region of the device. This provides an economical way to improve the deleterious effects of chromium, one of the impurities present in metallurgical grade silicon material.

4,311,953
Fukuda, Hiroaki; Sasaki, Takehiko; Mori, Hiroshi, inventors; Sharp Kabushiki Kaisha, assignee. *Charger Using One or More Solar Batteries*. January 19, 1982.

A charger, which is useful to power a variety of compact type electronic appliances such as an electronic wristwatch, includes one or more solar batteries as a primary battery, and a sealed type silver oxide battery as a secondary battery. Both the amount of charging current amplitude and of charging voltage are limited to protect the sealed silver oxide battery from its own expanse phenomenon.

4,312,330
Holdridge, David W., inventor; Swedlow, Inc., assignee. *Focusing Device for Concentrating Radiation*. January 26, 1982.

A focusing device for concentrating radiation, such as sunlight, and producing a prescribed distribution of energy over a target surface. The principles of the device have both photovoltaic and photothermal applications, and can be embodied in either a lens or a mirror, having a plurality of discrete focusing surfaces for redirecting radiation onto a target surface. The angle for each of the respective focusing surfaces, relative to the direction of the radiation being received, is selected to redirect an increment of such radiation to a unique portion of the target surface, whereby a superposition of the radiation increments redirected by all of the focusing surfaces produces the prescribed distribution of energy on the target. In one embodiment, a plurality of focusing segments is provided each having a plurality of the focusing surfaces for irradiating the target surface with a prescribed energy distribution. Apparatus is provided for selectively masking predetermined ones of the focusing segments for controllably adjusting the magnitude of light energy concentrated upon the target surface in a plurality of known and discrete steps.

4,312,700
Helmreich, Dieter; Sirtl, Erhard; Zöllner, Theo, inventors; Helictronic Forschungs- und Entwicklungs- Gesellschaft fur Solarzellen-Grundstoffe mbH, assignee. *Method for Making Silicon Rods*. January 26, 1982.

To make solar energy competitive, as compared against other sources of energy, inexpensive solar cells are required. To accomplish this goal, a method is provided which enables one to produce silicon rods having a columnar structure made of monocrystalline zones with preferential crystallographic orientation. This is effected by feeding a silicon melt into a crystallization chamber having a vertically movable cooled bottom face under the influence of a temperature gradient directed parallel to the rod axis, so that the rods can be made continuously or semicontinuously with high drawing speeds.

4,313,022
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Solar Cell Array*. January 26, 1982.

An array of photovoltaic cells in a back wall-type configuration supported by a rigid transparent vitreous substrate, such as glass, for admitting incident radiation to the cells. A plurality of cells are interconnected into a desired electrical configuration by one or more layers of electrically conducting materials which overlie the entire heterojunction of each cell to minimize the internal resistance of the cell and may conveniently protect the heterojunction form degrading environmental conditions. Various component layers forming the photovoltaic cells are selectively removed and strips of insulating material are applied prior to forming the heterojunction. The electrically conductive material is thereafter applied and separated at areas protected by insulating material. The resulting series array contains no exposed heterojunction areas, thereby obtaining improved operating stability and performance.

4,313,023
Stephens, Richard B., inventor; Exxon Research & Engineering Co., assignee. *Solar Cell Module*. January 26, 1982.

A solar cell module is provided in which a plurality of solar cells is linearly arrayed on a support structure, preferably in a close packed configuration. Adjacent the linearly arrayed cells is a lengthwise land area having facets with light reflective surfaces, the grooves defined by the facets running the length of the linearly arrayed cells. A light transparent optical medium couples the facets and the solar cells. Importantly the facet surfaces are angularly disposed at a predetermined angle such that solar radiation incident on the facet surface will be reflected upwardly into the optical medium where it will be internally reflected downwardly onto a solar cell thereby enhancing the output of the module.

4,313,024
Horne, William E., inventor. *Conversion of Solar to Electrical Energy*. January 26, 1982.

Solar energy is collected by a concave mirror and directed onto a body located within a container which is lined with solar cells. The heated body radiates energy to the solar cells. The solar cells convert a portion of such radiated energy to electricity. Another portion is converted to heat which is removed by a heat exchanger. A third portion of the radiated energy which is not absorbed by the solar cells or their support structure is reflected back to the radiating body to help maintain its temperature.

4,313,078
Bilsky, Herbert W.; Callen, Patrick J., inventors; RCA Corporation, assignee. *Battery Charging System*. January 26, 1982.

A highly efficient battery charging system in which the ampere-hour discharge of the battery is sensed for controlling the battery charging rate. The battery is charged at a relatively high charge rate during a first time period proportional to the extent of battery discharge and at a second lower rate thereafter.

4,313,254
Feldman, Charles; Charles, Harry K.; Satkiewicz, Frank G., inventors; The Johns Hopkins University, assignee. *Thin-Film Silicon Solar Cell with Metal Boride Bottom Electrode*. February 2, 1982.

The invention relates to an improved thin film semiconductor p-n junction device and its method of fabrication, utilizing vacuum deposition techniques, whereby continuous/batch processing may be utilized, capable of mass producing p-n junction devices, e.g. solar cells, with large surface areas and good operating efficiency and at low cost. A novel feature of the proposed device and its method of fabrication is the formation of the bottom electrode of the device, located between the nonconducting substrate and the overlying silicon semiconductor layer, as a metal boride region which possesses several characteristics particularly necessary to the fabrication of thin film silicon solar cells for example, having improved structural and operating properties, as well as good operating efficiency.

4,314,128
Chitre, Sanjeev R., inventor; Photowatt International, Inc., assignee. *Silicon Growth Technique and Apparatus Using Controlled Microwave Heating*. February 2, 1982.

Control of thermal gradients in a crystal being pulled from a melt is achieved using stratified microwave coupling. Plural microwave radiators are arranged along the crystal path. The radiators are driven by power sources having stepped energy levels so that the radiated microwave energy heats successive regions of the crystal to progressively decreasing temperature levels. Each power source is swept in frequency, thereby controlling the depth of heating so as to achieve at each region a selected lateral temperature distribution (e.g., constant temperature across the crystal). Advantageously, the shape of each cavity conforms to the cross-sectional geometry of the crystal being pulled, which may be non-circular. This facilitates the growth of crystals having rectangular, trapezoidal or other shapes. In such embodiment, the frequency sweep range, and possibly power, is separately controlled at different locations about the crystal so as to achieve the desired lateral temperature distribution.

4,314,192
Caro, Charles R., inventor; CWM Corporation, assignee. *Electrical Power Generation Apparatus and Method Utilizing Electron Beam Discharge*. February 2, 1982.

An apparatus and a method for generating electrical current in which electron beams are discharged through a succession of elongate electron beam channels arranged in a parallel array while a magnetic field is imposed on the array with flux directed perpendicularly to the longitudinal axes of the channels. Beams are directed successively through channels spaced one from another in a direction generally perpendicularly to both the axes of the channels and the magnetic flux. Electrical energy for operating the apparatus is derived from a suitable low current source such as a photovoltaic or solar cell.

4,314,198
Rogers, William E., inventor; Solar Physics, Inc., assignee. *Solar Power Source for a Lighting System*. February 2, 1982.

A solar recharged power supply circuit for a lighting system which circuit includes a rechargeable power source, a solar powered recharger connected to that rechargeable power source and which circuit prevents discharge of that rechargeable power source through the solar powered recharger during times when the recharger is inactive; prevents overcharging of that power source; prevents discharging that power source below a predetermined level; and automatically connects and disconnects the lighting system to and from the rechargeable power source.

4,314,525
Hsu, George C.; Levin, Harry; Hogle, Richard A.; Praturi, Ananda; Lutwack, Ralph, inventors; California Institute of Technology, assignee. *Fluidized Bed Silicon Deposition from Silane*. February 9, 1982.

A process and apparatus for thermally decomposing silicon containing gas for deposition on fluidized nucleating silicon seed particles is disclosed. Silicon seed particles are produced in a secondary fluidized reactor by thermal decomposition of a silicon containing gas. The thermally produced silicon seed particles are then introduced into a primary fluidized bed reactor to form a fluidized bed. Silicon containing gas is introduced into the primary reactor where it is thermally decomposed and deposited on the fluidized silicon seed particles. Silicon seed particles having the desired amount of thermally decomposed silicon product thereon are removed from the primary fluidized reactor as ultra pure silicon product. An apparatus for carrying out this process is also disclosed.

4,315,096
Tyan, Yuan-Sheng; Perez-Albuerne, Evelio A., inventors; Eastman Kodak Company, assignee. *Integrated Array of Photovoltaic Cells Having Minimized Shorting Losses*. February 9, 1982.

There are disclosed an integrated array of photovoltaic cells each comprising, on a support, a first electrode segment, a semiconductor segment, and a second electrode segment; and a process for making it, wherein no insulating material need be applied to exposed semiconductor materials before applying the second electrode segment. The array is composed of sub-cells, groups of which are series-connected to form sub-arrays. The sub-arrays are in turn connected in parallel so that a short in any one sub-cell only minimally affects the output of the entire array.

4,315,097
Solomon, Allen L., inventor; McDonnell Douglas Corporation, assignee. *Back Contacted MIS Photovoltaic Cell*. February 9, 1982.

This photovoltaic cell in a principal embodiment comprises a P-type substrate having an unshadowed first surface adapted to receiving incident radiation and a second surface which contains at least one ohmic contact and at least one metal-insulator-semiconductor contact, this structure thereby forming a back contacted minority carrier MIS cell.

4,315,973
Manassen, Joost; Hodes, Gary; Cahen, David, inventors; Yeda Research and Development Co., assignee. *Photoelectrochemical Cell Assembly Having Electrolyte Contacts between Semiconductor Surfaces*. February 16, 1982.

An assembly comprising at least two semiconductor electrodes, each of the semiconductor electrodes having a positive and negative surface, and an electrolyte for electrically connecting

the surfaces of opposite polarity of said semiconductor electrodes, the electrolyte comprising at least one redox couple capable of a reversible redox reaction with one of said surfaces of opposite polarity of said semiconductor electrodes whereby the composition of said electrolyte remains substantially unchanged as charge is passed between said electrodes.

An electrolysis assembly for electrolyzing a liquid comprising an electrolysis compartment connected with the above assembly.

4,316,048
Woodall, Jerry M., inventor; International Business Machines Corporation, assignee. *Energy Conversion*. February 16, 1982.

Energy conversion capable of receiving input energy in thermal or radiant form at a variable rate and releasing energy in thermal, radiant or electrical form independent of rate is accomplished by providing a buffer member of a material that has three criteria, a melting temperature above 1300°K, a thermal conductance greater than 0.1 in calories per square centimeter per centimeter per degree per second, and a latent heat of fusion on the order of 1 kilocalorie per mole. The converter can absorb energy of multiple types, store it and then release it in a form compatible with the prospective use. Sunlight of daylight duration and varying intensity is converted to steady 24 hour a day electrical output.

4,316,049
Hanak, Joseph J., inventor; RCA Corporation, assignee. *High Voltage Series Connected Tandem Junction Solar Battery*. February 16, 1982.

A high voltage series connected tandem junction solar battery which comprises a plurality of strips of tandem junction solar cells of hydrogenated amorphous silicon having one optical path and electrically interconnected by a tunnel junction. The layers of hydrogenated amorphous silicon, arranged in a tandem configuration, can have the same bandgap or differing bandgaps. The tandem junction strip solar cells are series connected to produce a solar battery of any desired voltage.

4,316,448
Dodge, Robert J., inventor; Pennwalt Corporation, assignee. *Solar Energy Concentrator System*. February 23, 1982.

Solar energy concentrator system employs structure permitting ready adjustability of flexible sheet concentrators to maximize solar radiation reflectability therefrom in accordance with seasonal posture of the sun. The invention utilizes structural components which represent various parameters of an ellipse. Thus, the concentrators are shaped in the form of an inverted-V and their apexes shiftable, by means of a pivotable rod, along a curve of substantially constant radius when the free ends of the concentrators are substantially secured at points forming the foci of the ellipse to thereby vary the angles the faces of the concentrators make with the sun.

4,317,689
Bowers, John E.; Schmit, Joseph L., inventors; Honeywell, Inc., assignee. *Mercury Containment for Liquid Phase Growth of Mercury Cadmium Telluride from Tellurium-Rich Solution*. March 2, 1982.

$Hg_{1-x}Cd_xTe$ is an important semiconductor for use in photovoltaic and photoconductive infrared photon detectors. $Hg_{1-x}Cd_xTe$ can be grown by liquid phase epitaxy at atmospheric pressure from a Te-rich solution in which case the Hg vapor pressure is below 0.1 atm at 500°C. This low vapor pressure makes possible the use of open-tube, slider growth techniques. The present invention describes a covered graphite slider system which provides an additional source of Hg, minimizes loss of Hg from the source wafer and virtually prevents loss of Hg from the $(Hg_{1-x}Cd_x)_{1-y}Te_y$ growth solution.

4,318,938
Barnett, Allen M.; Baron, Bill N.; Masi, James V.; Russell, T. W. Fraser, inventors; The University of Delaware, assignee. *Method for the Continuous Manufacture of Thin Film Solar Cells*. March 9, 1982.

A technique for manufacturing durable, reliable solar cells by a continuous process suitable for large-scale manufacture involves, in substance, providing a reel of thin metal foil substrate and forming on the substrate a series of layers operative to form a photovoltaic junction, short prevention blocking layers, contacts and integral encapsulation. The foil substrate is processed as a continuous reel substantially until final testing at which point, if desired, it can be cut into individual cells for deployment. In comparison with a batch process, the continuous technique can reduce manufacturing cost by as much as a factor of two.

4,318,942
Woerner, Lloyd M.; Moore, Edward B., inventors; J. C. Schumacher Company, assignee. *Process for Producing Polycrystalline Silicon*. March 9, 1982.

An economical, low temperature, closed loop, thermal decomposition process is provided for producing a controllable mixture of heterogeneously and homogeneously nucleated ultrahigh purity polycrystalline silicon suitable for use in the manufacture of semiconductor devices and photovoltaic solar cells. The process manipulates the equilibrium expressed by the chemical reaction $Si + 2H_2 + 3SiBr_4 \underset{\leftarrow 750°C}{650°C \rightarrow} 4SiHBr_3$.

4,319,069
Tyan, Yuan-Sheng, inventor; Eastman Kodak Company, assignee. *Semiconductor Devices Having Improved Low-Resistance Contacts to p-Type CdTe, and Method of Preparation*. March 9, 1982.

There are disclosed a semiconductor device comprising a layer of polycrystalline p-type CdTe and a variety of metals in low-resistance contact, and a process and preferred etchant for obtaining the contact. A layer comprising tellurium is provided between the metal contact and the layer of p-type CdTe. The surface portion of the CdTe layer adjacent to the tellurium-containing layer is cadmium-deficient, and the grain boundaries of the CdTe layer are preserved intact.

4,319,187
Crandall, Richard S., inventor; RCA Corporation, assignee. *Method for Measuring the Drift Mobility in Doped Semiconductors*. March 9, 1982.

A method for measuring the drift mobility of majority carriers in semiconductors consists of measuring the current transient in a Schottky-barrier device following the termination of a forward bias pulse. An example is given using an amorphous silicon hydrogenated material doped with 0.2% phosphorous. The method is particularly useful with material in which the dielectric relaxation time is shorter than the carrier transit time. It is particularly useful in material used in solar cells.

4,319,310
Kingsley, Vernon T., inventor. *Solar Signs*. March 9, 1982.

Self-contained solar signs utilizing incident solar energy employing solar cells or thermal absorbers for generating electricity which is stored and later used for energizing sign illuminating lamp or lamps.

Des. 263,393
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Solar Cell*. March 16, 1982.

The ornamental design for a solar cell, as shown and described.

4,319,953
Grabmaier, Josef, inventor; Siemens Aktiengesellschaft, assignee. *Method for Producing Disc or Band-Shaped Si Crystals with Columnar Structure for Solar Cells*. March 16, 1982.

Si-crystals with columnar structures are produced by casting a silicon melt through a gap provided in a crucible onto a melt-resistant carrier body having periodically spaced crystallization-seed centers on a surface thereof facing the melt, and allowing the so-cast molten silicon to cool so that crystallization of the melt onto the seed centers occurs. In a preferred embodiment, an elongated traveling band-shaped substrate having a select hole pattern therein functioning as the seed centers, is utilized as the carrier body.

4,320,154
Biter, William J., inventor; Westinghouse Electric Corp., assignee. *Method of Forming Solar Cells by Grid Contact Isolation*. March 16, 1982.

A solar cell structure is produced by a method comprising baking the solar cell, containing a gridded top layer of cuprous sulfide formed on a base of cadmium sulfide, for 20 minutes to 10 hours, to produce a copper doped CdS electrically insulating region in the cadmium sulfide base near the interface of the cuprous sulfide and the cadmium sulfide; removing the cuprous sulfide, and the copper doped CdS insulating region not covered by the grid, to provide a bare cadmium sulfide area; and then forming a cuprous sulfide layer on the exposed areas not covered by the grid.

4,320,168
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Forming Semicrystalline Silicon Article and Product Produced Thereby*. March 16, 1982.

A method of forming a semicrystalline silicon solar energy cell having individual grains of silicon at the light-receiving surface of the cell. Impurities in the silicon concentrated in the grain boundaries are removed by etching away at least substantial portions of the boundaries at the wafer surface and between adjoining grains so that, upon subsequent diffusion, a photovoltaic junction will be formed at the light-receiving surface and will extend into the interior of the wafer between adjoining grains.

4,320,246
Russell, George F., inventor. *Uniform Surface Temperature Heat Pipe and Method of Using the Same*. March 16, 1982.

A heat pipe includes an elongated, heat conductive shell containing heat transfer fluid which is vaporizable and condensable, and cooling means within the shell to condense the heat transfer fluid from the vapor form to the liquid form and thereby to cool the shell to approximately the same temperature throughout its length. The cooling means can include a conduit or conduits running longitudinally inside the shell of the heat pipe and carrying a circulating coolant which can be a liquid or a gas. The substantially uniform cool surface temperature of the heat pipe adapts it for use as an efficient solar energy collector with the circulating coolant serving as a heat extracting medium. Alternatively, a row of photovoltaic cells may be mounted on the uniformly cool heat pipe shell and an elongated lens used to refract solar rays to impinge concentrated or high intensity solar energy onto the targets of such cells.

4,320,247
Gatos, Harry C.; Chi, Jim-Yong, inventors; Massachusetts Institute of Technology, assignee. *Solar Cell Having Multiple P-N Junctions and Process for Producing Same*. March 16, 1982.

A solar cell with improved energy conversion characteristics is formed from ordinary Czochralski or other types of silicon crystals that are sliced parallel to the growth axis or pulling direction. The slices are heat treated at a sufficiently high temperature and for a sufficiently long period of time to activate oxygen donor states in the slices. The heat treatment is of sufficient duration that at periodic maxima of oxygen concentration in the crystal it produces n-type regions where a background p-type dopant is overcompensated. Each n-type region thus formed is adjacent to a p-type region with a p-n junction therebetween. Collector contacts are applied at the faces of the slices to permit collection of carriers.

4,320,248
Yamazaki, Shunpei, inventor. *Semiconductor Photoelectric Conversion Device*. March 16, 1982.

An MIS type semiconductor photoelectric conversion device which comprises a semiconductor layer, a light-transparent, current-permeable, insulating or semi-insulating layer disposed on the semiconductor layer, a first conductive layer disposed on the light-transparent, current-permeable, insulating or semi-insulating layer, and a second conductive layer disposed on the semiconductor layer on the opposite side from the light-transparent, current-permeable, insulating or semi-insulating layer, and in which when light is incident to the semiconductor layer from the outside of the first conductive layer, a photoelectric conversion function is obtained by the presence of a barrier set up by the light-transparent, current-permeable, insulating or semi-insulating layer. In such an MIS type semiconductor photoelectric conversion device, the light-transparent, current-permeable, insulating or semi-insulating layer is formed of a nitride. The nitride layer is formed of silicon nitride or silicon nitride and a conductive metal nitride. In the MIS type semiconductor photoelectric conversion device, the first conductive layer has a comb- or grid-like pattern and an anti-reflection layer is formed to cover the first conductive layer. The light-transparent, current-permeable, insulating or semi-insulating layer and the anti-reflecting layer are both formed of a nitride.

4,320,249
Yamazaki, Shunpei, inventor. *Heterojunction Type Semiconductor Photoelectric Conversion Device*. March 16, 1982.

A heterojunction type semiconductor photoelectric conversion device which comprises a semiconductor layer, a light-transparent, conductive layer disposed on the semiconductor layer to form therebetween a heterojunction, and a conductive layer disposed on the semiconductor layer on the opposite side from the light-transparent, conductive layer, and in which when light is incident to the semiconductor layer from the outside of the light-transparent, conductive layer, a photoelectric conversion function is obtained by the presence of the barrier of the heterojunction formed between the semiconductor layer and the light-transparent, conductive layer. In such a heterojunction type semiconductor photoelectric conversion device, a light-transparent, current-permeable nitride layer is artificially formed in the barrier of the heterojunction formed between the semiconductor layer and the light-transparent, conductive layer. The light-transparent, current-permeable nitride layer is an insulating, semi-insulating, or conductive layer. The insulating nitride layer is made of a silicon nitride. The semi-insulating nitride layer is made of a silicon nitride and a conductive metal nitride. The conductive nitride layer is made of a conductive metal nitride. In the abovesaid heterojunction type semiconductor photoelectric conversion device, the light-transparent, conductive layer is made of a light-transparent, conductive nitride, which is a conductive metal nitride.

4,320,250
Corwin, Rudolph E.; Riemer, Dietrich E.; Stanbery, Billy J., inventors; The Boeing Company, assignee. *Electrodes for Concentrator Solar Cells, and Methods for Manufacture Thereof*. March 16, 1982.

An improved light transducer such as a solar cell and, especially, a concentrator solar cell, together with processes for forming the same which permit the formation of light transducers characterized by their improved efficiency, especially at concentration ratios on the order of 100 Suns and greater; and, more particularly, an improved process for forming concentrator solar cell electrodes, and improved concentrator solar cells produced thereby, characterized in that the electrodes comprise a multiplicity of closely spaced, fine-line—i.e., preferably on the order of less than about

1.0 mils in width—electroplated electrodes which are on the order of as least as thick as they are wide and, preferably which are at least 0.7 mils in thickness yet, which are characterized by their relatively sharp, vertical edge profiles and which are essentially devoid of lateral "spread" of the electroplated electrode materials.

4,320,251
Narasimhan, Mandayam C.; Roessler, Barton; Loferski, Joseph J., inventors; Solamat Inc., assignee. *Ohmic Contacts for Solar Cells by Arc Plasma Spraying*. March 16, 1982.

The method of applying ohmic contacts to a semiconductor, such as a silicon body or wafer used in solar cells, by the use of arc plasma spraying, and solar cells resulting therefrom.

4,321,099
Stirn, Richard J.; Yeh, Yea-Chuan M., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Fabricating Schottky Barrier Solar Cell*. March 23, 1982.

A Schottky barrier solar cell consists of a thin substrate of low cost material with at least the top surface of the substrate being electrically conductive. A thin layer of heavily doped n-type polycrystalline germanium, with crystalline sizes in the submicron range, is deposited on the substrate. But first a passivation layer may be deposited on the substrate to prevent migration of impurities into the polycrystalline germanium on a substrate of low-cost conductive material. Then the polycrystalline germanium is recrystallized to increase the crystal sizes in the germanium layer to not less than 5 microns, and preferably considerably more. It serves as a base layer on which a thin layer of gallium arsenide is vapor-epitaxially grown to a selected thickness. Then, a thermally-grown oxide layer of a thickness of several tens of angstroms is formed on the gallium arsenide layer. A metal layer, of not more than about 100 angstroms thick, is deposited on the oxide layer, and a grid electrode is deposited to be in electrical contact with the top surface of the metal layer. An antireflection coating may be deposited on the exposed top surface of the metal layer. In another embodiment, the recrystallized germanium layer serves as the substrate for a Schottky barrier solar cell with more than one active semiconductor layer. The techniques of forming the oxide layer are also applicable in forming an oxide layer between a metal layer and a semiconductor material which together form a Schottky barrier junction in any solar cell.

4,321,246
Surma, Kalluri R.; Rice, M. John, Jr.; Lesk, I. Arnold; Nikirk, Roger G., inventors; Motorola, Inc., assignee. *Polycrystalline Silicon Production*. March 23, 1982.

Polycrystalline silicon is produced by a high pressure plasma process. A silicon halide or halosilane is reacted with hydrogen in the presence of a high pressure plasma to deposit silicon on a heated substrate. The effluent from this reaction is collected, the silicon-bearing compounds separated out and re-introduced to the deposition reaction. The initial silicon bearing compound can be inexpensive silicon tetrachloride. Maximum utilization of all silicon bearing reaction products maximizes polycrystalline silicon production efficiency.

4,321,283
Patel, Kirit B.; Gonsiorawski, Ronald, inventors; Mobil Tyco Solar Energy Corporation, assignee. *Nickel Plating Method*. March 23, 1982.

A simple method for plating nickel onto silicon which renders unnecessary any catalyzing pretreatment of the silicon surface which is to receive the nickel. The method comprises the immersion of a silicon substrate in a suitable nickel bath in order that nickel ions in the bath will be reduced to solid nickel and deposited onto the substrate so as to form an adhering layer thereon. The method is especially advantageous in plating nickel onto silicon shallow junction devices for the purpose of providing ohmic contacts.

4,321,416
Tennant, Robert J., inventor; AMP Incorporated, assignee. *Photovoltaic Power Generation*. March 23, 1982.

A photovoltaic module is disclosed in the form of a shingle having an active portion containing photovoltaic cells and an inactive mounting portion. Flat flexible ribbon-like positive and negative leads extend from the terminals in the active portion. The individual modules are mounted on a surface by means of fasteners extending through the inactive portions of the modules. At the time of installation, the flexible leads are folded to provide a servicing loop and the ends of the leads are then connected into the electrical network of the system. Individual modules can be removed from the system by moving the modules in their own planes away from the array of modules with accompanying straightening of the loops so that modules can be replaced. Improved circuit arrangements for connecting modules in an array and improved installation methods are disclosed which take advantage of the flat flexible conductors extending from the modules.

4,321,417
Kurth, William T.; Andrulitis, William B., inventors; Exxon Research & Engineering Co., assignee. *Solar Cell Modules*. March 23, 1982.

Solar cell modules having light scattering surfaces at least in the land areas between a plurality of arrayed solar cells and optically coupled to the cells provide increased module output over modules not provided with light scattering land areas. Insolation impinging on the light scattering surfaces is diffused upwardly through the optical coupling medium and then downwardly toward a solar cell, thereby increasing the output of the module.

4,321,418
Dran, Maurice; Dages, Daniel; Le Gravier, Serge, inventors; Saint Gobain Vitrage, assignee. *Process for Manufacture of Solar Photocell Panels and Panels Obtained Thereby*. March 23, 1982.

A panel of a plurality of electrically connected photocells wherein each photocell has a lower face, a side face, and a radiation receiving face, is produced by (a) embedding at least the lower faces and side faces of the photocells and their electrical connectors in a thermoplastic resin in particulate form which resin becomes transparent upon fusion; (b) enclosing the photocells embedded in step (a) between two rigid sheets to form a sandwich-type assembly, with at least the rigid sheet enclosing the receiving faces of the photocells being optically transparent; (c) disposing the stacked assembly formed in step (b) within a flexible bag; (d) subjecting the interior of the flexible bag to a vacuum while applying relatively high pressure to the outside of the bag, and raising the temperature within the bag to fuse the thermoplastic resin particles; and (e) cooling the contents of the bag to solidify the resin and form thereby the panel comprising the photocells adhesively embedded in the solidified resin between the rigid sheets, and restoring atmospheric pressure to the interior of the bag.

4,321,419
Hanafin, Maurice C., inventor. *Solar Panel Cover Assembly*. March 23, 1982.

The invention provides a transparent protective cover for a solar panel. The cover provides for the positioning of lengths of clean covering film over the solar panel thereby removing dust and other accumulations. A pair of rollers on opposite sides of the solar panel support a supply of film material which extends over the panel surface. Clean film material is advanced at a predetermined rate across the solar panel thereby continuously replacing the panel cover and preventing excessive dust accumulation.

4,321,420
Kaplan, Daniel; Sol, Nicole; Landouar, Pierre, inventors; Thomson-CSF, assignee. *Process for Producing a Layer Containing Silicon and Photoelectric Conversion Device Utilizing this Process*. March 23, 1982.

Process for producing layers of silicon or one of its alloys in pure or doped form and able to absorb optical radiation, the layers being of limited thickness, it comprising a first stage of depositing the layer by chemical decomposition of a gaseous mixture containing silane at a temperature close to the crystallization temperature and a second stage of treating in a hydrogen plasma at a lower temperature.

4,322,253
Pankove, Jacques I.; Wu, Chung P., inventors; RCA Corporation, assignee. *Method of Making Selective Crystalline Silicon Regions Containing Entrapped Hydrogen by Laser Treatment*. March 30, 1982.

A novel hydrogen rich single crystalline silicon material having a band gap energy greater than 1.1 eV can be fabricated by forming an amorphous region of graded crystallinity in a body of single crystalline silicon and thereafter contacting the region with atomic hydrogen followed by pulsed laser annealing at a sufficient power and for a sufficient duration to recrystallize the region into single crystalline silicon without out-gasing the hydrogen. The new material can be used to fabricate semi-conductor devices such as single crystalline silicon solar cells with surface window regions having a greater band gap energy than that of single crystalline silicon without hydrogen.

4,322,261
Dubois, Pierre, inventor; Societe Anonyme dite: Compagnie Generale d'Electricite, assignee. *Method of Manufacturing a Solar Cell Panel*. March 30, 1982.

The photovoltaic cells are retained and protected by a transparent elastomer layer extruded when hot prior to vulcanization and applied against the cells with a slight pressure to cause it to go into the spaces between cells, and vulcanized by heating, for example at 110°C or at 180°C, thanks to the presence of incorporated peroxides. Application in the production of electricity from solar energy.

4,322,379
Kilby, Jack S.; McKee, William R.; Porter, Wilbur A., inventors; Texas Instruments Incorporated, assignee. *Fabrication Process for Semiconductor Bodies*. March 30, 1982.

A system and method is provided for forming semiconductor teardrop shaped bodies having minimal grain boundaries. Semiconductor material is melted in a capillary tube at the top of a tower and forced under gas pressure through a nozzle. Separate semiconductor bodies are formed. They are passed through a free fall path over which a predetermined temperature gradient controls solidification of the bodies. The resultant bodies are tear-drop semiconductor bodies of near uniform size with minimal grain boundaries.

4,322,571
Stanbery, Billy J., inventor; The Boeing Company, assignee. *Solar Cells and Methods for Manufacture Thereof*. March 30, 1982.

An improved light transducer such as a solar cell and, especially, a concentrator solar cell, together with processes for forming the same which permit the formation of improved light transducers characterized by their high thermal stability and by optimized impurity atom dispersion zones at the surface of either a p-type or an n-type substrate—such, for example, as a silicon substrate—defining: (i) a thermally stable deep junction with relatively high surface concentrations of dopant dispersed in those areas where metallic electrodes are to be formed, thus providing excellent ohmic contact characteristics in such areas; and (ii), an efficient energy conversion shallow junction with relatively lower surface concentrations of dopant in the inter-electrode photoactive regions preferably being texturized, thereby optimizing current generation per unit of incident radiation and minimizing reflection losses. More particularly, a deep junction (on the order of 0.5 μm or greater) is first formed throughout the substrate's entire near-surface area which is to be exposed to incident radiation; such deep junction is then entirely removed in the inter-electrode regions of the substrate by subjecting such regions to an acid etch, preferably with a texturizing etchant but, in some instances, with a polish etchant; and a relatively uniform shallow junction (on the order of 0.3 μm $\pm$ or—0.1 μm) is then formed in the etched inter-electrode near-surface regions either (i) by subjection of the substrate to a gas diffusion dopant process, or (ii) by conventional ion implantation techniques.

4,322,908
McCrory, Roy E., inventor. *Animated Wildfowl Decoy*. April 6, 1982.

An improved animated wildfowl decoy with self-contained power and control systems featuring selectable solar energy power or alternative battery power, continuous solar energy re-charge of battery, unique new highly efficient capstan type torque conversion system, positive movement back and forth across the water, automatic direction reversal, sporatic movements, and is unaffected by wind, currents or shallow water.

4,323,052
Stark, Virgil, inventor. *Solar Energy System*. April 6, 1982.

Disclosed are solar energy systems which provide for the distillation of liquids and/or the production of electricity using photovoltaic cells. Apparatus are disclosed which include an undulated system for conducting the liquid to be distilled, a linear lens disposed to concentrate solar energy on or below the undulated system, and a conduit transparent to visible light interposed between the undulated system and the linear lens. A cooling fluid is supplied to the conduit for assisting condensation of liquid evaporated from the undulated system on the lower wall of the conduit. The condensed liquid, the condensate and a concentrate of the liquid being distilled are collected. An array of photovoltaic cells may be disposed in the undulated system at a location of the concentration of solar energy to thereby provide for both distillation of the liquid and generation of electricity. Instead of an undulated system for conducting the liquid to be distilled, in one embodiment, a first transparent tube is disposed in a second transparent tube. The liquid to be distilled evaporates in the first transparent tube and is condensed on the upper wall thereof which has an outer surface in contact with the cooling fluid. If desired, photovoltaic cells may also be disposed in the first transparent tube. In another disclosed embodiment, a collector comprises tubes one disposed in the other with a fluid being circulated through each tube and insulation surrounding the lower portion of the tubes. Photovoltaic cells may be disposed in the innermost tube which is transparent.

4,323,417
Lam, Hon W., inventor; Texas Instruments Incorporated, assignee. *Method of Producing Monocrystal on Insulator*. April 6, 1982.

A method for producing monocrystal on insulator is disclosed. Initially, an epitaxial layer is created on the single crystal substrate. This epitaxial layer may be formed by direct deposition of the monocrystal layer, or through epitaxial monocrystal growth induced after a polycrystal or amorphous layer has been deposited upon the substrate. By appropriately scanning a laser or other focused energy source beginning at some point within the epitaxial layer, and moving into the polycrystalline or amorphous layer over the insulator region, the polycrystalline or amorphous layer will melt, then upon resolidifying it will be monocrystal in structure due to its monocrystal neighbor, the epitaxial layer.

4,323,419
Wakefield, G. Felix, inventor; Atlantic Richfield Company, assignee. *Method for Ribbon Solar Cell Fabrication*. April 6, 1982.

A method and apparatus for casting material into a ribbon shape in which molten material to be cast is extruded in a thin ribbon onto a moving sheet of foil of a metal having a sufficiently lower melting point or which forms an alloy with the molten material which has a sufficiently lower melting pont than the molten material, to cause almost immediate melting of at least a portion of the foil which comes in contact with the ribbon of molten casting material, with crystallization of the cast material occuring on a layer of liquified foil or foil-cast material alloy. Also disclosed is the disposing of the metal foil, in the vicinity of the contact with the ribbon of molten casting material, on a cooled surface which is moving past the region of extrusion of the molten material. The method and apparatus are disclosed to be particularly useful in making cast ribbon of semiconductor material with a foil backing and desirable properties for photovoltaic solar cell applications. In addition, it is disclosed to add dopant to the solidifying semiconductor material after extrusion onto the metal foil and/or to add dopant to the surface of the metal foil prior to contact with the molten material, and also to thermally control the rate of crystallization of the molten material.

4,323,719
Green, Martin A., inventor; Unisearch Limited, assignee. *Integrated Solar Cells and Shunting Diodes*. April 6, 1982.

A method of connecting a shunting diode in parallel with a solar cell for the purpose of improving the tolerance of an array of solar cells to mismatch in cell output, whether caused by physical differences in the cells, cell breakage, or the effect of shading, is disclosed. Also disclosed is a method of forming a plurality of interconnected solar cells on a single sheet of semiconductor material, wherein if required, each cell in the array of cells may be shunted by a diode.

4,324,946
Gravisse, Philippe, inventor. *Solar Radiation Concentrator*. April 13, 1982.

A luminescent solar radiation concentrator is disclosed. Incident radiation of flux Φ_1, and wavelength λ_1, impinges enclosure wall V_1 having a double index of refraction n_1,n_2(where $n_2>n_1$) and then is absorbed by cascade fluorescent concentrator/converter CL, which isotropically re-emits fluorescent radiation at wavelength λ^2 and flux Φ^2 (where $\lambda_2>\lambda_1$, and $\Phi_2>\lambda_1$) which then is absorbed by a solar photovoltaic cell. The double index of refraction wall prevents escape of fluorescence radiation from the enclosure.

4,325,986
Baron, Bill N.; Rocheleau, Richard E.; Russell, T. W. Fraser, inventors; University of Delaware, assignee. *Method for Continuous Deposition by Vacuum Evaporation*. April 20, 1982.

An apparatus to deposit material on a substrate, such as in the making of thin film solar cells, consists of two chambers. A manifold chamber having a plurality of spaced nozzles assures efficient and uniform deposition on a substrate. The rate of depositions is controlled by an orifice in a passageway connecting the manifold chamber to an evaporation chamber.

4,326,012
Charlton, Walter T., inventor. *Solar Power Building Block*. April 20, 1982.

A building unit for exterior walls and the like comprising a molded block of glass having a recess in the side face which is to face the exterior, the recess having a side wall and an open outer end on which a Fresnel lens is disposed, the inner end of the recess having a solar cell disposed therein so that sunlight passing through the Fresnel lens impinges on the solar cell for the generation of electric power together with a battery disposed within a cavity molded in the block connected by a circuit to the solar cell for storing the generated electric power for subsequent use as needed in a residence or the like. A further embodiment has attached to the interior wall a black painted duct containing vertical radiant fins. This unit contains a "window" through which the concentrated radiation is directed by the lens arrangement of the side walls and front lens to create a highly energetic radiant impingement upon the black duct heating it. Air flowing vertically in the duct is used for heating interior air or removal of superheated interior air by using the force of the rising air for an "air cooling" effect.

4,326,013
Jacobi, Edgar F.; Madden, Mark R., inventors. *Energy System*. April 20, 1982.

A central photovoltaic collection array is used on a shared basis to recharge transportable fuel cell trailers each provided with an electrolysis cell. The electrolysis cell is fed by a container of water and when connected to the array the water is broken down into the constitutent elements. The resulting oxygen is stored under pressure while the hydrogen is fed to a reactive bed to form metallic hydride. The heat of reaction of the metallic hydride is cooled by a heat exchanger immersed in the bed and connected between two insulated containers of water. Thus the water warmed up in the course of cooling the metallic hydride reaction is returned to an insulated chamber and in this manner serves as a source of heat for the decomposition thereof when hydrogen is desired. Once some hydrogen is released the heat of combination with oxygen may be used to continue the decomposition and as a source of power.

4,327,119
Lis, Steven A.; Serreze, Harvey B.; Sienkiewicz, Peter M., inventors; Radiation Monitoring Devices, Inc., assignee. *Method to Synthesize and Produce Thin Films by Spray Pyrolysis*. April 27, 1982.

Forming a film by spraying onto a heated substrate an atomized solution containing the appropriate salt of a constituent element of the film and an agent in sufficient amount to change the oxidation state of at least one solute element of the spray solution after contacting the heated substrate.

4,327,316
Fujikubo, Yoshitake; Tanaka, Mamoru, inventors; Nissan Motor Company, Limited, assignee. *Battery Recharging Solar Cell Arrangement for an Automotive Vehicle*. April 27, 1982.

In a battery recharging arrangement for an automotive vehicle, one or more solar batteries, together with recharging current control means to charge an automotive vehicle battery, are disposed with supporting metal fixtures at a plurality of different positions to which solar energy is applied so as to prevent the rechargeable batteries mounted in an automotive vehicle body from becoming excessively discharged. The solar batteries are positioned on the roof of a vehicle or mainly within the passenger comartment at appropriate elevation angles, so that as long as the vehicle is in the condition wherever solar energy is applied, solar energy can be obtained at any position of the sun regardless of the direction the vehicle is moving in or of the place the vehicle is parked since at least one of the disposed solar batteries will be effectively exposed to sunlight. The solar batteries so disposed at a plurality of different positions within the passenger compartment are protected from dirt or splashes of mud to keep the batteries in good working conditions at all times. In addition, if appropriate light focusing devices, such as Fresnel lenses, are positioned over the solar batteries, the solar energy collecting performance will further be enhanced.

4,327,318
Kwon, Yiduk; Lawson, Paul, inventors; Exxon Research & Engineering Co., assignee. *Source Shedding Regulator*. April 27, 1982.

A voltage regulator for controlling the photovoltaic charging of storage batteries selectively includes or sheds portions of the photovoltaic array into or from the charging system.

4,328,258
Coleman, John H., inventor; Plasma Physics Corp., assignee. *Method of Forming Semiconducting Materials and Barriers*. May 4, 1982.

In a gaseous glow-discharge process for coating a substrate with semiconductor material, a variable electric field in the region of the substrate and the pressure of the gaseous material are controlled to produce a uniform coating having useful semiconducting properties. Electrodes having concave and cylindrical configurations are used to produce a spacially varying electric field. Twin electrodes are used to enable the use of an AC power supply and collect a substantial part of the coating on the substrate. Solid semiconductor material is evaporated and sputtered into the glow discharge to control the discharge and improve the coating. Schottky barrier and solar cell structures are fabricated from the semiconductor coating. Activated nitrogen species is used to increase the barrier height of Schottky barriers.

4,328,260
Whitehouse, Daniel L., inventor; Solarex Corporation, assignee. *Method for Applying Antireflective Coating on Solar Cell*. May 4, 1982.

A method, and the composition, for the application of an antireflective coating on solar cells and the subsequent application of metal contacts comprising applying a screen to the surface of a solar cell, applying a paste comprising a metal alkoxide over the screen, heat treating the cell and metal alkoxide paste, and nickel plating the resultant cell.

4,328,389
Stern, Theodore G.; Peterson, David M., inventors; General Dynamics Corporation, assignee. *Inherent Spectrum-Splitting Photovoltaic Concentrator System*. May 4, 1982.

A solar energy splitting photovoltaic concentrator system that includes a first reflector that concentrates and directs sunlight to a high energy bandgap first photovoltaic array that absorbs and converts into electricity high energy photons. A second reflector formed integrally with the first photovoltaic array concentrates and reflects low energy photons back through the first photovoltaic array, which is transparent to the low energy photon, to a low energy bandgap second photovoltaic array that absorbs and converts the low energy photons.

4,328,390
Meakin, John D.; Bragagnolo, Julio, inventors; The University of Delaware, assignee. *Thin Film Photovoltaic Cell*. May 4, 1982.

A thin film photovoltaic cell having a transparent electrical contact and an opaque electrical contact with a pair of semiconductors therebetween includes utilizing one of the electrical contacts as a substrate and wherein the inner surface thereof is modified by microroughening while being macro-planar.

4,328,417
Himes, Roger, inventor. *Solar Tracking Mechanism*. May 4, 1982.

A mechanism for tracking the sun and positioning a solar energy collector, photovoltaic cells being utilized to energize pairs of electric coils rotatably mounted within magnetic rings. When the sun's rays fall upon a bank of photovoltaic cells a pair of coils are energized, setting up electromotive forces in opposition to the force field of the magnetic ring, and rotating the coils and solar collector mounted thereto.

4,329,189
Noad, Julian P.; Springthorpe, Anthony J.; Look, Christopher M., inventors; Northern Telecom Limited, assignee. *Channelled Substrate Double Heterostructure Lasers*. May 11, 1982.

In fabricating a III-V compound, for example, GaAs, having a layered structure, a first layer is grown on a planar substrate by a vapor deposition process adapted to produce differential growth while a subsequent layer is grown by a deposition process which restores planarity. In this way a uniformly thick combination layer is produced with a non-planar junction between its composite layers. Particularly in the fabrication of channelled substrate double heterostructure lasers, a channelled blocking layer is grown by organo-metallic pyrolysis (OMP) and a subsequent confining layer is grown using liquid phase epitaxy (LPE). The OMP process produces a channel with flanking shoulder portions which permit LPE growth of a very thin confining layer immediately above the shoulder portions thereby improving linearity of the device.

4,329,195
Kudo, Bosshi, inventor; Mitsubishi Kinzoku Kabushiki Kaisha; Toyo Silicon Co., Ltd., assignee. *Lateral Pulling Growth of Crystal Ribbons*. May 11, 1982.

The lateral pulling growth of a crystal ribbon is established under precise heat control by pulling laterally the crystal ribbon from the melt of a crystalline substance having the same crystal structure as that of the crystal ribbon.

4,329,534
Hodgson, Rodney T.; Hovel, Harold J., inventors; International Business Machines Corporation, assignee. *Uniform Incident Light High Voltage Solar Cell Array*. May 11, 1982.

A fluorescent material member covering a series array of solar cells that produce a high voltage operates to convert incident light to a uniform number of photons per cell.

4,329,535
Rapp, Charles F., inventor; Owens-Illinois, Inc., assignee. *Solar Cells and Collector Structures*. May 11, 1982.

Disclosed is a composite collector and concentrator structure comprising a laminate having a self-supporting layer of solid light transmitting material of extended area in one plane in optical and physical contact with a relatively thin layer of host material containing at least one species of luminescent material which absorbs electromagnetic radiation and emits electromagnetic radiation of a longer wavelength. Use with photovoltaic solar cells is also disclosed.

4,329,699
Ishihara, Shin-ichiro; Mori, Koshiro; Tanaka, Tsuneo; Nagata, Seiichi; Fukai, Masakazu, inventors; Matsushita Electric Industrial Co., Ltd., assignee. *Semiconductor Device and Method of Manufacturing the Same*. May 11, 1982.

A semiconductor device utilizing amorphous $Si_{1-x}Cx(0 \leqslant x \geqslant 1)$ containing hydrogen. Through a high frequency glow discharge process or a high frequency sputtering process, the composition x is varied to form a heterojunction between amorphous $Si_{1-x}C_x$ layers, and electrodes are mounted to the layers to complete the device. The amorphous material is desirably selected to have a forbidden band width of 1.7 to 3.2 eV so that the sensitivity of the device can cover the visible range. Because of the amorphous layers, freedom of type and shape of the substrate of the device is large. The dark resistance of the layers is large to improve the photoconductive characteristics of the semiconductor device.

4,330,182
Coleman, John H., inventor; Plasma Physics Corporation, assignee. *Method of Forming Semiconducting Materials and Barriers*. May 18, 1982.

Photovoltaic junctions useful for solar energy conversion and for electrophotographic image formation are fabricated from a layer of amorphous boron in contact with a layer of amorphous silicon. The amorphous boron is preferably deposited at a reduced temperature on the amorphous silicon; or, alternatively, the amorphous silicon is deposited on a boron-bearing body previously deposited on an opaque metallic substrate.

4,330,358
Grabmaier, Christa; Otto, Franz; Thomann, Helmut, inventors; Siemens Aktiengesellschaft, assignee. *Method of Producing Plate- or Tape-Shaped Silicon Crystal Bodies Having Crystalline Pillar-Like Structures Therein, Equivalent to Crystalline Columnar Structures, for Large Surface Solar Cells*. May 18, 1982.

Selectively shaped silicon crystal bodies, such as plate- or tape-shaped bodies, having crystalline pillar-like structures therein are produced by forming a slurry from an admixture of relatively fine sized silicon particles and a liquid binder, extruding such slurry as a relatively thin layer onto a first support member, drying such extruded layer until it becomes self-supporting and removing such support member, and then sintering such dried layer in a protective gas atmosphere at temperatures below about 1430°C until a layer of crystalline silicon particles are generated or grown having an average diameter substantially corresponding to the thickness of the dried slurry layer.

4,330,359
Schlichta, Paul J., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Electromigration Process for the Purification of Molten Silicon during Crystal Growth*. May 18, 1982.

A process for the purification of molten materials during crystal growth by electromigration of impurities to localized dirty zones. The process has particular applications for silicon crystal growth according to Czochralski techniques and edge-defined film-fed growth (EFG) conditions. In the Czochralski crystal growing process, the impurities are electromigrated away from the crystallization interface by applying a direct electrical current to the molten silicon for electromigrating the charged impurities away from the crystal growth interface. In the EFG crystal growth process, a direct electrical current is applied between the two faces which are used in forming the molten silicon into a ribbon. The impurities are thereby migrated to one side only of the crystal ribbon. The impurities may be removed or left in place. If left in place, they will not adversely affect the ribbon when used in solar collectors. The migration of the impurity to one side only of the silicon ribbon is especially suitable for use with asymmetric dies which preferentially crystallize uncharged impurities along one side or face of the ribbon.

4,330,680
Goetzberger, Adolf, inventor; Fraunhofer Gesellschaft zur Forderung der angewandten Forschung e.v., assignee. *Integrated Series-Connected Solar Cell*. May 18, 1982.

A row of strip-shaped semiconductor junctions is arranged on each of the two surfaces of a semiconductor substrate possessing a high ohmic resistance, these junctions having p^+- and n^+-conduction characteristics in alternation and being parallel to each other and spaced at intervals, in such a way that a semiconductor junction having a p^+-conduction characteristic on one surface of the semiconductor substrate is, in each case, located opposite a semiconductor junction having an n^+-conduction characteristic on the other surface, and printed circuit tracks are arranged, in alternation, on one surface and on the other surface of the semiconductor substrate, these tracks connecting, in each case, one series of solar cell junctions with a neighboring series, in series-connection.

4,331,492
Dominguez, Ramon; Anderson, Jack R., inventors; Solarex Corporation, assignee. *Method of Making a Solar Panel*. May 25, 1982.

A solar panel in which interconnected photovoltaic cells are maintained in light-receiving position by electrically conductive clips secured to the base of the panel. When the cells and clips are encapsulated in a protective resin, a vacuum is drawn during encapsulation to remove air bubbles trapped beneath the cells.

4,331,494
Duchateau, Jacques; Nicolas, Maurice, inventors; BFG Glassgroup, assignee. *Solar Panel and Method of Manufacturing a Solar Panel*. May 25, 1982.

A solar panel comprising at least one solar energy transducer laminated between a transparent vitreous sheet and a second sheet in which the transducer is imbedded in a layer of transparent polymeric material which bonds the sheets together. The polymeric material comprises an acrylic compound. A method of making the aforesaid solar panel in which the acrylic compound is allowed to set in situ is described.

4,331,703
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Forming Solar Cell Having Contacts and Antireflective Coating*. May 25, 1982.

A photovoltaic cell is formed by applying electrical contact material through an antireflective coating on the light receiving surface of the cell by flame, arc or plasma spraying. The cell so formed has a metal contact, spaced portions of which are in electrical contact with the light-receiving surface of the cell.

4,331,707
Muruska, H. Paul; Sansregret, Joseph L.; Young, Archie R., inventors; Exxon Research & Engineering Co., assignee. *Process for Thin Film Deposition of Cadmium Sulfide*. May 25, 1982.

The present invention teaches a process for depositing layers of cadmium sulfide. The process includes depositing a layer of cadmium oxide by spray pyrolysis of a cadmium salt in an aqueous or organic solvent. The oxide film is then converted into cadmium sulfide by thermal ion exchange of the O^{-2} for S^{-2} by annealing the oxide layer in gaseous sulfur at elevated temperatures.

4,331,829
Palazzetti, Mario; Boero, Angioletta; Demichelis, Francesca; Minetti-Mezetti, Enrica; Ferrari, Giancarlo, inventors; Centro Ricerche Fiat S.p.A.; Politecnico di Torino, assignee. *Thermophotovoltaic Converter*. May 25, 1982.

A thermophotovoltaic converter of the type comprising a concentrating optical system and a transducer for solar radiation provided with at least one lens and with at least one photovoltaic cell is described. The principal feature of this converter is that the aforementioned transducer comprises at least a radiator having an irradiating surface substantially facing the sensitive surface of the photovoltaic cell and a selective filter disposed between the photovoltaic cell and the aforementioned radiator.

4,332,838
Wegrzyn, James E., inventor. *Particulate Thin Film Fabrication Process*. June 1, 1982.

A method for the farication of large surface area thin films of vaporizable solids upon substrate materials is provided. The method is particularly applicable to the fabrication of thin films having semiconducting properties useful as solar cells, in the production of microelectronic devices, and other similar purposes. A solid material is vaporized in a temperature-zoned furnace in association with a flowing carrier gas. The vaporized solid is allowed to condense to form an aerosol of disperse sized particles; the smaller of these particles are again vaporized leaving a lesser

number of seed aerosol nuclei which are then grown to a larger size and diverted through an orifice to impact upon a substrate moving beneath the orifice thereby forming a particulate film on the substrate.

4,332,973
Sater, Bernard L., inventor. *High Intensity Solar Cell*. June 1, 1982.

This invention discloses: (1) A high intensity solar cell; (2) a method of making an array of high intensity solar cells in an economical manner; and (3) a lens system for concentrating incident radiation onto the most responsive region of its structure.

4,332,974
Fraas, Lewis M., inventor; Chevron Research Company, assignee. *Multilayer Photovoltaic Cell*. June 1, 1982.

A new high efficiency, multijunction photovoltaic solar cell for use with a concentrating lens. This cell comprises an elemental single crystal substrate without an internal light sensitive junction, upon which are two or more successive homogenous layers of semiconductor material, each layer containing within it a light sensitive p/n junction of a similar polarity, each layer having essentially the same lattice constant as the single crystal substrate, each layer having a shorting junction contact with the layer immediately above and below it, each successive layer absorbing light energy at a shorter wavelength, and each layer being of sufficient thickness and appropriate composition to develop essentially the same current as the other layers. The outer surfaces of the top layer and the substrate are provided with electrical contacts for distribution of the electric current. The top contact comprises a layer of a transparent conductive material with electrical connections and the whole structure is completed with an antireflection coating over the top.

4,333,136
Baker, Richard H., inventor. *Solar Powered Automatic Turn-On Control (SPA-TOC) Unit and Method*. June 1, 1982.

Orderly control of power applied by a photovoltaic solar panel d.c. source to a load is attained despite varying long and short term solar conditions by coupling power from the panel to an inverter in response to the panel voltage exceeding a predetermined level and preventing coupling of power from the panel to the inverter in response to the panel voltage being less than a predetermined level. The switching frequency of the inverter is controlled in response to the panel voltage so that approximately maximum power which the panel is capable of generating is supplied to the inverter for the incident solar energy on the panel at a given temperature. Power is supplied to the inverter by a series switch between the panel and inverter. The switch is activated into a conducting state in response to the panel voltage exceeding a predetermined value. The panel voltage controls the turn-on and turn-off levels of the series switch by a hysteresis effect, provided by connecting a dummy power dissipating load in shunt with the panel while the series switch is cut off. The dummy load has a value causing the panel output voltage to be less than the voltage for maximum panel output power. A similar series switch and hysteresis control is provided for control circuitry for the inverter. The series switch for supplying power to the control circuitry can be activated in response to the same voltage which activates the series switch for the inverter, or in response to a different voltage level.

4,333,262
Kimura, Akira, inventor. *Solar Powered Toy*. June 8, 1982.

A solar powered toy has a plurality of legs each with angularly related sections connected together. Certain sections are mounted for relative turning movement, and electric motors powered by solar cells are mounted to turn adjacent sections of the legs, so that movements of the legs of the device change the degree of exposure of the solar cells to the light source.

4,334,120
Yamano, Masaru; Kuwano, Yukinori, inventors; Sanyo Electric Co., Ltd., assignee. *Sunlight-Into-Energy Conversion Apparatus*. June 8, 1982.

The present application discloses a sunlight-into-energy conversion apparatus in whch at least one amorphous silicon solar cell having a thickness thin enough to permit the sunlight to pass therethrough is formed on the surface of a heat collecting plate attached to a heating medium tube in a thermal conductive manner, thereby permitting the sunlight to be effectively converted into thermal energy and electrical energy. When a plurality of such amorphous silicon solar cells is formed on the surface of the heat collecting plate through insulating films, respectively and connected in series to each other, high electromotive force may be obtained.

4,334,354
Luft, Werner; Kennedy, Robert E.; Mesch, Hans G., inventors; TRW Inc., assignee. *Method of Fabricating a Solar Array*. June 15, 1982.

A solar array having solar cells mounted on a substrate and electrically joined by rear connector elements on the substrate and front connector elements secured between the cells to the substrate is fabricated by placing the array components in assembled relation and utilizing induction heating to heat to their fusion temperatures a thermoplastic adhesive layer on the substrate and contacting fusible cladding on the solar cells and the connector elements while retaining the components in firm contact to effect adhesive bonding of the solar cells and front connector elements to the substrate and metallic bonding of the solar cells and connector elements to one another.

4,335,266
Mickelsen, Reid A.; Chen, Wen S., inventors; The Boeing Company, assignee. *Methods for Forming Thin-Film Heterojunction Solar Cells from I-III-VI_2 Chalcopyrite Compounds, and Solar Cells Produced Thereby*. June 15, 1982.

An improved thin-film, large area solar cell, and methods for forming the same, having a relatively high light-to-electrical energy conversion efficiency and characterized in that the cell comprises a p-n type heterojunction formed of: (i) a first semiconductor layer comprising a photovoltaic active material selected from the class of I-III-VI_2 chalcopyrite ternary materials which is vacuum deposited in a thin "composition-graded" layer ranging from on the order of about 2.5 microns to about 5.0 microns ($\cong$2.5μm to $\cong$5.0μm) and wherein the lower region of the photovoltaic active material preferably comprises a low resistivity region of p-type semiconductor material having a superimposed region of relatively high resistivity, transient n-type semiconductor material defining a transient p-n homojunction; and (ii) a second semiconductor layer comprising a low resistivity n-type semiconductor material; wherein interdiffusion (a) between the elemental constituents of the two discrete juxtaposed regions of the first semiconductor layer defining a transient p-n homojunction layer, and (b) between the transient n-type material in the first semiconductor layer and the second n-type semiconductor layer, causes the transient n-type material in the first semiconductor layer to evolve into p-type material, thereby defining a thin layer heterojunction device characterized by the absence of voids, vacancies and nodules which tend to reduce the energy conversion efficiency of the system.

4,335,503
Evans, John C., Jr.; Chai, An-Ti; Goradia, Chandra P., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Method of Making a High Voltage V-Groove Solar Cell*. June 22, 1982.

A method is provided for making a high voltage multijunction solar cell which comprises a plurality of discrete voltage generating regions, or unit cells, which are formed in a single semiconductor wafer and are connected together so that the voltages of the

individual cells are additive. The unit cells comprise doped regions of opposite conductivity types separated by a gap. The method includes forming V-shaped grooves in the wafer and thereafter orienting the wafer so that ions of one conductivity type can be implanted in one face of the groove while the other face is shielded. A metallization layer is applied and selectively etched away to provide connections between the unit cells.

4,336,281
Van Mourik, Jacobus H. C., inventor; U.S. Philips Corporation, assignee. *Method of Manufacturing a Solar Cell*. June 22, 1982.

A method of manufacturing a solar cell comprising a silicon disc having a region of the n-conductivity type adjoining a major surface, in which an electrode containing silver is provided on the n-type region by means of a silk-screening process, characterized in that during the silk-screening process a paste is used which, in addition to silver, contains an addition in an elementary form, which addition belongs to the group of elements consisting of bismuth, magnesium and indium, that after providing the electrode a thermal treatment in an oxidizing atmosphere is carried out, and that the electrode is then subjected to a chemical or mechanical treatment to improve the junction resistance with the silicon.

4,336,413
Tourneux, Michel, inventor; R.T.C. La Radiotechnique Compelec, assignee. *Solar Panels*. June 22, 1982.

The invention concerns a photovoltaic generating panel easily adaptable to a roof. The panel is equipped with a peripheral frame formed by the assembly of straight light alloy shapes. The particular form of these shapes makes possible the laying of adjacent panels with overlapping of the edges of the latter.

4,336,648
Pschunder, Willi; Steinmetz, Gerhard, inventors; Licentia Patent-Verwaltungs-GmbH, assignee. *Method of Contacting a Solar Cell*. June 29, 1982.

A solar cell comprises a semiconductor body with a p-n-junction, a metallized area on the light receiving surface of the semiconductor body, a connection or contact area on the light receiving surface, a reflection reducing layer completely covering the metallized area and the connection or contact area and a further contact on the rear face. A metal connector is fixed to the connection or contact area by placing the connector against the reflection reducing layer and conductively connecting the connector to the connection area while concurrently eliminating the reflection reducing layer from that area.

4,337,758
Meinel, Aden B.; Meinel, Walter B., inventors. *Solar Energy Collector and Converter*. July 6, 1982.

A single reflective afocal optical module collects and concentrates solar energy onto a receiving surface extending substantially parallel to the focal axis of the optical system and to the central axis of the module. The reflective surface of the collector is shaped to reflect incoming energy and distribute it uniformly over the full surface of the receiver, with the reflective surface preferably consisting of a plurality of discrete reflective surface portions each distributing its portion of reflected energy over the full receiver surface so that the energy portions from the respective reflective surface portions are superimposed on one another on the receiver. The reflector and receiver are housed in a sealed enclosure having a transparent window for admitting incoming energy, and a heat extracting means removes excess heat from the enclosure.

4,337,759
Popovich, John M.; Parkyn, William A., Jr.; Pelka, David G., inventors; John M. Popovich, William A. Parkyn, Jr., David G. Pelka, assignees. *Radiant Energy Concentration by Optical Total Internal Reflection*. July 6, 1982.

A radiant energy redirecting system comprises: (a) a radiant energy transmitting body means, (b) said means comprising multiple elements, each of which acts as a radiant energy redirecting module, having on its cross-sectional perimeter an entry face to receive incidence of said energy into the interior of said perimeter, an exit face to pass said energy to the exterior of said perimeter in a direction towards the reverse side of the body from the side of said incidence, and a Totally Internally Reflecting face angled relative to said entry and exit faces to redirect towards said exit face the radiant energy incident from said entry face, (c) said body means generally redirecting incident radiant energy towards a predetermined target zone situated apart from and on the reverse side of said body relative to the side of said incidence.

4,338,180
Nakamura, Michihiro, inventor; Kuraray Co., Ltd., assignee. *Photoelectrodes for Photoelectrochemical Cells*. July 6, 1982.

The present invention provides photoelectrodes for photoelectrochemical cells, which photoelectrodes are essentially composed of a surface-chalcogenated molybdenum or tungsten metal. These photoelectrodes have long life, are highly efficient in energy conversion, and are inexpensive.

4,338,362
Turcotte, Richard L., inventor; Radiation Monitoring Devices, Inc., assignee. *Method to Synthesize and Produce Thin Films by Spray Pyrolysis*. July 6, 1982.

Forming a film by spraying onto a heated substrate an atomized solution containing the appropriate salt of a constituent element of the film and a reducing agent at a concentration greater than 1 M and greater than 10 times the stoichiometric amount of reducing agent.

4,338,480
Antypas, George A.; Bell, Ronald L.; Moon, Ronald L., inventors; Varian Associates, Inc., assignee. *Stacked Multijunction Photovoltaic Converters*. July 6, 1982.

Solar cells with different bandgaps are stacked to form a multijunction photovoltaic converter with a high conversion efficiency. By stacking the cells mechanically rather than by growing them all at one time, the most convenient combination of materials may be selected for the cells. The stacking is completed by means of a glass sealing layer with moats containing inter-cell contacts which are bonded to the cells.

4,338,481
Mandelkorn, Joseph, inventor. *Very Thin Silicon Wafer Base Solar Cell*. July 6, 1982.

The performance and ruggedness of very thin silicon back surface field (BSF) solar cells are improved by the formation of a relatively thick, epitaxially grown, highly doped layer at the back of the cell and the formation of an arsenic doped layer at the top of the cell within the phosphorous diffused front region. As a result of these modifications and the method used for fabricating the modified cell, highly effective barriers, which diminish mobile charge loss by recombination, are created at the front and back of the cell base. The cell, consisting of a high resistivity, high minority carrier lifetime, very thin base sandwiched between effective barriers, permits achievement of almost ideal performance and has improved radiation damage resistance. The ruggedness of the very thin base cell is due to the addition of the relatively thick epitaxial layer in back of the base.

4,338,482
Gordon, Roy G., inventor; Gordon, Roy G., assignee. *Photovoltaic Cell*. July 6, 1982.

An improved structure for solar cells is disclosed. It incorporates a layer of titanium dioxide between previously used layers of tin

oxide and silicon. The new cells show increased efficiency and improved thermal stability.

4,339,470
Carlson, David E., inventor; RCA Corporation, assignee. *Fabricating Amorphous Silicon Solar Cells by Varying the Temperature of the Substrate During Deposition of the Amorphous Silicon Layer*. July 13, 1982.

An improved process for fabricating amorphous silicon solar cells in which the temperature of the substrate is varied during the deposition of the amorphous silicon layer is described. Solar cells manufactured in accordance with this process are shown to have increased efficiencies and fill factors when compared to solar cells manufactured with a constant substrate temperature during deposition of the amorphous silicon layer.

4,339,626
Fisher, Gerald M.; Maget, Henri J. R., inventors; Varian Associates, Inc., assignee. *Solar Pond Power Plant*. July 13, 1982.

Method of operation and apparatus for a salt gradient solar pond employing a novel barge carrying a plurality of two axis stabilized high temperature concentrator solar cell arrays including means to control the flow rate of the concentrator solar cell array cooling fluid to optimize power station characteristics.

4,339,627
Arnould, Jacques, inventor; Le Silicium Semiconducteur SSC, assignee. *Process for Cooling a Solar Cell and a Combined Photovoltaic and Photothermic Solar Device*. July 13, 1982.

A solar cell cooling process. The device implementing this process comprises a transparent assembly disposed in front of a photovoltaic cell. The transparent assembly, through which flows the cooling fluid leaving a radiator integral with the cell, absorbs the wavelengths greater than 1.1 micron. Thus, heating of the cell is limited and the fluid leaving the radiator is heated by the beam striking the cell.

4,340,507
Naarmann, Herbert; Naegele, Dieter; Penzien, Klaus; Schlag, Johannes, inventors; BASF Aktiengesellschaft, assignee. *Preparation of Electrically Conductive Polyaromatics, and Their Use in the Electrical Industry and for Rendering Plastics Antistatic*. July 20, 1982.

A process for the preparation of electrically conductive polyaromatics having conductivities greater than 10^{-2}S/cm., wherein from 0.5 to 5% by weight, based on the polyaromatics, of sodium, potassium, rubidium, cesium or their amides, preferably in tetrahydrofuran, dimethoxyglycol, anthracene, naphthalene or 2-methylstyrene, are incorporated into polyaromatics, in the absence of moisture and of oxygen. The conductive polyaromatics obtained may be used in the electrical industry for the manufacture of solar cells, for the conversion of radiation and for the manufacture of electrical and magnetic switches, and may also be used to render plastics antistatic.

4,340,627
Herzog, Heinz; Mohn, Heinrich; Schulke, Karl-Albert; Grzybowski, Holger, inventors; Heraeus Quarzschmelze GmbH, assignee. *Wound and Sintered Vitreous Silica Article and Method of Making*. July 20, 1982.

A method is described for the production of porous bodies from vitreous silica without the use of tools. Vitreous silica wool and/or threads are wound in layers on a form. After the coil has attained a certain minimum thickness, the threads of each succeeding layer are permanently bonded by heating the threads of the preceding layer at the points where the threads cross. The form is removed, and then the threads on the inside of the body are bonded together. The bodies are used for the production of high-purity blocks of silicon for solar cells.

4,340,803
Coyle, Peter J., inventor; RCA Corporation, assignee. *Method for Interconnecting Solar Cells*. July 20, 1982.

A method for interconnecting the body of a solar cell to an adjacent solar cell to form a solar cell array capable of withstanding high temperatures and rugged terrestrial applications, but minimizing the electrical degradation of the peak power output of the solar cells comprises the parallel gap welding of an interconnect metal layer perpendicular to the direction of force applied on the solar cell by the interconnect layer connecting adjacent solar cells wherein the width of the weld perpendicular to the direction of force is greater than the length of the weld.

4,341,589
Grabmaier, Josef, inventor; Siemens Aktiengesellschaft, assignee. *Method for Producing Large Surface Plate or Disc-Shaped Si Crystals with Columnar Structure*. July 27, 1982.

Large surface silicon crystal layers with a columnar structure are produced by directing a plurality of spaced-apart cooling gas streams arranged relative to one another to correspond to a desired columnar structure and positioned a relatively short distance above a free surface of a silicon melt surface located below such system so that a spontaneous seed crystal formation occurs at the regions or areas of the melt immediately below each gas stream and thereafter the affected melt surface is solidified, and then removing the so-formed plate or disc-shaped silicon body from the melt. Dopant material can be incorporated within the so-formed plate or disc-shaped silicon crystal so that a pn-juncture parallel to the surface of such plate or disc is attained.

4,341,607
Tison, Raymond R., inventor; E:F Technology, Inc., assignee. *Solar Power System Requiring No Active Control Device*. July 27, 1982.

A solar power system has a photovoltaic array having a locus of peak power points for various insolation levels, a voltage-dependent variable resistance load such as a water electrolysis unit electrically connected to the array, and a demand-dependent variable resistance load such as a DC to AC inverter connected in parallel with the electrolysis unit. The electrolysis unit or other voltage-dependent variable resistance load has a voltage-current characteristic in which the operating point is displaced from the array's peak power point for most insolation levels. The characteristic is displaced towards higher voltage-lower current operating points. The inverter may move the operating point of the photovoltaic array toward its peak power point when the load requires power. The system may be designed so that the array operates within about 5 percent of its peak power point over a wide range of inverter power demands. A fuel cell may be connected in parallel with the array to provide power to the inverter at low insolation levels, at night or in low sunlight. The fuel cell may use the hydrogen produced by the electrolysis unit for fuel. The total photovoltaic power made available by the system of this invention is generally greater than 95 percent and often greater than 98 percent of the maximum power which the photovoltaic array may produce for many insolation levels.

4,341,918
Evans, John C., Jr.; Chai, An-Ti; Goradia, Chandra P., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *High Voltage Planar Multijunction Solar Cell*. July 27, 1982.

A high voltage multijunction solar cell is provided wherein a plurality of discrete voltage generating regions or unit cells are formed in a single generally planar semiconductor body. The unit cells comprise doped regions of opposite conductivity type separated by a gap or undiffused region. Metal contacts connect adjacent cells together in series so that the output voltages of the individual cells are additive. In some embodiments, doped field regions separated by gaps overlie the unit cells but the cells may be formed in both faces of the wafer.

4,342,044
Ovshinsky, Stanford R.; Izu, Masatsugu, inventors; Energy Conversion Devices, Inc., assignee. *Method for Optimizing Photoresponsive Amorphous Alloys and Devices*. July 27, 1982.

The production of improved photoresponsive amorphous alloys and devices, such as photovoltaic, photoreceptive devices, and the like; having improved wavelength threshold characteristics is made possible by adding one or more band gap adjusting elements to the alloys and devices. The adjusting element or elements are added at least to the active photoresponsive regions of amorphous devices containing silicon and fluorine, and preferably hydrogen. One adjusting element is germanium, which narrows the band gap from that of the materials without the adjusting element incorporated therein. Other adjusting elements can be used such as tin. The silicon and adjusting elements are concurrently combined and deposited as amorphous alloys by vapor deposition, sputtering or glow discharge decomposition. The addition of fluorine bonding and electronegativity to the alloy acts as a compensating or altering element to reduce the density of states in the energy gap thereof. The fluorine bond strength allows the adjusting element(s) to be added to the alloy to adjust the band gap without reducing the electronic qualities of the alloy. Hydrogen also acts as a compensating or altering element to compliment fluorine when utilized therewith. The compensating or altering element(s) can be added during deposition of the alloy or following deposition. The addition of the adjusting element(s) to the alloys adjusts the band gap to a selected optimum wavelength threshold for a particular device to increase the photoabsorption efficiency to enhance the device photoresponsive without adding states in the gap which decrease the efficiency of the devices. The adjusting element(s) can be added in varying amounts, in discrete layers or in substantially constant amounts in the alloys and devices.

4,342,795
Marcus, Sanford M.; Rellick, Joseph R., inventors; E. I. Du Pont de Nemours and Company, assignee. *Solar Cell Metallizations Comprising a Nickel-Antimony Alloy*. August 3, 1982.

A silicon solar cell is metallized with a nickel-antimony alloy to provide external contacts.

4,342,879
Catalano, Anthony W.; Bhushan, Manjul, inventors; The University of Delaware, assignee. *Thin Film Photovoltaic Device*. August 3, 1982.

A thin film photovoltaic solar cell which utilizes a zinc phosphide semiconductor is of the homojunction type comprising an n-type conductivity region forming an electrical junction with a p-type region, both regions consisting essentially of the same semiconductor material. The n-type region is formed by treating zinc phosphide with an extrinsic dopant such as magnesium. The semiconductor is formed on a multilayer substrate which acts as an opaque contact. Various transparent contacts may be used, including a thin metal film of the same chemical composition as the n-type dopant or conductive oxides or metal grids.

4,343,829
Tochikubo, Hiroo; Kanai, Akira, inventors; Hitachi, Ltd., assignee. *Method of Fabricating Single-Crystalline Silicon Films*. August 10, 1982.

Herein disclosed is a method of fabricating a thick single-crystalline silicon film at a low temperature less than 1000°C. The method is characterized in that, simultaneously as silicon polycrystals are grown on a substrate to form polycrystalline silicon, said polycrystals are irradiated and annealed with a laser or electron beam so that said polycrystalline silicon is single-crystallized to fabricate a single-crystalline silicon film.

4,343,830
Sarma, Kalluri R.; Legge, Ronald N., inventors; Motorola, Inc., assignee. *Method for Improving the Efficiency of Solar Cells Having Imperfections*. August 10, 1982.

Method and apparatus for minimizing the deleterious effects of structural imperfections in polycrystalline silicon solar cells uses a high pressure plasma system. The high pressure plasma system is used to introduce atomic hydrogen into the polycrystalline silicon substrates or into polycrystalline silicon solar cells. The silicon can be subjected to the hydrogenation either before or after it has a junction. The high pressure plasma system includes a high pressure chamber having a first and a second auxiliary chamber coupled to the high pressure chamber.

4,343,870
Heller, Adam; Lewerenz, Hans J.; Miller, Barry, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Semiconductor Liquid Junction Photocell Having a P-Type Photoactive Electrode*. August 10, 1982.

A semiconductor liquid junction photocell having a photovoltaic junction between a p-type photoactive electrode comprising InP or Si and an electrolyte comprising a redox couple selected from the group consisting of V^{2+}/V^{3+}, Nb^{4+}/Nb^{5+}, and Ti^{3+}/Ti^{4+} produces a stable photocurrent output.

4,343,962
Neugroschel, Arnost; Pao, Shing-Chong; Fossum, Jerry G., inventors. *Oxide Charge Induced High Low Junction Emitter Solar Cell*. August 10, 1982.

A high-low junction emitter silicon solar cell including an electron accumulation layer formed by oxide-charge-induction

4,343,963
Thomas, Donald E., inventor; Westinghouse Electric Corp., assignee. *Substrate for Silicon Solar Cells*. August 10, 1982.

A substrate is made for silicon solar cells by heating a sheet of large-grained silicon steel at a temperature of at least about 1300°C in an atmosphere of hydrogen and tungsten hexafluoride (or hexachloride) at a partial pressure ratio of hydrogen to tungsten hexafluoride of about 3 to about 6 to deposit an epitaxial layer of tungsten on said sheet of silicon steel. Epitaxial silicon can then be deposited in a conventional manner on the layer of epitaxial tungsten.

4,344,984
Kaplan, Daniel; Landouar, Pierre; Criton, Eric, inventors; Thomson-CSF, assignee. *Process for Producing a Layer Containing Silicon*. August 17, 1982.

The process consists of introducing into the silicon-containing layer at the same time as silicon deposition, another element of column IVa of the periodic classification in a proportion equal to or below 5% of the number of silicon atoms and greater than 0.1%. According to a preferred variant, this element is germanium. Deposition takes place at a temperature close to the crystallization temperature T. The process can comprise a subsequent phase during which the deposited layer undergoes heat treatment in an atmosphere of a plasma containing hydrogen or one of its isotopes at a temperature below the crystallization temperature T of the layer.

4,345,107
Fulop, Gabor F.; Betz, Jacob F.; Meyers, Peter V.; Doty, Mitchell E., inventors; Ametek, Inc., assignee. *Cadmium Telluride Photovoltaic Cells*. August 17, 1982.

Photovoltaic cell comprises thin film cadmium telluride in ohmic contact with a conductive substrate, preferably comprising a cadmium surface, through a cadmium-rich layer at the interface with the substrate. The cell further includes a rectifying barrier layer

which may be a Schottky barrier. The film is electrodeposited on the substrate surface and the substrate materials and electrodeposition conditions are controlled so as to produce a substantially stoichiometric deposit. Preferably, the film or cell is subsequently treated to enhance its efficiency.

4,345,582
Aharon, Naaman B., inventor. *System for the Utilization of Solar Energy*. August 24, 1982.

A dynamic system for the utilization of solar energy which is most of the time in the ideal position in relation to the sun. Said device comprises at least one unit consisting of a solar collector and a stand carrying said collector, means for rotating the solar collector around its horizontal axis and means for rotating the solar collector and/or the stand around the vertical axis; means for simultaneous or independent actuation of the rotation means, means for the tracking control of said actuation means; and means for the transfer of the energy obtained.

4,345,967
Cook, Melvin S., inventor. *Method of Producing Thin Single-Crystal Sheets*. August 24, 1982.

A method of producing thin single-crystal sheets is disclosed. A thin single-crystal layer is formed on a substrate, with the material of the layer having a different absorption coefficient for laser radiation than does the material of the substrate at their interface. The laser radiation is focused into a region contiguous to the interface and extending the width of the interface, and is swept across the entire interface region. The energy that is absorbed from the laser radiation in the focus region liquifies material in this region. The layer is progressively separated from the substrate as the laser radiation is swept across the interface, until the entire layer is separated from the substrate. The method is applicable to the production of thin single-crystal sheets of semiconductor material which may be used, for example, in the manufacture of solar cells or integrated circuits.

4,346,131
Yoldas, Bulent E., inventor; Westinghouse Electric Corp., assignee. *Polymerized Solutions for Depositing Optical Oxide Coatings*. August 24, 1982.

A clear solution is prepared by reacting metal alkoxide with a mixture of critical amounts of water and/or acid in an alcohol diluted medium. Alkoxides may be $Ti(OR)_4$ or $Ta(OR)_5$, or another metal alkoxide such as $Si(OR)_4$ in admixture with these alkoxides. Acids may be HCl or HNO_3. Quarter wave inorganic optical coatings are deposited by applying the alkoxide solution to a substrate then heating the coating at over 350°C. The coatings reduce reflectivity on silicon solar cells. The index of refraction of the coating can be varied by several techniques, including altering the proportion of titanium and silicon in the coating firing temperature, firing atmosphere. Thicknesses of the coating can be controlled by varying the rpm in spin application, withdrawal rate in dipping application, by concentration of the solution, by the type of solvent or the degree of polymerization of the titanium complexes.

4,347,262
Marcus, Sanford M., inventor; E. I. Du Pont de Nemours and Company, assignee. *Aluminum-Magnesium Alloys in Low Resistance Contacts to Silicon*. August 31, 1982.

An Al-Mg alloy is mixed with a Ni-Sb alloy or Al, in powder form, to form a thick-film metallizing paste useful for making low resistance electrically conductive contacts to a silicon solar cell coated with Si_3N_4.

4,347,263
Whitehouse, Daniel L., inventor; Solarex Corporation, assignee. *Method of Applying an Antireflective and/or Dielectric Coating*. August 31, 1982.

A method of applying an antireflective and/or dielectric coating for solar energy cells by directing from different sources (1) a vapor comprising a metal halide or metal alkoxide and (2) oxygen to the heated surface of a silicon wafer. The metal is deposited on the silicon in the form of an oxide.

4,347,264
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Applying Contacts to a Silicon Wafer and Product Formed Thereby*. August 31, 1982.

Metal contacts are deposited on a clean surface of a silicon wafer by coating the wafer with a glass during diffusion to form a junction inwardly of the surface, applying a photoresist layer to the glass, phtographing and developing a pattern for the contacts on the photoresist layer, etching out underlying portions of the glass layer, depositing the metal contacts in the voids so created, and then removing the entirety of the photoresist and glass layers.

4,348,254
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Making Solar Cell*. September 7, 1982.

A silicon solar energy cell having improved anti-reflective properties and resistance to radiation is composed of a light receiving surface having spaced indentations in the form of inverted pyramids therein. The pyramids, which have their bases in the plane of the light-receiving surface, are produced by masking the surface with a layer resistant to attack by a silicon etchant, forming open regions in the mask, then etching the major surface through the exposed regions.

4,348,428
Rockley, Mark G.; Mains, Gilbert J., inventors; Board of Regents for Oklahoma Agriculture and Mechanical Colleges acting for and on behalf of Oklahoma State University of Agriculture and Applied Sciences, assignee. *Method of Depositing Doped Amorphous Semiconductor on a Substrate*. September 7, 1982.

A method of depositing a doped amorphous semiconductor on a base material including the steps of subjecting the base to an environment including a semiconductor gas such as silane or germane, a dopant gas such as arsine, phosphine, or diborane, and mercury vapor, and exposing the base in such environment to ultraviolet radiation to effect decomposition of the semiconductor and dopant materials onto the base.

4,348,545
Arnould, Jacques, inventor; Le Silicium Semiconducteur SSC, assignee. *Process for Mounting a Protection Diode on a Vertical Multijunction Photovoltaic Cell Structure and Photovoltaic Cells Obtained*. September 7, 1982.

In a stack of diodes forming a vertical multijunction photovoltaic cell, an inversely connected diode is firmly secured to this stack with possible insertion of an intermediate wafer made from a conducting material.

4,348,546
Little, Roger G., inventor; Spire Corporation, assignee. *Front Surface Metallization and Encapsulation of Solar Cells*. September 7, 1982.

Method and apparatus for the front surface metallization and encapsulation of solar cells of the type comprising p and n semiconductor strata separated by a barrier junction, and front and rear conducting strata constituting electrical contacts, wherein the front conducting stratum is a novel metallic grid permitting transmission of solar radiation to the semiconductor strata. This metallic grid is in the form of a mesh of wires of sufficiently high tensile strength to be self-supporting while being drawn from spools or the like into contact with one or more components of the solar cell before completion of the cell's fabrication. The method is characterized in that the metallic grid,

in the form of the mesh of wires, is encapsulated between a transparent cover plate and the exposed front surface of the semiconductor strata, the mesh forming an electrical contact with the front surface of the semiconductor strata simultaneously that the plate is electrostatically bonded thereto. The apparatus is preferably automated and conveyorized.

4,349,691
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Method of Making Constant Voltage Solar Cell and Product Formed Thereby Utilizing Low-Temperature Aluminum Diffusion*. September 14, 1982.

A method of making a silicon solar energy cell having a substantially constant voltage despite significant increases in illumination, in which the back surface junction of the cell is formed by aluminum alloying at relatively low temperatures.

4,349,775
Kwon, Yiduk; Lawson, Paul, inventors; Exxon Research & Engineering Co., assignee. *Temperature Compensated Voltage Regulator for Photovoltaic Charging Systems*. September 14, 1982.

A voltage regulator for use in photovoltaic charging of storage batteries includes a temperature compensated reference voltage. The circuitry of the invention permits fixed temperature coefficient and variable temperature coefficient temperature compensated regulation. The voltage regulator comprises an operational amplifier including a linearly temperature dependent current source coupled to an input terminal of said operational amplifier and a voltage source having a selectable voltage which is connected to another input of said operational amplifier, said reference voltage circuit being operable to provide a reference voltage about equal to a maximum charging voltage for said batteries; a comparator for comparing said reference voltage with an output voltage of said photovoltaic array; and a switch responsive to said comparator to inhibit charging whenever said array output exceeds said reference voltage.

4,350,561
Little, Roger G., inventor; Spire Corporation, assignee. *Single Crystal Processes and Products*. September 21, 1982.

The surface of a starting single crystal of specified composition (e.g., silicon) is etched to produce a relief texture; a stratum of release composition (e.g., aluminum) is deposited on the relief texture to acquire a replica texture and is released to provide a replica master; a replica stratum of the specified composition in the amorphous or polycrystalline state is deposited on the replica master in order to acquire the original relief texture. It has been found that, when the replica stratum is recrystallized, it assumes a replica single crystal structure corresponding to the starting single crystal structure.

4,350,836
Crouthamel, Marvin S.; Coyle, Peter J., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Solar Array Construction*. September 21, 1982.

An interconnect tab on each cell of a first set of circular solar cells connects that cell in series with an adjacent cell in the set. This set of cells is arranged in alternate columns and rows of an array and a second set of similar cells is arranged in the remaining alternate columns and rows of the array. Three interconnect tabs on each solar cell of the said second set are employed to connect the cells of the second set to one another, in series and to connect the cells of the second set to those of the first set in parallel. Some tabs (making parallel connections) connect the same surface regions of adjacent cells to one another and others (making series connections) connect a surface region of one cell to the opposite surface region of an adjacent cell; however, the tabs are so positioned that the array may be easily assembled by depositing the cells in a certain sequence and in proper orientation.

4,350,837
Clark, Stephan R., inventor. *Spectrovoltaic Solar Energy Conversion System*. September 21, 1982.

A spectrovoltaic energy conversion system is disclosed having a refracting and wavelength dispersing medium variably placed in the path of photons of parallel rays directed from a concentrating and focusing device, causing selective spectral dispersion of said photons onto a photovoltaic cell array.

4,352,722
Ohkawa, Tihiro, inventor; General Atomic Company, assignee. *Integrated Photovoltaic Electrolytic Cell*. October 5, 1982.

A photovoltaic-electrolytic unit is provided to produce an electric current from solar energy and utilize the current to produce hydrogen by the electrolysis of water. The unit floats in an aqueous medium so that photoelectric cells are exposed to solar radiation, and electrodes submerged in the medium produce oxygen which is vented and hydrogen which is collected in the unit.

4,352,868
Skotheim, Terje, inventor. *Double Photoelectrochemical Cell for Conversion of Solar Energy to Electricity*. October 5, 1982.

A double photoelectrochemical cell for converting solar energy directly to electricity. The device in one embodiment has two semiconductors which are separated from each other by a polymer electrolyte. The two semiconductors have a different band gap, for example, one is n-type CdS and the other is p-type CdTe. The polymer electrolyte, for example, is a thin film polyethylene oxide acting as a polymer matrix containing a polysulfide redox couple, for example, Na_2S_4. The polymer electrolyte is transparent, insulating, and capable of transporting ions. At least one of the semiconductors is semi-transparent. The short wavelengths of light are absorbed by the semi-transparent wide band gap semiconductor, and the long wavelengths pass there-through, and through the polymer film electrolyte, and are absorbed by the narrow band gap semiconductor. The output of the cell is double; one from each semiconductor, i.e. they are series-connected. Output voltage, for example, is about 0.625 volts. The theoretical efficiencies in the example are about 35%, compared with about 25% for a standard photovoltaic cell, having a single junction. Also included is a method of manufacturing such a cell.

4,352,948
Kaplow, Roy; Frank, Robert I.; Goodrich, Joel, inventors; Massachusetts Institute of Technology, assignee. *High-Intensity Solid-State Solar-Cell Device*. October 5, 1982.

The invention contemplates a solar-cell construction wherein plural spaced elongate unit cells of an array are formed from a parallel-grooved single wafer or body of substrate material of a first conductivity type, with adjacent sidewalls of adjacent units at each inter-unit groove formation. Both sidewalls at each of a succession of grooves are formed with regions of second conductivity type, and an electrically conductive coating lines each sidewall having a second conductivity type region. A first output-terminal interconnect extends along one margin of the body and has ohmic contact with the coatings of the sidewalls having regions of the second conductivity type. A second output-terminal connection has ohmic contact to the body in a surface region of first conductivity type. Various embodiments are disclosed.

4,353,160
Armini, Anthony J.; Little, Roger G., inventors; Spire Corporation, assignee. *Solar Cell Junction Processing System*. October 12, 1982.

An integrated system and process for the continuous formation of p-n junctions in solar cells in a cost-effective manner and under computer control. The integrated system essentially comprises

an ion beam implanter, an electron beam annealer and a combination vacuum lock-and-wafer transport system, all disposed within a unitary housing maintained under a common vacuum environment. The integrated system employs no wet chemistry operations and is characterized by high reproducibility and narrow solar cell performance distribution.

4,353,161
Turner, Gary B., inventor; Atlantic Richfield Company, assignee. *Process for Fabricating Solar to Electrical Energy Conversion Units*. October 12, 1982.

A process for fabricating solar to electrical energy conversion units, includes the forming of arrays of parallel-connected strings of series connected solar cells selected from a number of different categories of cells. The categories are defined by different ranges of cell currents at a set cell voltage, a set level of incident cell face radiation and a set temperature. Each string of an array consists of cells from the same category; but strings of cells from different categories are used in the same array. A goal array current range for the arrays may be correlated with the average current of a group of cells at the set conditions, or with the estimated average for a group of cells to be manufactured, so that a selected number of strings for the arrays multiplied by such average falls within the range. According to a particular fabricating process, nine solar cell categories covering a total of approximately 0.9 amperes are established to form arrays of six parallel-connected strings of eleven series-connected solar cells having a goal array current range of 12.95 amperes plus or minus 2.2 percent. According to this particular process, hundreds of string combinations are possible, including combinations having strings from the lowest and highest categories.

4,355,196
Chai, An-Ti, inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Cell Having Improved Back Surface Reflector*. October 19, 1982.

This invention is concerned with reducing the operating temperature and increasing the output of a solar cell. A solar cell constructed in accordance with the invention carries electrodes in a grid finger pattern on its back surface. These electrodes are sintered at the proper temperature to provide good ohmic contact. After sintering, a reflective material is deposited on the back surface by vacuum evaporation. Thus, the application of the back surface reflector is separate from the back contact formation. Back surface reflectors formed in conjunction with separate grid finger configuration back contacts are more effective than those formed by full back metallization of the reflector material.

4,355,630
Fattor, Arthur, inventor. *Concentrating Solar Collector with Tracking Multipurpose Targets*. October 26, 1982.

A parabolic solar concentrator whose focused solar rays impinge as a line focus upon one or more daily and seasonably tracking target collectors made to move generally parallel along two or more tracks through the use of sensor activated motors.

4,355,896
Laue, Eric G., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Cloud Cover Sensor*. October 26, 1982.

An apparatus is described which provides a numerical indication of the cloudiness at a particular time of a day. The apparatus includes a frame holding several light sensors such as photovoltaic cells, with a direct sensor mounted to directly face the sun and indirect sensors mounted to face different portions of the sky not containing the sun. A light shield shields the direct sensor from most of the sky except a small portion containing the sun, and also shields each of the indirect sensors from direct sunlight. The relative values of the outputs from the direct and indirect sensors enables the generation of a numerical indication of the degree of cloudiness at a particular time of day.

4,356,141
Sanjurjo, Angel; Rowcliffe, David J.; Bartlett, Robert W., inventors; SRI International, assignee. *Method of Casting Silicon into Thin Sheets*. October 26, 1982.

Silicon (Si) is cast into thin shapes within a flat-bottomed graphite crucible by providing a melt of molten Si along with a relatively small amount of a molten salt, preferably NaF. The Si in the resulting melt forms a spherical pool which sinks into and is wetted by the molten salt. Under these conditions the Si will not react with any graphite to form SiC. The melt in the crucible is pressed to the desired thinness with a graphite tool at which point the tool is held until the mass in the crucible has been cooled to temperatures below the Si melting point, at which point the Si shape can be removed.

4,356,341
Borden, Peter G.; Saxena, Ram R., inventors; Varian Associates, Inc., assignee. *Cascade Solar Cell Having Conductive Interconnects*. October 26, 1982.

Direct ohmic contact between the cells in an epitaxially grown cascade solar cell is obtained by means of conductive interconnects formed through grooves etched intermittently in the upper cell. The base of the upper cell is directly connected by the conductive interconnects to the emitter of the bottom cell. The conductive interconnects preferably terminate on a ledge formed in the base of the upper cell.

4,357,179
Adams, Arthur C.; Aspnes, David E.; Bagley, Brian G., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Method for Producing Devices Comprising High Density Amorphous Silicon or Germanium Layers by Low Pressure CVD Technique*. November 2, 1982.

Layers of controllably dopable amorphous silicon and germanium can be produced by means of low pressure chemical vapor deposition, at a reaction temperature between about 450°C and about 630°C, for Si, and between about 350°C and about 400°C for Ge, in an atmosphere comprising a Si-yielding or Ge-yielding precursor such as SiH_4 or GeI_4, at a pressure between about 0.05 Torr and about 0.7 Torr, preferably between about 0.2 and 0.4 Torr. For undoped Si and P-doped Si, the preferred temperature range is from about 550°C to about 630°C, for B-doped Si, it is from about 480°C to about 540°C. The material produced has a density in excess of 0.9 of the corresponding crystalline density, and contains less than 1 atomic percent of hydrogen. An advantageous doping method is addition of dopant-forming precursor, e.g., PH_3 or B_2H_6, to the atmosphere. The material produced can be transformed into high quality crystalline material, and has many device applications in amorphous form, e.g., in solar cells, vidicon tubes, photocopying, and in integrated circuits, either as a conductor or nonconductor. The layers produced show conformal step coverage.

4,357,200
Grabmaier, Christa, inventor; Siemens Aktiengesellschaft, assignee. *Method for Producing Plate-, Tape- or Film-Shaped Si Crystal Bodies for Solar Cells*. November 2, 1982.

Large surfaced, pore-free silicon bodies useful for processing into solar cells are produced by providing at least two layers formed from at least two distinct silicon materials, each containing different amounts of germanium therein and thus having different melting points. A laminate is formed of such layers and sintered at a temperature at which only one of the silicon materials becomes molten so that the resultant molten layer effectively seals the pores of the other layers and upon cooling a unitary silicon body is attained. In certain embodiments, a molten silicon

material is applied as a liquified film onto a solidified layer composed of different silicon material.

4,357,201
Grabmaier, Christa; Holzapfel, Heinz, inventors; Siemens Aktiengesellschaft, assignee. *Method for Producing Plate-, Tape- or Film-Shaped Si Crystal Bodies for Solar Cells*. November 2, 1982.

Selectively shaped silicon crystal bodies, such as plate-, tape- or film-shaped bodies, having crystalline pillarlike structures therein are produced as substantially porefree bodies by forming a slurry from an admixture of relatively fine sized silicon particles, optional additives and a liquid binder, extruding such slurry as a relatively thin layer onto a first support member, drying such extruded layer until it becomes self-supporting and removing such support member, applying a substantially uniform layer of a germanium powder onto a surface of such self-supporting layer and then sintering the resultant structure in a protective gas atmosphere at temperatures below about 1430°C until a layer of crystalline silicon particles is generated, which particles have an average diameter substantially corresponding to the thickness of the dried layer.

4,357,400
Appleby, Anthony J., inventor; Electric Power Research Institute, Inc., assignee. *Photoelectrochemical Cell Employing Discrete Semiconductor Bodies*. November 2, 1982.

A photovoltaic cell includes a substrate having two conductive layers thereon and a plurality of discrete semiconductor bodies positioned on the conductive layers. In one embodiment discrete silicon particles of one conductivity type are positioned on one conductive layer and discrete silicon particles of opposite conductivity type are positioned on the other conductive layer. A redox system electrolyte contacts the particles whereby a voltage potential is generated across the two conductive layers in response to photons impinging on the semiconductor particles. In an alternative embodiment, a plurality of spaced conductive layers are provided with both P type and N type silicon particles on each conductive layer. A redox electrolyte serially connects the bipolar cells of each conductive layer thereby providing a higher voltage potential. In making the devices, electrical potentials are applied to the conductive layers whereby charged silicon particles are attracted to selected conductive layers and repulsed by other conductive layers. The particles are affixed to the conductive layers by suitable finders or adhesives such as silicone resins.

4,357,486
Blieden, Harry R.; Yerkes, John W., inventors; Atlantic Richfield Company, assignee. *Luminescent Solar Collector*. November 2, 1982.

A photovoltaic device composed of a luminescent member having a plurality of large area sides connected by an edge face, and at least one photovoltaic means carried by at least one of said sides.

4,358,331
Schmidt, Eckehard; Rüsch, Dieter; Tauber, Manfred, inventors; Licentia Patent-Verwaltungs-G.m.b.H., assignee. *Method of Embedding Semiconductor Components in Plastics*. November 9, 1982.

A method of embedding semiconductor components in plastics comprising inserting components into the plastics material and thereafter hardening the plastics material by irradiation with high energy beams.

4,359,367
Zukotynski, Stefan; Ma, Ki B.; Perz, John; Szadkowski, Andrzej; Yacobi, Ben-Gur, inventors; Governing Council of the University of Toronto, assignee. *Silicon-Based Semiconductor Devices*. November 16, 1982.

A new silicon based semiconductor device comprises a layer of amorphous silicon in which the density of energy states in the energy gap has been reduced by hydrogenation; this layer is deposited on a layer of a hydrogen-containing substrate material that can supply hydrogen in atomic form to the amorphous silicon. In processes of the invention the silicon layer and a substrate layer are hydrogenated separately to permit optimum hydrogenation; the silicon layer may be deposited without hydrogenation and hydrogenated subsequently with hydrogen from the substrate material. A specific example consists of a layer of hydrogenated amorphous silicon of about 1 micrometer thickness deposited on a hydrogen-containing chromium layer which is itself deposited on a carrier, the silicon then forming the active element of a photovoltaic cell particularly functional as a solar cell.

4,359,487
Schneider, Michael, inventor; Exxon Research & Engineering Co., assignee. *Method for Applying an Anti-Reflection Coating to a Solar Cell*. November 16, 1982.

The present invention teaches a method for applying an anti-reflection coating to solar cells whereby the coating is interdispersed among the cell's electrodes on the cell's junction surface. The method includes coating the solar cell's surface with an anti-reflection layer, selectively etching a pattern through the anti-reflection layer, which corresponds to the desired electrode pattern and electrolessly plating a layer of nickel onto the cell's surface.

4,360,542
Loeffler, Otto E.; Jain, Nirmal S.; Kauder, Otto S., inventors; Argus Chemical Corporation, assignee. *Process for the Preparation of Thin Films of Cadmium Sulfide and Precursor Solutions of Cadmium Ammonia Thiocyanate Complex Useful Therein*. November 23, 1982.

A process is provided for the preparation of thin films of cadmium sulfide by deposition of cadmium sulfide formed in the thermal decomposition of an aqueous solution of cadmium ammonia thiocyanate complex, useful particularly in the preparation of thin cadmium sulfide films on electrically-conductive substrates useful in photovoltaic cells, and on thermally-conductive substrates useful in solar energy absorbers, for energy conversion systems.

4,360,701
Evans, John C., Jr., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Heat Transparent High Intensity High Efficiency Solar Cell*. November 23, 1982.

A heat transparent high intensity solar cell has improved efficiency. A surface of each solar cell has a plurality of grooves. Each groove has a vertical face and a slanted face that is covered by a reflecting metal. Light rays are reflected from the slanted face through the vertical face where they traverse a photovoltaic junction. As the light rays travel to the slanted face of an adjacent groove, they again traverse the junction. The underside of the reflecting coating directs the light rays toward the opposite surface of the solar cell as they traverse the junction again. When the light rays travel through the solar cell and reach the saw toothed grooves on the under side, the process of reflection and repeatedly traversing the junction again takes place. The light rays ultimately emerge from the solar cell. These solar cells are particularly useful at very high levels of insolation because the infrared or heat radiation passes through the cells without being appreciably absorbed to heat the cell.

4,360,702
Feng, Tom; Ghosh, Amal K., inventors; Exxon Research & Engineering Co., assignee. *Copper Oxide/N-Silicon Heterojunction Photovoltaic Device*. November 23, 1982.

A photovoltaic device having characteristics of a high efficiency solar cell comprising a Cu_xO/n-Si heterojunction. The Cu_xO layer is formed by heating a deposited copper layer in an oxygen containing ambient.

4,360,703
Bolton, James R.; Ho, Te-Fu; McIntosh, Alan R., inventors; National Research Council of Canada, assignee. *Photovoltaic Cell Having P-N Junction of Organic Materials*. November 23, 1982.

A "molecular p-n junction" is formed by an organic compound which has a molecular portion susceptible of electron donation and another molecular portion susceptible of electron acceptance, each of these two portions being within the same compound or molecule and interconnected by a linkage portion. Thus the compound consists of three molecular parts which may in other environments exist as separate molecules. The electron donation molecule and electron acceptance molecule are separated by an intramolecular linkage or chain so that the three form one composite molecule. The donor and acceptor molecules, if the intermolecular linkage is adequate and generally in the preferred range of 15 Å to 25 Å, or generally between 10 Å to 40 Å, is susceptible, under the influence of light, of donating an electron to the acceptor. As such, the compound functions as a "molecular p-n junction".

4,361,295
Wenzel, Joachim, inventor. *Solar Power Station*. November 30, 1982.

Solar power station with semiconductor solar cells for generating electric power, wherein the semiconductor solar cells are provided on a member such as a balloon or a kite which carries the solar cells into the air. The function of the balloon or kite can also be fulfilled by a glider or airship. The solar power station can be operated by allowing the system to ascend at sunrise and descend at sunset or when the wind is going to be too strong in order to avoid any damage.

4,361,529
Hanke, Leopold; Schmelz, Helmut, inventors; Siemens Aktiengesellschaft, assignee. *Method for Producing Plate or Tape Shaped Silicon Crystal Bodies Having Crystalline Pillar-Like Structures, Equivalent to Columnar Structures, for Large Surface Solar Cells*. November 30, 1982.

The invention provides an improved method for producing plate-shaped or tape-shaped silicon crystal bodies having pillar-like structures therein which are equivalent to columnar structures comprising conducting the sintering process, for purposes of particle enlargement, in a gas atmosphere comrised of argon and a minimum amount of hydrogen. In a preferred embodiment, the hydrogen concentration in such atmosphere is about 6% by volume. The so-produced silicon bodies are useful for further processing into large-surface solar cells.

4,361,598
Yoldas, Bulent E., inventor; Westinghouse Electric Corp., assignee. *Polymerized Solutions for Depositing Optical Oxide Coatings*. November 30, 1982.

A clear solution is prepared by reacting metal alkoxide with a mixture of critical amounts of water and/or acid in an alcohol diluted medium. Alkoxides may be $Ti(OR)_4$ or $Ta(OR)_5$, or another metal alkoxide such as $Si(OR)_4$ in admixture with these alkoxides. Acids may be HCl or HNO_3. Quarter wave inorganic optical coatings are deposited by applying the alkoxide solution to a substrate then heating the coating at over 350°C. The coatings reduce reflectivity on silicon solar cells. The index of refraction of the coating can be varied by several techniques, including altering the proportion of titanium and silicon in the coating firing temperature, firing atmosphere. Thickness of the coating can be controlled by varying the rpm in spin application, withdrawal rate in dipping application, by concentration of the solution, by the type of solvent or the degree of polymerization of the titanium complexes.

4,361,717
Gilmore, Robert S.; Glascock, Homer H., II; Webster, Harold F., inventors; General Electric Company, assignee. *Fluid Cooled Solar Powered Photovoltaic Cell*. November 30, 1982.

Concentrated sunlight impinges on a large area photovoltaic device which is bonded to a highly pliable and thermally and electrically conductive structured copper strain relieving member; the lower face of the structured copper is sealed to a fluid cooled metal heat sink. Large power densities of sunlight are absorbed without appreciable temperature rise. The structured copper accommodates to the difference in expansion between the metal heat sink and the semiconductor wafer. Three embodiments utilize a single planar junction diode, an interdigitated diode, and series connected isolated junction diodes.

4,361,718
Marcus, Sanford M.; Rellick, Joseph R., inventors; E. I. Du Pont de Nemours and Company, assignee. *Silicon Solar Cell N-Region Metallizations Comprising a Nickel-Antimony Alloy*. November 30, 1982.

The n-type region of a silicon solar cell is metallized with a nickel-antimony alloy to provide an external contact.

4,361,950
Amick, James A., inventor; Exxon Research & Engineering Co., assignee. *Method of Making Solar Cell with Wrap-Around Electrode*. December 7, 1982.

A solar cell is provided which has a front electrode which wraps around the edge of the cell and onto a portion of the back of the cell. A second electrode is also provided on the back of the cell thereby permitting all electrical connections to be made on one side of the cell. A method for making such a cell also is disclosed.

4,362,895
Gupta, Amitava; Yavrouian, Andre H., inventors; California Institute of Technology, assignee. *Ultraviolet Absorbing Copolymers*. December 7, 1982.

Photostable and weather stable absorbing copolymers have been prepared from acrylic esters such as methyl methacrylate containing 0.1 to 5% of a 2-hydroxyallyl benzophenone, preferably the 4, 4'dimethoxy derivative thereof. The pendant benzophenone chromophores protect the acrylic backbone and when photoexcited do not degrade the ester side chain, nor abstract hydrogen from the backbone.

4,362,896
Singh, Vijay P., inventor; Photon Power, Inc., assignee. *Polycrystalline Photovoltaic Cell*. December 7, 1982.

A photovoltaic cell is formed by combining a spray process, forming a crystalline layer containing cadmium and sulfur, and an evaporation process, depositing copper chloride for converting to Cu_xS. The crystals containing cadmium and sulfur are heated in an atmosphere of cadmium and chlorides to obtain crystals having at least one dimension greater than 0.5 micron and a planar layer of Cu_xS is formed on the large crystals. A layer of Cu_xS having a thickness of 0.5-1.0 micron is obtained. Electrodes are formed from evaporated gold or chromium or a metallic paste including silver or copper. $Zn_xCd_{1-x}S$ may be substituted for CdS through at least part of the crystalline layer for improved Voc.

4,364,508
Lazzery, Angelo G.; Crouthamel, Marvin S.; Coyle, Peter J., inventors; The United States of America as represented by the United States Department of Energy, assignee. *Method of Fabricating a Solar Cell Array*. December 21, 1982.

A first set of pre-tabbed solar cells are assembled in a predetermined array with at least part of each tab facing upward, each tab being fixed to a bonding pad on one cell and abutting a bonding pad on an adjacent cell. The cells are held in place with a first vacuum support. The array is then inverted onto a second vacuum

support which holds the tabs firmly against the cell pads they abut. The cells are exposed to radiation to melt and reflow the solder pads for bonding the tab portions not already fixed to bonding pads to these pads.

4,364,532
Stark, Virgil, inventor; North American Construction Utility Corp., assignee. *Apparatus for Collecting Solar Energy at High Altitudes and On Floating Structures*. December 21, 1982.

Disclosed is apparatus for collecting solar energy with means of producing electricity by concentrating solar energy on sets of photovoltaic cells to be either positioned at high altitudes and which may be fitted to balloons or to structures floating on water.

4,365,107
Yamauchi, Yutaka, inventor; Sharp Kabushiki Kaisha, assignee. *Amorphous Film Solar Cell*. December 21, 1982.

An amorphous film solar cell of p-i-n heterojunction type, which is produced through the combination of group III-V compound amorphous semiconductor films with a layer of fluorinated or hydrogenated amorphous silicon semiconductor material. Selection of the p-i-n layer construction is easier compared to film solar cells of conventional fluorinated or hydrogenated amorphous silicon semiconductor material, efficiency is improved, and there is an increased degree of freedom in choice of the apparatus.

4,366,024
Ast, Gerhard; Dietl, Josef; Helmreich, Dieter; Miller, Hans-Dieter; Sirtl, Erhard, inventors; Heliotronic Forschungs-und Entwicklungsgesellschaft fur Solarzellen-Grundstoffe mbH, assignee. *Process for Making Solar Cell Base Material*. December 28, 1982.

Competitive current generation by the exploitation of solar energy requires cheap solar cells. A process is described which makes it possible to manufacture from silicon a base material for solar cells of this type in an economical manner and in large quanities. This is achieved by bringing silicon from a supply container into contact with a non-elemental lubricating melt, which is immiscible with silicon but will not wet silicon and has a melting point below that of silicon, and by drawing off a silicon film, sliding on this lubricating melt, and solidifying the silicon continuously by cooling to below its melting point.

4,366,334
de Cremoux, Baudouin; Poulain, Pierre; Sol, Nicole, inventors; Thomson-CSF, assignee. *Photovoltaic Cell Usable as a Solar Cell*. December 28, 1982.

The invention relates to a low cost photovoltaic cell, using a minimum thickness layer of semiconductor compounds able to provide the photovoltaic effect and specifically in polycrystalline form. On a molybdenum sheet an auxiliary polycrystalline germanium layer is deposited in order to facilitate subsequent depositions. This is followed by an intermediate polycrystalline layer of gallium aluminum arsenide and an active layer of polycrystalline gallium arsenide. The presence of the intermediate layer with a wider forbidden band than that of the active layer compensates the effect on the efficiency of the limited thickness of the active layer.

4,366,335
Feng, Tom; Ghosh, Amal K., inventors; Exxon Research & Engineering Co., assignee. *Indium Oxide/n-Silicon Heterojunction Solar Cells*. December 28, 1982.

A high photo-conversion efficiency indium oxide/n-silicon heterojunction solar cell is spray deposited from a solution containing indium trichloride. The solar cell exhibits an Air Mass One solar conversion efficiency in excess of about 10%.

4,366,336
Donaghey, Lee F., inventor; Chevron Research Company, assignee. *Age and Heat Stabilized Photovoltaic Cells*. December 28, 1982.

Improved age and heat stabilized photovoltaic solar cells comprising a semiconducting layer, a barrier layer containing the metal M_1 and a stabilizing metal electrode containing two or more metals, one of which is M_1, such that the tendency for M_1 to diffuse between the electrode and the barrier layer is approximately zero.

4,366,337
Alessandrini, Paolo; De Angelis, Lucio; Galluzzi, Fabrizio; Losciale, Francesco; Scafé, Ernesto, inventors; E.N.I. Ente Nazionale Idrocarburi, assignee. *p-Si/n-CdS Heterojunction Photovoltaic Cells*. December 28, 1982.

The invention provides photovoltaic cells of new design in which the two semiconductors have lattice parameters which differ by more than 5%. The n-type semiconductor material is constituted by high conductivity CdS doped with indium in a percentage higher than 1%, and the p-type semiconductor material is constituted by Si. The active surface of said cells is equal to or greater than 1.5 cm^2.

4,366,338
Turner, George W.; Fan, John C. C.; Salerno, Jack P., inventors; Massachusetts Institute of Technology, assignee. *Compensating Semiconductor Materials*. December 28, 1982.

A method of compensating grain boundaries or dislocations causing interstices to form particularly in polycrystalline semiconductor materials is disclosed which comprises selectively diffusing opposite impurity-type donor semiconductor material into the interstice to thereby reduce the conductivity of the interstice.

1983

4,366,771
Bowers, John E.; Schmit, Joseph L., inventors; Honeywell, Inc., assignee. *Mercury Containment for Liquid Phase Growth of Mercury Cadmium Telluride from Tellurium-Rich Solution*. January 4, 1983.

$Hg_{1-x}Cd_xTe$ is an important semiconductor for use in photovoltaic and photoconductive infrared photon detectors. $Hg_{1-x}Cd_xTe$ can be grown by liquid phase epitaxy at atmospheric pressure from a Te-rich solution in which case the Hg vapor pressure is below 0.1 atm at 500°C. This low vapor pressure makes possible the use of open-tube, slider growth techniques. The present invention describes a covered graphite slider system which provides an additional source of Hg, minimizes loss of Hg from the source wafer and virtually prevents loss of Hg from the $(Hg_{1-x}Cd_x)_{1-y}Te_y$ growth solution.

4,367,365
Spencer, Robert M., inventor; Acurex Solar Corporation, assignee. *Solar Energy Conversion Arrangement Utilizing Photovoltaic Members*. January 4, 1983.

An arrangement for converting solar energy directly to electrical energy is disclosed herein and utilizes a group of photovoltaic-like panel members, each of which is designed to convert solar energy into electrical energy by developing a voltage across opposite terminals thereof in response to and dependent upon its collection of solar energy. These panel members are electrically interconnected together in a specific way which combines their voltages in order to drive a given load. In addition, individual bypass circuitry is electrically connected with each photovoltaic-like member for diverting current around the latter in the event the resistance between its terminals increases above a certain level, for example due to an open circuit or undesirable shadowing. In this way, a malfunction of one photovoltaic-like member will not disrupt the operation of the overall arrangement. In order to locate

these malfunctioning members, the circuitry associated with each includes means for indicating (preferably visually) when its bypass circuitry is operating in a bypass mode.

4,367,366
Bloss, Werner H.; Hewig, Gert H.; Laub, Gerhard; Reinhardt, Erich, inventors; Bloss, Werner H., assignee. *Solar Cell Arrangement*. January 4, 1983.

A solar cell arrangement with an associated optical collecting lens system. The lens system focuses a light impingement area onto the solar cell to intensify incident radiation. The collecting lens system includes an optically active layer provided between the light impingement area and the solar cells. The optically active layer images and disperses the incident light in a manner adapted to the surface and light absorption characteristics of the solar cells.

4,367,367
Reisfeld, Renata; Neuman, Samuel, inventors. *Collector for Solar Energy*. January 4, 1983.

The present invention relates to a collector adapted to concentrate solar energy onto a photoelectric cell comprising in combination at least one glass plate doped with a substance resulting in fluorescence when said plate is irradiated by sunlight, a photoelectric cell being attached to a lateral side of the plate, the other lateral edges of the plate being provided with a reflective coating, said cell having a high efficiency in the range of wavelength of the fluorescent radiation. A plurality of such glass plates can be stacked one upon the other, each doped to absorb at a predetermined region of the spectrum and to fluoresce in a region where a certain photocell is sensitive. A fluorescent dye in a suitable carrier can be applied as a surface layer on such glass plates, and this improves the overall efficiency of the collector.

4,367,368
Wolf, Martin., inventor; University Patents, Inc., assignee. *Solar Cell*. January 4, 1983.

An improved solar cell structure is described wherein the cell's front region is provided with a plurality of raised structures, each structure comprising a multilayer of a highly doped region and a high-low junction. On these raised structures sit the solar cell's conductive grid. By emplacing the multilayer structure directly underneath the front region metallized conductive grid, the efficiency losses which would have been present had the highly doped region extended entirely or partially across the front layer, are avoided and the high surface recombination velocity associated with the grid is masked.

4,367,369
Mizutani, Fumio; Yoshiura, Masahiko; Iriyama, Keiji; Sasaki, Kanji; Tsuda, Keishiro, inventors; Agency of Industrial Science and Technology; Ministry of International Trade & Industry, assignees. *Solar Battery*. January 4, 1983.

A solar battery is formed by forming a film of a specific merocyanine dye on an n-type semiconductor substrate thereby producing a p-n junction in the interface between the dye film and the semiconductor substrate and connecting electrodes one each to the two layers.

4,367,403
Miller, Arthur, inventor; RCA Corporation, assignee. *Array Positioning System with Out-of-Focus Solar Cells*. January 4, 1983.

A solar array positioning system includes first light sensor means facing the same direction as the solar array and second light sensor means facing the opposite direction. A third sensor, this one responsive to gravity, is employed to indicate the direction about a diurnal slew axis that the array is tilted. These sensors are employed to determine the initial array slewing direction to insure that during slewing and subsequent tracking, the array never is rotated through more than a given angle, less than 360°, between two fixed limits. This permits connection to the array by hard wiring rather than slip rings. The system includes also fourth sensor means for providing fine tracking signals which assume control of the array position during tracking. A vane structure reduces the sensitivity of various of the sensors to obscuration by foreign particles. A low cost uncorrected lens may be used with the fourth.

4,367,581
Köhler, Kranz, inventor; Messerschmitt-Bolkow-Blohm GmbH, assignee. *Method of Manufacturing an Array of Solar Cells*. January 11, 1983.

An arrangement or array of solar cells comprises a plurality of cells each having contacting connectors which establish an electrically conducting connection between the individual solar cells. Each solar cell has a connector which projects slightly from the edge thereof and is of a selected profile or shape such that the contacting connectors of adjacent cells may be overlapped and connected to each other for electrical connection in an arrangement in which they do not come in contact with each other adjacent the solar cells.

4,367,633
Strathman, Ronald L., inventor. *Battery and Solar Powered Refrigerating System*. January 11, 1983.

The system includes a container and a door therefor, each comprised of inner and outer shells made of a moisture impervious material having sealed therebetween an insulating material. A holding plate, containing a eutectic solution and a refrigerant evaporator coil, is disposed within the container. A refrigerating circuit is provided including a compressor and condenser coil connected to the evaporator coil. A control unit monitors the eutectic solution temperature and the refrigerant temperature at the compressor output. It minimizes the operating times of the compressor and condenser fan necessary to maintain preferred temperatures inside the container in order to minimize the drain on batteries which are provided for powering the same. In addition, an array of solar cells is provided and the control is adapted for powering the compressor and condenser fan with their output when it is above the predetermined minimum operating level.

4,368,083
Bruel, Michel; Floccari, Michel, inventors; Commissariat a l'Energie Atomique, assignee. *Process for Doping Semiconductors*. January 11, 1983.

The present invention relates to a process for doping semiconductors, comprising the sucessive steps of: effecting implantation by recoil consisting in depositing on the surface of the substrate a layer of material containing dopant particles and in bombarding said layer by means of a beam of bombarding particles, which are in particular non-dopant, so as to cause the dopant particles to penetrate in the substrate; eliminating the layer of material deposited on the surface of the substrate; and effecting transitory annealing. The invention is applicable to the manufacture of solar cells.

4,368,216
Manassen, Joost; Cahen, David; Hodes, Gary, inventors; Yeda Research and Development Co., assignee. *Process for Preparation of Semiconductor and Semiconductor Photoelectrode*. January 11, 1983.

Process for forming a semiconductor finding use in solid state and PEC cells as a photoelectrode, comprising preparing a slurry of at least one semiconductor starting material used to form the semiconductor, a flux and a liquid vehicle; applying a layer of the slurry to an electrically conductive substrate; and annealing the layer. The semiconductor produced by the process and a photoelectrochemical cell including the semiconductor.

4,369,099
Kohl, Paul A.; Ostermayer, Frederick W., Jr., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Photoelectrochemical Etching of Semiconductors*. January 18, 1983.

A process is described for etching p-type semiconductors using a photoelectrochemical etching process. This etching process is highly advantageous because the etching site is highly defined by the incident light and the etching rate can be controlled in a number of ways including light intensity and electrode potential.

4,369,498
Schulte, Eric F., inventor; Texas Instruments Incorporated, assignee. *Photoluminescent Powered Calculator*. January 18, 1983.

A photoluminescent dye is suspended in a transparent medium. When exposed to light, the dye re-emits light in a narrow frequency range. Photovoltaic cells responsive to the re-emitted light are arranged around the sides of the collector medium, and are electrically connected to a low power demand device, such as a calculator. A reflective surface is placed next to the collector medium and kept a slight distance away such that an air gap is formed between the collector and the reflective surface. This gap increases the efficiency of the collector to the point that the collector will operate a small calculator even though exposed to low light levels such as are normal in an office environment.

4,369,629
Lockwood, Lawrence B., inventor. *Natural Energy Extractor*. January 25, 1983.

The invention is a multiple-mode energy utilization device combining elements which extract solar energy, those which utilize wind energy, and those utilizing rising convection currents caused by heated air. In one principal embodiment, a wind rotor on a vertical axis is provided with solar cells on its surfaces and a heat conductive axle in direct contact with a hot water tank in which there are paddle blades for pumping and frictionally stirring water or other fluid, and an electric heater in the water to utilize extra energy from the electric generator run by the shaft as well as the solar cells, which electrical energy would ordinarily charge storage batteries unless such charge was not needed which would cause the water heater to energize. Additional rotational and heat energy are generated by a hood disposed beneath the rotor which houses a heat sink which passes therethrough hot updrafts from a flat plate collector on which the rotor is mounted, as well as water from the flat plate collector to provide additional heat to the flat plate system.

4,370,175
Levatter, Jeffrey I., inventor; Katz, Bernard B., assignee. *Method of Annealing Implanted Semiconductors by Lasers*. January 25, 1983.

A high power excimer laser emits a pulsed output at a high repetition rate in the ultraviolet wavelength region and a uniform power output across the laser beam. By subjecting doped silicon wafers to the pulsed laser output, epitaxial regrowth of silicon crystals can be induced to repair damage to the silicon crystal structure which normally occurs during implantation of the dopant materials.

4,370,509
Dahlberg, Reinhard, inventor; Licentia Patent-Verwaltungs-GmbH, assignee. *Solar Cell Array*. January 25, 1983.

A solar cell array comprising a plurality of solar cells connected together by electrical contact means comprising amorphous metal alloy conductors.

4,370,510
Stirn, Richard J., inventor; California Institute of Technology, assignee. *Gallium Arsenide Single Crystal Solar Cell Structure and Method of Making*. January 25, 1983.

A production method and structure for a thin-film GaAs crystal for a solar cell on a single-crystal silicon substrate comprising the steps of growing a single-crystal interlayer of material having a closer match in lattice and thermal expansion with single-crystal GaAs than the single-crystal silicon of the substrate, and epitaxially growing a single-crystal film on the interlayer. The material of the interlayer may be germanium or graded germanium-silicon alloy, with low germanium content at the silicon substrate interface, and high germanium content at the upper surface. The surface of the interface layer is annealed for recrystallization by a pulsed beam of energy (laser or electron) prior to growing the interlayer. The solar cell structure may be grown as a single-crystal n^+/p shallow homojunction film or as a p/n or n/p junction film. A Ga(Al)As heteroface film may be grown over the GaAs film.

4,370,974
Maxey, Donald R., inventor. *Inverted Channel Focusing Solar Collector*. February 1, 1983.

A solar energy collector in the shape of an inverted geometric cusp of the second kind which permits the collection of direct and diffuse solar radiation, and which attenuates losses by thermal convection, conduction, and reverse radiation or re-radiation of energy to the cold or night sky. The solar collector when utilized in a composite unit is compact, has an aesthetically pleasing low profile, and alleviates the need for elaborate sensing and tracking mechanisms.

4,371,738
Staebler, David L., inventor; RCA Corporation, assignee. *Method of Restoring Degraded Solar Cells*. February 1, 1983.

Amorphous silicon solar cells have been shown to have efficiencies which degrade as a result of long exposure to light. Annealing such cells in air at a temperature of about 200°C for at least 30 minutes restores their efficiency.

4,371,739
Lewis, Kathy; Avery, James E., inventors; Atlantic Richfield Company, assignee. *Terminal Assembly for Solar Panels*. February 1, 1983.

A terminal assembly for providing external electrical connection to a solar panel having at least one solar cell and an electrically conductive layer located behind the cell. The terminal assembly has a substantially flat conductive portion between the cell and the conductive layer, and an insulating member of high dielectric strength positioned behind the flat portion to electrically isolate the flat portion from the conductive layer. A connector portion preferably extends rearwardly from the flat portion and through an opening in the conductive layer, the insulating member extending about the connector portion.

4,371,740
Clem, Katherine V., inventor; Eastman Kodak Company, assignee. *Conductive Elements for Photovoltaic Cells*. February 1, 1983.

A conductive element such as an electrode useful in photovoltaic cells comprises a soda-lime glass support having thereon a layer containing polycrystalline SnO_2 and a fluorine dopant, said conductive electrode being substantially haze-free and having a transmittance of radiation between 400 and 800 nm greater than 70% and an electrical resistance less than 30 ohm per square. The conductive element is particularly useful in thin film cadmium sulfide/cadmium telluride photovoltaic cells.

4,372,680
Adams, Richard R.; MacConochie, Ian O.; Poole, Bordie D., Jr., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Miniature Spectrally Selective Dosimeter*. February 8, 1983.

The present invention discloses a miniature spectrally selective dosimeter capable of measuring selected bandwidths of radiation exposure on small mobile areas. This is achieved by the combination of photovoltaic detectors, electrochemical integrators (E-cells) and filters in a small compact case which can be easily attached in close proximity to and substantially parallel to the surface being measured. In one embodiment two photovoltaic detectors, two E-cells, and three filters are packaged in a small case with attaching means consisting of a safety pin. In another embodiment, two detectors, one E-cell and three filters are packaged in a small case with attaching means consisting of a clip to clip over a side piece of an eye glass frame. In a further embodiment, the electro-optic elements are packaged in a wristwatch case with attaching means being a watchband. The filters in all embodiments allow only selected wavelengths of radiation to be detected by the photovoltaic detectors and then integrated by the E-cells.

4,372,989
Menzel, Guenther, inventor; Siemens Aktiengesellschaft, assignee. *Process for Producing Coarse-Grain Crystalline/Mono-Crystalline Metal and Alloy Films*. February 8, 1983.

Coarse-grained crystalline or monocrystalline metal or alloy regions are produced on substrates composed of a material selected from the group consisting of a ceramic, a glass and silicon, and which are provided with a layer of an amorphous or disordered metallic film, for example tantalum, by controllably irradiating select regions of the amorphous film with a focused beam of thermal-energy and/or light-energy, such as obtained from a focused laser beam, while substantially simultaneously maintaining the temperature of such substrate at about the temperature utilized in depositing the amorphous film on the substrate, whereby crystallization seeds are generated at the point of beam irradiation and function as a starting point for the crystalline or monocrystalline front on the metallic surface. Via controlled beam guidance, as by a computer, over the amorphous metal coated substrate surface, the crystallization front is extended uniformly in a desired path along the irradiated surface. The process is useful in producing metallizations for integrated semiconductor circuits, manufacture of contact electrodes for silicon solar cells, etc.

Re. 31,151
King, William J., inventor. *Inexpensive Solar Cell and Method Therefor*. February 15, 1983.

Solar cells are manufactured by a simplified method in which a single protective layer acts as an anti-reflection coating and an encapsulation. In cases where the junction is formed by ion implantation techniques, the same layer also serves as the implantation oxide. In addition, this multi-purpose layer may also serve as a mass analyzer, allowing the desired species of ions to reach the surface of the semiconductor but blocking the heavier undesired species. The necessary contacts may be formed prior to implantation, and the use of alloyed aluminum contacts with aluminum oxide passivation permits a simplified contacting procedure. A fully automatic contacting method and configuration for linear materials is also disclosed.

4,373,308
Whittaker, Ralph E., inventor; Atlantic Richfield Company, assignee. *Housing Structure Utilizing Solar Energy*. February 15, 1983.

A solar cell array consisting of individually rotatable elongated segments is flexibly supported beneath a translucent panel in the exterior roof of a building. A thermal solar collector is supported beneath the solar cell array for maximum utilization of the solar energy received through the roof opening.

4,373,809
Gobrecht, Klaus, inventor. *Solar Energy Flux Integrator*. February 15, 1983.

A solar energy flux integrator includes a semiconducting solar cell positioned to receive solar radiation, and a micro-coulombmeter connected to receive current from the solar cell. The micro-coulombmeter comprises a glass capillary filled with a mercury salt electrolyte having an indicating bubble and two mercury electrodes. A series resistor is provided which has a resistance value to slow the movement of the bubble when low levels of solar energy are incident on the cell so that movement of the bubble is directly proportional to the incident solar flux. This series resistor compensates for the spectral shift towards blue of the indirectly received solar radiation, which spectral shift otherwise causes the measured integrated value of solar flux to be too high due to the greater sensitivity of the solar cell to light of shorter wavelengths. A parallel resistor is provided to scale the output of the solar cell to the micro-coulombmeter and a reversing switch is connected to permit travel of the indicating bubble in opposite directions.

4,374,182
Gaul, John H.; Weyenberg, Donald R., inventors; Dow Corning Corporation, assignee. *Preparation of Silicon Metal Through Polymer Degradation*. February 15, 1983.

What is disclosed is a method of forming silicon from the degradation of polychlorosilanes, a method of coating a substrate with said silicon and a product of said coating method. The method of forming silicon consists essentially of pyrolyzing said polychlorosilanes in an inert atmosphere or in a vacuum at a temperature of 500°C to 1450°C.

4,374,406
Hepp, James, inventor. *Lightweight Attachment for Solar Cell Array Next to a Fluorescent Tube*. February 15, 1983.

A lightweight attachment for a solar cell array in combination with spacing means for spacing the array consisting of a plurality of solar cells on a support next to a fluorescent tube to provide thereby a power package which is fitted with conductors to connect the solar cells in series to a remote motor adapted for the rotation of a remote display. A holding means is provided for the support to hold it close to the tube, which holding means may be a magnetic tape. The holding means may be a flexible strap having a tooth portion at the sides of the strap, the tooth sides being adapted to holding the support in closely spaced relation with the plurality of solar cells directly below the fluorescent tube. Spacing means is provided to fix the spacing between the surface of the cells on the support and the tube. Since there is no tension from the conductors and no substantial weight to dislodge the fluorescent tube due to the cells or support, the power package overcomes the safety hazards of the prior art.

Re. 31,156
Dessert, Richard, inventor. *Energy Efficient Passenger Vehicle*. February 22, 1983.

An energy efficient passenger carrying vehicle for road use. The vehicle basically comprises a long, narrow body carrying two passengers in a back-to-back relationship. The vehicle is basically a battery powered electric vehicle that can be charged by all free energy sources, namely the sun, the wind, human muscles and momentum. The vehicle comprises four modules, namely body, solar, and two power modules. An electric power module is located within each end of the body module. This module includes electric motors driving the vehicle supporting wheels and rechargeable batteries to power the motors. Pedals, similar to those on a bicycle, located at each power module, drive generators to help recharge the batteries during operation of the vehicle, or directly help drive the vehicle wheels. A solar module comprising a large electricity

generating solar cell panel covers most of the vehicle roof to aid in charging the batteries. Means are provided to tilt the solar cell panel toward the sun about a longitudinal axis. A unique flexible duct below the solar panel serves to cool the cells and, if desired, heat the passenger compartment. Further energy savings are obtained by canting the rear wheels while steering with the front wheels, so that the vehicle moves down the road at a crab angle which provides a sail effect when wind is from the vehicle beam or aft of the beam. Regenerative braking means can be used when slowing down, on a long downgrade, when sailing speed is greater than required, or any other time when vehicle momentum is greater than necessary for vehicle operation, to use the excess forward momentum to drive generators to charge the batteries. Thus, a single battery carge will be conserved and vehicle operation will be assisted in a manner giving maximum vehicle range and speed.

4,374,955
Gupta, Amitava; Ingham, John D.; Yavrouian, Andre H., inventors; California Institute of Technology, assignee. *N-Butyl Acrylate Polymer Composition for Solar Cell Encapsulation and Method*. February 22, 1983.

A polymer syrup for encapsulating solar cell assemblies. The syrup includes uncrosslinked poly(n-butyl)acrylate dissolved in n-butyl acrylate monomer. Preparation of the poly(n-butyl)acrylate and preparation of the polymer syrup are disclosed. Methods for applying the polymer syrup to solar cell assemblies as an encapsulating pottant are described. Also included is a method for solar cell construction utilizing the polymer syrup as a dual purpose adhesive and encapsulating material.

4,375,007
Marcus, Sanford M., inventor; E.I. DuPont de Nemours & Co., assignee. *Silicon Solar Cells with Aluminum-Magnesium Alloy Low Resistance Contacts*. February 22, 1983.

An Al-Mg alloy is mixed with a Ni-Sb alloy or Al, in powder form, to form a thick-film metallizing paste useful for making low resistance electrically conductive contacts to a silicon solar cell coated with Si_3N_4.

102,801
Hovel, Harold J., inventor. *Silicon Solar Cell*. March 1, 1983.

A high efficiency silicon solar cell may be constructed by providing a two-stage drift field emitter with a 1 micron thickness on a drift field base region with a back surface field region. The stage of the drift field emitter adjacent to the junction is moderately doped from 10^{18} to 10^{16} atoms/cc adjacent to the junction to minimize bandgap shrinkage and to maximize carrier lifetime while the stage of the emitter adjacent the surface is highly doped at 10^{19} atoms/cc to minimize sheet resistance. The drift field is aiding in both the emitter and base regions. The size of the base is less than an effective diffusion length. There is a difference in doping level in the base depending on the conductivity type of the silicon. For n-conductivity type the base is doped 10^{13} atoms/cc at the pn junction, increasing to 10^{16} atoms/cc in the drift field region. For p-conductivity type the base is doped 10^{16} at the junction, increasing to 10^{18} atoms/cc in the drift field. A back surface field is provided adjacent the ohmic contact on the part of the base remote from the junction by doping to 10^{20} to 10^{21} atoms/cc. A passivating antireflective layer is added to the light incident surface. The 1 micron emitter region contains a 0.1 to 0.2 microns thick high conducting region adjacent the antireflective coating on the light incident surface and a drift field region 0.3 to 0.9 microns thick. The base region has a drift field region 20 to 100 microns thick and the overall base region is 50 to 450 microns thick. The back surface field region is 1 micron thick.

4,375,662
Baker, Richard H., inventor; Exxon Research & Engineering Co., assignee. *Method of and Apparatus for Enabling Output Power of Solar Panel to be Maximized*. March 1, 1983.

The d.c. power supplied by a photovoltaic solar panel to a load is controlled by monitoring the slope of the panel voltage vs. current characteristic and adjusting the current supplied by the panel to the load so that the slope is approximately unity. The slope is monitored by incrementally changing the panel load and indicating whether the resulting change in current derived from the panel is above or below a reference value, indicative of the panel voltage. In response to the change in the monitored current being above the reference value, the slope of a voltage vs. current curve is greater than unity and the load is adjusted to decrease the current supplied by the panel to the load. Conversely, in response to the current being less than the reference value, the slope of the voltage vs. current curve is less than unity and the load is adjusted to increase the current supplied by the panel to the load.

4,376,228
Fan, John C. C.; Bozler, Carl O., inventors; Massachusetts Institute of Technology, assignee. *Solar Cells Having Ultrathin Active Layers*. March 8, 1983.

Improvements in solar cells based upon low cost semiconductors, such as amorphous silicon, are disclosed. The improved solar cells of this invention have ultrathin active semiconductor layers having a thickness between 0.1 t_α and L_m wherein t_α is the solar spectrum absorption length and L_m is the diffusion length for photogenerated minority charge carriers in the active layer. The back surface reflector has a solar spectrum reflectivity of 70% or greater, so that incident energy not absorbed in a direct pass through the active layer is reflected for another pass. The most preferred embodiment of the cells described herein are shaped to have a light-trapping structure so that light makes multiple passes through the thin semiconductor layers.

4,376,347
Thompson, Marion E., inventor. *Light Powered Mobile*. March 15, 1983.

A display assembly is provided which most desirably comprises a lamp mobile having a base, a d.c. motor mounted within the base with a shaft extending outwardly from it, and the mobile mounted to the shaft. The interconnection between the mobile and the shaft can be a curved distal end of the shaft engaging an abutment surface of a similar radius of curvature formed within a body member of the mobile, with the shaft loosely received by the mobile, so that the mobile will rotate at a slower speed than the shaft. The base is screw-threaded onto the top of a cylindrical projection from a lamp harp, and a solar cell which powers the d.c. motor is also mounted to the lamp so that it receives light from the lamp light bulb. A pair of planar portions, one received by the lamp socket and the other mounting the solar cell, and interconnected by a hinge, may be utilized to properly position the cell to receive light from the lamp. The mobile includes a rod mounted at its central portion to the mobile body member with a weight mounted to one end of the rod and a display item, such as an airplane model, mounted to the other end of the rod. Cooperating magnets disposed on the rod and base can cause the plane to move up and down as it rotates.

4,376,872
Evans, John C.; Chai, An-Ti; Goradia, Chandra P., inventors; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *High Voltage V-Groove Solar Cell*. March 15, 1983.

A high voltage multijunction solar cell comprises a plurality of discrete voltage generating regions, or unit cells, which are formed in a single semiconductor wafer and are connected together so that the voltages of the individual cells are additive. The unit cells comprise doped regions of opposite conductivity types separated by a gap. The method includes forming V-shaped grooves in the wafer and thereafter orienting the wafer so that ions of one conductivity type can be implanted in one face of the groove while the other face is shielded. A metallization layer is applied and selectively etched away to provide connections between the unit cells.

4,377,445
Grimes, Patrick G., inventor; Exxon Research and Engineering Co., assignee. *Shunt Current Elimination for Series Connected Cells*. March 22, 1983.

Electrochemical systems having a plurality of cells which are hydraulically and electrically connected in series develop shunt currents in the electrolyte of adjacent cells. The shunt currents are reduced or eliminated by the placing of an electrical bypass across two adjacent intercell conduits, and applying a protective current through the electrical bypass in a direction of the shunt currents and of a magnitude that can effectively reduce the shunt currents.

4,377,564
Dahlberg, Reinhard, inventor; Licentia Patent-Verwaltungs-GmbH, assignee. *Method of Producing Silicon*. March 22, 1983.

A method of producing silicon comprising producing a plasma in a gas flow laden with at least one silicon compound so that the silicon compound is reduced or decomposed to silicon and transporting the silicon which may have reacted with other material if present in the plasma and reaction products out of the plasma in the gas flow.

4,377,604
Schneider, Ronald A., inventor; Chevron Research Company, assignee. *Copper Stabilized Dipping Solution for a Photovoltaic Device Incorporating a Cu_xS Layer*. March 22, 1983.

A copper stabiized dipping solution for a photovoltaic device incorporating a Cu_xS layer. The dipping solution contains copper metal which stabilizes the solution by providing a source of copper to continuously reduce Cu^{++} ions to Cu^{+} ions. The copper has no adverse effect on the topochemical formation of a copper sulfide layer on, for example, a semiconductor cadmium sulfide layer in a photovoltaic device. Preferably, the copper stabilized dipping solution has a pH less than about 4.5 and includes counter ions such as chloride or bromide ions.

4,377,722
Wested, Jens., inventor; Elektronikcentralen, assignee. *Solar Cell Unit and a Panel or Battery Composed of a Plurality of Such Solar Cell Units*. March 22, 1983.

The effective area of a solar cell unit may be enlarged or increased considerably relative to its physical area by providing its exposed surface layer with a periodic structure or pattern, by which a local field is generated, a so-called Hartree harmonics field. The periodic structure is preferably a grating structure or pattern, and by orienting the solar cell edgewise so that the sunlight is grazing rather than oblique or directly perpendicular to the surface, its response factor may be increased up to a factor 11 theoretically.

4,377,723
Dalal, Vikram L., inventor; The University of Delaware, assignee. *High Efficiency Thin-Film Multiple-Gap Photovoltaic Device*. March 22, 1983.

A photovoltaic device includes at least two solar cells made from Group IV elements or their alloys in the amorphous state mounted on a substrate. The outermost or first cell has a larger bandgap than the second cell. Various techniques are utilized to improve the efficiency of the device.

4,377,901
David, Gerard-Robert; Pincon, Daniel M., inventors; U.S. Philips Corporation, assignee. *Method of Manufacturing Solar Cells*. March 29, 1983.

A method of manufacturing solar cells in a semiconductor wafer uses a first doped glassy layer which is spaced apart from the edges of the wafer, in combination with a second undoped glassy layer, so that, when the dopants are diffused from the first layer into the wafer, only that portion of the wafer beneath the first layer is doped. This simple and economical method results in solar cells having improved leakage characteristics.

4,378,460
Williams, Richard, inventor; RCA Corporation, assignee. *Metal Electrode for Amorphous Silicon Solar Cells*. March 29, 1983.

An amorphous silicon solar cell having an N-type region wherein the contact to the N-type region is composed of a material having a work function of about 3.7 electron volts or less. Suitable materials include strontium, barium and magnesium and rare earth metals such as gadolinium and yttrium.

4,378,786
Comeau, Joseph E., Jr., inventor. *Apartment Solar Heating Panel*. April 5, 1983.

A Solar Heating Panel that can be placed in a south facing window with the heat collecting fins facing outside, light will then hit the photovoltaic cells causing the fan to operate, air is drawn into the top of the panel by the fan which blows the air down into the panel and across the heat absorbing fins, as the air passes down across the heat collecting fins it will be heated, and will exit the panel at the bottom of said panel and into the room, thus heating it.

4,379,020
Glaeser, Andreas M.; Haggerty, John S.; Danforth, Stephen C., inventors; Massachusetts Institute of Technology, assignee. *Polycrystalline Semiconductor Processing*. April 5, 1983.

A process for forming large-grain polycrystalline films from amorphous films for use as photovoltaic devices. The process operates on the amorphous film and uses the driving force inherent to the transition from the amorphous state to the crystalline state as the force which drives the grain growth process. The resultant polycrystalline film is characterized by a grain size that is greater than the thickness of the film. A thin amorphous film is deposited on a substrate. The formation of a plurality of crystalline embryos is induced in the amorphous film at predetermined spaced apart locations and nucleation is inhibited elsewhere in the film. The crystalline embryos are caused to grow in the amorphous film, without further nucleation occuring in the film, until the growth of the embryos is halted by impingement on adjacently growing embryos. The process is applicable to both batch and continuous processing techniques. In either type of process, the thin amorphous film is sequentially doped with p and n type dopants. Doping is effected either before or after the formation and growth of the crystalline embryos in the amorphous film, or during a continuously proceeding crystallization step.

4,379,202
Chalmers, Bruce, inventor; Mobil Solar Energy Corporation, assignee. *Solar Cells*. April 5, 1983.

A solar cell having a periodic front surface electrode is provided with a transparent cover chosen and configured to provide refractive discontinuities of the same spatial frequency as and aligned with the conductive grid. The refractive discontinuities are so controlled, through selection of the shape, disposition, and refractive index of the cover, as to cause a ray initially normal to the surface of the cell which would otherwise be intercepted by the electrode to miss the electrode and fall on the photosensitive material.

4,379,324
Thompson, Marion E., inventor. *Bulb Mounting of Solar Cell*. April 5, 1983.

An energy converting assembly is provided for parasiting of light from a fluorescent light bulb utilizing a solar cell. The solar cell is mounted on a base memeber elongated in the dimension of elongation of the fluorescent bulb, and electrical interconnections

to the cell are provided. A flexible sheet of opaque material having a flat white interior reflective surface surrounds the fluorescent bulb and reflects light emitted from the bulb back toward the bulb and the solar cell. The reflective sheet is tightly held in contact with the bottom of the bulb by adhesive, a tie strap, an external clip, or the like.

4,379,588
Speice, Donald G., inventor. *Revolving Solar Lounger*. April 12, 1983.

A solar lounger is disclosed which rotates in response to energization from the sun's rays. The solar lounger has a chaise type chair which is rotatably supported on a base. Photovoltaic solar cells are mounted on said chair and generate electrical energy in response to the sun's rays. Said electrical energy is used to power a drive motor which causes said chair to rotate relative to said base.

4,379,943
Yang, Chi C.; Madan, Arun; Ovshinsky, Stanford R.; Adler, David, inventors; Energy Conversion Devices, Inc., assignee. *Current Enhanced Photovoltaic Device*. April 12, 1983.

The disclosure is directed to photovoltaic devices having enhanced short circuit currents and efficiencies. The devices are made by depositing on a previously deposited doped amorphous semiconductor alloy layer a body of intrinsic amorphous semiconductor alloys including a first intrinsic layer, adjacent the doped layer, formed from the deposition of a non-etching starting material and a second intrinsic layer different in composition from the first intrinsic layer. The second intrinsic layer preferaby includes silicon and fluorine while the first intrinsic amorphous alloy layer does not include fluorine. The first intrinsic layer may be formed by the glow discharge decomposition of silane gas alone. The thicknesses of the first and second intrinsic layers are adjusted so as to match the respective potential drops thereof with the first intrinsic layer being relatively thin as compared to the second intrinsic layer.

4,379,944
Borden, Peter G.; Bell, Ronald L.; Hyder, Syed B., inventors; Varian Associates, Inc., assignee. *Grooved Solar Cell for Deployment at Set Angle*. April 12, 1983.

A grooved solar cell for deployment at a set angle with respect to incoming radiation has reduced contact obscuration and series resistance. A regular array of walls formed by grooves in a crystalline semiconductor substrate is exposed to incoming radiation. Metallic contacts are formed on those walls of the grooves which are not to be exposed to sunlight. The solar cell is mounted in an apparatus at a set angle with respect to incoming radiation. The array of walls is exposed to incoming radiation while the walls with metal contacts are substantially shadowed. In a preferred embodiment the grooves are formed by using orientation specific etches.

4,380,112
Little, Roger G., inventor; Spire Corporation, assignee. *Front Surface Metallization and Encapsulation of Solar Cells*. April 19, 1983.

Method and apparatus for the front surface metallization and encapsulation of solar cells of the type comprising p and n semiconductor strata separated by a barrier junction, and front and rear conducting strata constituting electrical contacts, wherein the front conducting stratum is a novel metallic grid permitting transmission of solar radiation to the semiconductor strata. This metallic grid is in the form of a mesh of wires of sufficiently high tensile strength to be self-supporting while being drawn from spools or the like into contact with one or more components of the solar cell before completion of the cell's fabrication. The method is characterized in that the metallic grid, in the form of the mesh of wires, is encapsulated between a transparent cover plate and the exposed front surface of the semiconductor strata, the mesh forming an electrical contact with the front surface of the semiconductor strata simultaneously that the plate is electrostatically bonded thereto. The apparatus is preferably automated and conveyorized.

4,381,233
Adachi, Toshio; Arakawa, Tatsumi, inventors; Asahi Kasei Kogyo Kabushiki Kaisha, assignee. *Photoelectrolyzer*. April 26, 1983.

There is presented a photoelectrolyzer comprising a number of minute solar cell elements suspended in an electrolyte. Each element is made of, for example, a first thin film of intrinsic amorphous silicon having specific properties and/or N-type amorphous silicon and a second thin film of a P-type amorphous silicon. This apparatus is high in the sunlight collection efficiency and also is capable of electrolyzing an electrolyte with high electrolysis voltage such as water.

4,381,978
Gratzel, Michael; Kiwi, John; Kalyanasundaram, Kuppuswamy; Philp, John, inventors; Engelhard Corporation, assignee. *Photoelectrochemical System and a Method of Using the Same*. May 3, 1983.

A photoelectrochemical system for conducting endoergic chemical processes driven by light energy. This system consists essentially of an illuminated halfcell and a darkened halfcell joined via electrodes and an external circuit to allow for the transport of electrons. Also, the said halfcells are joined by an ion conducting junction so as to allow for the transport of ions. The illuminated halfcell contains a photosensitizer, an electron relay substance and a catalyst, and the darkened halfcell may contain a second electron relay and a catalyst. Illumination with visible light results in the simultaneous and separate generation of oxidation and reduction products.

4,382,099
Legge, Ronald N.; Sarma, Kalluri R., inventors; Motorola, Inc., assignee. *Dopant Predeposition from High Pressure Plasma Source*. May 3, 1983.

A method is provided for predepositing dopant material on semiconductor substrates. The semiconductor substrates are positioned within a high pressure plasma reactor apparatus. A high pressure rf plasma is generated in the apparatus at a pressure of about one atmosphere or greater. Dopant materials such as B_2H_6, PH_3, or AsH_3 are introduced to the plasma and form ionized species of the dopant. The plasma and the ionized species are directed to the surface of the semiconductor substrates whereon a uniform layer of the dopant is deposited.

4,382,833
Coyle, Peter J.; Crouthamel, Marvin S., inventors; RCA Corporation, assignee. *Vacuum Lamination Fixture*. May 10, 1983.

An apparatus for laminating a solar cell structure includes upper and lower housing members and an intermediate member which includes a flexible membrane. The members form upper and lower sealed chambers which can be selectively evacuated. The solar cell structure is placed between the membrane and a parallel rib structure in the lower chamber. Heater elements and reflectors between the ribs are employed for radiating heat energy to the solar cell structure during the laminating process for melting a potting material therein, while both chambers are evacuated. Then air is admitted to the upper chamber to cause the membrane to compress the laminated structure against the parallel rib support means while the laminated structure cools.

4,382,838
Authier, Bernhard, inventor; Wacker-Chemie GmbH, assignee. *Novel Silicon Crystals and Process for Their Preparation*. May 10, 1983.

A plate-like silicon crystal having a columnar structure formed along the direction of the shortest axis, produced by cooling

molten silicon, which may contain a doping agent, in a temperature gradient between the two largest boundary surfaces of the melt, one of which has a maximum temperature of 1200°C, and the opposite surface being at least 200° to 1000°C higher, but below the melting point of silicon.

4,383,129
Gupta, Amitava; Ingham, John D.; Yavrouian, Andre H., inventors; California Institute of Technology, assignee. *Solar Cell Encapsulation*. May 10, 1983.

A polymer syrup for encapsulating solar cell assemblies. The syrup includes uncrosslinked poly(n-butyl)acrylate dissolved in n-butyl acrylate monomer. Preparation of the poly(n-butyl)acrylate and preparation of the polymer syrup is disclosed. Methods for applying the polymer syrup to solar cell assemblies as an encapsulating pottant are described. Also included is a method for solar cell construction utilizing the polymer syrup as a dual purpose adhesive and encapsulating material.

4,383,130
Uroshevich, Miroslav, inventor; Alpha Solarco, Inc., assignee. *Solar Energy Cell and Method of Manufacture.* May 10, 1983.

The disclosure illustrates a ribbon like photovoltaic cell that is formed by first applying a thin layer of tungsten or other conductive, temperature resistant material on a base ribbon of high temperature resistant, and electrically non-conductive material. A thin coat of silicon up to several atoms thick is deposited over the ribbon and/or tungsten to enable the ribbon to be drawn through a bath of molten silicon to grow a layer of silicon which is subsequently doped with impurities. A conductive grid over the silicon and a connector through a perforation in the base ribbon enable the cell to be connected in an electrical circuit to produce a current flow. The use of the base ribbon enables continuous flow process techniques to greatly reduce the cost of production for a photovoltaic cell. In addition, the base ribbon may be split lengthwise after processing on both sides to enable the production of two (2) ribbons.

4,384,259
Capewell, Maurice J., inventor; Data Beta Limited, assignee. *Electrical Power Supplies*. May 17, 1983.

A power supply suitable for energizing an isolation amplifier requiring its input section to be isolated electrically from its output section. The power supply consists of a primary circuit, which, when energized by an electrical supply, converts the electrical energy to infrared radiation, and a secondary circuit which includes a solar cell or cells arranged to receive the infrared radiation. Electrical energy is generated by the solar cell or cells when irradiated. The primary circuit of the new power supply includes a plurality of infrared emitting diodes which are energized electrically to provide infrared radiation. The current produced by the solar cell or cells in response to the radiation is applied to a regulating circuit.

4,385,102
Fitzky, Hans G; Ebneth, Harold, inventors; Bayer Aktiengesellschaft, assignee. *Large-Area Photovoltaic Cell*. May 24, 1983.

In a large-area photovoltaic cell containing a photoactive semiconductor layer which contacts another semiconductor layer, metal or an electrolyte to form a depletion layer, and further containing an electrode and a counter electrode for current collection, the improvement which comprises employing as a substrate for said photoactive semiconducting layer a metallized textile sheet, the metal constituting one of the electrodes, the sheet having been metallized by depositing the metal thereon wet-chemically without current. The metal thickness may be built up with or without current. Such cells have low internal resistances and are highly efficient.

4,385,198
Rahilly, W. Patrick, inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Gallium Arsenide-Germanium Heteroface Junction Device*. May 24, 1983.

Doping with one of the Group Ia elements Li, Na or K near the heteroface junction produces P^+ conductivity in the gallium arsenide and N^+ conductivity in the germanium. The device can be used, for example, as a dual bandgap solar cell. The fabrication includes implanting the Group Ia dopant in a Ge wafer. This dopant diffuses into the GaAs when it is subsequently deposited on the Ge.

4,385,199
Hamakawa, Yoshihiro; Tawada, Yoshihisa, inventors. *Photovoltaic Cell Having a Hetero Junction of Amorphorous Silicon Carbide and Amorphous Silicon*. May 24, 1983.

A photovoltaic cell having a hetero junction of amorphous silicon and amorphous silicon carbide has at least one of its p and n layers composed of amorphous silicon carbide of the general formula $a\text{-}Si_{1-x}C_x$ obtained by glow discharge decomposition of a mixture of at least one gas selected from among silane, silicon fluoride and the derivatives thereof, and at least one gas selected from among hydrocarbons, alkylsilanes, the fluorides thereof and the derivatives thereof.

4,385,200
Hamakawa, Yoshihiro; Tawada, Yoshihisa, inventors. *Photovoltaic Cell Having a Hetero Junction of Amorphous Silicon Carbide and Amorphous Silicon*. May 24, 1983.

A photovoltaic cell having a hetero junction of amorphous silicon and amorphous silicon carbide has at least one of its p and n layers composed of amorphous silicon carbide of the general formula $a\text{-}Si_{1-x}C_x$ obtained by glow discharge decomposition of a mixture of at least one gas selected from among silane, silicon fluoride and the derivatives thereof, and at least one gas selected from among hydrocarbons, alkylsilanes, the fluorides thereof and the derivatives thereof.

4,385,430
Bartels, Frederick T. C., inventor; Spectrolab, Inc., assignee. *Method of Forming an Energy Concentrator*. May 31, 1983.

A focusing muti-point high-concentrator optical system is disclosed. The system is useful for concentrating energy such as solar radiation for use in solar energy conversion systems. The configuration of the optical system incorporates thin metallized Fresnel reflector elements applied to panels formed into focusing surfaces having a common axis. The Fresnel elements are oriented axially to the axis of the focusing surfaces. The optical configuration produces a substantially rectangular focal zone centered over each panel. For a plurality of panels of a given width, there will be a plurality of focal zones, each separated by a distance equivalent to the panel width. At least one energy absorber is maintained substantially at each focal zone and may comprise a photovoltaic cell, thermal absorber, etc. and combinations thereof.

4,385,971
Swartz, George A., inventor; RCA Corporation, assignee. *Electrolytic Etch for Eliminating Shorts and Shunts in Large Area Amorphous Silicon Solar Cells*. May 31, 1983.

The present invention relates to a method for removing electrical shorts and shunts from solar cells, such as amorphous silicon solar cells. The method involves back-biasing the solar cells while they are in an electrolytic solution. It has been found that the process results in the removal of the shorts and shunts present in the cell.

4,386,142
Hodes, Gary; Manassen, Joost; Cahen, David, inventors; Yeda Research and Development Company, assignee. *Surface Treatment of Semiconductor Materials*. May 31, .1983.

A process for preparing the surface of a metal chalcogenide. The metal chalcogenide is immersed in a suitable electrolyte. The electrolyte is selected such that the metal chalcogenide is relatively stable therein in the dark, but unstable as a photoelectrode under illumination. The metal chalcogenide is connected to another electrode and the electrode is immersed in the electrolyte. The metal chalcogenide is illuminated to photo-etch the chalcogenide thereby improving the surface electronic properties of the semiconductor. A process for the surface treatment of metal chalcogenides includes immersing the metal chalcogenide in an aqueous solution containing Zn and/or Cr ions.

4,387,116
Bucker, Edward R., inventor; Exxon Research & Engineering Co., assignee. *Conditioner for Adherence of Nickel to a Tin Oxide Surface*. June 7, 1983.

The present invention is a solution and a method for its use in adhering nickel to a tin-oxide surface.

4,387,265
Dalal, Vikram L., inventor; University of Delaware, assignee. *Tandem Junction Amorphous Semiconductor Photovoltaic Cell*. June 7, 1983.

A photovoltaic stack comprising at least two $p^+ i\, n^+$ cells in optical series, said cells separated by a transparent ohmic contact layer(s), provides a long optical path for the absorption of photons while preserving the advantageous field-enhanced minority carrier collection arrangement characteristic of $p^+ i\, n^+$ cells.

4,387,999
Shelley, Edwin F., inventor. *Electronic Sundial Apparatus*. June 14, 1983.

An electronic sundial apparatus which signals the passage of each hour by a chime, bell or other audible indication and which requires no external source of power other than the sun. Inner and outer concentric hemispheres with vertically extending apertures, specifically slits, configured so as to diverge at their uppermost ends and having a location, length and shape corresponding to the azimuths and distance between the maximum and minimum altitudes of the sun in the sky at each hour throughout the year at predetermined latitudes collimate the sunlight once each hour. The collimated sunlight is detected by a photoelectric cell coupled to a signaling circuit powered by a photovoltaic cell.

4,388,346
Bickler, Donald B., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Electrodes for Solid State Devices*. June 14, 1983.

Contact electrodes on a semiconductor device such as a photovoltaic solar cell are formed by screening through a mask onto a surface, a pattern of ink containing a dispersion of lower melting, sinterable metal (tin), coated base metal (copper) particles dispersed in a liquid vehicle including a vaporizable binder polymer and a fluorocarbon polymer. On firing the screen coated device in an oven, the binder polymer is vaporized; the fluorocarbon vapors etch the surface and the coated metal particles sinter without being oxidized to form an adherent, coherent, contact electrode.

4,388,382
Bachmann, Klaus Jurgen; Lewerenz, Hans-Joachim; Menezes, Maria T.A.S., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Photoelectrochemical Cells*. June 14, 1983.

Photovoltaic devices are fabricated by forming a thin passivating layer, for example, an oxide layer on a semiconductor material. The passivating layer on the semiconductor material is then contacted with an electrolyte such as an electrolyte containing vanadium ions. The resulting electrolyte/passivating layer/semiconductor (EPLS) structure exhibits excellent solar conversion efficiencies and good stability.

4,388,383
Heller, Adam, inventor; Bell Telephone Laboratories, Incorporated, assignee. *Devices Having Chemically Modified p-Type InP Surfaces*. June 14, 1983.

Semiconductor devices comprising p-type phosphorus containing semiconductor materials chosen from InP, GaP and InGaAsP have chemically treated surfaces comprising a monolayer or less of a metal chosen from silver, ruthenium, gold, platinum, and rhodium. Photoelectrochemical electrodes and Schottky barrier photovoltaic cells made from such treated semiconductors have reduced surface or grain boundary carrier recombination.

4,388,384
Rauh, R. David; Boudreau, Robert A., inventors; EIC Laboratories, Inc., assignee. *Photoelectrochemical Cell*. June 14, 1983.

A photoelectrochemical cell comprising a sealed container having a light-transmitting window for admitting light into the container across a light-admitting plane, an electrolyte in the container, a photoelectrode in the container having a light-absorbing surface arranged to receive light from the window and in contact with the electrolyte, the surface having a plurality of spaced portions oblique to the plane, each portion having dimensions at least an order of magnitude larger than the maximum wavelength of incident sunlight, the total surface area of the surface being larger than the area of the plane bounded by the container, and a counter electrode in the container in contact with the electrolyte.

4,388,481
Uroshevich, Miroslav, inventor; Alpha Solarco, Inc., assignee. *Concentrating Photovoltaic Solar Collector*. June 14, 1983.

The disclosure illustrates a concentrating photovoltaic collector comprising an elongated deep reflector having a rim angle of close to 90° and an elongated series of photovoltaic cells positioned in a plant extending parallel to and spaced beyond the focal axis of the reflector. The cells are mounted in an extrusion that provides a passage for a cell coolant fluid and which has a pair of elongated opposed reflectors inclined toward one another at an angle of 70° with respect to the plane of the photovoltaic cells. The mirrors re-reflect rays to compensate for the shadows cast by the cells and to provide more uniform distribution of solar energy while at the same time permitting a more compact collector.

4,388,482
Hamakawa, Yoshihiro; Tawada, Yoshihisa, inventors. *High-Voltage Photovoltaic Cell Having a Heterojunction of Amorphous Semiconductor and Amorphous Silicon*. June 14, 1983.

A p-i-n amorphous siicon photovoltaic cell of improved conversion efficiency is obtained by incorporating, as either the p or n type side of the cell exposed to the incident light, an amorphous semiconductor which satisfies the requirements that the optical band gap, Eg.opt, be not less than about 1.85 eV, the electric conductivity be not less than about $10^{-8}(\Omega.\text{cm})^{-1}$ the p-i-n junction diffusion potential, Vd, be not less than about 1.1 volts, and be formed of a substance represented by one of the general formulas, $a\text{-}Si_{1-x}C_x$ and $a\text{-}Si_{1-y}N_y$.

4,388,483
Basol, Bulent M.; Tseng, Eric S.; Rod, Robert L., inventors; Monosolar, Inc., assignee. *Thin Film Heterojunction Photovoltaic Cells and Methods of Making the Same*. June 14, 1983.

A method of fabricating a thin film heterojunction photovoltaic cell which comprises depositing a film of a near intrinsic or n-type semiconductor compound formed of at least one of the metal elements of Class II B of the Periodic Table of Elements and at least tellurium and then heating said film at a temperature between about 250°C and 500°C for a time sufficient to convert said film to a suitably low resistivity p-type semiconductor compound. Such film may be deposited initially on the surface of an n-type semiconductor substrate. Alternatively, there may be deposited on the converted film a layer of n-type semiconductor compound different from the film semiconductor compound. The resulting photovoltaic cell exhibits a substantially increased power output over similar cells not subjected to the method of the present invention.

4,388,487
Petrossian-Avakian, Edmond, inventor; Siemens Aktiengesellschaft, assignee. *Arrangement for Preventing the Formation of a Foreign Layer on a High-Voltage Insulator*. June 14, 1983.

An arrangement for preventing the formation of a layer of foreign material on a high-voltage insulator. In situations where wind and rain are not available to clean a high-voltage insulator and thereby prevent arcing, this invention provides blowers which move a stream of air around the insulator. The blowers may be provided with motors which are supplied electrical energy from local low-voltage networks, or from a plurality of solar cells which are disposed on grounded parts of the support structure of the power line network. In some embodiments, the blowers may be of a motorless type and mounted directly on a high-voltage carrying conductor. In such a motorless blower arrangement, the blower blade is configured so as to have points which generate and repel ions in accordance with the known point-effect principle.

4,389,291
Kohl, Paul A.; Ostermayer, Frederick W., Jr.; Wolowodiuk, Catherine, inventors; Bell Telephone Laboratories, Incorporated, assignee. *Photoelectrochemical Processing of InP-Type Devices*. June 21, 1983.

A process is described for photoelectrochemically etching n-type indium phosphide and closely related compound semiconductors such as indium gallium arsenide and indium gallium arsenide phosphide. Such a process is advantageous because the etching is confined to where light is incident to the surface of the semiconductor. In addition, the shape of the configuration etched out of the semiconductor can be controlled by the light incident on the surface of the semiconductor. For example, undercutting can be minimized by use of parallel rays incident on the surface of the semiconductor to be etched.

4,389,533
Ames, Douglas A., inventor. *Photovoltaic Device for Producing Electrical and Heat Energy*. June 21, 1983.

A photovoltaic device including a solar panel and a container housing phase change materials positioned together so that heat generated during operation of the cells in the panel will melt the phase change materials, thereby storing heat and lowering the operating temperature of the cells.

4,389,534
Winterling, Gerhard, inventor; Messerschmitt-Bölkow-Blohm GmbH, assignee. *Amorphous Silicon Solar Cell Having Improved Antireflection Coating*. June 21, 1983.

A semiconductor solar cell for the conversion of light to electric energy comprises at least one layer of amorphous silicon, a cover layer of poly-crystalline silicon and an anti-reflection layer of semiconducting transparent oxide of a refractive index of less than 2.8. The cover layer of poly-crystalline silicon has an optical density λ light/4 or it may be 3λ light/4. The cover layer is arranged between the anti-friction layer and the layer of amorphous silicon.

4,390,743
Dahlberg, Reinhard, inventor; Licentia Patent Verwaltungs-GmbH, assignee. *Silicon Layer Solar Cell and Method of Producing It*. June 28, 1983.

A silicon layer solar cell comprises a low resistance silicon substrate produced by powder metallurgy, to which an active silicon layer is applied. The invention also includes a method of producing such a solar cell.

4,390,770
Köhler, Franz; Meggl, Albert, inventors; Messerschmitt-Bölkow-Blohm Gessellschaft mit beschränkter Haftung, assignee. *Automatic Welding Apparatus for Solar Cells*. June 28, 1983.

Automatic welding apparatus is provided for welding contact tabs to solar cells which are particularly adapted for use in space vehicular solar generators. The apparatus comprises a plurality of welding electrodes arranged to extend across the direction of movement of a solar cell conveying table. The electrodes are movable in two directions perpendicular to each other and both perpendicular to the direction of movement of the conveying table. Furthermore, the apparatus is provided with the capacity for controlling the conveying table to effect automatic positioning of welding points on the solar cells beneath the welding electrodes, high-power current supply for enabling control of the welding current applied to the electrode heads, a protective gas line for feeding each of the electrode heads, an ohmmeter for monitoring the effective contact resistance of each of the welding points, a device for enabling individual visual inspection of the welds produced by each of the electrode heads, and a program control for monitoring the operational parameters of the apparatus, including the number of welds produced, the welding period, the voltage and current, and other parameters whereby the operation of the apparatus may be appropriately managed.

4,390,940
Corbefin, René; Vacelet, Gabriel, inventors; Societe Nationale Industrielle Aerospatiale, assignee. *Process and System for Producing Photovoltaic Power*. June 28, 1983.

The invention relates to a process and system for obtaining the maximum power from an assembly of photovoltaic cells. According to the invention, the D.C. power furnished by said assembly is converted, with the aid of a converter controlled by a modulated signal, into an A.C. power, and the value of the rate of modulation corresponding constantly to the maximum power, is determined for example with the aid of a microprocessor. The invention is applicable to the generation of solar energy with coupling on the network of a converter.

4,392,006
Apelian, Lawrence, inventor. *Solar Cell Activation System*. July 5, 1983.

A system for activating solar cells involves the use of phosphorescent paint, the light from which is amplified by a thin magnifying lens and used to activate solar cells. In a typical system, a member painted with phosphorescent paint is mounted adjacent a thin magnifying lens which focuses the light on a predetermined array of sensitive cells such as selenium, cadmium or silicon, mounted on a plastic board. A one-sided mirror is mounted adjacent the cells to reflect the light back onto said cells for purposes of further intensification. The cells may be coupled to rechargeable batteries or used to directly power a small radio or watch.

4,392,007
Barkats, Gérard; Girard, Alain; Marchal, Jean; Morel, Charles, inventors; Societe Nationale Industrielle Aerospatiale, assignee. *Solar Generator Providing Electricity and Heat*. July 5, 1983.

The invention relates to a support for at least one photovoltaic cell, comprising at least one block made of heat-conducting material with which said cell is in close thermal contact. According to the invention, this support comprises at least one tube the wall of which may be traversed by the heat, said tube being fastened to said block, in thermal contact therewith, and closed at its end to define a closed cavity inside which an evaporable and condensable fluid is enclosed. The invention is particularly applicable to a solar generator.

4,392,008
Cullis, Herbert M.; Stamminger, Reinhard, inventors; Monegon, Ltd., assignee. *Combined Electrical and Thermal Solar Collector*. July 5, 1983.

A solar panel assembly consisting of a shallow rectangular housing with a glass top cover, the housing enclosing a plurality of side-by-side metal plate members with depending longitudinal webs connecting the plate members to longitudinal liquid flow tubes, the plate members, webs and flow tubes being integrally formed by extrusion. Respective enlarged transverse header tubes are connected by coupling sleeves to the opposite ends of the flow tubes, the header tubes extending through and being secured in opposite side walls of the housing, so that the metal plate extrusions are supported in the housing. The plate members are interlocked in coplanar relationship by slidable tongue-and-groove connections at their longitudinal edges. Silicon photovoltaic cells are mounted in row-and-column arrays on the plate members. The depending webs are relatively deep and thin to limit the heat flow rate between the solar plate members and the flow tubes so as to prevent excessive temperature gradients and thermal stresses at the plate areas carrying the silicon cells and to thereby prevent the cells from cracking. The housing contains heat-insulating material which covers the flow tubes and covers the major portions of the header tubes.

4,392,009
Napoli, Joseph D., inventor; Exxon Research & Engineering Co., assignee. *Solar Power Module*. July 5, 1983.

A solar power module comprising an array of solar cells arranged on a flat panel, said panel being supported by a substantially rigid, easily assembled frame comprising spaced apart side channels that each interlock with adjacent and channels.

4,392,010
Lindmayer, Joseph, inventor; Solarex Corporation, assignee. *Photovoltaic Cells Having Contacts and Method of Applying Same*. July 5, 1983.

Electrically conductive contacts containing zinc or other solderable metals, and aluminum are formed on the front and/or back surfaces of a solar cell. They are deposited by spraying the metals onto the cell surfaces, together or as layers, with the aluminum-containing layer in direct contact with the cell surfaces.

4,392,011
Pankove, Jacques I.; Wu, Chung P., inventors; RCA Corporation, assignee. *Solar Cell Structure Incorporating a Novel Single Crystal Silicon Material*. July 5, 1983.

A novel hydrogen rich single crystal silicon material having a band gap energy greater than 1.1 eV can be fabricated by forming an amorphous region of graded crystallinity in a body of single crystalline silicon and thereafter contacting the region with atomic hydrogen followed by pulsed laser annealing at a sufficient power and for a sufficient duration to recrystallize the region into single crystal silicon without out-gassing the hydrogen. The new material can be used to fabricate semiconductor devices such as single crystal silicon solar cells with surface window regions having a greater band gap energy than that of single crystal silicon without hydrogen.

4,392,297
Little, Roger G., inventor; Spire Corporation, assignee. *Process of Making Thin Film High Efficiency Solar Cells*. July 12, 1983.

Process of making thin film materials for high efficiency solar cells on low-cost silicon substrates. The process comprises forming a low-cost silicon substrate, forming a graded transition region on the substrate and epitaxially growing a thin gallium arsenide film on the graded transition region. The process further includes doping the thin gallium arsenide film and forming a junction therein. The graded transition region preferably is a zone refined mixture of silicon and germanium characterized by a higher percentage of germanium at the surface of the region than adjacent the substrate. The process also includes the formation of homojunctions in thin gallium arsenide films. Solar cells made from the materials manufactured according to the process are characterized by a high conversion efficiency, improved stability and relatively low unit cost.

4,392,451
Mickelsen, Reid A.; Chen, Wen S., inventors; The Boeing Company, assignee. *Apparatus for Forming Thin-Film Heterojunction Solar Cells Employing Materials Selected from the Class of I-III-VI$_2$ Chalcopyrite Compounds*. July 12, 1983.

Apparatus for forming thin-film, large area solar cells having a relatively high light-to-electrical energy conversion efficiency and characterized in that the cell comprises a p-n-type heterojunction formed of: (i) a first semiconductor layer comprising a photovoltaic active material selected from the class of I-III-VI$_2$ chalcopyrite ternary materials which is vacuum deposited in a thin "composition-graded" layer ranging from on the order of about 2.5 microns to about 5.0 microns (≅2.5 μm to ≅5.0 μm) and wherein the lower region of the photovoltaic active material preferably comprises a low resistivity region of p-type semiconductor material having a superimposed region of relatively high resistivity, transient n-type semiconductor material defining a transient p-n homojunction; and (ii), a second semiconductor layer comprising a low resistivity n-type semiconductor material wherein interdiffusion (a) between the elemental constituents of the two discrete juxtaposed regions of the first semiconductor layer defining a transient p-n homojunction layer, and (b) between the transient n-type material in the first semiconductor layer and the second n-type semiconductor layer, causes the transient n-type material in the first semiconductor layer to evolve into p-type material, thereby defining a thin layer heterojunction device characterized by the absence of voids, vacancies and nodules which tend to reduce the energy conversion efficiency of the system.

4,392,931
Maniv, Shmuel; Westwood, William D., inventors; Northern Telecom Limited, assignee. *Reactive Deposition Method and Apparatus*. July 12, 1983.

Using a sputter deposition system to reactively deposit a material such as an oxide, it is relatively easy to achieve either an oxygen-doped film with appreciable metallic content or an oxide film. However it is difficult with known systems to obtain an intermediate film having an accurately controlled resistivity, transparency, and composition, such films being of much use in semiconductor applications, in displays and in photovoltaic cells. It is now proposed that an apertured barrier be used to accurately fix the flow rate of target material to the substrate and in addition, that reactive gas flow be regulated and directed only to the immediate vicinity of the substrate. In this way the composition of the film can be accurately fixed. By establishing an r.f. field at the substrate, increased dissociation of the reactive gas can be achieved to render the gas more reactive and so enhance certain film properties such as transparency.

4,393,267
Peterson, Terry M., inventor; Chevron Research Company, assignee. *Method for Improving the Efficiency of a Solar Cell and an Improved Cadmium Sulfide/Copper Sulfide Photovoltaic Cell.* July 12, 1983.

A CdS/Cu_xS solar cell and method of fabricating the solar cell. The CdS layer of the solar cell is fabricated on a conductive substrate and forms an ohmic contact thereto. Thereafter, a layer of Cu_xS is fabricated on the CdS layer and the combined structure is rinsed in an aqueous acidic rinse having a pH less than about pH3 prior to curing the device in hydrogen at an elevated temperature and fabricating a copper containing electrical contact to the Cu_xS layer. The rinsing of the device prior to curing improves the performance of the finished solar cell.

4,393,576
Dahlberg, Reinhard, inventor; Licentia Patent-Verwaltungs-GmbH, assignee. *Method of Producing Electrical Contacts on a Silicon Solar Cell.* July 19, 1983.

A method of producing electrical contacts on a Silicon Solar Cell comprises stamping contact shapes from a carrier with a metallic film or foil adhered thereto and applying the stamped out film or foil to the silicon surface to adhere thereto while removing the carrier therefrom.

4,394,529
Gounder, Raj N., inventor; RCA Corporation, assignee. *Solar Cell Array with Lightweight Support Structure.* July 19, 1983.

A panel comprising an aluminum honeycomb core and outer face skins of Kevlar, a bi-directional epoxy-reinforced polyparabenzamide fabric which is a thermal and electrical insulator adhering to the core and forming the opposite flat surfaces of the panel. Solar cells are glued directly to one face skin while a set of epoxy-reinforced carbon fiber stiffeners are glued to the other face skin. The composite structure has a coefficient of thermal expansion closely matching that of the solar cells providing a very lightweight and stiff structure.

4,395,293
Knechtli, Ronald C.; Loo, Robert Y.; Kamath, Sanjiv, inventors; Hughes Aircraft Company, assignee. *Accelerated Annealing of Gallium Arsenide Solar Cells.* July 26, 1983.

A method is provided for accelerating and improving the recovery of GaAs solar cells from the damage which they experience in space under high energy particle irradiation such as electrons, protons and neutrons. The method comprises combining thermal annealing with injection annealing. Injection annealing is the recovery from radiation damage resulting from minority carrier injection into the damaged semiconductor, nonradiative minority carrier combination of the injected minority carriers, transfer of the recombination energy to the crystal lattice and utilization of this energy to remove the defects caused by the high energy particle irradiation. The combined annealing of this invention is implemented by heating the solar cells to a moderate temperature (on the order of about 200°C to 300°C or less), while at the same time injecting the minority carriers by either of two methods: current injection (by applying an adequate forward bias voltage) or photoinjection (by exposing the cell to adequate light intensity). Sunlight directed onto the solar cells may be employed for heating the solar cells. Alternatively, energy dissipation in the solar cells caused by the flow of a forward bias current may be used to heat the solar cells. In one example, thermal annealing at 200°C alone was observed to bring the power output up to a level of about 75% of its original value from a level of about 50%, resulting from radiation-induced damage. Combined annealing, employing thermal annealing at 200°C in conjunction with simultaneous injection of minority carriers at a current density of 125 mA/cm^2, was observed to bring the power output to a level of nearly 90%.

4,395,497
Naarmann, Herbert; Naegele, Dieter; Penzien, Klaus; Schlag, Johannes, inventors; BASF Aktiengesellschaft, assignee. *Preparation of Electrically Conductive Soluble Heteropolyphenylenes.* July 26, 1983.

A process for the preparation of electrically conductive heteropolyphenylenes, wherein from 0.5 to 5 per cent by weight of an activating additive is introduced, in the absence of moisture and of oxygen, into a heteropolyphenylene of the general formula where X is O, S, Se, SO or SO_2 and Y has one of the meanings given for X or is NH, CH_2, CO or C_6H_4, and n is from 2 to 250. The activating additive is preferably one of the compounds AsF_5, SbF_5, UF_6, $HClO_4$, $NO^+SbF_6^-$, $NO_2^+SbF_6^-$, $NO^+PF_6^-$, $SbCl_5$, $NO_2^+PF_6^-$, $NO^+BF_4^-$, $NO^+ClO_4^-$, $(CF_3)_2SO_4$, 2,4,6-trinitrophenol, 2,4,6-trinitrophenylsulfonic acid and 2,4,6-trinitrophenylcarboxylic acid, or is sodium, potassium, rubidium, cesium, calcium or barium or one of their amides, the latter being added, if appropriate, in tetrahydrofuran, dimethoxyglycol, anthracene, naphthalene or 2-methylstyrene. The conductive heteropolyphenylenes may be used in the electrical industry for the production of solar cells, for conversion and fixing of radiation and for the production of electrical and magnetic switches, or may be used for the antistatic treatment of plastics.

4,395,581
Girard, Alain, inventor; Societa Nationale Industrielle Aerospatiale, assignee. *Concave Mirror Constituted by a Plurality of Plane Facets and Solar Generator Comprising Such a Mirror.* July 26, 1983.

The present invention relates to a concave mirror composed of a plurality of planar facets. According to the invention, all the facets are identical and the two dimensions of said facets are such that the square root of their product is at least approximately equal to the ratio of the focal distance of the mirror and of the square root of the rate of concentration of the mirror. The invention finds application in the concentration of solar energy in solar generators.

4,395,582
Damsker, Dorel J., inventor; Gibbs & Hill, Inc., assignee. *Combined Solar Conversion.* July 26, 1983.

A combined solar converter which has a photovoltaic cell for converting the energy of solar radiation of a particular range of wavelengths to electricity and which has a thermal heat absorber spaced from the cell which converts solar radiation of longer wavelengths passing from the cell to useful heat. A method of utilizing solar energy comprising the step of subjecting a photovoltaic cell to solar radiation to convert energy of a particular range of wavelengths to which the cell is sensitive to electricity and transferring long wave radiations passing from a cell to a heat absorber spaced from the cell where the energy of the long wave radiation is transferred to useful heat.

4,395,583
Meulenberg, Andrew, Jr., inventor; Communications Satellite Corporation, assignee. *Optimized Back Contact for Solar Cells.* July 26, 1983.

The surface recombination velocity at the back portion of a solar cell is reduced in a first embodiment by reducing the back surface metal contact area without increasing series resistance. The back surface is provided with a p^+ layer deposited on the solar cell p layer in order to further reduce the surface recombination velocity and therefore the diffusion current generated in the back layer of the cell. The p^+ layer is provided with an oxide coating. Micro holes are etched through the oxide layer, and a thin layer of metal is evaporated over the entire surface. In a second embodiment the surface recombination velocity at the back portion of the cell is reduced by depositing a thin non-conductive coating on the p^+ layer. A selected metal coating is then deposited on the non-conductive coating to thereby form a Mott-Schottky barrier, the metal coating retarding the transport of minority carriers through the non-conductive coating without impeding the flow of majority carriers through the non-conductive coating. In a third

embodiment, the surface recombination velocity is reduced by depositing a conductive oxide on the p^+ layer, and a metal coating is further deposited on the conductive oxide coating. The conductive oxide coating reduces surface recombination at the interface of the p^+ and conductive oxide layers, and provides majority carriers to the p^+ layer.

4,396,485
Gordon, Arnold Z.; Hardee, Kenneth L., inventors; Diamond Shamrock Corporation, assignee. *Film Photoelectrodes*. August 2, 1983.

Photoactive n-type and p-type semiconductor film electrodes utilizable in photoassisted reactions in photoelectrochemical cells and/or photovoltaic cells comprising a true solid/solid solution of a specific composition of non-oxide metal compounds which when fired produce a photoactive true solid/solid solution of mixed metal oxides providing an effective band gap and/or optical response optimally matched to the part of the energy spectrum desired for a particular utilization. The photoactive semiconductor film electrodes have a film layer of true solid/solid solution mixed metal oxide disposed upon a suitable substrate in either one or more coats.

4,396,793
Madan, Arun, inventor; Chevron Research Company, assignee. *Compensated Amorphous Silicon Solar Cell*. August 2, 1983.

A hydrogenated amorphous silicon solar cell incorporating a compensated photoactive intrinsic region containing N-type and P-type dopants.

4,398,053
Orillion, Alfred G., inventor. *Pyramidal Energy Collector*. August 9, 1983.

A radiation energy collector system in which an energy absorber is positioned within a pyramidal enclosure of which approximately one-half of the side area is radiation energy transmissive, and the other side and base area having a reflective inner surface, whereby radiation energy passing through the transmissive side area in part directly impinges on the absorber, and in part is reflected onto the absorber.

4,398,054
Madan, Arun, inventor; Chevron Research Company, assignee. *Compensated Amorphous Silicon Solar Cell Incorporating an Insulating Layer*. August 9, 1983.

A P-I-N type compensated amorphous silicon solar cell which incorporates an insulating layer adjacent to the compensated intrinsic amorphous silicon layer.

4,398,055
Ijaz, Lubna R.; Burton, Larry C., inventors. *Radiant Energy Converter Having Sputtered $CdSiAs_2$ Absorber*. August 9, 1983.

Thin film radiant energy converter having a sputtered $CdSiAs_2$ photovoltaic absorber layer and a thermally evaporated CdS top layer. The sputtering technique with multiple targets (Cd, Si, As) is used to obtain stoichiometric $CdSiAs_2$ thin films which are polycrystalline and have large grain size to thereby reduce grain boundary recombinations of the photogenerated electrons.

4,398,056
Sheng, Ping, inventor; Exxon Research & Engineering Co., assignee. *Solar Cell with Reflecting Grating Substrate*. August 9, 1983.

A solar cell which includes a thin layer of active material bounded on the side toward the incident light with an antireflection coating and bounded on the other side by a reflecting diffraction grating to internally reflect the incident light back into the active material.

4,398,343
Yamazaki, Shunpei, inventor. *Method of Making Semi-Amorphous Semiconductor Device*. August 16, 1983.

A semi-amorphous semiconductor device manufacturing method in which a non-single crystal semiconductor layer is provided on a substrate to form therebetween a PN, PIN, PI or NI junction and a current is applied to the non-single crystal semiconductor layer to provide a semi-amorphous semiconductor layer. When the current is applied to the non-single crystal semiconductor layer, it is irradiated by light and/or heated at the same time.

4,400,221
Rahilly, W. Patrick, inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Fabrication of Gallium Arsenide-Germanium Heteroface Junction Device*. August 23, 1983.

Doping with one of the group Ia elements Li, Na or K near the heteroface junction produced P^+ conductivity in the gallium arsenide and N^+ conductivity in the germanium. The device can be used, for example, as a dual bandgap solar cell. The fabrication includes implanting the group Ia dopant in a Ge wafer. This dopant diffuses into the GaAs when it is subsequently deposited on the Ge.

4,400,244
Kroger, Ferdinand A.; Rod, Robert L.; Panicker, M.P. Ramachandra, inventors; Monosolar, Inc., assignee. *Photo-Voltaic Power Generating Means and Methods*. August 23, 1983.

A photo-voltaic power cell based on a photoelectric semiconductor compound and the method of using and making the same. The semiconductor compound in the photo-voltaic power cell of the present invention can be electrolytically formed at a cathode in an electrolytic solution by causing discharge or decomposition of ions or molecules of a non-metalic component with deposition of the non-metallic component on the cathode and simultaneously providing ions of a metal component which discharge and combine with the non-metallic component at the cathode thereby forming the semiconductor compound film material thereon. By stoichiometrically adjusting the amounts of the components, or otherwise by introducing dopants into the desired amounts, an N-type layer can be formed and thereafter a P-type layer can be formed with a junction therebetween. The invention is effective in producing homojunction semiconductor materials and heterojunction semiconductor materials. The present invention also provides a method of using three electrodes in order to form the semiconductor compound material on one of these electrodes. Various examples are given for manufacturing different photovoltaic cells in accordance with the present invention.

4,400,409
Izu, Masatsugu; Cannella, Vincent D.; Ovshinsky, Stanford R., inventors; Energy Conversion Devices, Inc., assignee. *Method of Making P-Doped Silicon Films*. August 23, 1983.

The production of improved photovoltaic solar cells and the like comprising both p and n type deposited silicon film regions is made possible by a process which provides more efficient p-doped silicon films with higher acceptor concentrations. The process utilizes previously known p-dopant metal or boron gaseous materials in unique forms and conditions in a glow discharge silicon preferably hydrogen fluorine compensated deposition process. Thus, p-dopant metals like aluminum may be used in an elemental evaporated form, rather than in a gaseous compound form heretofore ineffectively used and deposited with the glow discharge deposited silicon on substrates kept at lower temperatures where fluorine and hydrogen compensation is most effective. Preferably boron in a gaseous compound form like diborane and other p-dopant metals in a gaseous form are used uniquely during the glow discharge deposition of silicon by heating the substrate to heretofore believed undesirably higher temperatures, like at least about 450°C to 800°C where at least fluorine compensation, if desired, is still effective. The improved devices, such

as solar cells, can be manufactured in a continuous process on a web type substrate moved through a plurality of film deposition chambers. Each of the chambers is dedicated to depositing a particular type of film layer (p, i or n) and is isolated from the other chambers.

4,400,451
Gordon, Arnold Z., inventor; Diamond Shamrock Corporation, assignee. *Solar Energy Converter*. August 23, 1983.

Liquid-junction photoelectrochemical semiconductor cells adapted for providing electricity, fuel, chemicals and/or chemical energy, preferably solar cells, which utilize a photoactive true solid/solid solution semiconductor mixed metal oxide material bulk or film electrode. Useful electrolytes include liquid, sol, gel, or a solid electrolyte system, e.g., a film of an ionomer or of a polymer solvated with a liquid electrolyte.

4,400,577
Spear, Reginald G., inventor. *Thin Solar Cells*. August 23, 1983.

Solar cells and arrays of solar cells are made as thin films on insulating substrates. In an exemplary embodiment, a thin conductive film is deposited on glass and a semi-conductor film is deposited over the metal. The semi-conductor film has a P-N junction parallel to the substrate. Another conductive film is deposited over the semi-coductor and is insulated from the first conductive film. Contacts made to edges of the conductive films form solar cells. In an array of such cells the edge of the second conductive film of one cell can overlap the edge of the first conductive film of an adjacent film for connecting the cells in series. In one aspect of the invention the films are thin enough to be transparent. In another aspect, a plurality of semi-transparent films are stacked to absorb selective portions of the spectrum. In another aspect, a technique of stacking thin films using diagonal displacement of a mask provides successive layers with exposed and covered edges for suitable electrical connections.

4,400,868
Antypas, George A.; Bell, Ronald L.; Moon, Ronald L., inventors; Varian Associates, Inc., assignee. *Method of Making a Transparent and Electrically Conductive Bond*. August 30, 1983.

Solar cells with different bandgaps are stacked to form a multijunction photovoltaic converter with a high conversion efficiency. By stacking the cells mechanically rather than by growing them all at one time, the most convenient combination of materials may be selected for the cells. The stacking is completed by means of a glass sealing layer with moats containing inter-cell contacts which are bonded to the cells.

4,401,052
Baron, Bill N.; Rocheleau, Richard E.; Russell, T. W. Fraser, inventors; The University of Delaware, assignee. *Apparatus for Continuous Deposition by Vacuum Evaporation*. August 30, 1983.

An apparatus to deposit material on a substrate, such as in the making of thin solar cells, consists of two chambers. A manifold chamber having a plurality of spaces nozzles assures efficient and uniform deposition on a substrate. The rate of depositions is controlled by an orifice in a passageway connecting the manifold chamber to an evaporation chamber.

4,401,545
Naarmann, Herbert; Naegele, Dieter; Penzien, Klaus; Schlag, Johannes; Kiener, Volker; Boehm, Hugo, inventors; BASF Aktiengesellschaft, assignee. *Electrically Conductive Polypyrrole Derivatives*. August 30, 1983.

Electrically conductive complexes of polypyrroles with nitroaromatic anions are prepared by polymerizing pyrrole, an N-alkylpyrrole and/or an N-arylpyrrole by anodic oxidation in a polar solvent, in the presence of a salt of an acidic nitroaromatic compound.

4,401,839
Pyle, Bruce D., inventor; Atlantic Richfield Company, assignee. *Solar Panel with Hardened Foil Back Layer*. August 30, 1983.

A solar panel has at least one solar cell and a sheet of hardened alumimum foil underlying the cell. The panel preferably has a rigid transparent sheet above the cell, the foil sheet being bonded to the cell and to the transparent sheet. The foil sheet may be substantially continuous and provide a hermetic seal near the lower surface of the panel.

4,401,840
Chitre, Sanjeev R., inventor; Photowatt International, Inc., assignee. *Semicrystalline Solar Cell*. August 30, 1983.

A solar cell is provided which utilizes a semicrystalline semiconductor starting material. The solar cell has a metallic layer deposited over the grain boundaries between adjacent active grain areas of the material to collect the current generated in the grain areas. The metallic layer also shields the grain boundaries from illumination, thereby passivating the boundaries.

4,402,762
John, Puthenveetil K.; Tong, Bok Y.; Wong, Sau K.; Chik, Kin P., inventors. *Method of Making Highly Stable Modified Amorphous Silicon and Germanium Films*. September 6, 1983.

A method of modifying amorphous films of Group IV elements such as silicon and germanium and alloys thereof with carbon by the addition of Group I elements hydrogen and/or Group VII elements fluorine and chlorine in which an amorphous film of the Group IV elements or alloys thereof is vacuum deposited on a substrate at a temperature equal to or slightly above room temperature, the film is annealed in an inert gas or in a vacuum and the annealed film is modified by bombardment with an energetic current of ions or atoms of the Group I and/or Group VII elements by means of a plasma gun or ion gun having characteristics similar to a thetatron.

4,402,771
Thomas, Donald E., inventor; Westinghouse Electric Corp., assignee. *Substrate for Silicon Solar Cells*. September 6, 1983.

A substrate is made for silicon solar cells by heating a sheet of large-grained silicon steel at a temperature of at least about 1300°C in an atmosphere of hydrogen and tungsten hexafluoride (or hexachloride) at a partial pressure ratio of hydrogen to tungsten hexafluoride of about 3 to about 6 to deposit an epitaxial layer of tungsten on said sheet of silicon steel. Epitaxial silicon can then be deposited in a conventional manner on the layer of epitaxial tungsten.

4,403,239
Yamazaki, Shunpei, inventor. *MIS Type Semiconductor Photoelectric Conversion Device*. September 6, 1983.

A MIS type semiconductor photoelectric conversion device in which a first electrode, a first insulating or semi-insulating layer, a semiconductor layer, a second insulating or semi-insulating layer and a second electrode are formed in this order on a supporting member. The first electrode, the first insulating or semi-insulating layer and the semiconductor layer constitute a first MIS structure which uses the first insulating or semi-insulating layer as a first barrier. The semiconductor layer, the second insulating or semi-insulating layer and the second electrode constitute a second MIS structure which uses the second insulating or semi-insulating layer as a second barrier. The first and second MIS structures are formed on the supporting member in such a manner that they are placed one on the other mechanically and connected in series with each other electrically.

4,403,398
Laurie, Alexander S.; Whelan, Robert C., inventors; Prutec Limited, assignee. *Method of Manufacturing a Cadmium Sulphide Photo-Voltaic Device*. September 13, 1983.

The invention relates to the manufacture of a cadmium sulphide photovoltaic device. A substrate such as a glass is coated with successive layers which are made, in order, of tin oxide, cadmium sulphide, cuprous sulphide and copper to build up a photovoltaic junction. In order to achieve a fast deposition rate of the cadmium sulphide while achieving a well ordered crystal structure the cadmium sulphide layer is deposited in two stages, the first involving spraying of a weak precursor solution and the second a substantially more concentrated solution to achieve at least a five times increase in the deposition rate. The invention also describes improved techniques for spraying and reducing the effects of the resistivity of the tin oxide first electrode.

4,404,076
Nakagawa, Katsumi; Fukada, Tadaji, inventors; Canon Kabushiki Kaisha, assignee. *Film Forming Process Utilizing Discharge*. September 13, 1983.

A film forming process comprising introducing gas for forming a film from an inlet part for gas into a pressure-reducible deposition chamber wherein a substrate for forming a film thereon is supported by a fixing member, at least one of said substrate and fixing member are used so as to act as a first electrode, at least one portion of the wall of said deposition chamber is employed so as to act as a second electrode, the surface of said second electrode is arranged substantially in parallel to the surface for forming a film thereon, of said substrate, and said inlet part for gas and an outlet part for gas are arranged substantially in the positional relationship of rotation symmetry; and generating a glow discharge in said deposition chamber, thereby forming a film on said substrate.

4,404,126
Muench, Volker; Naarmann, Herbert; Penzien, Klaus, inventors; BASF Aktiengesellschaft, assignee. *Preparation of Electrically Conductive Polymeric Systems*. September 13, 1983.

A process for the preparation of electrically conductive polymers, having conductivities greater than 10^{-2} S/cm, wherein from 0.1 to 95% by weight of black phosphorus and from 0.5 to 25% by weight of sodium, potassium, rubidium, or cesium or of an amide of these, preferably in tetrahydrofuran, dimethoxyglycol, nitromethane or methylene chloride (the molar ratio of alkali metal or amide to organic compound preferably being from 1:1 to 1:5) are added to an organic polymer chosen from the group comprising the polyphenylenes, heteropolyphenylenes and polyacetylenes, in the absence of moisture and of oxygen. The electrically conductive polymers obtained can be used in the electrical industry for the production of solar cells, for conversion and fixing of radiation and for the production of electrical and magnetic switches, and can also be used for the antistatic treatment of plastics.

4,404,421
Fraas, Lewis M., inventor; Chevron Research Company, assignee. *Ternary III-V Multicolor Solar Cells and Process of Fabrication*. September 13, 1983.

Ternary III-V multicolor solar cells incorporating layers of $GaAs_{1-x-y}P_xSb_y$ and an improved process of fabricating multicolor photovoltaic III-V compound photovoltaic devices.

4,404,422
Green, Martin A.; Blakers, Andrew W., inventors; Unisearch Limited, assignee. *High Efficiency Solar Cell Structure*. September 13, 1983.

The invention relates to a new-type of solar cell structure, and to a method of manufacturing same. The solar cell is designated as an MINP cell (Metal-Insulator-NP junction solar cell). Essentially, the MINP solar cell is an extremely shallow N-P junction cell with a MIS (Metal-Insulator-Semiconductor) type contact made to the top of the cell. Although combining features of the two technologies, no more processing steps are required than for a conventional P-N junction cell. The advantage of the MINP structure is its substantially improved efficiency.

4,404,465
Miller, Arthur, inventor; RCA Corporation, assignee. *Array Positioning System*. September 13, 1983.

A solar array positioning system includes first light sensor means facing the same direction as the solar array and second light sensor means facing the opposite direction. A third sensor, this one responsive to gravity, is employed to indicate the direction about a diurnal slew axis that the array is tilted. These sensors are employed to determine the initial array slewing direction to insure that during slewing and subsequent tracking, the array never is rotated through more than a given angle, less than 360°, between two fixed limits. This permits connection to the array by hard wiring rather than slip rings. The system includes also fourth sensor means for providing fine tracking signals which assume control of the array position during tracking. A vane structure reduces the sensitivity of various of the sensors to obscuration by foreign particles. A low cost uncorrected lens may be used with the fourth.

4,404,734
Singh, Vijay P., inventor; Photon Power, Inc., assignee. *Method of Making a CdS/Cu_xS Photovoltaic Cell*. September 20, 1983.

A photovoltaic cell is formed by combining a spray process, forming a crystalline layer containing cadmium and sulfur, and an evaporation process, depositing copper chloride for converting to Cu_xS. The crystals containing cadmium and sulfur are heated in an atmosphere of cadmium and chlorides to obtain crystals having at least one dimension greater than 0.5 micron and a planar layer of Cu_xS is formed on the large crystals. A layer of Cu_xS having a thickness of 0.5 - 1.0 micron is obtained. Electrodes are formed from evaporated gold or chromium or a metallic paste including silver or copper. $Zn_xCd_{1-x}S$ may be substituted for CdS through at least part of the crystalline layer for improved Voc.

4,405,435
Tateishi, Hideki; Kamei, Tsuneaki; Abe, Katsuo; Kobayashi, Shigeru; Aiuchi, Susumu; Nakatsukasa, Masashi; Takahashi, Nobuyuki; Suqimoto, Ryuji, inventors; Hitachi, Ltd.; Anelva Corporation, assignee. *Apparatus for Performing Continuous Treatment in Vacuum*. September 20, 1983.

An apparatus for performing continuous treatment in vacuum including an inlet chamber, a first intermediate chamber, at least one vacuum treating chamber, a second intermediate chamber and a withdrawing chamber arranged in the indicated order in a direction in which base plates are successively transferred. An opening device normally closed and opened when a base plate is transferred therethrough is mounted on a wall at the inlet of the inlet chamber, between the adjacent chambers and on a wall at the outlet side of the withdrawing chamber. A conveyor device for conveying each base plate in a horizontal direction through the opening device is mounted in each of the chambers, and an evacuating device is also mounted in each chamber. A base plate storing device for storing a plurality of base plates in a magazine is mounted in the first and second intermediate chambers. At least one vacuum treating device is mounted in the vacuum treating chamber.

4,406,709
Celler, George K.; Leamy, Harry J.; Trimble, Lee E., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Method of Increasing the Grain Size of Polycrystalline Materials by Directed Energy-Beams*. September 27, 1983.

Crystal grain size in a material is increased by scanning the material with an appropriately directed energy beam. Short-term

oscillation in the scan, and a particular temperature gradient configuration in the wake of the scan, results in growth of large-grain crystallites.

4,406,913
Weyrich, Claus, inventor; Siemens Aktiengesellschaft, assignee. *Solar Cell with Increased Efficiency*. September 27, 1983.

A solar cell has a semiconductor body with a radiation-receiving surface having a ribbed structure and having a small pn-junction in the semiconductor body which is matched to follow the contour of the surface of the ribbed structure, and the interstices between adjacent ribs are filled with a material which is highly permeable to the solar radiation and which contains particles for scattering the solar radiation to a high degree situated therein.

4,407,061
Grodkiewicz, William H.; Singh, Shobha; Van Uitert, LeGrand G., inventors; Bell Telephone Laboratories, Incorporated, assignee. *Fabrication Procedure Using Arsenate Glasses*. October 4, 1983.

A fabrication technique is described for making various devices in which a certain type of glass is used as a surface protection layer. The glass layers are formed by particle bombardment (generally sputtering of E-beam) of a glass target. Devices with such surface layers are also described. Such glass layers are highly advantageous as encapsulating layers, diffusion barrier layers, etc., particularly for optical type devices and certain semiconductor devices. Particularly important is the preparation procedure for the glass target used in the bombardment process. The glass layers are moisture stable, act as excellent barriers against diffusion, and are usable up to quite high temperatures (i.e., in diffusion doping procedures) without cracking or peeling. The glass layers also provide long-term protection against atmosphere components including water vapor, oxygen, atmosphere pollution contaminants, etc., and can be removed by standard etching techniques.

4,407,320
Levine, Jules D., inventor; Texas Instruments Incorporated, assignee. *Large Area, Fault Tolerant Solar Energy Converter*. October 4, 1983.

Semiconductor spheres are arranged within a plastic sheet, and laminated between two metal foil layers to make electrical contacts. A portion of each sphere is exposed on one side to allow light entry. The back ohmic contact has a spreading resistance which protects large array configurations from short circuits. Series interconnections of cells, for higher voltage, can be made in the same processing sequence and are coplanar with the array. All manufacturing steps are completed at temperatures less than 400°C.

4,407,710
Moustakas, Theodore D.; Morel, Don L.; Abeles, Benjamin, inventors; Exxon Research and Engineering Co., assignee. *Hybrid Method of Making an Amorphous Silicon P-I-N Semiconductor Device*. October 4, 1983.

The invention is directed to a hydrogenated amorphous silicon PIN semiconductor device of hybrid glow discharge/reactive sputtering fabrication. The hybrid fabrication method is of advantage in providing an ability to control the optical band gap of the P and N layers, resulting in increased photogeneration of charge carriers and device output.

4,409,134
Yamazaki, Shunpei, inventor. *Photoelectric Conversion Semiconductor and Manufacturing Method Thereof*. October 11, 1983.

A semi-amorphous, photoelectric conversion semiconductor which is formed of a mixture of a microcrystalline semiconductor and a non-crystalline semiconductor and in which the mixture is doped with a dangling bond neutralizer, such as hydrogen, chlorine or fluorine, and the microcrystalline semiconductor has a lattice strain and a particle size of 5 to 200 Å.

4,409,422
Sater, Bernard L., inventor. *High Intensity Solar Cell*. October 11, 1983.

A high intensity solar cell is comprised of a plurality of semiconductor bodies each having adjacent regions of opposite conductivity type defining a P-N junction therebetween. The adjacent bodies have a layer of aluminum material therebetween. The first and last bodies have electrical contacts connected to their exposed surfaces so that electrical energy may be obtained therebetween in response to receipt of light rays in a direction substantially parallel to the P-N junctions of the bodies.

4,409,423
Holt, James F., inventor; The United States of America as represented by the Secretary of the Air Force, assignee. *Hole Matrix Vertical Junction Solar Cell*. October 11, 1983.

An improved vertical junction solar cell is provided which comprises a thin silicon chip having on one surface thereof a plurality of holes therein closely spaced in a desired array, the walls of the holes defining the vertical junction of the cell. The resulting structure provides improved light utilization during the entire life of the cell, and improved radiation resistance, as compared to grooved structure cells.

4,409,424
Devaud, Genevieve, inventor; The United States of America as represented by the U.S. Department of Energy, assignee. *Compensated Amorphous Silicon Solar Cell*. October 11, 1983.

An amorphous silicon solar cell including an electrically conductive substrate, a layer of glow discharge deposited hydrogenated amorphous silicon over said substrate and having regions of differing conductivity with at least one region of intrinsic hydrogenated amorphous silicon. The layer of hydrogenated amorphous silicon has opposed first and second major surfaces where the first major surface contacts the electrically conductive substrate and an electrode for electrically contacting the second major surface. The intrinsic hydrogenated amorphous silicon region is deposited in a glow discharge with an atmosphere which includes not less than about 0.02 atom percent mono-atomic boron. An improved N.I.P. solar cell is disclosed using a BF_3 doped intrinsic layer.

4,409,537
Harris, William A., inventor; Honeywell, Inc., assignee. *Interconnection of Primary Cells*. October 11, 1983.

A method and apparatus for interconnecting one or more groups of primary electric cells in which cells in each group are further divided into two series-connected subgroups which, in twin, are connected to a three-conductor transmission system having a positive, a negative and a neutral or return conductor. One subgroup of each group is connected between the negative terminal and the neutral and the other subgroup is connected between the positive terminal and the neutral such that the line to line voltage is twice that of the line to neutral voltage similar to a three-wire traditional AC supply system.

4,409,538
Tabata, Junichi, inventor; Kabushiki Kaisha Daini Seikosha, assignee. *Charge Control Circuit*. October 11, 1983.

A charge control circuit has an excess charge detecting circuit for preventing the excess charge of a secondary battery responsive to the voltage of the secondary battery, and a switching circuit responsive to the output of the excess charge detecting circuit. The switching circuit and the excess charge detecting circuit are operated by the electromotive force of a solar cell without the power dissipation of the secondary battery.

4,409,605
Ovshinsky, Stanford R.; Madan, Arun, inventors; Energy Conversion Devices, Inc., assignee. *Amorphous Semiconductors Equivalent to Crystalline Semiconductors*. October 11, 1983.

An amorphous semiconductor body, most advantageously a glow discharge deposited silicon-containing host matrix film, is provided containing at least fluorine as a compensating or altering agent, and most preferably at least one complementary compensating or altering agent, such as hydrogen, both of which reduce the localized defect states in the energy gap of the amorphous semiconductor material to a degree which either one alone could not achieve. The silicon and/or other elements of the host matrix film are deposited by the glow discharge decomposition of gaseous compounds preferably with fluorine as one element of a compound, the hydrogen and other compensating and altering material being preferably a molecular gas or an element of a compound of silicon or other host matrix element.

4,410,558
Izu, Masatsugu; Cannella, Vincent D.; Ovshinsky, Stanford R., inventors; Energy Conversion Devices, Inc., assignee. *Continuous Amorphous Solar Cell Production System*. October 18, 1983.

The continuous production of solar cells by the glow discharge (plasma) deposition of layers of varying electrical characteristics is achieved by advancing a substrate through a succession of deposition chambers. Each of the chambers is dedicated to a specific material type deposition. The chambers are mutually isolated to avoid the undesired admixture of reaction gases therebetween. Each plasma deposition is carried out in its glow discharge area, chamber, or chambers, with isolation between the plasma regions dedicated to different material types. Masking, mechanical or lithographic, can be employed relative to the substrate to cause the deposition in the desired configuration. After the semiconductor deposition is complete, top contact and antireflection layer or layers are deposited, followed by a protective lamination.

4,410,559
Hamakawa, Yoshihiro; Tawada, Yoshihisa, inventors. *Method of Forming Amorphous Silicon Films*. October 18, 1983.

In a method of forming a layer of an amorphous silicon compound by subjecting a gas containing a silane compound to glow discharge decomposition, the improvement wherein the substrate on which the amorphous silicon compound is to be deposited is positioned within 3 cm above or below the end of a positive column formed by said glow discharge.

4,410,757
Stamminger, Reinhard; Cullis, Herbert M., inventors; Monegon, Ltd., assignee. *Adjustable Collection Members for Solar Energy Systems*. October 18, 1983.

A solar energy collecting assembly consisting of a rectangular supporting frame with a plurality of vane structures mounted in parallel relationship therein. Each vane structure consists of a generally Z-shaped bar member of extruded aluminum with an integral conduit at the corner between the lower flange and the web of the bar member. The conduit has extended end portions pivotally engaged through the front and rear supporting frame elements and these end portions are clampingly communicatively connected to respective inlet and outlet liquid manifolds located outwardly adjacent the front and rear frame elements. Each vane structure has a top flange provided with a blackened surface acting as a radiation absorber which generates heat, this heat being conducted to the associated conduit via the adjacent web portion of the bar member. The lower flange has an array of photovoltaic cells mounted thereon which can receive solar radiation either directly or via a plane mirror surface provided on the adjacent web portion of the vane structure. The coupling means connecting the conduit end portions to the manifolds includes coupling sleeves with surrounding clamps having tightening screws. The screws are employed for locking the vane structures in pivotally adjusted positions relative to the supporting frame, so that the vane structures can be set for optimum orientation. Each vane structure includes a block of heat-insulating material surrounding its conduit and covering the bottom surfaces of its web and flanges, to minimize heat loss.

4,410,758
Grolitzer, Arthur J., inventor; Columbia Chase, assignee. *Photovoltaic Products and Processes*. October 18, 1983.

A photovoltaic cell and the method of manufacturing the same. The cell includes a substrate of, e.g., aluminum, having a layer of cesium fluoride-like material with the outer surface thereof containing a p^+ boron doped outer layer. A substantially transparent electrically conductive coating is applied over the surface of said cesium fluoride-like material and appropriate electrical contacts are made to the conductive layer for protective purposes.

4,411,490
Daniel, Maurice, inventor. *Apparatus for Collecting, Distributing and Utilizing Solar Radiation*. October 25, 1983.

The apparatus for collecting, distributing and utilizing solar radiation includes a solar collection panel having an array of solar gathering cells which provide radiation to a light collecting unit. This light collecting unit provides radiation as a single beam to a lens system which provides a coherent beam to a lightpipe. This beam is then directed to use units such as a light to electricity converter, heat distributing elements and light distributing elements.

4,411,703
Whitehouse, Daniel L., inventor; Solarex Corporation, assignee. *Composition for Applying Antireflective Coating on Solar Cell*. October 25, 1983.

A method, and the composition, for the application of an antireflective coating on solar cells and the subsequent application of metal contacts comprising applying a screen to the surface of a solar cell, applying a paste comprising a metal alkoxide over the screen, heat treating the cell and metal alkoxide paste, and nickel plating the resultant cell.

4,411,826
Naarmann, Herbert; Penzien, Klaus; Schlag, Johannes; Simak, Petr, inventors; BASF Aktiengesellschaft, assignee. *Preparation of Stable Electrically Conductive Polymers*. October 25, 1983.

Stable electrically conductive polymers having conductivities greater than 10^{-2}S/cm are prepared by heating p-doped polyacetylenes, in the absence of oxygen and moisture, for from 0.1 to 3 hours, preferably from 0.5 to 1.0 hour, at from 500° to 1,100°C, preferably from 550° to 850°C. The electrically conductive polymers obtained can be used in the electrical industry for the production of solar cells, for the utilization and fixing of radiation, for the production of electrical and magnetic switches and stores, and for the antistatic treatment of plastics.

4,412,091
Jordan, John F.; Lampkin, Curtis M., inventors; Photon Power, Inc., assignee. *Polycrystalline Photovoltaic Cell*. October 25, 1983.

A photovoltaic cell having an electrically conductive substrate, which may be glass having a film of conductive tin oxide; a first layer containing a suitable semiconductor, which layer has a first component film with an amorphous structure and a second component film with a polycrystalline structure; a second layer forming a heterojunction with the first layer; and suitable electrodes where the heterojunction is formed from a solution containing copper, the amorphous film component is superposed above an electrically conductive substrate to resist permeation of the copper-containing material to shorting electrical contact with the substrate. The penetration resistant amorphous layer permits a variety of processes to be used in forming the heterojunction with

even very thin layers (1-6μ thick) of underlying polycrystalline semiconductor materials. In some embodiments, the amorphous-like structure may be formed by the addition of aluminum or zirconium compounds to a solution of cadmium salts sprayed over a heated substrate.

4,412,942
Naarmann, Herbert; Penzien, Klaus; Schlag, Johannes; Simak, Petr, inventors; BASF Aktiengesellschaft, assignee. *Preparation of Electrically Conductive Polymers*. November 1, 1983.

A process for the preparation of stable electrically conductive polymers, having conductivities greater than 10^{-2} S/cm, wherein a polyacetylene is reacted with from 1 to 100, preferably from 10 to 33, % by weight of tosylmethyl isocyanide and from 0.1 to 70, preferably from 5 to 35, % by weight of an alkali metal or its amide, or of a Lewis acid. The polymers obtained can be used in electrical engineering for the production of solar cells, for the conversion and fixing of radiation and for the production of electrical and magnetic switches and electrical storage devices, and can also be used for the antistatic treatment of plastics.

4,413,157
Ames, Douglas A., inventor. *Hybrid Photovoltaic-Thermal Device*. November 1, 1983.

An improved photovoltaic device including a solar panel and a container housing salt hydrate materials, in which the container is positioned in close proximity to the lower portion of the panel, which has no support-providing bottom wall, so that heat generated during operation of the photovoltaic cells will pass easily to the container for the salt hydrate materials, thus lowering the operating temperature of the cells.

4,414,252
Lampkin, Curtis M., inventor; Photon Power, Inc., assignee. *Spray Forming Thin Films*. November 8, 1983.

An improved spray booth is provided for use in forming high quality thin films by controlling the spray parameters related to film formation. A spray nozzle design is selected which permits control of the spray footprint on a heated substrate. A projected atomized liquid is formed to the selected spray configuration by directing spray cones of air toward the atomized liquid. Dwell time of the spray material adjacent the hot substrate is then controlled by controlling the velocity of airflow within the spray chamber and adjacent the substrate. To promote a gas phase reaction, a roof section is provided with reduced airflow wherein sufficient dwell time is provided for the vapor reaction to occur. Where a liquid phase reaction is provided, high velocity airflow is maintained to promptly remove reaction products and spray material which has not reached the surface after a selected time period. The spray booth is designed for frequent cleaning by providing separately removable sections where the frequency of cleaning may be varied as a function of the accumulated condensate. Thus, regions of the spray booth in contact with the sprayed solution may be removed without removing the entire spray booth. Particular uses employing the particular design principles include application of a film of SnO_x which is highly transparent and electrically conductive and thin films of CdS suitable for use in forming large area photovoltaic panels.

4,414,300
Wrighton, Mark S.; Ellis, Arthur B.; Kaiser, Steven W., inventors; Massachusetts Institute of Technology, assignee. *Visible Light to Electrical Energy Conversion Using Photoelectrochemical Cells*. November 8, 1983.

Sustained conversion of low energy visible or near i.r. light (<1.25 eV) to electrical energy has been obtained using wet photoelectrochemical cells where there are no net chemical changes in the system. Stabilization of n-type semi-conductor anodes of CdS, CdSe, CdTe, GaP, GaAs and InP to photoanodic dissolution is achieved by employing selected alkaline solutions of Na_2S, Na_2S/S, Na_2Se, Na_2Se/Se, Na_2Te and Na_2Te/Te as the electrolyte. The oxidation of (poly)sulfide, (poly)selenide or (poly)telluride species occurs at the irradiated anode, and reduction of polysulfide, polyselenide or polytelluride species occurs at the dark Pt cathode of the photoelectrochemical cell. Optical to electrical energy conversion efficiencies approaching 15% at selected frequencies have been observed in some cells. The wavelength for the onset of photocurrent corresponds to the band gap of the particular anode material used in the cell.

4,415,133
Phillips, William H., inventor; The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, assignee. *Solar Powered Aircraft*. November 15, 1983.

A cruciform wing structure for a solar powered aircraft is disclosed. Solar cells are mounted on horizontal wing surfaces. Wing surfaces with spanwise axis perpendicular to horizontal wing surfaces maintain these surfaces normal to the sun's rays by allowing aircraft to be flown in a controlled pattern at a large bank angle. The solar airplane may be of conventional design with respect to fuselage, propeller and tail, or may be constructed around a core and driven by propeller mechanisms attached near the tips of the airfoils.

4,415,760
Madan, Arun, inventor; Chevron Research Company, assignee. *Amorphous Silicon Solar Cells Incorporating an Insulating Layer in the Body of Amorphous Silicon and a Method of Suppressing the Back Diffusion of Holes into an N-Type Region*. November 15, 1983.

Hydrogenated amorphous silicon solar cells which incorporate a thin insulating layer between a photoactive layer of intrinsic hydrogenated amorphous silicon and a heavily doped radiation incident N or N^+-type layer of hydrogenated amorphous silicon.

4,416,052
Stern, Theodore G., inventor; General Dynamics, Convair Division, assignee. *Method of Making a Thin Film Solar Cell*. November 22, 1983.

A method of making a thin gallium arsenide solar cell having a reflecting back surface and coplanar electrical contacts. A photovoltaic cell comprising gallium arsenide is produced in a self-supporting thickness by conventional methods. A pattern of contact lines and a bus contact are formed on the front surface of the cell and a transparent coverslide is bonded thereover. The back of the cell is chemically etched away until the minimum effective thickness is reached, then etching in the bus contact region is continued until the bus is exposed. Any stop-etch material used to prevent excessive etching of the cell material is removed and a reflective contact material is applied to the back of the cell. The resulting solar cell is light in weight and both front and back connections can be made from the back of the cell, making it particularly suitable for use in space-based arrays.

4,416,959
Skotheim, Terje, inventor. *Photoelectrochemical Cells for Conversion of Solar Energy to Electricity*. November 22, 1983.

A double photoelectrochemical cell for converting solar energy directly to electricity. The device in one embodiment has two semiconductors which are separated from each other by a dry solid polymer electrolyte. The two semiconductors have a different band gap; for example, one is n-type CdS and the other is p-type CdTe. The polymer electrolyte, for example, is a thin film polyethylene oxide acting as a polymer matrix containing a polysulfide redox couple, for example, Na_2S_4. The polymer electrolyte is transparent, insulating and capable of transporting ions. At least one of the semiconductors is semi-transparent. The short wavelengths of light are absorbed by the semi-transparent wide band gap semiconductor, and the long wavelengths pass therethrough, and through the polymer film electrolyte, and are

absorbed by the narrow band gap semiconductor. The output of the cell is double; one from each semiconductor, i.e., they are series-connected. Output voltage, for example, is about 0.625 volts. The theoretical efficiencies in the example are about 35%, compared with about 25% for a standard photovoltaic cell having a single junction. Also included is a method of manufacturing such a cell.

4,417,092
Moustakas, Theodore D.; Friedman, Robert A., inventors; Exxon Research & Engineering Co., assignee. *Sputtered PIN Amorphous Silicon Semi-Conductor Device and Method Therefor*. November 22, 1983.

A high efficiency amorphous silicon PIN semi-conductor device is constructed by the sequential sputtering of N, I and P layers of amorphous silicon and at least one semi-transparent ohmic electrode. A method of construction produces a PIN device, exhibiting enhanced physical integrity and facilitates ease of construction in a singular vacuum system and vacuum pump down procedure.

4,418,187
Muench, Volker; Naarmann, Herbert; Penzien, Klaus, inventors; BASF Aktiengesellschaft, assignee. *Preparation of Electrically Conductive Polymers*. November 29, 1983.

A process for the preparation of electrically conductive polymers by polymerizing acenaphthylene, N-vinyl-heterocyclics, eg. N-vinylcarbazole or N-vinylpyridine, or N,N-divinylaniline at from $-80°$ to $+100°C$ in the presence of a cationtic catalyst, wherein from 1 to 50 percent by weight of an oxidizing Lewis acid, preferably $FeCl_3$, $FeBr_3$, $SbCl_5$, SbF_5, AsF_5 or CF_3-SO_3H, or a combination of $AlCl_3$ or $TiCl_4$ with the said compounds or with $Cr0_3$ or OsO_4 is used as the catalyst. In a preferred embodiment of the process, thin films of the monomers to be polymerized, applied to glass or to a polymeric base, preferably to a plastic film, are treated with gaseous $SbCl_5$, SbF_5 or AsF_5. The conductive polymers obtained can be used in the electrical industry for the production of solar cells, for the conversion and fixing of radiation and for the production of electrical and magnetic switches, as well as for the antistatic treatment of plastics.

4,418,238
Lidorenko, Nikolai S.; Afian, Viktor V.; Vartanian, Albert V.; Martirosian, Ruben G.; Ryabikov, Stanislav V.; Strebkov, Dmitry S., inventors. *Photoelectric Solar Cell Array*. November 29, 1983.

A photoelectric solar cell device comprises a dispersing element exposed to the sun's radiation and followed in the optical path by photocells having different spectral sensitivities. Each photocell has its working surface so oriented that the light beam with the wavelength corresponding to the maximum spectral sensitivity of that photocell impinges on its working surface. The dispersing element is a hologram representing light sources with different wavelengths. The photocells are positioned in the image planes of the light sources producing the light beams of the corresponding wavelengths.

4,419,178
Rode, Daniel L., inventor. *Continuous Ribbon Epitaxy*. December 6, 1983.

A process for growing an epitaxial ribbon of monocrystalline material involves formation of an endless belt of monocrystalline composition. The belt is driven about a closed path to bring portions sequentially to epitaxial growth and ribbon stripping zones. One or more epitaxial layers of monocrystalline material at least initally compositionally different from the belt are grown on the belt in the epitaxial growth zone(s). Stripping of such epitaxial layer(s) occurs in the stripping zone to form an epitaxial ribbon of indefinite length. Finally, the ribbon is wound upon a mandrel for storage or transport before further processing. The belt is formed by slicing a boule into flat strips of uniform thickness, their ends being then beveled to preselected crystallographic orientation. Ends of the strips are juxtaposed, defining a notch between them. Material is epitaxially grown on the beveled end surfaces to fill each notch. Excess grown material is polished to coincident flatness, providing an elongated belt of uniform thickness with beveled ends. They are juxtaposed then by bending the belt within critical bending limit rules to define a final notch which similarly is filled by further epitaxial growth. Excess material thickness is polished to coincident flatness to provide a constant thickness endless belt.

4,419,424
Julian, John D., inventor. *Electrodes for Electrochemical Cells Current Generating Cells and Rechargeable Accumulators*. December 6, 1983.

Electrodes using essentially insoluble active material are disclosed which can be used in a variety of electrochemical cells and rechargeable accumulators. Plastic materials are used to ensure porosity and strength and to sinter the electrode ingredients and active material together. Details of the essentially insoluble compound active material are disclosed and of an electrolyte recommended for use with the electrodes. Aspects of this invention are applicable particularly to Ni-Cd, Ag-Cd, Ag-Zn, Ni-Fe, Ni-Zn, Metal-Air, fuel or solar cells.

4,419,530
Nath, Prem, inventor; Energy Conversion Devices, Inc., assignee. *Solar Cell and Method for Producing Same*. December 6, 1983.

A method of electrically isolating portions of a large surface area semidconductor body for various purposes such as the production of improved photovoltaic and semiconductor devices is disclosed herein. In the preferred embodiment, the photovoltaic devices are of the type which include a common, electrically conductive substrate layer, a semiconductor body deposited upon the substrate layer, and a transparent electrically conductive coating layer is deposited atop the amorphous body. The method includes the steps of dividing the semiconductor body into a plurality of electrically-isolated portions which may include a grid pattern, testing the electrical output of each of the isolated portions of the semiconductor body, connecting only those isolated portions providing satisfactory electrical output to an electrically conductive strip which provides an electrical contact from the semiconductor body, and providing an electrical contact on the substrate, whereby the overall efficiency of the photovoltaic or semiconductor device is improved. The improved solar cell includes a plurality of electrically isolated portions into which the semiconductor body thereof is divided, at least one electrically conductive strip, each isolated portion of the semiconductor which provides satisfactory electrical output is electrically connected to the conductive strip to provide an electrical contact associated with the semiconductor body, an electrical contact associated with the substrate layer, and an upper, electrically-insulating, protective layer and a lower electrically-insulating layer encapsulate the solar cell. A plurality of such solar cells are electrically connected to form a solar cell panel. Other methods of utilizing electrically isolated portions of a semiconductor body include the production of small surface area semiconductor devices from larger surface area semiconductor devices and a process for improving the electrical output of those isolated portions of a semiconductor body which provide unsatisfactory electrical output.

4,419,531
Lang, Josef; Hollaus, Reinhard; Reeh, Ulrike; Denk, Hans; Habrich, Reiner, inventors; Siemens Aktiengesellschaft, assignee. *Photo-Voltaic Solar Module*. December 6, 1983.

A photovoltaic solar module having at least one solar cell embedded in synthetic resin and resting on a flexible supporting element and which further includes a sheet-like rigid element reinforcing the solar cell.

4,419,532
Severns, James G., inventor; The United States of America as represented by the Secretary of the Navy, assignee. *Thermophotovoltaic Power Source*. December 6, 1983.

A thermophotovoltaic power source comprising a Cassegrain solar collector and concentrator, a thermal vessel including a containment vessel holding thermal storage material therein, the containment vessel having the shape of an annulus closed at one end and disposed with its open end in registry with an aperture in the thermal vessel, with a selective band radiating layer coating the internal surface of the annulus cavity, and further including an external array of photovoltaic cells mounted on a cooled cylinder disposed for insertion by a positioning motor to a desired depth into the annulus cavity and thus into adjacency with the selective band radiating layer. Concentrated solar energy is applied by the solar collector through a second aperture into the thermal vessel to heat the thermal storage material in the containment vessel and thereby cause the selective radiating layer to radiate energy to excite a current in the photovoltaic array. Constant current control and/or load-matching are obtained by varying the degree of insertion of the photovoltaic array into the thermal storage annular cavity.

4,419,533
Czubatyj, Wolodymyr; Singh, Rajendra; Doehler, Joachim; Allred, David D.; Reyes, Jaime M., inventors; Energy Conversion Devices, Inc., assignee. *Photovoltaic Device having Incident Radiation Directing Means for Total Internal Reflection*. December 6, 1983.

There is disclosed new and improved photovoltaic devices which provide increased short circuit currents and efficiencies over that previously obtainable from prior devices. The disclosed devices include incident radiation directing means for directing at least a portion of the incident light through the active region or regions thereof at angles sufficient to substantially confine the directed radiation in the devices. This allows substantially total utilization of photogenerated electron-hole pairs. Further, because the light is directed through the active region or regions at such angles, the active regions can be made thinner to also increase collection efficiencies. The incident radiation directors can be random surface or bulk reflectors to provide random scattering of the light, or periodic surface or bulk reflectors to provide selective scattering of the light. While the present invention is applicable to photovoltaic devices, formed from any type of semiconductor material, as for example, crystalline, polycrystalline, or amorphous semiconductor alloys or any combination thereof, disclosure herein is primarily directed to photovoltaic devices formed from amorphous silicon alloys preferably incorporating fluorine as a density of states reducing element. The disclosure is also directed to, without limitation, photovoltaic devices of the p-i-n configuration, both as single cells and multiple cells arranged in tandem.

4,420,650
Wise, Joseph F.; Holt, James F., inventors; The United States of America as represented by the Secretary of the Air Force, assignee. *Wedged Channel Vertical Junction Silicon Solar Cell*. December 13, 1983.

An improved vertical junction solar cell is provided which comprises a thin single-crystalline silicon chip having on one surface thereof a plurality of short channels etched therein in a desired array, the length l of the channels being related to the depth d of the channels by a relationship approximating $d = \frac{1}{2}\sqrt{3}$. The resulting structure provides improved light utilization at end-of-life condition, conversion efficiency, mechanical strength and radiation resistance.

4,420,752
Davis, Murray W.; Diedzic, Matthew J.; Knapp, Robert F.; Whitney, Bruce F., inventors; Murray W. Davis, assignee. *Real-Time Parameter Sensor-Transmitter*. December 13, 1983.

A system for monitoring at least one parameter of either an energized electrical power line conductor or at least one parameter adjacent to the power line conductor, on a real time basis and transmitting signals indicative of the parameter to a remote location where the power line conductor itself is the transmission medium for transmitting the signals to the remote location. The transmitter is powered by either the electric or the electromagnetic field of the energized power line conductor and the transmitter receives induced energy from the conductor via a plurality of turns of wire wound around a mandrel, with the plurality of turns of wire formed as the secondary winding of a transformer, and with the mandrel being at the same electrical potential as the conductor.

4,421,592
Shuskus, Alexander J.; Cowher, Melvyn E., inventors; United Technologies Corporation, assignee. *Plasma Enhanced Deposition of Semiconductors*. December 20, 1983.

Semiconductor thin films are produced using plasma assisted chemical vapor deposition on alkali halide single crystal substrates. Deposition is formed at relatively low temperatures so that sublimation of the substrate is not a problem. The invention process permits at high rate deposition of high quality semiconductors.

4,421,943
Withjack, Eric M., inventor; Cities Service Company, assignee. *Collapsible Mobile Solar Energy Power Source*. December 20, 1983.

An apparatus for collecting solar energy and converting it to electrical energy utilizing solar panels pivotally mounted to a base such that the panels may be pivoted to a storage position inside said base. Additional solar panels may be pivotally mounted on retractable frame trays which stow inside the base when the panels are pivoted to a horizontal position.

4,422,031
Vigerstøl, Ole K., inventor; SAB Nife AB, assignee. *Method and Device for Charging an Electrical Accumulator Battery by Means of Solar-Cells*. December 20, 1983.

The invention relates to a method of charging an electrical accumulator battery by means of solar panels with solar-cells. The battery is charged by means of two or more solar panels included in charging branches connected in parallel, at least one charging branch being permitted to charge the accumulator battery to a higher voltage than the other charging branch or branches. Only the charging branch or branches which charge to the highest voltage are permitted to deliver current to the accumulator battery during maintenance charging, when the accumulator battery is fully charged. A device for carrying out the method consists of charging branches comprising at least one solar-cell panel and connected in parallel, the charging branches being adapted to deliver charging current at different voltages. At least one voltage is permitted to be higher than the other or others. The charging branch which delivers the highest voltage is adapted to deliver a voltage which is somewhat higher than the voltage of the fully charged accumulator battery.

Indexes

ASSIGNEE

Acurex Corporation
1979: 4,177,083
1983: 4,367,365

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1966: 3,229,579
1969: 3,427,200

Agence Nationale de Valorisation de la Recherche (ANVAR)
1980: 4,187,124
1982: 4,309,239

Agency of Industrial Science and Technology
1977: 4,046,594
1983: 4,367,369

Aiken Industries, Inc.
1968: 3,375,141

Air Reduction Company, Inc.
1969: 3,437,328

Alfred G. Cohen and Paul Weiss
1960: 2,960,094

Allied Chemical Corporation
1977: 4,011,149
1978: 4,094,751

Alpha Solarco, Inc.
1983: 4,383,130
4,388,481

American Cyanamid Company
1974: 3,811,953
1977: 4,048,372

American Solar Systems, Inc.
1980: 4,223,214

Ametek, Inc.
1979: 4,173,497
1981: 4,260,427
4,261,802
1982: 4,345,107

ARCO Solar, Inc.
1978: 4,105,471

Argus Chemical Corporation
1982: 4,360,542

Arthur D. Little, Inc.
1963: 3,077,539

Asahi Kasei Kogyo Kabushiki Kaisha
1983: 4,381,233

Asahi Kogaku Kogyo Kabushiki Kaisha
1975: 3,879,740

Atlantic Richfield Company
1978: 4,116,718
4,127,425
4,130,445
1979: 4,135,537
4,140,544
4,141,811
4,144,097
4,153,813
4,155,371
4,158,591
4,159,212
4,165,241
4,175,980
1980: 4,189,881
4,193,819
4,198,262
4,199,376
4,226,256
1981: 4,251,288
4,265,422
4,298,587
1982: 4,323,419
4,353,161
4,357,486
1983: 4,371,739
4,373,308
4,401,839

Avco Corporation
1970: 3,513,536

ACEC (Ateliers de Constructions Electriques de Charleroi)
1975: 3,896,368

AMP Inc.
1980: 4,203,646
1982: 4,310,211
4,321,416

Battelle Development Corporation
1978: 4,101,341

Bayer Aktiengesellschaft
1983: 4,385,102

Beam Engineering Kabushiki Kaisha
1981: 4,264,962

Beam Engineering, Inc.
1976: 3,988,166

Beiersdorf AG
1981: 4,275,525

Bell Telephone Laboratories, Inc.
1951: 2,537,255
2,537,256
2,537,257
1953: 2,631,356
1957: 2,780,765
2,794,846
1958: 2,861,018
1959: 2,874,341
1962: 3,015,590
1963: 3,106,489
1965: 3,175,929
3,215,571
1966: 3,253,951
1969: 3,475,609
1970: 3,530,053
3,547,596
1974: 3,839,084
1975: 3,865,625
1976: 3,941,624
3,974,002
3,975,632
3,978,510
3,982,265
3,988,172
1977: 4,039,357
1978: 4,074,305
4,081,290
4,082,682
4,084,044
4,115,633
4,118,548
4,121,238
4,127,449
1979: 4,154,625
4,180,625
1980: 4,213,801
1981: 4,256,544
4,273,594
4,291,323
1982: 4,309,460
4,310,405
4,343,870
4,357,179
1983: 4,369,099
4,388,382
4,389,291
4,406,709
4,407,061

Bendix Corporation
1965: 3,186,873

Bloss, Werner H.
1981: 4,283,590
1983: 4,367,366

Boeing Airplane Company
1962: 3,031,520

Boeing Company
1966: 3,232,795
1976: 3,973,996
1978: 4,097,309
4,108,704
1979: 4,152,535
1980: 4,199,377
4,234,351
1981: 4,278,831
4,294,602
1982: 4,320,250
4,322,571
4,335,266
1983: 4,392,451

Braun Aktiengesellschaft
1973: 3,774,023

Brown, Boveri & Cie, A. G.
1979: 4,171,997

BASF Aktiengesellschaft
1982: 4,340,507
1983: 4,395,497
4,401,545
4,404,126
4,411,826
4,412,942
4,418,187

BFG Glassgroup
1981: 4,249,958
1982: 4,331,494

California Institute of Technology
1978: 4,090,213
1979: 4,163,194
1980: 4,227,939
1981: 4,301,409
1982: 4,314,525
4,362,895
1983: 4,370,510
4,374,955
4,383,129

Canadian Patents & Development Ltd.
1980: 4,197,142

Canon Kabushiki Kaisha
1978: 4,076,977
1983: 4,404,076

Carnegie-Mellon University
1976: 3,993,533

Centre Electronique Horloger S. A.
1977: 4,006,583

Centre National d'Etudes Spatiales
1979: 4,168,124
1980: 4,191,593

Centre National de la Recherche Scientifique
1968: 3,382,099

Centro Ricerche Fiat S.p.A.
1981: 4,280,853
1982: 4,331,829

Chevron Research Company
1979: 4,143,235
1980: 4,234,353
1981: 4,255,211
4,287,383
1982: 4,332,974
4,366,336
1983: 4,377,604
4,393,267
4,396,793
4,398,054
4,404,421
4,415,760

Chrysler Corporation
1968: 3,419,484

Cities Service Company
1983: 4,421,943

Citizen Watch Company, Ltd.
1975: 3,890,776
1979: 4,165,604
1980: 4,234,947

Clevite Corporation
1958: 2,820,841
1968: 3,373,059
1971: 3,571,915

Columbia Chase
1983: 4,410,758

Commissariat a l'Energie Atomique
1977: 4,053,326
1979: 4,171,003
1981: 4,244,750
1983: 4,368,083

Communications Satellite Corporation
1973: 3,769,558
1974: 3,811,954
3,819,417
3,849,880
1975: Re. 28,610
3,874,931
3,888,698
3,895,975
3,904,453
3,907,595
3,922,774
1976: 3,943,003
3,949,463
3,977,905
3,982,964
1977: 4,053,327
1978: 4,072,541
1979: 4,133,699
4,135,950
1983: 4,395,583

Conoco, Inc.
1980: 4,187,126

Consortium für Elektrochemische Industrie GmbH
1981: 4,304,763

Cornell Aeronautical Laboratory, Inc.
1969: 3,433,677

Corning Glass Works
1971: 3,599,059
1973: 3,732,471
1977: 4,019,884
1979: 4,166,917
4,180,618

CWM Corporation
1982: 4,314,192

D. H. Baldwin Company
1965: 3,226,271
1975: 3,880,633
3,902,920
1976: 3,971,672

Data Beta Ltd.
1983: 4,384,259

Davis, Murray W.
1983: 4,420,752

De Laval Turbine Inc.
1979: 4,164,145

Desert Sunshine Exposure Tests, Inc.
1977: 4,031,385

Deutsche Gold- und Silber-Scheideanstalt vormals Roessler
1972: 3,681,036

Diamond Shamrock Corporation
1983: 4,396,485
4,400,451

Dornier System GmbH
1971: 3,626,198

Dow Corning Corporation
1975: 3,866,285
3,900,943
1976: 3,953,876
1981: 4,247,528
1983: 4,374,182

E. I. du Pont de Nemours and Company
1967: 3,310,439
1980: 4,235,644
1982: 4,342,795
4,347,262
4,361,718
1983: 4,375,007

E.N.I. Ente Nazionale Idrocarburi
1982: 4,366,337

E-Cel Corporation
1981: 4,251,679

E-Systems, Inc.
1978: 4,069,812

E:F Technology, Inc.
1982: 4,341,607

Eastman Kodak Company
1977: 4,035,197
1978: 4,125,414
1979: 4,149,902
4,164,431
1980: Re. 30,412
4,207,119
1981: 4,281,053
1982: 4,315,096
4,319,069
1983: 4,371,740

Ebauches S.A.
1980: 4,183,628

Electric Power Research Institute, Inc.
1980: 4,234,352
1982: 4,357,400

Electric Storage Battery Company
1962: 3,057,945

Electro-Optical Systems, Inc.
1967: 3,330,700
3,359,137

Elektronikcentralen
1983: 4,377,722

Energy Conversion Devices, Inc.
1979: 4,177,473
4,178,415
1980: 4,217,374
1982: 4,342,044
1983: 4,379,943
4,400,409
4,409,605
4,410,558
4,419,530
4,419,533

Energy Integrated Systems, Inc.
1981: 4,304,955

Energy Materials Corporation
1981: 4,289,571

Engelhard Corporation
1983: 4,381,978

Erno Raumfahrttechnik GmbH
1979: 4,153,474

Exxon Research and Engineering Co.
1977: 4,064,522
1978: 4,127,738
1979: 4,132,570
4,135,235
4,137,570
4,167,644
4,177,093
1980: 4,192,720
4,193,821
4,214,920
4,235,643
4,242,374
1981: 4,243,928
4,251,289
4,259,122
4,266,984
4,268,347
4,285,762
4,287,382
4,289,602
4,291,318
4,292,959
4,301,322
1982: 4,311,728
4,311,869
4,313,023
4,321,417
4,327,318
4,331,707
4,349,775
4,359,487
4,360,702
4,361,950
4,366,335

1983: 4,375,662
4,377,445
4,387,116
4,392,009
4,398,056
4,407,710
4,417,092
4,536,608

EIC Laboratories, Inc.
1983: 4,388,384

Fair, James W.
1977: 4,045,663

Fairchild Camera and Instrument Corporation
1978: 4,087,571

Farbenfabriken Bayer Aktiengesellschaft
1967: 3,309,226
3,351,516

Ferranti, Ltd.
1975: 3,912,539

Fraunhofer Gesellschaft
1978: 4,110,123
1982: 4,330,680

Fuji Photo Film Company, Ltd.
1980: 4,231,808

Futaba Denshi Kogyo K. K.
1978: 4,066,527
1979: 4,161,418
1980: 4,233,613
4,139,857
4,140,610

General Aniline & Film Corporation
1961: 3,009,006

General Atomic Company
1982: 4,352,722

General Dynamics Corporation
1962: 3,053,923
1982: 4,328,389
1983: 4,416,052

General Electric Company
1951: 2,554,225
1959: 2,903,631
1961: 2,997,415
1963: 3,095,324
1966: 3,290,175
1969: 3,479,573
1976: 3,936,319
1978: 4,089,576
1980: 4,227,942
1982: 4,361,717

General Instrument Corporation
1980: 4,238,436

General Motors Corporation
1967: 3,331,707
1969: 3,433,676
3,483,037
1971: 3,615,855
3,620,829

General Solar Power Corporation
1977: 4,009,051

George L. Haywood Co.
1978: 4,082,947

Giannini Controls Corporation
1963: 3,104,188

Gibbs & Hill, Inc.
1983: 4,395,582

Globe-Union, Inc.
1968: 3,361,594
3,376,164
3,378,407
3,411,952
1969: 3,454,774
3,462,311
3,471,924
3,493,822
1970: 3,509,431

Globe-Union, Inc.
1968: 3,361,594
1969: 3,462,311
1970: 3,493,822

Gordon, Roy G.
1982: 4,338,482

Gould Inc.
1973: 3,713,893

GTE Automatic Electric Laboratories Inc.
1977: 4,041,389

GTE Products Corporation
1981: 4,254,093

Harshaw Chemical Company
1965: 3,186,874

Hartman Systems Co., Inc.
1970: 3,546,460

Hayakawa Denki Kogyo K. K.
1966: 3,278,811

Helictronic Forschungs- und Entwicklungs-Gesellschaft für Solarzellen-Grundstoffe mbH
1981: 4,308,245
1982: 4,312,700
4,366,024

Heraeus Quarzschmelze GmbH
1982: 4,340,627

Hitachi, Ltd.
1982: 4,343,829
1983: 4,405,435

Hoffman Electronics Corporation
1958: 2,862,160
1959: 2,889,490
2,894,173
2,904,613
2,919,298
2,919,299
2,919,353
1960: 2,938,938
2,946,945
2,951,163
1962: 3,025,335
3,040,416
3,046,324
1963: 3,089,070
1966: 3,252,023
1967: 3,334,217
3,350,234
3,350,775

Hoffman Engineering Corporation
1978: 4,090,071

Honeywell, Inc.
1968: 3,384,806
1978: 4,112,135
4,128,680
1979: 4,137,355
1981: 4,252,861
1982: 4,317,689
1983: 4,366,771
4,409,537

Hughes Aircraft Company
1968: 3,369,939
1970: 3,490,950
1975: 3,903,427
3,903,428
1976: 3,952,324
3,956,687
3,993,505
1978: 4,095,004
4,107,723
4,108,684
4,113,531
4,128,733
1979: 4,156,310
4,163,987
4,171,235
1980: 4,235,651
1983: 4,395,293

Ilford Ltd.
1970: 3,513,317

Imperial Chemical Industries Ltd.
1976: 3,957,537
1980: 4,204,933
4,225,408

Independent Power Company, Inc.
1980: 4,224,082

Innotech Corporation
1977: 4,016,586
4,024,558

Institute of Gas Technology
1980: 4,235,955
4,240,882

International Business Machines Corporation
1961: 2,986,591
1962: 3,046,459
1963: 3,072,507
3,082,283
3,111,611
1965: 3,212,921
1966: 3,247,428
1972: 3,675,026
1975: 3,903,324
1977: 4,018,626
4,062,038
4,062,698
1978: 4,116,641
4,122,407
4,122,476
1979: 4,132,571
4,135,998
4,141,020
4,155,785
1980: 4,202,704
4,229,233
4,239,734
4,239,810
1981: 4,243,471
4,258,647
4,276,137
4,289,920
4,292,461
4,295,002
1982: 4,316,048
4,329,534

International Nickel Company, Inc.
1981: 4,253,919

International Rectifier Corporation
1961: 2,989,575
1962: 3,053,926
1963: 3,108,021
3,115,424
1964: 3,128,213
3,147,414
3,151,378
3,151,379
1966: 3,255,047
3,278,337
1967: 3,344,334
3,350,635
1969: 3,422,527
3,483,039
1972: 3,643,260

International Research and Development Company Ltd.
1977: 4,036,645

Ion Physics Corporation
1970: 3,539,883

Itek Corporation
1968: 3,376,163
1970: 3,527,619

J. C. Schumacher Company
1978: 4,084,024
1980: 4,227,291
1982: 4,318,942

Japanese Government
1978: 4,104,083

Jenaer Glaswork Schott and Gen.
1963: 3,094,436

Johns Hopkins University
1982: 4,313,254

Kabushiki Kaisha Daini Seikosha
1983: 4,409,538

Kabushiki Kaisha Suwa Seikasha
1973: 3,780,519
3,747,327
1974: 3,786,624
3,818,691
1976: 3,979,656
1977: 4,038,104
1978: 4,087,960
1979: 4,144,096
1981: 4,266,178

Katz, Bernard B.
1983: 4,370,175

Kewanee Oil Company
1968: 3,374,108
3,416,956
1969: 3,442,007
3,472,690
3,480,473
1970: 3,531,335

Kilby, Jack S.
1978: 4,100,051
1979: 4,173,494

Kobe Steel, Ltd.
1979: 4,178,175

Kuraray Company, Ltd.
1982: 4,338,180

Laitram Corporation
1978: 4,088,121

Lawrence Peska Associates, Inc.
1976: 3,943,726

Le Silicium Semiconducteur SSC
1982: 4,339,627
4,348,545

Licentia Patent-Verwaltungs-GmbH
1971: 3,574,925
1973: 3,736,180
3,772,768
3,772,770
3,778,684
1974: 3,802,924
1975: 3,887,935
3,888,697
1976: 3,956,765
1977: 4,009,054
4,043,834
1979: 4,147,560
1981: 4,291,191
1982: 4,336,648
4,358,331
1983: 4,370,509
4,377,564
4,390,743
4,393,576

Litton Business Systems, Inc.
1977: 4,017,725

Lockheed Missiles and Space Company
1972: 3,658,596

London Post Office
1981: 4,307,680

Lonza Electric and Chemical Works Limited
1961: 2,972,521

Lucas Industries Ltd.
1981: 4,306,183

Madison College Foundation, Inc.
1971: 3,617,137

Martin Marietta Corporation
1968: 3,419,434

Massachusetts Institute of Technology
1970: 3,549,960
1975: 3,899,689
1977: 4,042,417
4,059,461
1978: 4,086,485
4,110,122
4,117,364
4,128,732
4,129,458
1979: 4,131,984
4,162,174
4,179,318
1980: 4,193,081
4,197,141
4,227,941
4,229,231
4,242,580
1981: 4,248,675
4,283,589
4,287,485
1982: 4,309,225
4,320,247
4,352,948
4,366,338
1983: 4,376,228
4,379,020
4,414,300

Matsushita Electric Industrial Company, Ltd.
1970: 3,492,187
3,520,732
1971: 3,568,306
1972: 3,649,383
1975: 3,928,865
1981: 4,256,513
1982: 4,329,699

Max-Planck-Gesellschaft zur Forderung der Wissenschafter
1979: 4,169,740

McDonnell Douglas Corporation
1982: 4,315,097

Merck & Co., Inc.
1965: 3,172,791

Messerschmitt-Bölkow-Blohm GmbH
1976: 3,977,904
1979: 4,159,427
1981: 4,296,270
1983: 4,367,581
4,389,534
4,390,770

Mid-Continent Manufacturing Company
1969: 3,484,606

Minnesota Mining and Manufacturing Company
1962: 3,051,636
1978: 4,108,540
1980: 4,190,321

Minolta Camera K.K.
1973: 3,734,632
1977: 4,001,863

Mitsubishi Denki K.K.
1975: 3,925,802

Mitsubishi Kinzoku K.K.
1982: 4,329,195

Mobil Solar Energy Corporation
1983: 4,379,202

Mobil Tyco Solar Energy Corporation
1976: 3,976,508
3,982,260
1977: 4,019,924
4,036,666
4,045,246
4,056,404
1978: Re. 29,833
4,078,944
4,078,945
4,095,329
1979: 4,134,387
4,144,095
4,152,536
4,152,824
1980: 4,239,555
4,239,583
1982: 4,321,283

Monegon, Ltd.
1983: 4,392,008
4,410,757

Monosolar, Inc.
1983: 4,388,483
4,400,244

Monsanto Company
1962: 3,023,079
3,023,080
3,026,175
3,046,323

1965: 3,224,913
1966: 3,261,726
1967: 3,322,575
1970: 3,496,024
1977: 4,003,770
4,143,233
1979: 4,143,234
1982: 4,309,241

Motorola, Inc.
1973: 3,743,847
3,757,511
1976: 3,977,934
1977: 4,004,949
4,027,053
4,045,245
1978: 4,070,444
4,070,689
4,120,743
4,131,485
4,131,488
4,131,755
1979: 4,137,123
4,138,509
4,170,507
4,170,667
4,171,989
1980: 4,196,041
4,199,397
4,227,298
4,231,807
1981: 4,250,148
4,251,327
4,273,421
4,292,342
1982: 4,321,246
4,343,830
1983: 4,382,099

National Aeronautics and Space Administration
1966: 3,229,682
1967: 3,311,510
3,325,723
3,346,419
1968: 3,396,057
3,419,433
1969: 3,434,885
3,437,527
3,446,676
3,466,198
3,472,698
1970: 3,490,965
3,493,437
3,541,679
1971: 3,565,719
3,591,420
1972: 3,636,539
3,653,970
3,664,874
1973: 3,780,424
1975: 3,912,540
1976: 3,961,997
3,966,499
3,989,541
3,996,067
1977: 4,040,867
1978: 4,077,818
4,082,569
4,083,097
4,084,985
4,089,705
4,104,084
4,104,091
4,121,965
4,122,214
4,131,486
1979: 4,135,290
4,149,665
4,156,309
4,175,249
4,217,633
1980: 4,184,903
1981: 4,262,206
1982: 4,335,503
4,341,918
4,355,196
4,360,701
1983: 4,372,680
4,376,872
4,415,133

National Cash Register Company
1964: 3,148,084
1971: 3,586,541

National Patent Development Corporation
1981: 4,252,865

National Research Council of Canada
1982: 4,360,703

National Research Institute for Metals
1979: 4,176,370

New England Institute, Inc.
1976: 3,935,031

Nicholas R. duPont
1969: 3,444,946

Nippon Electric Varian, Ltd.
1975: 3,897,325

Nissan Motor Company, Ltd.
1982: 4,327,316

North American Construction Utility Corporation
1982: 4,364,532

North American Philips Company, Inc.
1959: 2,873,303
1963: 3,092,725
3,102,828
1965: 3,194,700
1966: 3,261,074
3,268,366
3,284,252
1967: 3,357,857
1969: 3,436,625

North American Rockwell Corporation
1969: 3,483,040
1972: 3,696,286

North American Utility Construction Corporation
1980: 4,238,246
1981: 4,249,516
4,289,118

Northern Telecom Ltd.
1982: 4,329,189
1983: 4,392,931

Oklahoma State University of Agriculture and Applied Sciences
1982: 4,348,428

Omron Tateisi Electronics Company, Ltd.
1972: 3,679,949
1976: 3,952,323
1977: 4,005,468
4,016,589

Optical Coating Laboratory, Inc.
1966: 3,247,392
1977: 4,015,117
4,055,442
1979: 4,180,414
1980: 4,227,940
1981: 4,268,711
4,293,732

Organisation Europeenne de Recherches Spatiales
1980: 4,193,820

Owens-Illinois, Inc.
1979: 4,164,432
4,173,495
1980: 4,184,895
4,186,033
4,188,238
4,188,239
4,190,465
4,238,247
1981: Re. 30, 584
4,251,284
4,268,709
1982: 4,329,535

Pacific Semiconductors, Inc.
1961: 2,995,473

Pennwalt Corporation
1982: 4,316,448

Peters, Walter Todd; Peters, Margot Elizabeth; Kronman, Albert F.; Steller, Arthur H.; Steller, Grace B.
1981: 4,248,643

Philco Corporation
1963: 3,113,047
3,114,658
1966: 3,284,241

Philco-Ford Corporation
1974: 3,844,843
1975: 3,900,945

Photon Power, Inc.
1978: Re. 29,812
4,086,101
4,095,006
4,104,420
1979: Re. 30,147
4,159,914
4,167,805
4,178,395
1980: 4,224,355
4,228,570
4,233,085
4,239,809
1981: Re. 30,504
4,243,432
4,262,411
4,265,933
4,304,607
4,307,681
1982: 4,313,022
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1983: 4,404,734
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1982: 4,314,128
1983: 4,401,840

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1959: 2,877,284
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1960: 2,929,859
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1966: 3,264,707
1968: 3,368,125

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1976: 3,961,472

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Rand Corporation
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1963: 3,081,370
1964: 3,132,057

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1979: 4,172,925

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1979: 4,179,702

Rhone-Poulenc Industries
1980: 4,225,367

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1974: 3,823,551

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1977: 4,052,657
1978: 4,066,481
1980: 4,227,943
1981: 4,270,972

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1969: 3,483,038
1976: 3,960,620
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1982: 4,334,120

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Semicon, Inc.
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1979: 4,174,561
1981: 4,256,681
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Semix, Inc.
1979: 4,169,739
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Sensor Technology, Inc.
1976: 3,990,914
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1979: 4,140,545
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1981: 4,262,161

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1964: 3,134,906

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1972: 3,694,739
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1975: 3,884,779
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1981: 4,246,043
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1982: Des. 263,393
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Sony Corporation
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Sotec Corporation
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1978: 4,115,625
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1963: 3,076,861

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1983: 4,385,430

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1982: 4,348,546
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1981: 4,289,112

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1980: 4,223,174

Sundstrand Corporation
1963: 3,085,565

Superior Oil Company
1977: 4,042,758

Swedlow, Inc.
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Swiss Aluminium Ltd.
1980: 4,233,270

SAB Nife AB
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SRI International
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1963: 3,078,328
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1970: 3,549,411
1971: 3,591,431
1974: 3,836,399
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1977: 4,021,323
1978: 4,092,446
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1979: 4,133,698
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1982: 4,322,379
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Timex Corporation
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1972: 3,634,424
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1975: 3,879,228
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1983: 4,421,592

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1981: 4,252,573
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1982: 4,325,986
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1980: 4,206,002

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1978: 4,099,199
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University of Toronto
1982: 4,359,367

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1980: 4,204,216
1983: 4,367,368

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1976: 3,993,506
1977: 4,002,031
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1978: 4,115,149
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1981: 4,246,050
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1982: 4,338,480
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1983: 4,379,944
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1980: 4,239,585
1983: 4,382,838

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1961: 3,009,841
1964: 3,129,061
1968: 3,370,986
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1969: 3,421,943
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1970: 3,533,850
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1971: 3,589,946
1972: 3,682,708
1973: 3,758,348
1976: 3,975,211
1977: 4,042,418
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1963: 3,072,507
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1981: 4,294,811

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1959: 2,874,341

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Bordina, Ninel Mineevna
1976: 3,948,682

Boron, Wilfred R.
1969: 3,459,597

Bottini, Manfred Hermann
1977: 4,039,357

Boudreau, Robert A.
1983: 4,388,384

Bowers, Grover W.
1967: 3,317,809

Bowers, John E.
1982: 4,317,689
1983: 4,366,771

Bozler, Carl O.
1980: 4,197,141
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1981: 4,248,675
1983: 4,376,228

Bradley, Arthur
1980: 4,214,916

Bragagnolo, Julio
1982: 4,328,390

Brandhorst, Henry W., Jr.
1976: 3,989,541
1978: 4,104,091
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Brattain, Walter H.
1951: 2,537,255
2,537,256
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Brimhall, George H.
1977: 4,050,907

Briska, Marian
1980: 4,239,810

Brockes, Andreas
1967: 3,309,226
3,351,516

Broder, Jacob D.
1969: 3,434,885
1973: 3,780,424
1975: 3,912,540
1976: 3,996,067

Brody, Philip S.
1980: 4,236,938

Brooks, Gilbert R.
1976: 3,952,324

Brown, Richard W.
1976: 3,961,998

Bruel, Michel
1983: 4,368,083

Bube, Kenneth R.
1979: 4,163,678

Buchanan, Bobby L.
1969: 3,431,150

Bucker, Edward R.
1980: 4,192,720
1983: 4,387,116

Buehler, Ernest
1976: 3,988,172
1977: 4,039,357
1978: 4,081,290

Bunnell, Edward D.
1982: 4,310,211

Burgess, Edward L.
1979: 4,152,175

Burgess, Ronald R.
1973: 3,757,511

Burton, Larry C.
1983: 4,398,055

Butera, Richard A.
1980: 4,206,002

Butler, David M.
1978: 4,075,034

Cacheux, Jean A.
1980: 4,191,593

Cahen, David
1981: 4,296,188
1982: 4,315,973
1983: 4,368,216
4,386,142

Cairo, Fred J.
1979: 4,149,665

Calgari, Seba
1980: 4,212,932

Callen, Patrick J.
1981: 4,281,278
1982: 4,313,078

Calvin, Melvin
1962: 3,057,947

Cameron, Angus E.
1960: 2,932,592

Campbell, William Patrick, III
1978: 4,081,289
1979: 4,172,740

Cannella, Vincent D.
1983: 4,400,409
4,410,558

Capewell, Maurice J.
1983: 4,384,259

Carbajal, Bernard G.
1979: 4,133,698
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Carey, James E.
1981: 4,262,161

Carlson, Allan E.
1958: 2,820,841

Carlson, David E.
1977: 4,064,521
1978: 4,126,150
1979: 4,142,195
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1980: 4,196,438
4,200,473
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4,226,643
1982: 4,339,470

Caro, Charles R.
1982: 4,314,192

Caruso, Paul J.
1979: 4,132,570

Caryl, Coleman R.
1960: 2,945,417

Casey, Horace Craig, Jr.
1976: 3,974,002

Castel, Egil D.
1979: 4,167,805

Catalano, Anthony W.
1982: 4,342,879

Cavitt, Roy L.
1972: 3,671,291

Celler, George K.
1983: 4,406,709

Chai, An-Ti
1982: 4,335,503
4,341,918
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1983: 4,376,872

Chalmers, Bruce
1983: 4,379,202

Chamberlin, Rhodes R.
1964: 3,148,084
1971: 3,586,541
1980: 4,228,570

Chambers, Robert R.
1978: 4,127,425
1979: 4,144,097

Chang, Kuang-Chou
1978: 4,082,682
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Chang, Leroy L.
1975: 3,929,527

Chapin, Daryl M.
1957: 2,780,765

Chapman, Ralph L.
1980: 4,227,941
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Chapman, Richard A.
1976: 3,980,915

Chappell, Terry I.
1980: 4,200,472
1981: 4,255,212
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Charles, Harry K.
1982: 4,313,254

Charlton, Walter T.
1982: 4,326,012

Chen, Schoen-Nan
1979: 4,172,925

Chen, Wen S.
1982: 4,335,266
1983: 4,392,451

Chenevas-Paule, André
1981: 4,244,750

Chern, Shy Shiun
1978: 4,090,213

Chernyshov, Vyacheslav V.
1979: 4,140,142

Chi, Jim-Yong
1982: 4,320,247

Chiang, Chwan K.
1980: 4,204,216

Chiang, Shang-Yi
1979: 4,133,698
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Chiarelli, Carl
1977: 4,040,566

Chieffo, Joseph M.
1982: 4,310,987

Chik, Kin P.
1983: 4,402,762

Chiola, Vincent
1981: 4,254,093

Chitre, Sanjeev R.
1978: 4,081,820
1981: 4,273,950
1982: 4,314,128
1983: 4,401,840

Cho, Alfred Yi
1974: 3,839,084
1975: 3,865,625
1976: 3,941,624
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Christian, Schuyler M.
1958: 2,847,585

Chu, Ting L.
1976: 3,961,997
1978: 4,077,818

Chubrikov, Boris A.
1979: 4,174,978

Ciszek, Theodore F.
1978: 4,116,641
1980: 4,239,734
1981: 4,243,471
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Ciszek, Theodore Frank
1978: 4,116,641

Clampitt, Bert H.
1962: 3,031,520

Clark, Harold A.
1975: 3,866,285

Clark, Leslie
1977: 4,036,645

Clark, Stephan R.
1982: 4,350,837

Clark, William D. K.
1981: 4,253,919

Clarke, Stephen
1972: 3,643,260

Clawson, Arthur R.
1981: 4,263,064

Cleland, John W.
1978: 4,129,463

Clem, Katherine V.
1983: 4,371,740

Cleveland, Hugh M.
1959: 2,874,341

Clifton, Jack K.
1977: 4,016,586

Cline, Harvey E.
1976: 3,936,319

Cluff, C. Brent
1979: 4,148,301
1981: 4,296,731

Cobarg, Claus Christian
1973: 3,774,023

Coburn, John F., Jr.
1981: 4,292,959

Cohen-Solal, Gerard David
1974: 3,845,494

Cohen, Eli
1980: 4,184,482

Cohen, Marshall J.
1980: 4,227,943

Colehower, Edgar Warren
1968: 3,419,434

Coleman, John H.
1982: 4,328,258
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Coleman, Michael G.
1973: 3,757,511
1977: 4,045,245
1978: 4,070,689
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1979: 4,137,123
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Collignon, Pierre
1981: 4,249,958

Comeau, Joseph E., Jr.
1983: 4,378,786

Conrad, Ernest E.
1965: 3,212,921

Cook, Melvin S.
1981: 4,303,463
1982: 4,345,967

Corbefin, René
1983: 4,390,940

Corwin, Rudolph E.
1980: 4,199,377
1981: 4,278,831
1982: 4,320,250

Costogue, Ernest N.
1979: 4,149,665

Cota, Marlo E.
1981: 4,250,148

Courvoisier, Jean
1963: 3,102,828

Cowher, Melvyn E.
1983: 4,421,592

Coyle, Peter J.
1982: 4,340,803
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1983: 4,382,833

Crandall, Richard S.
1982: 4,319,187

Crisman, Everett
1976: 3,978,333
1979: 4,165,558

Criton, Eric
1982: 4,344,984

Crosher, Frederick K.
1977: 4,055,442

Crouse, Allen G.
1981: 4,270,972

Crouthamel, Marvin S.
1982: 4,350,836
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Cullis, Herbert M.
1983: 4,392,008
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Cuomo, Jerome J.
1977: 4,062,038
1979: 4,132,571
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Currin, Cedric G.
1975: 3,900,943
1976: 3,953,876

Curtin, Denis John
1975: 3,888,698

Cusano, Dominic A.
1963: 3,095,324
1966: 3,290,175

Czubatyj, Wolodymyr
1983: 4,419,533

D'Aiello, Robert Vincent
1978: 4,070,206
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Dages, Daniel
1982: 4,321,418

Dahlberg, Reinhard
1981: 4,291,191
1983: 4,370,509
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Dahly, Harold W.
1967: 3,353,191

Dalal, Vikram L.
1976: 3,988,167
1981: 4,251,287
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1983: 4,377,723
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Dale, Brian
1964: 3,150,999

Damen, Cornelus P. T.
1977: 4,011,578

Damsker, Dorel J.
1983: 4,395,582

Danforth, Stephen C.
1983: 4,379,020

Daniel, Arthur F.
1960: 2,962,539

Daniel, Maurice
1983: 4,411,490

Daud, Taher
1981: 4,249,957

David, Gerard R.
1974: 3,802,920
1980: 4,219,368
1983: 4,377,901

David, Gerard A.
1980: 4,242,696

Davis, Murray W.
1983: 4,420,752

Davis, Richard S.
1963: 3,077,539

Davis, Robert E.
1952: 2,588,254

Davis, Robert R.
1979: 4,175,980

De Angelis, Lucio
1982: 4,366,337

Dean, Raymond H.
1976: 3,999,283

Deb, Satyendra K.
1979: 4,172,925

Debenham, Colin H.
1981: 4,267,003

de Cremoux, Baudouin
1982: 4,366,334

Dejong, Pieter N.
1975: 3,903,428

Della-Vedowa, Richard P.
1978: 4,131,123

Demichelis, Francesca
1982: 4,331,829

Deminet, Czeslaw
1979: 4,152,535
1980: 4,234,351

Dendall, Robert John
1975: 3,904,453
1976: 3,943,003

Denk, Hans
1983: 4,419,531

Dermatis, Steve N.
1964: 3,129,061

Dessert, Richard
1983: Re. 31,156

Desso, Jerome A.
1980: 4,203,646

Dettling, Joseph R.
1977: 4,021,267

Deutscher, Siegfried G.
1981: 4,255,208

Devaud, Genevieve
1983: 4,409,424

DeToia, Vincent D.
1980: 4,242,147

Diamond, Ronald M.
1979: 4,180,414

Dickson, Donald C., Jr.
1960: 2,938,938

Diedzic, Matthew J.
1983: 4,420,752

Diepers, Heinrich
1978: 4,099,986
1979: 4,155,781

Dietl, Josef
1981: 4,304,763
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Diggs, Richard E.
1980: 4,187,123

Diguet, Daniel
1980: 4,242,696

Dillard, Paul A.
1980: 4,184,903

Dixon, Jack R.
1976: 3,961,998

DiStefano, Thomas H.
1979: 4,132,571
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DiStefano, Thomas Herman
1977: 4,062,038

Doan, Duc
1980: 4,200,904

Dodge, Robert J.
1982: 4,316,448

Doehler, Joachim
1983: 4,419,533

Doellner, Oscar Leonard
1978: 4,090,359

Dolan, Russell P., Jr.
1969: 3,431,150

Dominguez, Ramon
1978: 4,116,207
1980: Re. 30,292
1981: 4,293,808
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Donaghey, Lee F.
1980: 4,234,353
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Dorer, Gary L.
1980: 4,190,321

Dorfeld, William G.
1979: 4,166,917

Dorian, Mark E.
1980: 4,223,214

Dormidontov, Anatoly A.
1979: 4,140,142

Dosaj, Vishu D.
1981: 4,247,528

Doss, Dwight E.
1979: 4,170,507
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Doty, Mitchell E.
1981: 4,260,427
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1982: 4,345,107

Downing, Roy G.
1979: 4,149,665

Dran, Maurice
1982: 4,321,418

Dreyfus, Bertrand Alain
1968: 3,416,044

Dubey, Michael B.
1963: 3,094,439
1964: Re. 25,647

Dubois, Pierre
1982: 4,322,261

Duchateau, Jacques
1982: 4,331,494

Duigon, Ferdinand C.
1980: 4,181,755

Duisman, Jack A.
1979: 4,143,235

Dumbaugh, William H., Jr.
1979: 4,180,618

Dunlap, William Crawford, Jr.
1965: 3,186,873

Durand, Henri
1978: 4,100,427

Durkee, Lawrence F.
1979: 4,144,139

Duy, Thuoc Nguyen
1975: 3,884,779
3,885,058
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Eakins, Thomas C.
1976: 3,952,324

Eannarino, George
1963: 3,115,424

Ebneth, Harold
1983: 4,385,102

Eckert, Joachim
1981: 4,275,525

Eisele, John A.
1974: 3,833,425
1976: 3,964,155

Elie, George T.
1966: 3,264,707

Elleman, Daniel D.
1977: 4,052,181

Ellis, Arthur B.
1983: 4,414,300

Ellis, Ralph J.
1978: 4,120,743

Ellis, Sidney G.
1958: 2,861,909
1967: 3,340,599
1968: 3,396,057

Elmer, Thomas H.
1977: 4,019,884

Endler, Wolfgang
1981: 4,255,206

Epple, Richard
1975: 3,905,836

Epstein, Arnold S.
1976: 4,000,505

Epstein, Joseph
1972: 3,664,874

Ernest, Alan W.
1969: 3,427,200

Ernick, Frederick G.
1969: 3,460,240
1970: 3,546,542

Esaki, Leo
1975: 3,929,527

Escher, William J. D.
1980: 4,210,463

Escoffery, Charles A.
1964: 3,151,379
1966: 3,255,047

Ettenberg, Michael
1976: 3,960,620
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1979: 4,179,308

Evans, John C.
1983: 4,376,872

Evans, John C., Jr.
1978: 4,082,569
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1979: 4,135,290
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1982: 4,335,503
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Evdokimov, Vladimir M.
1979: 4,174,978

Excoffon, Charles
1980: 4,233,338

Faktor, Marc M.
1981: 4,307,680

Falkenthal, Erwin E.
1953: 2,643,277

Fan, John C. C.
1977: 4,059,461
1980: 4,197,141
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1982: 4,309,225
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Fang, Pao-Hsien
1975: 3,914,856

Faraday, Bruce J.
1974: 3,833,425
1976: 3,964,155

Faria, Sixdeniel
1981: 4,254,093

Farrow, Robin Frederick C.
1976: 3,992,233

Fattor, Arthur
1982: 4,355,630

Faust, John W., Jr.
1961: 3,009,841
1964: 3,129,061

Fawcett, William R.
1980: 4,192,721

Feldman, Charles
1982: 4,313,254

Felsher, Hal C.
1980: 4,214,916

Feltner, William R.
1979: 4,156,309

Feng, Tom
1978: 4,127,738
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1982: 4,360,702
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Ferrari, Giancarlo
1982: 4,331,829

Ferreira, Paul F.
1968: 3,383,246

Feucht, Donald L.
1976: 3,993,533
1979: 4,159,354

Fey, Maurice G.
1978: 4,102,764
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Field, Richard L.
1979: 4,137,098

Finegan, Joel D.
1958: 2,820,841

Finn, George B., Jr.
1964: 3,151,378

Fischer, Artur
1980: 4,199,894

Fischer, Horst
1973: 3,736,180
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1975: 3,887,935
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Fisher, Gerald M.
1982: 4,339,626

Fitzky, Hans G
1983: 4,385,102

Fletcher, James C.
1976: 3,984,256
1977: 4,052,181
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Floccari, Michel
1983: 4,368,083

Galluzzi, Fabrizio
1982: 4,366,337

Garasi, Louis
1967: 3,359,137
1970: 3,513,040

Garavaglia, Paul M.
1982: 4,309,241

Garbis, Dennis
1980: 4,238,436

Garone, Lynne C.
1977: 4,056,404

Garwacki, Walter
1969: 3,479,573

Gatos, Harry C.
1982: 4,320,247

Gattone, Daniel H.
1962: 3,018,313

Gau, Shek-Chung
1980: 4,204,216

Gaul, John H.
1983: 4,374,182

Gault, John M.
1964: 3,128,213
1966: 3,278,337
1969: 3,422,527
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Gauthier, Andre
1975: 3,887,995

Gauthier, Michael K.
1981: 4,301,409

Gay, Charles F.
1979: 4,158,591
1980: 4,198,262

Gehrke, Jørg S.
1971: 3,574,925

Geisler, Diether
1981: 4,275,525

Genequand, Pierre
1980: 4,238,246

Gereth, Reinhard
1973: 3,736,180

German, Dale E.
1962: 3,031,520

Ghosh, Amal K.
1977: 4,064,522
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Ghosh, Arup K.
1980: 4,237,151

Gibbons, James F.
1977: 4,001,864
1980: 4,219,830
1981: 4,270,018

Gibson, Preston H.
1978: 4,108,405

Gilbert, Laurence R.
1981: 4,252,865

Gilles, Jean-Marie F.
1962: 3,039,896

Gillette, Roger B.
1966: 3,232,795

Gilmore, Robert S.
1982: 4,361,717

Girard, Alain
1983: 4,392,007
4,395,581

Glaeser, Andreas M.
1983: 4,379,020

Glascock, Homer H., II
1982: 4,361,717

Glass, Alastair Malcolm
1976: 3,975,632

Gleim, Paul S.
1970: 3,549,411

Gniewek, John J.
1979: 4,135,998

Gobrecht, Klaus
1983: 4,373,809

Gochermann, Hans
1977: 4,009,054
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Goetzberger, Adolf
1978: 4,110,123
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Goldsmith, John V.
1969: 3,446,676
1971: 3,616,528

Golovchenko, Jene A.
1979: 4,154,625

Golub, Seymour
1967: 3,330,700

Golubovic, Aleksandar
1970: 3,530,007
1972: 3,634,424

Gonsiorawski, Ronald
1978: 4,078,945
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Goodrich, Joel L.
1978: 4,129,458
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Goradia, Chandra P.
1982: 4,335,503
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Gordon, Arnold Z.
1983: 4,396,485
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Gordon, Roy G.
1979: 4,146,657
1982: 4,338,482

Gorski, Anthony J.
1978: 4,118,249

Gorski, Daniel A.
1965: 3,186,874

Gounder, Raj N.
1983: 4,394,529

Graae, Johan E. A.
1978: 4,118,249

Grabmaier, Christa
1982: 4,330,358
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Grabmaier, Josef
1981: 4,292,343
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1982: 4,319,953
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Granger, Jean-Claude
1970: 3,508,063

Gratzel, Michael
1983: 4,381,978

Graven, Robert M.
1978: 4,118,249

Gravisse, Philippe
1975: 3,912,931
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1982: 4,324,946

Grayson, Jerome H.
1967: 3,325,723

Grazier, James A.
1978: 4,122,396

Grazier, Leonard F.
1978: 4,122,396

Green, Martin A.
1982: 4,323,719
1983: 4,404,422

Greenberg, Leon S.
1964: 3,132,057

Grenon, Lawrence A.
1973: 3,757,511
1981: 4,251,327

Greubel, Waldemar
1978: 4,110,123
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Griesshammer, Rudolf
1978: 4,113,532
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Griffin, Thomas A.
1969: 3,442,007

Griffiths, Kenneth F.
1978: 4,095,997

Grimes, Patrick G.
1983: 4,377,445

Grimmeiss, Hermann Georg
1963: 3,092,725
1965: 3,194,700
1966: 3,284,252

Grodkiewicz, William H.
1983: 4,407,061

Grohoski, Theodore S.
1969: 3,448,575
1970: 3,509,712

Grolitzer, Arthur J.
1983: 4,410,758

Gruber, Robert P.
1979: 4,175,249

Grunbaum, Enrique
1981: 4,255,208

Grzybowski, Holger
1982: 4,340,627

Gukelberger, Thomas F., Jr.
1975: 3,903,324

Gulko, Arnold G.
1978: 4,101,923

Gupta, Amitava
1982: 4,362,895
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Gurev, Harold S.
1981: 4,268,711

Gurtler, Richard W.
1980: 4,196,041
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Gutsche, Heinrich
1965: 3,172,791

Gutsche, Henry W.
1982: 4,309,241

Guyot, Paul
1966: 3,268,366

Haacke, Gottfried
1977: 4,048,372

Haas, Gregory M.
1977: 4,042,758

Habrich, Reiner
1983: 4,419,531

Hadley, Henry C., Jr.
1981: 4,252,573

Haggerty, John S.
1983: 4,379,020

Haigh, John
1981: 4,307,680

Halfon, Leon
1979: 4,173,229

Hall, Dale E.
1981: 4,253,919

Hall, Robert B.
1980: 4,239,553

Hall, Robert N.
1980: 4,227,942

Halsted, Richard E.
1961: 2,997,415

Hamakawa, Yoshihiro
1981: 4,271,328
1983: 4,385,199
4,385,200
4,388,482
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Hamilton, George Henry
1977: 4,025,786

Hanafin, Maurice C.
1982: 4,321,419

Hanak, Joseph J.
1979: 4,162,505
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1981: 4,272,641
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1982: 4,316,049

Hanger, Randolph T.
1980: 4,219,926

Hanke, Leopold
1982: 4,361,529

Hansen, Thomas A.
1980: 4,229,233

Hardee, Kenneth L.
1983: 4,396,485

Harding, William R., Jr.
1970: 3,533,850

Hardy, Craig A.
1978: 4,101,925

Hardy, Edgar E.
1979: 4,143,233
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Harris, Cynthia B.
1979: 4,137,123

Harris, Douglas H.
1977: 4,003,770

Harris, James S., Jr.
1980: 4,227,943

Harris, William A.
1983: 4,409,537

Harsha, Karnamadakala S.
1978: 4,121,238

Hartman, David J.
1968: 3,384,806

Harvey, Donald J.
1970: 3,531,335

Harvey, Francis J., II
1978: 4,102,764
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Hasbach, Walter A.
1971: 3,616,528

Hasegawa, Akira
1977: 4,001,863

Hatch, Arthur E.
1980: 4,239,583

Hausler, Rudolf H.
1976: 3,972,732

Hawley, Wilbur W.
1980: 4,189,881
4,226,256

Hawrylo, Frank Z.
1980: 4,203,785

Haynos, Joseph G.
1974: 3,819,417

Haynos, Joseph Gabrial
1974: 3,849,880
1975: 3,874,931
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Haysahi, Hiaso
1977: 4,062,034

Haywood, George Lewis
1978: 4,082,947

Haywood, Wesley Joseph
1978: 4,082,947

Heaps, Joseph D.
1978: 4,112,135
4,128,680
1979: 4,137,355
1981: 4,252,861

Heath, George F.
1980: 4,222,371

Heeger, Alan J.
1980: 4,204,216

Heindl, Christine
1981: 4,287,848

Heiskell, Robert F.
1977: 4,031,385

Heller, Adam
1978: 4,082,682
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1981: 4,273,594
1982: 4,310,405
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1983: 4,388,383

Heller, Robert
1980: 4,238,436

Helmick, Walter E.
1960: 2,945,417

Helmreich, Dieter
1982: 4,312,700
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Henker, Heinz
1964: 3,134,906

Hepp, James
1983: 4,374,406

Herbst, Austin H.
1968: 3,411,952

Hermann, Allen M.
1970: 3,507,706

Herzog, Heinz
1982: 4,340,627

Hewig, Gert H.
1981: 4,283,590
1983: 4,367,366

Heyerdahl, Norman E.
1970: 3,531,335

Hezel, Rudolf
1981: 4,253,881

Hider, Ross B.
1979: 4,153,475

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1979: 4,153,475

Higashi, Kazuhiro
1972: 3,679,949

Hill, Edwin R.
1969: 3,442,007
3,472,690

Hill, James E.
1964: 3,148,084

Hill, Lawrence R.
1980: 4,238,436

Himes, Roger
1982: 4,328,417

Hirano, Taizö
1978: 4,104,083

Hirota, Eiichi
1970: 3,520,732

Hirota, Euchi
1970: 3,492,187

Hisatomi, Junichirou
1980: 4,224,081

Ho, Te-Fu
1982: 4,360,703

Hochwald, Walter
1977: 4,052,657

Hodes, Gary
1981: 4,296,188
1982: 4,315,973
1983: 4,368,216
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Hodgson, Rodney T.
1980: 4,202,704
1982: 4,329,534

Hofer, Johann
1979: 4,141,764

Hogle, Richard A.
1982: 4,314,525

Hogrefe, Arthur F.
1971: 3,582,923
1973: 3,740,636

Holdridge, David W.
1982: 4,312,330

Hollaus, Reinhard
1983: 4,419,531

Hollis, Ben R.
1979: 4,156,309

Holm, Claus
1981: 4,308,245

Holt, James F.
1983: 4,409,423
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Holzapfel, Heinz
1982: 4,357,201

Honda, Junichi
1980: 4,224,081

Horne, William E.
1978: 4,097,309
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1979: 4,152,535
1981: 4,294,602
1982: 4,313,024

Horton, Paul V.
1961: 2,986,591

Hou, Shou-Ling
1971: 3,599,059
1973: 3,732,471

Houghton, Alexander J.
1981: 4,246,042

House, Robert E.
1978: 4,082,570
1979: 4,174,561

Houston, Bland B., Jr.
1976: 3,961,998

Hovel, Harold J.
1977: 4,062,698
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Hovel, Harold John
1977: 4,062,698
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Howard, James K.
1979: 4,141,020

Howell, John R.
1966: 3,229,682

Hsiao, Cheng-Kuo
1979: 4,175,982

Hsieh, Jaw J.
1981: 4,287,485

Hsu, George C.
1982: 4,314,525

Hugle, Frances B.
1965: 3,226,271

Hugle, William B.
1965: 3,226,271

Hui, William L. C.
1969: 3,483,038

Humrick, Richard J.
1969: 3,442,007

Hunt, Lee P.
1981: 4,247,528

Hunter, Lloyd P.
1963: 3,111,611

Huth, John H.
1961: 2,993,945

Hyder, Syed B.
1983: 4,379,944

Ijaz, Lubna R.
1983: 4,398,055

Iles, Peter Albert
1967: 3,350,775
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1972: 3,653,970

Imai, Terutoyo
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Ingham, John D.
1983: 4,374,955
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Ingle, William M.
1978: 4,070,444
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Iriyama, Keiji
1983: 4,367,369

Irmler, Horst
1979: 4,171,997

Irvin, Robert A.
1978: 4,082,570
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Ishihara, Shin-ichiro
1982: 4,329,699

Isobe, Yoshiyuki
1979: 4,144,096

Ito, Takamichi
1979: 4,178,175

Iwatsuki, Yoshiharu
1977: 4,001,863

Izu, Masatsugu
1980: 4,217,374
1982: 4,342,044
1983: 4,400,409
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Jackson, Edmond D.
1960: 2,949,498

Jacobi, Edgar F.
1982: 4,326,013

Jacobson, J. Merritt
1980: 4,224,082

Jain, Faquir C.
1979: 4,160,678

Jain, Nirmal S.
1982: 4,360,542

James, Lawrence W.
1977: 4,017,332

Janowiecki, Richard J.
1977: 4,003,770

Janzen, Abram F.
1980: 4,197,142

Jebens, Robert W.
1981: 4,249,959

Jewett, David N.
1981: 4,289,571

John, Puthenveetil K.
1983: 4,402,762

Johnson, Claude, Jr.
1980: 4,229,233

Johnson, Elwin L.
1979: 4,173,494

Johnson, Gregory R.
1979: 4,143,234

Johnson, Mile R.
1976: 3,980,915

Johnson, Morris L.
1974: 3,798,140

Johnson, Steven A.
1981: 4,269,168
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Johnston, Wilbur D., Jr.
1976: 3,982,265
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Jones, Lloyd E.
1963: 3,078,328

Jordan, John F.
1975: 3,880,633
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Jordan, John P.
1981: 4,265,933

Joubert, Alain Francois
1972: 3,694,739

Julian, John D.
1983: 4,419,424

Julius, Richard F.
1968: 3,375,141

June, Malcolm Neville
1978: 4,092,446

Justi, Eduard
1973: 3,778,684

Kadelburg, Kurt
1964: 3,147,414

Kaiser, Steven W.
1983: 4,414,300

Kalbtzer, Siegfried
1979: 4,169,740

Kalyanasundaram, K.
1983: 4,381,978

Kamahara, Koichi
1975: 3,925,802

Kamasako, Shoji
1975: 3,879,740

Kamath, G. Sanjiv
1978: 4,107,723
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1983: 4,395,293

Kamei, Tsuneaki
1983: 4,405,435

Kamins, Theodore I.
1978: 4,087,571

Kanai, Akira
1982: 4,343,829

Kane, Daniel F.
1978: 4,082,570
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Kapany, Narinder S.
1979: 4,143,233

Kaplan, Daniel
1979: 4,151,058
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Kaplow, Roy
1977: 4,042,417
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1980: 4,193,081
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1981: 4,283,589
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Kapur, Vijay K.
1981: 4,298,587

Kaspaul, Alfred F.
1962: 3,051,636

Kasper, Horst Manfred
1976: 3,978,510
1978: 4,115,633

Kato, Yutaka
1979: 4,165,604

Kauder, Otto S.
1982: 4,360,542

Kausche, Helmold
1981: 4,245,386

Kawamura, Koichi
1979: 4,140,545
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Kawaziri, Kazuhiro
1980: 4,231,808

Kay, James C.
1980: 4,228,789

Kay, Robert E.
1974: 3,844,843
1975: 3,900,945

Kaye, Stephen
1967: 3,359,137
1970: 3,513,040

Kazacos, Maria S.
1981: 4,256,544

Kazis, Earle W.
1977: 4,009,051

Kearas, David Richard
1962: 3,057,947

Keeling, Michael C.
1978: 4,131,755
1979: 4,170,507
1980: 4,227,298
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Keeney, Joe W.
1977: 4,042,758

Kefes, Donn E.
1960: 2,946,945

Keller, Wolfgang
1978: 4,108,714

Kelley, Larry P.
1978: 4,101,925

1977: 4,023,368
1978: 4,119,863
1979: 4,173,213
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1980: 4,191,164
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1981: 4,257,821

Kelly, Joseph E.
1979: 4,137,097

Kendall, Dön Leslie
1976: 3,969,746

Kennedy, Francis H.
1967: 3,317,809

Kennedy, Kurt David
1969: 3,437,328

Kennedy, Paul B.
1976: 3,973,996

Kennedy, Robert E.
1979: 4,154,998
1981: 4,257,821
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Kennedy, William S.
1979: 4,177,083

Keramidas, Basilio G.
1968: 3,374,108
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Kerlin, Allen L.
1981: 4,273,608

Kern, Werner
1980: 4,241,108

Keys, Richard V.
1968: 3,378,407

Khemthong, Seksan
1980: 4,227,940

Kidyashev, Jury K.
1980: 4,211,581

Kiener, Volker
1983: 4,401,545

Kilby, Jack S.
1977: 4,021,323
1978: 4,100,051
1979: 4,136,436
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1982: 4,322,379

Kimura, Akira
1982: 4,333,262

Kimura, Kenjiro
1969: 3,427,797

King, Roger A.
1980: 4,209,346

King, William J.
1977: 4,028,206
1978: 4,086,102
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Kingsley, Vernon T.
1982: 4,319,310

Kisatsky, Paul J.
1972: 3,645,633

Kischio, Werner
1966: 3,284,252

Kisinko, Paul M.
1970: 3,546,542

Kittl, Emil
1973: 3,751,303
1975: 3,929,510

Kittler, Wilfred C.
1978: 4,067,764

Kiwi, John
1983: 4,381,978

Klaus, Ruth Elizabeth Barry
1969: 3,426,212

Kleeberg, Heinz
1979: 4,164,698

Klein, Norman S.
1980: 4,209,347

Klein, William Richard
1978: 4,097,308

Kleiner, Charles T.
1977: 4,052,657

Kleinfelder, Walter J.
1975: 3,903,324

Kleinman, David A.
1965: 3,175,929

Knapp, Robert F.
1983: 4,420,752

Knasel, Thomas M.
1981: 4,246,042

Knechtli, Ronald C.
1978: 4,128,733
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Knight, John R.
1979: 4,147,561

Knippenberg, Wilhelmus F.
1970: 3,521,350

Kobayashi, Shigeru
1983: 4,405,435

Kobayashi, Yoshinori
1977: 4,001,863

Kodaira, Hitoshi
1981: 4,264,962

Koelmans, Hein
1963: 3,092,725
1965: 3,194,700

Kofron, Vernon K.
1979: 4,153,907

Koguchi, Nobuyuki
1979: 4,176,370

Köhl, Franz
1980: 4,239,585

Kohl, Paul A.
1983: 4,369,099
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Köhler, Franz
1976: 3,977,904
1981: 4,296,270
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Koichi, Oguchi
1978: 4,087,960

Kojima, Yasuo
1969: 3,427,797

Kolb, Ernest D.
1970: 3,547,596

Koliwad, Krishna M.
1981: 4,249,957

Komiya, Yoshio
1977: 4,046,594

Köppl, Franz
1978: 4,113,532
4,131,659

Kosarev, Viktor S.
1972: 3,653,971

Kostelec, Jozé
1961: 3,009,006

Kotila, Carl Leroy
1978: 4,097,308

Kotval, Peshotan S.
1978: 4,124,410
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Kozlov, Alexander I.
1979: 4,174,978

Krams, Ira Leslie
1978: 4,097,308

Kravitz, Jerome H.
1978: 4,106,952

Kressel, Henry
1976: 3,988,167
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Kreuzer, Karl-Heinz
1973: 3,736,180

Kroger, Ferdinand A.
1983: 4,400,244

Kruehler, Wolfgang
1981: 4,292,343

Kudo, Bosshi
1982: 4,329,195

Kulifay, Stanley M.
1962: 3,023,079
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Kun, Zoltan K.
1972: 3,705,059

Kurek, Joseph
1980: 4,187,124

Kurth, William T.
1977: 4,019,924
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Kuwano, Yukinori
1981: 4,281,208
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Kwon, Yiduk
1982: 4,327,318
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L'Esperance, Paul M.
1977: 4,024,852

Ladany, Ivan
1976: 3,975,555

Laesser, Claude
1980: 4,183,628

Lally, Kenneth P.
1970: 3,546,460

Lam, Hon W.
1982: 4,323,417

Lambert, Vernon L.
1970: 3,513,536

Lamorte, Michael F.
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Lampert, Murray Alfred
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Lampkin, Curtis M.
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Landouar, Pierre
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Landsman, Arkady P.
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Lang, Josef
1983: 4,419,531

Lang, Winfried
1978: 4,113,532
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Lapeyre, James M.
1978: 4,088,121

Lapin, Ellis E.
1969: 3,427,200

Lapluye, Gerard
1967: 3,357,857

Lark-Horovitz, Karl
1952: 2,588,254

Larrabee, Robert D.
1978: 4,131,827
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Lasser, Marvin E.
1963: 3,113,047
1966: 3,284,241

Lathrop, Jay W.
1977: 4,021,323
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Laub, Gerhard
1983: 4,367,366

Laue, Eric G.
1982: 4,355,896

Laurie, Alexander S.
1983: 4,403,398

Lawrence, John E.
1977: 4,062,102

Laws, Kenneth L.
1962: 3,057,945

Lawson, Paul
1982: 4,327,318
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Lazzery, Angelo G.
1982: 4,364,508

Le Comber, Peter G.
1979: 4,169,740

Le Gravier, Serge
1982: 4,321,418

Leamy, Harry J.
1981: 4,273,594
1983: 4,406,709

Lebrun, Jean
1971: 3,553,030

Lee, Ray H.
1976: 3,990,914
1977: 4,052,782

Leger, Lucien
1981: 4,249,958

Legge, Ronald N.
1982: 4,343,830
1983: 4,382,099

Lehovec, Kurt
1971: 3,630,015

Leibenzeder, Siegfried
1981: 4,287,848

Leinkram, Charles Z.
1973: 3,769,091
1974: 3,811,181
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1976: 3,964,155

Leipold, Martin H.
1978: 4,121,965

Lepselter, Martin P.
1963: 3,106,489
1966: 3,253,951

Lesk, Israel Arnold
1976: 3,977,934
1977: 4,004,949
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1979: 4,137,123
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Lessley, Robert L.
1966: 3,229,579

Levatter, Jeffrey I.
1983: 4,370,175

Levi, Clifford A.
1961: 2,995,473

Levin, Harry
1982: 4,314,525

Levine, Jules D.
1983: 4,407,320

Lewerenz, Hans J.
1982: 4,343,870
1983: 4,388,382

Lewis, Kathy
1983: 4,371,739

Li, Chou H.
1970: 3,500,135
1971: 3,585,714
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Li, Seung P.
1978: 4,090,213

Lidorenko, Nikolai S.
1972: 3,653,971
1979: 4,174,978
1980: 4,234,354
1983: 4,418,238

Limm, Albert Chang
1976: 3,975,555

Lin, Hung Chang
1981: 4,301,592

Lindenman, Gerald A.
1976: 3,956,687

Lindmayer, Joseph
1973: 3,769,558
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1983: 4,392,010

Ling, Ku S.
1979: 4,180,414
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Lis, Steven A.
1982: 4,327,119

Litsenko, Tatyana A.
1979: 4,140,142
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1980: 4,234,354

Little, Roger G.
1982: 4,348,546
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1983: 4,380,112
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Liu, Shing-Gong
1976: 3,999,283
1980: 4,181,755

Locke, Peter
1980: 4,224,355
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1981: 4,307,681

Lockwood, Lawrence B.
1983: 4,369,629

Loeffler, Otto E.
1982: 4,360,542

Loferski, Joseph J.
1960: 2,929,859
1979: 4,166,880
1982: 4,320,251

Long, Alfred D.
1978: 4,106,482

Longshore, Randolph E.
1979: 4,160,045

Loo, Robert Y.
1983: 4,395,293

Look, Christopher M.
1982: 4,329,189

Lorans, Dominique Y.
1977: 4,041,271

Losciale, Francesco
1982: 4,366,337

Lott, Dan R.
1980: 4,184,903

Louderback, Anthony W.
1972: 3,695,910

Loutfy, Rafik O.
1979: 4,175,981
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Low, George M.
1971: 3,630,627

Lubbe, Werner
1971: 3,574,925

Lucovsky, Gerald
1966: 3,284,241

Ludeke; Rudolf
1975: 3,929,527

Ludlow, Ogden R.
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Luft, Werner
1979: 4,154,998
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Lum, Wing Y.
1981: 4,263,064

Luptovits, Roland
1979: 4,175,610

Luque, Antonio
1979: 4,169,738

Lutwack, Ralph
1982: 4,314,525

Lutz, Harry A., III
1980: 4,237,151

Ma, Ki B.
1982: 4,359,367

Macauley, Bill T.
1963: 3,085,565

Macha, Milo V.
1964: 3,147,414

MacConochie, Ian O.
1983: 4,372,680

MacDiarmid, Alan G.
1980: 4,204,216

MacDonald, Roderick W.
1979: 4,135,537

Madan, Arun
1983: 4,379,943
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Maddalena, Joseph R.
1969: 3,457,427

Madden, Mark R.
1982: 4,326,013

Magee, Thomas J.
1979: 4,147,564

Magee, Vincent
1975: 3,912,539

Maget, Henri J. R.
1982: 4,339,626

Mahoney, Edmund J.
1976: 3,982,963

Maier, Henry B.
1979: 4,137,096

Maillé, Jacques H.P.
1979: 4,132,999

Mains, Gilbert J.
1982: 4,348,428

Mamine, Takayoshi
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Manasevit, Harold M.
1978: 4,066,481

Manassen, Joost
1981: 4,296,188
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Mandalakas, John N.
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Mandelkorn, Joseph
1967: 3,311,510
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Manelas, Arthur J.
1978: 4,080,221

Maniv, Shmuel
1983: 4,392,931

Mann, Alfred E.
1963: 3,094,439
1964: Re. 25,647
1967: 3,340,096
1969: 3,450,568
1970: 3,489,615
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1971: 3,575,721

Manoliu, Juliana
1978: 4,087,571

Marchal, Jean
1983: 4,392,007

Marchetti, Alfred P.
1978: 4,125,414

Marcus, Sanford M.
1982: 4,342,795
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1983: 4,375,007

Marinaccio, Louis P.
1966: 3,253,951

Marinace, John C.
1963: 3,072,507

Mark, Robert
1977: 4,009,051

Marley, James A., Jr.
1973: 3,732,471

Martirosian, Ruben G.
1983: 4,418,238

Marx, Richard Everet
1977: 4,041,307

Maserjian, Joseph
1978: 4,090,213

Masi, James V.
1969: 3,484,606
1977: 4,016,586
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Masumoto, Katashi
1979: 4,176,370

Matlow, Sheldon L.
1962: 3,040,416
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Matsuda, Motonobu
1973: 3,734,632

Matsumoto, Masataka
1980: 4,234,947

Matsumura, Osamu
1979: 4,165,604

Matsushita, Takeshi
1976: 3,990,100
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Matsutani, Toshinobu
1977: 4,029,518

Mattes, Siegfried
1975: 3,888,697

Matthews, James D.
1978: 4,092,446

Matzen, Walter Theodore
1976: 3,969,746

Mauer, Paul B.
1979: 4,149,902

Maxey, Donald R.
1983: 4,370,974

Mayer, Gerhard
1981: 4,245,386

Mazaris, George A.
1978: 4,104,091

Mazelsky, Robert
1978: 4,102,767

McAleer, William J.
1965: 3,172,791

McCarter, Craig A.
1978: 4,090,071

McClelland, Robert W.
1980: 4,227,941
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McCrory, Roy E.
1982: 4,322,908

McDonald, Jack
1978: 4,102,765

McEwan, William S.
1975: 3,887,446

McFerren, John S.
1979: 4,173,494

McGill, Thomas C.
1978: 4,084,172

McGrew, Stephen P.
1980: 4,204,881

McIntosh, Alan R.
1982: 4,360,703

McIntyre, Lloyd F.
1979: 4,175,981

McKee, William R.
1982: 4,322,379

McKinney, Charles N.
1980: 4,187,126

McNeill, William
1971: 3,573,177

McWilliams, Gerald E.
1981: 4,263,064

Meakin, John D.
1982: 4,328,390

Meckler, Gershon
1981: 4,304,955

Meggl, Albert
1983: 4,390,770

Meiksin, Zvi H.
1980: 4,206,002

Meinel, Aden B.
1978: 4,131,485
1982: 4,337,758

Meinel, Walter B.
1978: 4,131,485
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Meixner, Arthur E.
1969: 3,447,234

Melehy, Mahmoud A.
1979: 4,160,678

Mellors, Geoffrey W.
1975: 3,921,049

Melnick, Igor
1981: 4,244,750

Memming, Rüdiger
1965: 3,194,700
1966: 3,284,252

Menezes, Maria T.A.S.
1983: 4,388,382

Menzel, Guenther
1983: 4,372,989

Merrin, Seymour
1977: 4,016,586
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Mesch, Hans G.
1967: 3,350,635
1974: 3,833,426
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Messier, Russell F.
1981: 4,252,865

Meuleman, Johannes
1978: 4,124,411

Meulenberg, Andrew, Jr.
1975: 3,888,698
1977: 4,053,327
1978: 4,072,541
1979: 4,133,699
1983: 4,395,583

Meyer-Simon, Eugen
1972: 3,681,036

Meyers, Peter V.
1981: 4,260,427
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1982: 4,345,107

Meyers, Siegfried S.
1971: 3,617,137

Mickelsen, Reid A.
1982: 4,335,266
1983: 4,392,451

Middleton, Orwin
1979: 4,149,665

Migliorato, Piero
1976: 3,978,510

Miles, Malcolm G.
1979: 4,143,234

Miles, Steven G.
1979: 4,167,644
1980: 4,241,493

Milewski, John V.
1980: 4,214,920

Miley, David C.
1970: 3,527,619

Miller, Arthur
1983: 4,367,403
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Miller, Barry
1978: 4,082,682
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1982: 4,343,870

Miller, Emmett L.
1981: 4,301,409

Miller, Hans-Dieter
1982: 4,366,024

Miller, John H.
1976: 3,943,726

Miller, Michael Brant
1978: 4,092,446

Miller, Richard G.
1972: 3,671,291

Miller, Solomon L.
1963: 3,081,370

Milnes, Arthur G.
1976: 3,993,533
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Minetti-Mezetti, Enrica
1982: 4,331,829

Mitchell, Kim W.
1981: 4,278,474

Miura, Nobuaki
1976: 3,952,323
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1976: 3,952,323
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Miyashita, Kazuhisa
1975: 3,925,802

Miyatani, Kazuo
1977: 4,061,555
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Mizutani, Fumio
1983: 4,367,369

Mlavsky, Abraham I.
1976: 3,976,508
1977: 4,036,666
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Moeller, Douglas E.
1980: 4,223,174

Mohn, Heinrich
1982: 4,340,627

Moncrieff-Yeates, A. J.
1963: 3,104,188

Montmory, Robert
1968: 3,382,099

Moon, Ronald L.
1976: 3,993,506
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Moore, Edward B.
1982: 4,318,942

Moore, James A.
1978: 4,092,446

Moore, Wallace H.
1978: 4,090,577

Morel, Charles
1983: 4,392,007

Morel, Don L.
1983: 4,407,710

Mori, Chiharu
1975: 3,879,740

Mori, Hiroshi
1966: 3,278,811
1982: 4,311,953

Mori, Koshiro
1982: 4,329,699

Mori, Takasuke
1979: 4,178,175

Morimoto, Kiyoshi
1978: 4,066,527
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Moross, John R.
1964: 3,128,213

Morris, Henry B.
1976: 3,980,915

Morton, T. R.
1978: 4,092,446

Moss, Rodney H.
1981: 4,307,680

Moustakas, Theodore D.
1981: 4,251,289
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Moyer, Richard L.
1981: 4,260,429

Mueller, Robert L.
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Muench, Volker
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Muller, Gerhard
1979: 4,169,740

Muller, Jean-Claude
1980: 4,187,124

Murphy, Gerald G.
1980: 4,235,221

Muruska, H. Paul
1982: 4,331,707

Myer, Jon H.
1968: 3,369,939
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Myers, Bruce P.
1981: 4,266,984

Myers, David J.
1979: 4,173,494

Naaijer, Geert Jan
1978: 4,100,427

Naarmann, Herbert
1982: 4,340,507
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Naegele, Dieter
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Nagao, Hisao
1979: 4,140,545

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Nakagawa, Katsumi
1983: 4,404,076

Nakajima, Koichiro
1981: 4,298,410

Nakajima, Yosuke
1980: 4,231,808

Nakamura, Michihiro
1982: 4,338,180

Nakatsukasa, Masashi
1983: 4,405,435

Nakayama, Nobuo
1970: 3,492,187
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Namiki, Ryo
1979: 4,165,604

Napierski, Reinhard
1973: 3,774,023

Napoli, Joseph D.
1983: 4,392,009

Napoli, Louis S.
1976: 3,999,283
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1980: 4,228,315

Narasimhan, K. S. V. L.
1980: 4,206,002

Narasimhan, Mandayam C.
1982: 4,320,251

Narayan, Jagdish
1979: 4,147,563
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Narita, Kiichi
1979: 4,178,175

Nasby, Robert D.
1979: 4,152,175

Nassenstein, Heinrich
1967: 3,351,516

Natanson, Paul S.
1976: 3,982,963

Nath, Prem
1983: 4,419,530

Nazimek, Kenneth
1981: 4,243,928

Needes, Christopher R. S.
1980: 4,235,644

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1969: 3,427,797

Nelson, David H.
1980: 4,223,214

Nelson, Norvell J.
1979: 4,158,717

Nelson, Richard B.
1979: 4,146,408

Nelson, Ronald J.
1981: 4,273,594

Neugroschel, Arnost
1982: 4,343,962

Neuman, Samuel
1983: 4,367,367

Newman, Peter Colin
1969: 3,436,625
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Nichols, Frank W.
1980: 4,219,926

Nicolas, Maurice
1982: 4,331,494

Nicoll, Frederick H.
1961: 2,999,240

Nikirk, Roger G.
1982: 4,321,246

Nikitin, Boris A.
1979: 4,140,142

Nikodem, Robert B.
1980: 4,239,809

Nishida, Keiichi
1977: 4,029,518

Nitta, Yoshiteru
1981: 4,271,328

Noad, Julian P.
1982: 4,329,189

Northrup, Leonard L., Jr.
1976: 3,991,741

Nostrand, Gerald E.
1979: 4,166,918

Nozik, Arthur J.
1974: 3,811,953
1977: 4,011,149
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1976: 3,975,555

O'Farrell, Herbert W.
1966: 3,262,694

O'Neill, Mark J.
1976: 3,991,741
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O'Rourke, Mary J.
1962: 3,046,459

Oades, John Willson
1977: 4,041,389

Oaks, William D.
1973: 3,769,091
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Oertle, Don H.
1980: 4,187,126

Oettel, Richard E.
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Ohkawa, Tihiro
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Okamoto, Hiroaki
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Oliver, Robert L.
1963: 3,094,439
1964: Re. 25,647

Olsen, Gregory H.
1979: 4,179,308

Opiela, Michael L.
1979: 4,169,970

Orillion, Alfred G.
1983: 4,398,053

Orofino, Thomas A.
1979: 4,143,233

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1979: 4,166,917

Osa, Tetsuo
1981: 4,255,501

Osborne, Bodwell D.
1972: 3,658,596

Oster, Eugene A., Jr.
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Ostermayer, Frederick W., Jr.
1983: 4,369,099
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Otake, Tsutomu
1976: 3,979,656

Otto, Franz
1982: 4,330,358

Ovshinsky, Stanford R.
1979: 4,177,473
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1981: 4,292,093

Pack, George J., Sr.
1975: 3,903,427
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1976: 3,969,746
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Paine, Thomas O.
1971: 3,615,853
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1978: 4,092,446

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Pankove, Jacques I.
1977: 4,028,720
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1982: 4,343,962

Pape, Heinz
1981: 4,298,802

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1959: 2,889,490
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Park, Yoon Soo
1977: 4,004,342

Parkins, William E.
1969: 3,483,040

Parkinson, Bruce A.
1981: 4,273,594

Parkyn, William A., Jr.
1982: 4,337,759

Pasierb, Edward F.
1968: 3,368,125

Pastor, Jose
1978: 4,088,116

Patel, Kirit B.
1982: 4,321,283

Paull, Peter L.
1978: 4,110,628

Pavlak, Alex
1977: 4,024,852

Payne, Richard
1975: 3,879,228

Pearson, Gerald L.
1957: 2,780,765

Peletier, Daniel P.
1971: 3,582,923

Pelfrey, Lowell S.
1964: 3,147,414

Pelka, David G.
1982: 4,337,759

Pensak, Louis
1959: 2,915,578

Penzien, Klaus
1982: 4,340,507
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1982: 4,315,096

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1966: 3,229,682

Perotte, Laurence F.
1959: 2,903,631

Perri, John A.
1966: 3,247,428

Person, Jerry K.
1979: 4,149,665

Perz, John
1982: 4,359,367

Peters, Melville F.
1981: 4,248,643

Peterson, David M.
1982: 4,328,389

Peterson, Terry M.
1981: 4,287,383
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Petrossian-Avakian, E.
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Pettijohn, Richard R.
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Pfisterer, Fritz
1981: 4,283,590

Phillips, James
1981: 4,252,573

Phillips, William H.
1983: 4,415,133

Philp, John
1983: 4,381,978

Pincon, Daniel M.
1983: 4,377,901

Pinder, Russell Stuart
1977: 4,036,645

Pinto, Olympio F.
1973: 3,774,865

Pizzi, Gilbert
1979: 4,168,124

Plaettner, Rolf
1981: 4,292,343

Pliskin, William A.
1965: 3,212,921

Pohl, Dieter W.
1981: 4,258,647

Pollak, Fred H.
1980: 4,214,916

Polyakov, Vladimir I.
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Ponpon, Jean-Pierre
1980: 4,187,124

Ponti, Cesare
1981: 4,280,853

Poole, Bordie D., Jr.
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Popovich, John M.
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Porter, Wilbur A.
1977: 4,021,323
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Potapov, Valery N.
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Poulain, Pierre
1982: 4,366,334

Powell, Roger A.
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Power, Roy B.
1964: 3,152,926

Powers, Robert A.
1975: 3,921,049

Pratt, Baruch
1962: 3,053,926

Praturi, Ananda
1982: 4,314,525

Prevot, Michel
1975: 3,912,931

Provisor, Henri
1967: 3,357,857

Pruett, George R.
1971: 3,591,431
1974: 3,836,399

Pryor, Robert A.
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Pschunder, Willi
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Purwin, Paul E.
1981: 4,259,122

Pyle, Bruce D.
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Quella, Ferdinand
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Radd, Fred J.
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Rahilly, W. Patrick
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Rahilly, William P.
1976: 3,985,579
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Ralph, Eugene L.
1962: 3,025,335
1963: 3,089,070
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1964: Re. 25,647
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Ralph,Eugene L.
1962: 3,040,416

Raman, Ramaswamy V.
1980: 4,229,231

Rancourt, James D.
1981: 4,293,732

Rapp, Charles F.
1979: 4,173,495
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Ratajczak, Anthony F.
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Rath, Heinz J.
1979: 4,141,764

Rath, Heinz-Jørg
1978: 4,113,532
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1983: 4,388,384

Rauschenbach, Hans S.
1967: 3,334,217

Ravi, K. V.
1977: 4,056,404
1978: 4,095,329
1979: 4,152,536

Raychaudhuri, Pranab K.
1977: 4,035,197
1980: Re. 30,412

Raynaud, Jacques
1970: 3,508,063

Redfield, David
1976: 3,973,994

Reeh, Ulrike
1983: 4,419,531

Reese, Robert O.
1975: 3,928,960

Regnier, Norman J.
1959: 2,919,298
1960: 2,946,945

Reichman, Joseph
1979: 4,172,925

Reinhardt, Erich
1983: 4,367,366

Reinhart, Franz Karl
1975: 3,865,625

Reisfeld, Renata
1983: 4,367,367

Reith, Timothy M.
1979: 4,135,998

Reitz, Norman E.
1977: 4,042,447
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Reitz, Ronald P.
1979: 4,179,627

Rellick, Joseph R.
1982: 4,342,795
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Rembaum, Alan
1970: 3,507,706

Restrepo, Fabio
1978: 4,070,689

Retiz, Norman E.
1980: 4,235,662

Reuschel, Konrad
1978: 4,068,020
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Reuyl, John S.
1980: 4,182,960

Revesz, Akos G.
1976: 3,977,905

Revesz, Akos George
1975: 3,904,453

Rex, Dietrich
1979: 4,153,474

Reyes, Jaime M.
1983: 4,419,533

Reynolds, Donald C.
1958: 2,844,640
1961: 2,981,777

Reynolds, Frederick W.
1969: 3,447,234

Reynolds, John Harvey
1978: 4,072,541

Rhodes, Maurice
1980: 4,204,933
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Ricard, Jean
1980: 4,233,338

Rice, M. John, Jr.
1981: 4,292,342
1982: 4,321,246

Riddle, Peter Michael
1976: 3,957,537

Riedl, Harold R.
1976: 3,961,998

Riehl, Roger W.
1974: 3,823,551
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Riel, Robert K.
1969: 3,421,943
1970: 3,546,542

Riemer, Dietrich E.
1980: 4,199,377
1981: 4,278,831
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Rinnovatore, James V.
1962: 3,057,945

Riseman, Jacob
1966: 3,247,428

Ritchie, Donald W.
1969: 3,446,676

Ritchie, Leon T.
1980: 4,203,646

Rittner, Edmund S.
1959: 2,873,303
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Robbins, Murray
1978: 4,084,044

Robinson, Paul Harvey
1978: 4,070,206

Robinson, Thomas L.
1969: 3,433,677

Robison, Paul C.
1963: 3,076,861

Rocheleau, Richard E.
1982: 4,325,986
1983: 4,401,052

Rock, Edward B.
1980: 4,237,151

Rockley, Mark G.
1982: 4,348,428

Rod, Robert L.
1983: 4,388,483
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Rode, Daniel L.
1983: 4,419,178

Roderick, Guy A.
1980: 4,224,355
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Rodgers, Michael A.
1979: 4,170,667

Rodner, William H.
1967: 3,346,419

Rodot, Huquette
1982: 4,309,239

Roen, Stephen A.
1977: 4,017,725

Roessler, Barton
1979: 4,166,880
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Roger, Jacques
1974: 3,793,082

Rogers, William E.
1982: 4,314,198

Rolik, Geza P.
1970: 3,513,040

Roosild, Sven A.
1969: 3,431,150

Roseen, Rutger A.
1981: 4,289,112

Rosenberg, Robert
1977: 4,062,038
1979: 4,132,571
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Rosenberg, William D.
1979: 4,141,020

Rosinski, Louis S., Jr.
1978: 4,129,823

Ross, Bernd
1958: 2,862,160
1968: 3,361,594
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1969: 3,462,311
1980: 4,219,448

Ross, Ronald G.
1979: 4,163,194

Rossi, Vito A.
1969: 3,457,427
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1971: 3,589,946

Rothstein, Jerome
1955: 2,711,379

Rothwarf, Allen
1981: 4,267,398

Rousset, Paul
1979: 4,134,393
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Routh, Donald E.
1979: 4,156,309

Rowcliffe, David J.
1982: 4,356,141

Roy, Pradip K.
1981: 4,260,428

Roy, Rustum
1981: 4,252,865

Rubin, Irwin
1967: 3,344,334
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Rudenberg, Hermann G.
1963: 3,112,230
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Ruehrwein, Robert A.
1965: 3,224,913
1966: 3,261,726
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Ruiz-Urbieta, Manuel
1981: 4,252,573

Rüsch, Dieter
1977: 4,009,054
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Russak, Michael A.
1979: 4,172,925

Russell, Charles R.
1977: 4,052,228
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Russell, George F.
1981: 4,290,411
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Russell, Robert L.
1975: 3,925,103

Russell, T. W. Fraser
1982: 4,318,938
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Ryabikov, Stanislav V.
1979: 4,174,978
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Rym, Christian
1975: 3,896,368

Sabnis, Anant G.
1980: 4,206,002

Saiji, Tsutomu
1969: 3,427,797

Sakamoto, Tsunenori
1977: 4,046,594

Salama, Amal M.
1980: 4,201,622
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Salerno, Jack P.
1982: 4,366,338

Salles, Yvon
1974: 3,802,920
1977: Des. 245,330

Salyer, Ival O.
1979: 4,143,234

Sammells, Anthony F.
1980: 4,235,955
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Samuels, Ronald L.
1970: 3,515,594

Samulon, Henry A.
1963: 3,076,861

Sanjurjo, Angel
1982: 4,356,141

Sansregret, Joseph L.
1980: 4,242,374
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1982: 4,311,728
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Sapru, Krishna
1979: 4,178,415

Sarma, Kalluri R.
1981: 4,292,342
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Sasaki, Kanji
1983: 4,367,369

Sasaki, Takehiko
1982: 4,311,953

Sater, Bernard L.
1982: 4,332,973
1983: 4,409,422

Satkiewicz, Frank G.
1982: 4,313,254

Sato, Isao
1977: 4,061,555
1978: 4,124,464

Saurer, Eric
1980: 4,183,628

Savage, Fred L.
1978: 4,106,482

Sawyer, David E.
1981: 4,287,473

Saxena, Ram R.
1982: 4,356,341

Scafe', Ernesto
1982: 4,366,337

Schaefer, James C.
1968: 3,416,956

Scharlack, Ronald S.
1980: 4,239,555

Scharnhorst, Kurt Peter
1976: 3,961,998

Scheel, Hansjoerg
1981: 4,258,647

Schertz, William W.
1977: 4,029,519
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Schindehette, Donald J.
1968: 3,419,484

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Schlag, Johannes
1982: 4,340,507
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Schlichta, Paul J.
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Schmelz, Helmut
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1979: 4,175,610

Schmidt, Dietrich
1979: 4,141,764

Schmidt, Eckehard
1982: 4,358,331

Schmidt, Ferenc J.
1979: 4,173,497

Schmidt, Lawrence W.
1960: 2,946,945
1966: 3,252,023

Schmidt, Paul Herman
1978: 4,121,238

Schmidt, Walter
1980: 4,233,270

Schmit, Joseph L.
1982: 4,317,689
1983: 4,366,771

Schneider, Jens R. W.
1971: 3,574,925

Schneider, Martin V.
1969: 3,475,609

Schneider, Michael
1982: 4,359,487

Schneider, Ronald A.
1983: 4,377,604

Schock, Hans-Werner
1981: 4,283,590

Schoolar, Richard B.
1973: 3,716,424

Schröder, Hubert
1963: 3,094,436

Schueler, Donald G.
1979: 4,152,175

Schulke, Karl-Albert
1982: 4,340,627

Schulte, Eric F.
1983: 4,369,498

Schultz, Melvin L.
1959: 2,877,284
1960: 2,953,621

Schultz, Robert T.
1979: 4,177,795

Schumacher, John C.
1980: 4,227,291

Schumacher, Joseph C.
1978: 4,084,024

Schwarz, Rudolf
1972: 3,681,036

Schwuttke, Guenter H.
1977: 4,018,626
1981: 4,243,471
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Scott, Ralph R.
1970: 3,532,551

Scott, Richard F.
1970: 3,530,053

Scranton, Robert A.
1978: 4,084,172

Scudder, Larry R.
1978: 4,104,091

Seddon, Richard I.
1981: 4,293,732

Sekiguchi, Tsunetoshi
1979: 4,165,604

Selders, Matthias Peter
1978: 4,101,341

Seney, John S.
1967: 3,310,439

Sequeira, Edward A.
1967: 3,330,700

Sernberger, Richard L.
1963: 3,095,324

Serreze, Harvey B.
1982: 4,327,119

Severns, James G.
1983: 4,419,532

Shaffer, Marlin R.
1959: 2,919,298
1960: 2,951,163

Shaffer, Marlin R., Jr.
1979: 4,161,657

Shah, Pradeep L.
1978: 4,101,351

Shahryar, Ishaq M.
1978: 4,131,123

Shaikh, Mohammed S.
1968: 3,370,986
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1969: 3,421,943
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Share, Stewart
1976: 4,000,505

Sharp, James H.
1979: 4,175,981
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Sharples, Allan
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Shaw, Robert F.
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Shay, Joseph Leo
1976: 3,978,510
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Sheffield, Glenn W.
1975: 3,921,049

Shelley, Edwin F.
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Shelpuk, Benjamin
1979: 4,153,476

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1983: 4,398,056
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1979: 4,162,928

Sherliker, Francis R.
1980: 4,204,933
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Sherman, Benjamin F., Jr.
1979: 4,148,297
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1977: 4,062,034

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1977: 4,001,863

Shiezawa, Lebo R.
1958: 2,820,841

Shigemasa, Junichiro
1976: 3,956,017
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1964: 3,146,138
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Shockley, William
1962: 3,015,762

Shumka, Alex
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Shuskus, Alexander J.
1983: 4,421,592

Shuster, Saul
1963: 3,094,439
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Sienkiewicz, Peter M.
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Siffert, Paul
1980: 4,187,124

Sill, Richard C.
1979: 4,140,544
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1963: 3,072,507

Simak, Petr
1983: 4,411,826
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Simpson, William I.
1978: 4,066,481

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1983: 4,419,533

Singh, Shobha
1982: 4,309,460
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Singh, Vijay P.
1979: 4,178,395
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Singleton, Eben L.
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Sirtl, Erhard
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Sirtori, Vittorio
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Skotheim, Terje
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Slifer, Luther W., Jr.
1968: 3,419,433

Small, Samuel N.
1960: 2,960,094

Smith, Allen H.
1971: 3,615,855

Smith, Hugh R., Jr.
1969: 3,437,328

Smith, Peter D.
1979: 4,179,612

Smythe, Robert L.
1963: 3,091,555

Snyder, Howard E.
1966: 3,232,795

Sol, Nicole
1982: 4,321,420
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Sollow, Philip A.
1969: 3,427,200

Solomon, Allen L.
1982: 4,315,097

Sormberger, Richard L.
1966: 3,290,175

Sotolongo, Thomas J.
1982: 4,310,211

Sparks, Morgan
1953: 2,631,356

Spear, Reginald G.
1983: 4,400,577

Spear, Walter E.
1979: 4,169,740

Speice, Donald G.
1983: 4,379,588

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1978: 4,121,238

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1983: 4,367,365

Springthorpe, Anthony J.
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Staebler, David L.
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1982: 4,320,250
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1963: 3,108,021

Stark, Virgil
1979: 4,134,393
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1981: 4,249,516
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1964: 3,127,552

Stearns, Mary Beth
1962: 3,053,923

Stein, Frank S.
1969: 3,433,676

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1981: 4,245,386

Steinberg, Jacob H.
1978: 4,101,923

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1982: 4,336,648

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1978: 4,092,446

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Strathman, Ronald L.
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Strebkov, Dmitry S.
1972: 3,653,971
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1971: 3,591,420

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Strock, Harold B.
1978: 4,124,410
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1980: 4,237,151

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1960: 2,944,165

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1979: 4,135,998

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1959: 2,874,341

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1973: 3,740,636

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1974: 3,798,140

Sumeto, Takao
1972: 3,679,949

Suqimoto, Ryuji
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1983: 4,409,538

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1980: 4,231,808

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1978: 4,095,217

Taguchi, Tetsuya
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1978: 4,066,527
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1983: 4,405,435

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1981: 4,256,513

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1976: 3,979,656

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1966: 3,232,795

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Tanaka, Tsuneo
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1978: 4,125,414
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Tanimura, Shigeru
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1969: 3,480,818
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1966: 3,247,392

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Thiel, Klaus P.
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1982: 4,343,963
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1979: 4,134,387
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Tourneux, Michel
1980: 4,210,462
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Triano, Alfred R., Jr.
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Trimble, Lee E.
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Tsao, Thomas K.
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Tseng, Eric S.
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Turechek, Gene D.
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1980: 4,184,111
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1967: 3,350,234
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1978: 4,066,527
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1983: 4,390,940

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Varadi, Peter F.
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Vartanian, Albert V.
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Verspui, Gerrit
1970: 3,521,350

Vibronek, Robert D.
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Victoria, Rafael Oriando
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Viehmann, Walter
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Viennet, René
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Vieux-Rochaz, Line
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Volz, Frederic E.
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Vuilleumier, Raymond
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1969: 3,483,037

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1976: 3,978,510
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1976: 3,982,260

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1978: 4,067,764

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1977: 4,019,884

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Warner, Raymond M., Jr.
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1975: 3,925,802

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1970: 3,549,960

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Weinstein, David H.
1977: 4,042,758

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1967: 3,309,226
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Weisbrich, Robert L.
1960: 2,951,163

Wenzel, Joachim
1982: 4,361,295

Werth, John J.
1967: 3,331,707

Westbrook, Russell D.
1978: 4,129,463

Wested, Jens.
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Westwood, William D.
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Weyenberg, Donald R.
1983: 4,374,182

Weyrich, Claus
1983: 4,406,913

Whelan, Robert C.
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Whigham, Dale M.
1969: 3,457,467
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White, Clark W.
1980: 4,181,538
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White, James F.
1979: 4,135,998
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White, Richard M.
1980: 4,200,472
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Whitehouse, Daniel L.
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Whitney, Bruce F.
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Whittaker, Ralph E.
1983: 4,373,308

Wicklund, Joseph B., Jr.
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Wiedemann, Hans O.
1979: 4,159,427

Wiesmann, Harold J.
1980: 4,237,150
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Wihl, Manfred G.
1980: 4,236,937

Wilbarg, Robert R.
1980: 4,229,233

Wildi, Bernard S.
1962: 3,046,323

Wilkerson, Alan W.
1980: 4,200,833

Williams, Brown F.
1978: 4,126,150
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Williams, Edward W.
1980: 4,204,933
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Williams, Richard
1979: 4,160,816
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Willson, Michael C.
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Winegar, Donald M.
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Winston, Roland
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Winterer, Allen G.
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Winterling, Gerhard
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Wise, Joseph F.
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Withjack, Eric M.
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Witt, August F.
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Wittry, David Beryle
1978: 4,099,199
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Wizenick, Richard J.
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Woerner, Lloyd M.
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Wohlmut, Peter G.
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Wohlschläger, Michael
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Wolf, Martin
1963: 3,094,439
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Wolff, George
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Wolowodiuk, Catherine
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Wong, Sau K.
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Wood, Richard F.
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Woodall, Jerry M.
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1978: 4,122,476

Work, George A.
1973: 3,708,669

Wright, Franklin J.
1980: 4,214,920

Wright, Maurice J.
1981: 4,306,183

Wright, Warren H.
1971: 3,600,599

Wrighton, Mark S.
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Wrigley, Charles Y.
1980: 4,184,894

Wrobel, Joseph S.
1975: 3,911,469

Wronski, Christopher R.
1979: 4,142,195
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Wu, Chung P.
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1977: 4,062,102

Wysocki, Joseph J.
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Yacobi, Ben-Gur
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Yamaguchi, Kazufumi
1970: 3,492,187

Yamanaka, Tadashi
1970: 3,520,732

Yamano, Masaru
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Yamashita, Akio
1975: 3,928,865

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Yamazaki, Shunpei
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Yang, Kuei-Hsiung
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Yasui, Robert K.
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Yates, Douglas A.
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Yavrouian, Andre H.
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Yeager, Marvin L.
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Yeh, Yea-Chuan M.
1981: 4,278,830
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1968: 3,390,576

Yerkes, John W.
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1981: 4,251,285
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1981: 4,251,285

Yoshida, Manabu
1981: 4,256,513

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1974: 3,793,069

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1980: 4,209,735

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1983: 4,367,369

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1982: 4,331,707

Young, Danny J.
1977: 4,045,663

Young, Ralph H.
1978: 4,125,414

Young, Rosa T.
1978: 4,129,463
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Younskevicius, Robert E.
1978: 4,110,049

Yu, Michael
1969: 3,436,275

Yu, Phil Won
1977: 4,004,342

Zadde, Vitaly V.
1972: 3,653,971
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Zakhariya, Ramiz H.
1979: 4,147,157

Zanio, Kenneth R.
1978: 4,128,733
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1978: 4,108,684
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Zaromb, Solomon
1963: 3,113,047
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1979: 4,175,610

Zehner, David M.
1981: 4,292,093

Zeiger, Herbert J.
1977: 4,059,461

Zelazny, Stanley D.
1979: 4,169,970

Zerlaut, Gene A.
1977: 4,031,385

Zewail, Ahmed H
1980: 4,227,939

Zieger, Herbert J.
1982: 4,309,225

Ziemba, Georg
1980: 4,217,147

Zinchuk, Michael
1977: 4,060,426

Zöllner, Theo
1982: 4,312,700

Zook, J. David
1981: 4,252,861

Zook, Morris A., Jr.
1972: 3,695,910

Zschauer, Karl-Heinz
1981: 4,255,206

Zukotynski, Stefan
1982: 4,359,367

Zwan, Bryan J.
1981: 4,251,679

Zwerdling, Solomon
1977: 4,029,519

Zydzik, George J.
1982: 4,309,460

Zykov, Evgeny M.
1979: 4,140,142

SUBJECT

Cell Components (metallization, substrates, conductive coatings, antireflective coatings)

1958: 2,861,909

1959: 2,874,341

1961: 2,995,473
2,997,415

1962: 3,039,896

1963: 3,076,861
3,094,436
3,095,324
3,106,489
3,112,230

1964: 3,151,378

1965: 3,212,921

1966: 3,247,392
3,247,428
3,253,951
3,278,337

1967: 3,309,226
3,357,857

1968: 3,416,044

1969: 3,421,943
3,431,150
3,434,885
3,442,007
3,450,568
3,462,311
3,475,609
3,479,573
3,480,818

1970: 3,489,615
3,490,950
3,493,822
3,500,135
3,502,507
3,508,063
3,513,317
3,533,850
3,539,883
3,549,411

1971: 3,589,946
3,591,420
3,615,854
3,620,829

1972: 3,664,874
3,671,291
3,679,949
3,695,910

1973: 3,743,847
3,747,327

1974: 3,793,082
3,811,953
3,811,954
3,818,691
3,845,494
3,847,758

1975: Re. 28,610
3,887,935
3,888,698
3,903,324
3,903,427
3,903,428
3,904,453
3,907,595
3,912,539
3,912,540
3,912,931
3,922,774
3,925,103
3,925,802
3,928,073
3,928,865

1976: 3,935,031
3,943,003
3,949,463
3,952,323
3,961,998
3,966,499
3,973,994
3,975,555
3,977,905
3,978,333
3,980,915
3,982,260
3,982,964
3,988,167
3,989,541
3,990,100
3,993,505
3,996,067

1977: 4,005,468
4,016,589
4,019,884
4,024,558
4,025,944
4,041,271
4,048,372

1978: 4,066,481
4,074,305
4,078,945
4,082,568
4,084,172
4,089,576
4,104,084
4,105,470
4,105,471
4,107,723
4,124,455
4,126,150
4,128,680

1979: Des. 251,663
4,132,999
4,133,699
4,135,290
4,135,950
4,135,998
4,137,123
4,139,858
4,140,545
4,141,020
4,144,139
4,146,657
4,147,564
4,152,175
4,153,907
4,156,310
4,156,622
4,158,717
4,160,045
4,163,678
4,165,241
4,171,989
4,175,982

1980: 4,181,755
4,190,321
4,199,377
4,201,798
4,202,704
4,203,646
4,204,216
4,209,347
4,213,798
4,213,801
4,217,633
4,219,448
4,219,830
4,227,943
4,228,315
4,229,233
4,234,353
4,235,644
4,239,553
4,241,108
4,242,696

1981: 4,246,043
4,248,675
4,251,286
4,251,327
4,252,573
4,253,881
4,256,513
4,260,429
4,267,398
4,268,347
4,268,711
4,278,704
4,283,591
4,289,602
4,293,732
4,297,391
4,301,322
4,301,592

1982: Des. 263,393
4,309,460
4,319,069
4,320,248
4,320,250
4,320,251
4,321,283
4,323,719
4,328,260
4,331,703
4,336,648
4,338,180
4,338,480
4,340,507
4,342,795
4,343,963
4,346,131
4,347,262
4,347,263
4,347,264
4,348,545
4,355,196
4,356,341
4,359,487
4,361,598
4,361,718
4,361,950

1983: Re. 31,151
4,369,099
4,371,740
4,372,989
4,375,007
4,377,445
4,378,460
4,379,202
4,380,112
4,387,116
4,388,346
4,390,770
4,392,010
4,392,931
4,393,576
4,395,497
4,395,583
4,398,056
4,400,868
4,401,545
4,402,771
4,404,126
4,407,061
4,411,703
4,411,826
4,412,942
4,418,187
4,419,424
4,419,533

Cell Enhancement Techniques (surface and grain boundary passivation, annealing)

1963: 3,115,424

1967: 3,357,857

1969: 3,436,275
3,471,924

1976: 3,988,172

1977: 4,018,626
4,059,461
4,062,102

1978: 4,113,514

1979: 4,154,625
4,166,918
4,178,395

1980: 4,181,538
4,197,141
4,198,246
4,201,622
4,224,084

1981: 4,249,957
4,254,426
4,276,137
4,292,093

1982: 4,311,870
4,343,830
4,366,336
4,366,338

1983: 4,370,175
4,371,738
4,385,971
4,386,142
4,393,267
4,395,293
4,406,709

Cells and Materials

Amorphous Silicon Cells

1977: 4,059,461
4,062,034
4,064,521

1978: 4,068,020
4,070,206
4,109,271
4,126,150

1979: 4,132,571
4,139,857
4,141,764
4,142,195
4,151,058
4,161,418
4,162,505
4,163,677
4,166,919
4,167,015
4,169,740
4,177,473
4,178,415
4,180,618

1980: 4,192,720
4,196,438
4,200,473
4,213,798
4,217,148
4,217,374
4,226,643
4,227,291
4,233,338
4,237,150
4,237,151
4,239,554

1981 4,244,750
4,245,386
4,251,287
4,251,289
4,252,865
4,253,882
4,254,426
4,254,429
4,255,208
4,266,984
4,270,018
4,271,328
4,272,641
4,281,208
4,285,762
4,289,602
4,291,318
4,292,342
4,292,343
4,292,461

1982: 4,313,254
4,316,049
4,320,248
4,321,420
4,328,258
4,329,699
4,330,182
4,332,838
4,334,120
4,339,470
4,342,044
4,344,984
4,348,428
4,357,179
4,359,367
4,365,107

1983: 4,371,738
4,376,228
4,377,723
4,378,460
4,379,943
4,381,233
4,385,199
4,385,200
4,385,971
4,387,265
4,388,482
4,389,534
4,396,793
4,398,054
4,398,343
4,400,409
4,400,577
4,402,762
4,403,239
4,404,076
4,405,435
4,407,710
4,409,134
4,409,424
4,409,605
4,410,558
4,410,559
4,415,760
4,417,092
4,419,530
4,419,533

Cells from II-VI Materials

1953: 2,643,277

1958: 2,820,841
2,844,640

1959: 2,915,578

1960: 2,929,859
2,932,592

1961: 2,981,777
2,999,240

1962: 3,023,079
3,023,080
3,026,175

1963: 3,104,188
3,108,021

1964: 3,146,138

1965: 3,186,874

1966: 3,284,252
3,290,175

1967: 3,351,516

1968: 3,373,059
3,374,108
3,376,163
3,416,956

1969: 3,447,234
3,472,690
3,479,573
3,480,473

1970: 3,492,187
3,520,732
3,531,335

1971: 3,568,306
3,586,541
3,599,059
3,615,877

1973: 3,732,471
3,778,684

1974: 3,845,494

1975: 3,880,633
3,884,779
3,885,058
3,887,446
3,887,995
3,888,697
3,902,920

1976: 3,975,211
3,982,260

1977: 4,004,342
4,035,197
4,036,645
4,042,418

1978: Re. 29,812
4,082,569
4,086,101
4,104,420
4,120,705
4,127,424

1979: Re. 30,147
4,132,999
4,143,235
4,159,914
4,160,678
4,167,805
4,176,370
4,178,395

1980: Re. 30,412
4,191,794
4,192,721
4,203,785
4,204,933
4,207,119
4,225,408
4,228,570
4,231,808
4,234,353
4,239,553
4,239,809
4,242,374

1981: Re. 30,504
4,243,432
4,251,286
4,252,573
4,253,919
4,254,546
4,256,544
4,259,122
4,260,427
4,260,428
4,260,429
4,261,802
4,262,411
4,265,933
4,267,398
4,283,590
4,283,591
4,287,383
4,304,607
4,307,681

1982: 4,311,728
4,317,689
4,318,938
4,319,069
4,320,154
4,325,986
4,327,119
4,328,390
4,331,707
4,335,266
4,338,362
4,342,879
4,345,107
4,360,542
4,362,896
4,366,336

1983: 4,366,771
4,371,740
4,377,604
4,385,102
4,386,142
4,388,483
4,392,451
4,393,267
4,398,055
4,400,244
4,401,052
4,403,398
4,404,734
4,412,091
4,414,252

Cells from III-V Materials

1960: 2,929,859

1963: 3,082,283
3,092,725

1965: 3,215,571
3,224,913

1966: 3,264,707

1967: 3,322,575
3,340,599

1968: 3,368,125
3,373,321

1969: 3,436,625
3,457,467

1970: 3,508,126

1972: 3,675,026

1973: 3,758,348

1974: 3,836,399
3,839,084

1975: 3,865,625
3,929,527

1976: 3,941,624
3,975,555
3,982,265
3,990,101
3,992,233
3,993,506

1977: 4,002,031
4,017,332
4,053,918

1978: 4,070,205
4,082,569
4,107,723
4,116,717
4,122,476
4,126,930
4,128,733

1979: 4,154,625
4,155,781
4,156,310
4,158,577
4,159,354
4,163,987
4,171,235
4,179,308
4,179,702

1980: 4,191,593
4,197,141
4,206,002
4,213,801
4,227,941
4,235,651

1981: 4,246,050
4,248,675
4,255,206
4,255,211
4,258,647
4,263,064
4,273,594
4,274,890
4,276,137
4,278,473
4,278,474
4,278,830
4,287,485
4,287,848
4,291,323
4,307,680

1982: 4,321,099
4,329,189
4,332,974
4,338,480
4,356,341
4,365,107
4,366,334

1983: 4,370,510
4,385,198
4,388,383
4,389,291
4,392,297
4,395,293
4,400,221
4,404,421
4,416,052
4,421,592

Characterization and Analysis

1951: 2,554,225

1960: 2,945,417

1963: 3,077,539

1967: 3,325,723
3,334,217
3,350,635

1968: 3,390,576

1969: 3,435,328
3,480,781

1970: 3,513,536

1971: 3,617,137
3,630,627

1972: 3,670,202
3,694,739

1973: 3,734,632

1978: 4,076,977
4,082,682
4,090,071
4,122,383

1980: 4,184,111
4,205,265

1981: 4,273,421
4,287,473
4,301,409

1983: 4,372,680

Other PV Devices and Concepts

1952: 2,588,254
2,622,117

1958: 2,847,585

1959: 2,877,284
2,903,631
2,904,613

1960: 2,944,165
2,949,498
2,953,621

1961: 2,986,591
3,009,006
3,009,841

1962: 3,015,762
3,031,520
3,046,323
3,046,459
3,053,923
3,057,945
3,057,947

1963: 3,072,507
3,082,283
3,111,611
3,113,047
3,114,658

1964: 3,132,057
3,148,084

1965: 3,175,929
3,186,873
3,201,665
3,215,571
3,224,913
3,226,271

1966: 3,261,726
3,284,241

1967: 3,310,439
3,322,575

1968: 3,396,057

1969: 3,421,946
3,426,212
3,483,037

1970: 3,496,024
3,500,135
3,507,706
3,530,007
3,547,596

1971: 3,591,431
3,620,829

1972: 3,634,424
3,653,971
3,690,953
3,705,059

1973: 3,760,240

1974: 3,844,843

1975: 3,879,228
3,900,945
3,905,836

1976: 3,936,319
3,948,682
3,956,017
3,972,732
3,975,632
3,976,508
3,978,333
3,978,510
3,985,579
3,990,914
3,994,012
3,998,659

1977: 4,011,149
4,011,578
4,015,280
4,016,586
4,017,332
4,024,558
4,028,206
4,037,029
4,039,357
4,042,758
4,044,372
4,046,594
4,053,326
4,060,426
4,061,555
4,062,038
4,062,698
4,064,522

1978: 4,066,527
4,074,305
4,081,290
4,081,820
4,082,570
4,084,044
4,086,102
4,094,704
4,094,751
4,099,199
4,101,341
4,104,084
4,105,470
4,106,951
4,108,684
4,110,122
4,112,457
4,113,531
4,115,633
4,118,548
4,119,768
4,121,238
4,122,407
4,124,464
4,125,414
4,127,449
4,127,738
4,128,732
4,129,458

1979: 4,131,984
4,133,698
4,135,290
4,135,537
4,136,436
4,137,096
4,144,096
4,155,785
4,158,577
4,160,678
4,160,816
4,164,431
4,172,925
4,173,497
4,175,981
4,175,982
4,177,093
4,180,625

1980: 4,193,821
4,197,142
4,199,383
4,202,004
4,204,216
4,212,932
4,214,916
4,215,185
4,227,943
4,233,613
4,235,955
4,236,938
4,240,882

1981: 4,251,679
4,255,211
4,255,501
4,281,053
4,289,920
4,295,002
4,296,188
4,297,717

1982: 4,310,405
4,315,973
4,320,249
4,335,503
4,338,180
4,341,918
4,343,870
4,348,545
4,352,722
4,352,868
4,357,400
4,357,486
4,360,702
4,360,703
4,366,335
4,366,337

1983: 4,367,369
4,368,216
4,377,445
4,381,233
4,381,978
4,385,102
4,388,382
4,388,383
4,388,384
4,396,485
4,400,451
4,400,868
4,406,913
4,407,320
4,410,758
4,414,300
4,416,959

Polycrystalline and Ribbon Silicon Cells

1965: 3,201,665

1975: 3,900,943

1976: 3,961,997
3,984,256

1977: 4,003,770
4,004,949
4,036,666
4,056,404
4,062,034

1978: 4,070,206
4,077,818
4,095,329
4,099,986
4,101,923
4,101,925
4,113,532
4,124,410
4,128,680
4,129,463

1979: 4,137,355
4,152,535
4,152,536
4,171,997
4,175,610

1980: 4,187,124
4,187,126
4,194,212
4,230,508

1981: 4,249,957
4,250,148
4,273,950
4,289,571

1982: 4,309,225
4,323,419
4,329,195
4,343,829
4,343,830

1983: 4,379,020
4,383,130
4,390,743
4,401,840
4,402,771
4,406,913

Single Crystal Silicon Cells

1951: 2,537,255
2,537,256
2,537,257

1953: 2,631,356

1955: 2,711,379

1957: 2,780,765

1958: 2,862,160

1959: 2,873,303
2,919,299

1960: 2,938,938

1961: 2,993,945

1962: 3,015,590
3,015,762
3,046,324
3,053,926

1963: 3,076,861
3,078,328
3,081,370
3,091,555
3,102,828
3,112,230

1964: 3,128,213
3,147,414
3,150,999
3,151,379

1966: 3,247,428
3,261,074
3,278,337
3,278,811

1967: 3,311,510
3,350,775
3,359,137

1968: 3,361,594
3,369,939
3,373,321
3,411,952

1969: 3,421,946
3,422,527
3,434,885
3,460,240
3,462,311
3,471,924
3,483,039

1970: 3,490,965
3,493,822
3,513,040
3,541,679

1971: 3,591,420
3,615,855

1972: 3,653,971
3,664,874
3,682,708
3,690,953

1973: 3,736,180
3,769,558
3,772,768
3,772,770

1974: 3,793,082
3,802,924
3,811,954

1975: Re. 28,610
3,888,698
3,895,975
3,907,595
3,912,540
3,914,856
3,925,802
3,928,073

1976: 3,936,319
3,948,682
3,952,323
3,956,765
3,969,746
3,973,994
3,982,964
3,985,579
3,988,167
3,990,097
3,996,067
4,000,505

1977: 4,001,864
4,003,756
4,004,949
4,028,151
4,028,720
4,029,518
4,038,104
4,055,442
4,056,879
4,058,418

1978: 4,070,689
4,072,541
4,078,945
4,082,570
4,090,213
4,097,310
4,101,351
4,104,091
4,105,471
4,106,047
4,110,122
4,128,732
4,129,458
4,131,486
4,131,488

1979: 4,131,984
4,133,698
4,135,950
4,135,998
4,137,095
4,139,858
4,140,142
4,140,610
4,141,020
4,141,811
4,144,096
4,147,563
4,152,175
4,152,824
4,153,907
4,156,622
4,158,591
4,162,174
4,162,177
4,163,678
4,165,241
4,169,738
4,173,496
4,174,561
4,174,978
4,179,318

1980: 4,181,538
4,190,852
4,193,081
4,198,262
4,199,377
4,201,622
4,219,830
4,224,084
4,226,017
4,227,940
4,227,942
4,235,644
4,239,810
4,240,842

1981: 4,249,959
4,251,285
4,253,882
4,255,212
4,256,513
4,270,972
4,278,474
4,278,704
4,278,831
4,283,589
4,292,461
4,293,732
4,297,391
4,301,323
4,301,592

1982: 4,311,870
4,315,097
4,320,247
4,320,251
4,322,253
4,322,571
4,330,680
4,331,703
4,332,973
4,335,503
4,336,281
4,338,481
4,338,482
4,341,918
4,342,795
4,343,829
4,343,962
4,343,963
4,347,262
4,347,263

4,347,264
4,348,254
4,349,691
4,350,561
4,352,948
4,353,160
4,355,196
4,360,701
4,361,718
4,361,950

1983: Re. 31,151
102,801
4,367,368
4,368,083
4,375,007
4,376,872
4,377,901
4,379,202
4,379,944
4,392,011
4,393,576
4,404,422
4,409,422
4,409,423
4,420,650

Collectors

Concentrator Collectors (design, components, production)

1959: 2,919,298

1962: 3,018,313

1964: 3,134,906

1966: 3,229,579

1967: 3,350,234

1968: 3,376,165
3,419,434

1969: 3,427,200

1976: 3,988,166
3,999,283

1977: 4,003,756
4,019,924
4,021,267
4,023,368
4,024,852
4,029,519
4,042,417
4,045,246
4,056,405

1978: Re. 29,833
4,069,812
4,081,289
4,088,116
4,088,121
4,110,123
4,115,149
4,118,249
4,127,425
4,130,445
4,131,485

1979: 4,143,234
4,144,097
4,146,407
4,147,561
4,149,902
4,151,005
4,152,174
4,153,474
4,153,813
4,155,371
4,159,212
4,162,174
4,166,917
4,169,738
4,172,739
4,172,740
4,173,213
4,175,980
4,177,083
4,180,414

1980: 4,187,123
4,188,238
4,188,239
4,190,465
4,191,593
4,191,594
4,193,819
4,199,376
4,200,472
4,204,881
4,211,581
4,223,174
4,234,354
4,238,246

1981: 4,248,643
4,249,959
4,251,284
4,251,288
4,255,212
4,268,709
4,280,853
4,291,191
4,304,955

1982: 4,316,448
4,328,389
4,329,535
4,332,973
4,352,948
4,357,486
4,360,701
4,361,717

1983: 4,367,366
4,367,367
4,388,481
4,411,490

Flat Plate Collectors (design, components, production)

1959: 2,904,613

1960: 2,962,539

1961: 2,989,575

1962: 3,025,335
3,040,416

1963: 3,094,439

1964: Re. 25,647
3,152,926

1966: 3,232,795
3,255,047
3,262,694
3,268,366

1967: 3,330,700
3,340,096
3,346,419

1968: 3,369,939
3,370,986
3,375,141
3,376,164
3,378,407
3,411,952
3,418,170

1969: 3,421,943
3,422,527
3,427,459
3,433,677
3,437,527
3,438,120
3,446,676
3,450,568
3,454,774
3,457,427
3,459,597
3,466,198
3,472,698
3,483,038

1970: 3,493,437
3,502,507
3,509,355
3,509,431
3,527,619
3,532,551
3,541,679
3,546,542

1971: 3,553,030
3,562,020
3,565,719
3,571,915
3,574,925
3,575,721
3,615,853
3,616,528
3,620,847

1972: 3,653,970
3,654,036
3,658,596

1973: 3,713,893
3,769,091
3,780,424

1974: 3,802,920
3,811,181
3,819,417
3,833,425
3,833,426
3,837,924
3,849,880

1975: 3,866,285
3,874,931
3,887,935
3,912,539
3,925,103

1976: 3,952,324
3,953,876
3,957,537
3,964,155
3,971,672
3,973,996
3,977,904
3,989,541
3,994,012

1977: Des. 245,330
4,001,863
4,009,054
4,019,924
4,025,786
4,038,104
4,040,867
4,043,834
4,045,245
4,056,404

4,057,439
4,063,963

1978: 4,067,764
4,078,944
4,083,097
4,084,985
4,089,576
4,089,705
4,093,473
4,095,997
4,097,308
4,097,309
4,104,083
4,108,704
4,116,207
4,116,718
4,122,214
4,131,123
4,131,659
4,131,755

1979: Re. 30,147
4,132,570
4,133,697
4,139,399
4,140,142
4,140,545
4,147,560
4,149,665
4,151,005
4,152,174
4,153,475
4,153,476
4,154,998
4,156,309
4,162,928
4,167,644
4,170,507
4,173,494
4,173,496
4,173,820
4,179,318
4,179,627

1980: Re. 30,292
4,184,894
4,184,903
4,186,033
4,189,881
4,191,794
4,193,081
4,193,820
4,203,646
4,209,347
4,210,462
4,219,368
4,219,926
4,224,081
4,226,256
4,227,298
4,228,570
4,231,807
4,233,085
4,234,351
4,235,643
4,236,937
4,239,555
4,241,493

1981: 4,243,432
4,245,386
4,249,958
4,254,546
4,257,821
4,262,161
4,262,411
4,265,422
4,267,003
4,287,382
4,292,092
4,294,602
4,296,270

1982: 4,310,211
4,311,869
4,313,022
4,313,023
4,315,096
4,318,938
4,321,416
4,321,417
4,321,418
4,321,419
4,322,261
4,323,719
4,329,534
4,330,680
4,331,492
4,331,494
4,334,354
4,336,413
4,340,507
4,340,803
4,348,546
4,350,836
4,353,161
4,358,331
4,362,895
4,364,508

1983: 4,367,365
4,367,581
4,370,509
4,371,739
4,374,406
4,374,955
4,379,324
4,380,112
4,382,833
4,383,129
4,392,009
4,394,529
4,401,839
4,407,320
4,409,537
4,419,530
4,419,531
4,421,943

Materials Production and Processes (purification, deposition, doping)

1951: 2,537,255
2,537,256
2,537,257

1953: 2,631,356

1955: 2,711,379

1957: 2,794,846

1958: 2,861,018
2,861,909

1959: 2,903,631

1960: 2,932,592

1961: 2,972,521
2,997,415
3,009,841

1962: 3,015,590
3,023,079
3,023,080
3,026,175
3,039,896
3,046,324
3,051,636

1963: 3,072,507
3,091,555
3,095,324
3,102,828
3,106,489

1964: 3,128,213
3,129,061
3,148,084
3,151,378
3,151,379

1965: 3,172,791
3,194,700
3,212,921
3,226,271

1966: 3,253,951
3,261,074
3,261,726
3,264,707
3,284,252

1967: 3,340,599
3,350,775
3,351,516

1968: 3,361,594
3,368,125
3,373,059
3,374,108
3,382,099
3,396,057
3,416,956
3,419,484

1969: 3,431,150
3,437,328
3,442,007
3,460,240
3,472,690
3,480,473

1970: 3,490,965
3,492,187
3,496,024
3,508,063
3,509,431
3,520,732
3,521,350
3,530,053
3,531,335
3,546,542
3,547,596
3,549,411

1971: 3,568,306
3,571,915
3,573,177
3,585,714
3,586,541
3,591,431
3,599,059
3,615,855
3,615,877

1972: 3,649,383
3,671,291
3,679,949
3,681,036
3,695,910
3,705,059

1973: 3,716,424
3,732,471
3,736,180
3,758,348
3,764,325
3,772,768
3,772,770
3,778,684

1974: 3,793,069
3,798,140
3,839,084
3,847,758

1975: 3,865,625
3,880,633
3,884,779
3,885,058
3,887,446
3,887,995
3,888,697
3,895,975
3,897,325
3,900,943
3,902,920
3,903,324
3,904,453
3,905,836
3,911,469
3,914,856
3,922,774
3,929,527

1976: 3,941,624
3,949,463
3,953,876
3,960,620
3,961,997
3,961,998
3,969,163
3,974,002
3,975,211
3,977,904
3,977,934
3,982,265
3,990,097
3,990,100
3,992,233
3,993,533
3,998,659

1977: 4,003,770
4,004,342
4,018,626
4,019,884
4,027,053
4,028,151
4,028,206
4,035,197
4,036,666
4,039,357
4,042,447
4,048,372
4,052,181
4,056,879
4,058,418
4,062,102

1978: 4,066,481
4,066,527
4,068,020
4,070,205
4,070,444
4,070,689
4,077,818
4,082,568
4,084,024
4,086,101
4,086,102
4,087,571
4,092,446
4,095,004
4,095,006
4,099,986
4,101,351
4,101,925
4,102,764
4,102,765
4,102,766
4,102,767
4,102,985
4,104,091
4,104,420
4,108,714
4,112,135
4,113,532
4,115,625
4,116,641
4,120,705
4,120,743
4,121,965
4,122,407
4,124,410
4,124,411
4,124,455
4,129,463
4,131,659

1979: 4,132,571
4,137,096
4,137,123
4,137,355
4,138,509
4,139,857
4,140,610
4,141,764
4,141,811
4,142,195
4,143,235
4,144,139
4,146,657
4,147,563
4,147,564
4,151,058
4,152,535
4,155,781
4,155,785
4,158,717
4,159,354
4,160,045
4,161,418
4,165,558
4,166,880
4,167,805
4,169,739
4,169,740
4,170,667
4,171,235
4,171,991
4,171,997
4,174,234
4,174,561
4,174,978
4,175,610
4,177,093
4,177,473
4,178,175
4,178,415
4,180,618

1980: Re. 30,412
4,181,755
4,187,124
4,187,126
4,190,852
4,192,720
4,192,721
4,193,974
4,194,212
4,196,041
4,196,438
4,198,262
4,199,383
4,199,397
4,201,798
4,203,785
4,204,933
4,214,920
4,217,374
4,224,355
4,225,367
4,225,408
4,226,643
4,227,291
4,227,941
4,227,942
4,229,231
4,230,508
4,231,808
4,233,270
4,233,338
4,233,613
4,235,651
4,235,662
4,237,150
4,237,151
4,238,436
4,239,583
4,239,585
4,239,734
4,239,809
4,239,810
4,242,374

1981: 4,243,471
4,246,050
4,247,528
4,250,148
4,251,285
4,251,287
4,251,289
4,251,327
4,252,861
4,252,865
4,253,919
4,254,093
4,255,206
4,255,208
4,256,544
4,256,681
4,258,647
4,263,064
4,265,933
4,268,711
4,270,972
4,273,608
4,273,950
4,274,890
4,278,473
4,281,208
4,283,590
4,285,762
4,287,485
4,287,848
4,289,571
4,291,318
4,292,092
4,292,093
4,292,342
4,292,343
4,294,811
4,296,188
4,297,717
4,298,410

4,298,423
4,298,587
4,299,648
4,303,463
4,304,763
4,305,776
4,307,680
4,307,681
4,308,245

1982: 4,309,225
4,309,239
4,309,241
4,311,728
4,312,700
4,313,254
4,314,128
4,314,525
4,317,689
4,318,942
4,319,953
4,320,154
4,320,168
4,321,099
4,321,246
4,321,283
4,321,420
4,322,253
4,322,379
4,322,571
4,323,417
4,325,986
4,327,119
4,328,258
4,328,260
4,329,189
4,329,195
4,329,699
4,330,182
4,330,358
4,330,359
4,331,707
4,332,838
4,335,266
4,338,362
4,339,470
4,340,627
4,341,589
4,344,984
4,345,967
4,348,428
4,353,160
4,356,141
4,357,179
4,357,200
4,357,201
4,360,542
4,361,529
4,362,896
4,366,024
4,366,337

1983: 4,366,771
4,368,083
4,368,216
4,369,099
4,370,510
4,374,182
4,377,564
4,377,604
4,377,901
4,379,020
4,382,099
4,382,838
4,383,130
4,388,483
4,389,291
4,390,743
4,392,297
4,392,451
4,392,931
4,398,343
4,400,221
4,400,244
4,400,409
4,401,052
4,402,762
4,403,398
4,404,076
4,404,421
4,404,734
4,405,435
4,407,061
4,407,710
4,409,134
4,409,422
4,410,558
4,410,559
4,410,758
4,414,252
4,417,092
4,419,178
4,421,592

Optics and Trackers (lenses, reflectors, tracking devices, and related components)

1959: 2,877,284

1962: 3,018,313

1963: 3,085,565

1966: 3,229,682
3,252,023

1969: 3,484,606

1970: 3,491,237
3,515,594
3,546,460

1973: 3,751,303

1975: 3,912,931
3,929,510

1976: 3,958,970
3,971,672

1977: 4,002,499
4,021,267
4,031,385
4,041,307
4,052,228
4,053,327

1978: 4,082,947
4,086,485
4,088,116
4,088,121
4,088,508
4,108,540

1979: 4,134,387
4,140,544
4,144,097
4,146,408
4,147,561
4,148,297
4,148,298
4,148,299
4,149,902
4,153,475
4,153,476
4,153,813
4,155,371
4,164,432
4,172,739
4,173,495
4,179,612

1980: 4,184,482
4,188,238
4,188,239
4,190,465
4,199,376
4,202,704
4,223,214
4,227,939
4,237,332
4,238,246
4,242,147
4,242,580

1981: Re. 30,584
4,246,042
4,249,516
4,251,284
4,253,880
4,257,676
4,260,219
4,262,206
4,264,124
4,268,709
4,290,411
4,292,959
4,296,731
4,297,521
4,298,802
4,301,321

1982: 4,312,330
4,313,024
4,316,448
4,321,417
4,324,946
4,326,012
4,328,389
4,328,417
4,329,534
4,329,535
4,337,758
4,337,759
4,345,582
4,350,837
4,355,630

1983: 4,367,366
4,367,367
4,367,403
4,377,722
4,385,430
4,392,006
4,395,581
4,404,465
4,411,490
4,418,238

Systems

PV-Hybrid Systems (PV-thermal, photoelectrochemical)

1962: 3,031,520
3,053,923

1963: 3,113,047
3,114,658

1967: 3,331,707

1968: 3,383,246

1969: 3,427,459
3,433,676
3,444,946
3,483,040

1970: 3,549,960

1973: 3,751,303
3,774,865

1975: 3,929,510

1976: 3,956,017
3,971,454
3,976,508
3,988,166
3,990,914
3,991,741

1977: 4,002,031
4,021,323
4,040,566
4,050,907
4,052,782

1978: Re. 29,833
4,069,812
4,080,221
4,081,289
4,095,997
4,100,051
4,106,482
4,106,952
4,110,628
4,119,863
4,130,445

1979: 4,134,393
4,135,537
4,136,436
4,137,097
4,137,098
4,143,233
4,143,234
4,144,095
4,147,157
4,148,301
4,149,903
4,159,427
4,161,657
4,165,604
4,166,880
4,166,917
4,171,003
4,172,740
4,173,213
4,177,795

1980: 4,182,960
4,184,895
4,186,033
4,187,123
4,191,164
4,191,594
4,200,472
4,205,657
4,210,121
4,210,463
4,217,147
4,222,371
4,223,214
4,224,082
4,228,789
4,233,961
4,234,352
4,235,221
4,238,247
4,242,580

1981: 4,248,643
4,249,516
4,269,168
4,278,829
4,280,853
4,289,112
4,289,118
4,296,731
4,301,321
4,304,955

1982: 4,313,024
4,316,048
4,320,246
4,323,052
4,326,012
4,326,013
4,331,829
4,334,120
4,337,758
4,339,626
4,339,627
4,341,607

1983: Re. 31,156
4,369,629
4,370,974
4,373,308
4,378,786
4,381,978
4,389,533
4,392,007
4,392,008
4,395,582
4,398,053
4,410,757
4,413,157
4,419,532

Utility Independent Systems and Storage Technologies

1957: 2,780,765

1959: 2,889,490
2,894,173
2,919,353

1960: 2,946,945
2,951,163
2,960,094

1963: 3,089,070

1964: 3,127,552

1966: 3,252,023

1967: 3,317,809
3,344,334
3,353,191

1969: 3,427,797
3,448,575

1970: 3,509,712
1971: 3,582,923
3,600,599
3,630,015

1972: 3,636,539
3,643,260

1973: 3,740,636
3,747,327
3,757,511
3,774,023
3,774,865
3,780,519

1974: 3,786,624
3,818,691
3,823,551
3,844,840

1975: 3,890,776
3,896,368
3,899,689
3,921,049
3,928,960

1976: 3,943,726
3,961,472
3,971,454
3,979,656
3,982,963

1977: 4,006,583
4,009,051
4,009,535
4,017,725
4,041,389
4,045,663
4,062,371

1978: 4,087,960
4,090,359
4,090,577
4,095,217
4,100,427
4,108,405
4,117,364
4,122,396

1979: 4,164,145
4,164,698
4,169,970
4,173,229
4,179,633

1980: 4,183,628
4,199,894
4,200,904
4,209,346
4,209,735
4,227,327
4,234,947

1981: 4,243,928
4,264,962
4,274,044
4,275,525
4,281,278
4,281,369
4,293,808
4,306,183

1982: 4,310,987
4,311,953
4,313,078
4,314,192
4,314,198
4,319,310
4,322,908
4,327,316
4,327,318
4,333,136
4,333,262
4,349,775
4,361,295
4,364,532

1983: 4,367,633
4,369,498
4,376,347
4,379,588
4,384,259
4,387,999
4,388,487
4,409,538
4,415,133
4,422,031

Utility Interactive Systems and Interface Technologies (power conditioning)

1968: 3,384,806
3,419,433
1978: 4,075,034
4,131,827
1979: 4,135,235
4,137,570
4,175,249
1981: 4,281,369
1983: 4,420,752

Systems Support (testing, maintenance, operation, and control)

1960: 2,945,417
1963: 3,077,539
1967: 3,325,723
3,334,217
1968: 3,384,806
3,390,576
3,419,433
1969: 3,435,328
3,480,781
1971: 3,582,923
3,600,599
3,617,137
3,626,198
3,630,015
3,630,627
1972: 3,636,539
3,643,260
3,645,633
3,670,202
3,696,286
1973: 3,708,669
3,740,636
1975: 3,879,740
3,891,326
3,896,368
3,899,689
3,921,049
1976: 3,956,687
3,979,656
1977: 4,015,117
4,052,657
1978: 4,076,977
4,086,485
4,090,071
4,100,427
4,110,049
4,117,364
4,118,548
4,122,396
4,129,823
4,131,827
1979: 4,135,235
4,163,194
4,164,698
4,168,124
4,175,249
1980: 4,184,111
4,200,833
4,204,147
4,217,633
1981: 4,243,928
4,266,178
4,274,044
4,281,278
4,306,183
1982: 4,314,198
4,319,187
4,327,318
4,333,136
4,341,607
4,349,775
4,355,896
1983: 4,372,680
4,373,809
4,375,662
4,390,940
4,409,537
4,409,538
4,420,752

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