

PVMaT 1998 Overview

R.L. Mitchell, M. Symko-Davies,
H.P. Thomas, and C.E. Witt
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National Renewable Energy Laboratory
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Richard L. Mitchell, Martha Symko-Davies,
Holly P. Thomas, and C. Edwin Witt

National Renewable Energy Laboratory
National Center for Photovoltaics
MS-3221, 1617 Cole Blvd., Golden, CO, 80401, USA

Abstract. The Photovoltaic Manufacturing Technology (PVMaT) Project is a government/industry research and development (R&D) partnership between the U.S. federal government (through the U.S. Department of Energy [DOE]) and members of the U.S. PV industry. The goals of PVMaT are to assist the U.S. PV industry improve module manufacturing processes and equipment; accelerate manufacturing cost reductions for PV modules, balance-of-systems components, and integrated systems; increase commercial product performance and reliability; and enhance investment opportunities for substantial scale-ups of U.S.-based PV manufacturing plant capacities. The approach for PVMaT has been to cost-share the R&D risk as industry explores new manufacturing options and ideas for improved PV modules and components, advances system and product integration, and develops new system designs. These activities will lead to overall reduced system life-cycle costs for reliable PV end-products. The 1994 PVMaT Product-Driven BOS and Systems activities, as well as Product-Driven Module Manufacturing R&D activities, are just being completed. Fourteen new subcontracts have just been awarded in the areas of PV System and Component Technology and Module Manufacturing Technology. Government funding, subcontractor cost-sharing, and a comparison of the relative efforts by PV technology throughout the PVMaT project are also discussed.

INTRODUCTION

The goals of the Photovoltaic Manufacturing Technology (PVMaT) Project are to help the U.S. PV industry improve module manufacturing processes and equipment; accelerate manufacturing cost reductions for PV modules, balance-of-systems (BOS) components, and integrated systems; increase commercial product performance and reliability; and enhance the investment opportunities for substantial scale-ups of U.S.-based PV manufacturing plant capacities. This project strategy is to help the U.S. PV industry by establishing multiyear, cost-shared government/industry partnerships. Subcontracted research under these partnerships are based on competitive government procurements. They are focused on: 1) process-specific research and development (R&D) on industry-selected manufacturing technology developments, 2) teamed R&D on industry-identified common problem areas, and 3) improvements in balance-of-system performance integration and manufacturing, as detailed in previous papers [1-6]. All work in the PVMaT project is managed by a Technical Monitoring Team consisting of engineers and scientists from the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (SNL).

PVMaT has completed a series of cost-sharing procurements to support research on new manufacturing options and ideas for improved PV modules and other components, to advance system and product integration, and to develop new system designs, all of which will lead to overall reduced system life-cycle costs for reliable PV end-products. The six solicitations carried out since 1990 have covered: 1) identification of the industry's problems on a company-by-company basis; 2) R&D aimed at resolving company-specific module manufacturing problems and reducing manufacturing costs; 3) R&D directed toward resolving industry-generic issues in module manufacturing; and 4) R&D to facilitate advances in product-driven manufacturing involving BOS components as well as modules. The 1994 solicitation was directed at Product-Driven Manufacturing, and was divided into two parts C Product-Driven System and Component Technology, and Product-Driven PV Module Manufacturing Technology C and these R&D projects are now being completed.

Table 1 shows the relative cost-sharing by phase for the PVMaT project to date. The subcontracts awarded in 3, 4A1, and 5A1 are generally of the more generic or system component and integration type, with less emphasis on process-specific module manufacture. In addition, these awards were constrained to less effort, both in resources and time. The offerors in these areas have also been smaller companies, generally meeting the "small business" criterion for PVMaT participation. Consequently, they have not always been required to cost-share as heavily, and the data show this.

Table 1. PVMaT Funding and Cost-Share

Solicitation	DOE/NREL (\$K)	Contractor (\$K)	Cost-Share (%)
1992 - Process Specific	30,738	21,316	41
1993 - Process Specific	13,384	14,557	52
1993 - Generic/Teamed Research	2,220	752	25
1994 - Product-Driven BOS and Systems	5,281	1,742	25
1994 - Product-Driven Module Manufacturing	14,017	9,949	49
1998 - PV System and Component Technology	4,345	4,229	49
1998 - PV Module Manufacturing Technology	24,115	19,945	45
Totals	94,100	72,490	44

THE 1998 PVMaT SUBCONTRACT AWARDS

The competitive solicitation released in 1997 was also divided into two parts: PV System and Component Technology, and Module Manufacturing Technology. Out of the thirty-one offerors responding to the PVMaT 5A competitive Request for Proposal, a total of \$97 million worth of manufacturing research was proposed, with a cost-share of about 49% being offered as the subcontractors' share. This competitive solicitation, which has resulted in fourteen letter subcontracts being awarded, with an expected total value of \$53 million over a 3-year period. These are being cost-shared at around 46% by the industrial participants. Table 2 presents the 1998 research subcontractors and their respective areas of manufacturing R&D.

Table 2. PVMaT 1998 Subcontract Awards

Company	Area of Manufacturing R&D Focus
Ascension Technology, Inc.	Manufacture of the Advanced SunSineJ 325 AC Module
ASE Americas, Inc.	The EFG High-Volume PV Manufacturing Line
AstroPower, Inc.	Silicon-FilmJ Solar Cells by a Flexible Manufacturing System
Crystal Systems, Inc.	Production of Solar-Grade Silicon by Refining of Liquid Metallurgical-Grade Silicon
Energy Conversion Devices, Inc.	Efficiency and Throughput Advances in Continuous Roll-to-Roll a-Si Alloy PV Manufacturing Technology
Evergreen Solar, Inc.	Continuous, Automated Manufacturing of String Ribbon Si PV Modules
Global Solar Energy, L.L.C.	Throughput Improvements for Thin-Film-Based CIGS Modules
Omnion Power Engineering Corp.	Manufacturing and System Improvements for 1- and 2-kW Inverters
PowerLight Corp.	Advanced PowerGuard ⁷ Manufacturing
Siemens Solar Industries	R&D on Siemens Cz Silicon Product Manufacturing
Solar Cells, Inc.	R&D on CdTe Product Manufacturing
Solarex	Improvements in Polycrystalline Silicon PV Module Manufacturing
Spire Corp.	Post-Lamination Manufacturing Process Automation for Photovoltaic Modules
Utility Power Group, Inc.	Development of a Fully Integrated PV System for Residential Applications

PVMaT is technology neutral, and with the 1998 awards, the maturity of technology sectors has been apparent in their PVMaT research. Table 3 shows the total funding for PVMaT, by technology area, since the initial problem-identification efforts through the 1998 awards discussed above. The more mature crystalline-silicon technologies have received the largest share of the funding. The amorphous-silicon area is second in size and has probably benefitted from the large U.S. research funding of the 1980s in its apparent initial lead in thin-film efforts. However, we are now seeing continued interest in the area of PV System and Component Technology, as well as CIGS joining CdTe in the area of thin-film manufacturing, resulting in an increase in these technology shares of PVMaT funding.

Table 3. PVMaT Funding by Technology

Technology	Funding (\$K)	Technology (%)
Amorphous Silicon	19,741	21.0
CdTe - CIGS	12,462	13.2
Concentrators	6,162	6.6
Crystalline Silicon	41,027	43.6
Generic/Balance-of-Systems/Systems	14,708	15.6
Totals	94,100	100.0

CONCLUSIONS

PV manufacturing processes, technology, and cost reduction have been substantially advanced by the DOE's PVMaT project and by the U.S. PV industry. PV manufacturing improvements continue in module manufacturing in both the more mature crystalline-silicon approaches and the newer thin-film technologies, as well as BOS and systems. The fourteen subcontracted R&D activities initiated in 1998 have continued to focus on assisting the U.S. PV industry in developing these manufacturing improvements.

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REFERENCES

- [1] Witt, C.E., Herwig, L.O., Mitchell, R., and Mooney, G.D., "Status of the Photovoltaic Manufacturing Technology (PVMaT) Project," *Proceedings of the 22nd IEEE Photovoltaic Specialists Conference*, Las Vegas, Nevada, October, 1991.
- [2] Witt, C.E., Herwig, L.O., Mitchell, R.L., Thomas, H.P., Sellers, R., and Ruby, D.S., "Recent Progress in the Photovoltaic Manufacturing Technology Project (PVMaT)," *Proceedings of the 1st World Conference on Photovoltaics*, Waikoloa, Hawaii, December, 1994.
- [3] Mitchell, R.L., Witt, C.E., Thomas, H.P., Ruby, D.S., King, R., and Aldrich, C.C., "Progress Update on the U.S. Photovoltaic Manufacturing Technology Project," *Proceedings of the 26th IEEE Photovoltaic Specialists Conference*, Anaheim, California, October, 1997.
- [4] Bower, W.I., Thomas, H.P., Kroposki, B., Bonn, R., and Hund, T., "Balance-of-System Improvements for Photovoltaic Applications Resulting from the PVMaT Phase 4A1 Program," *Proceedings of the 26th IEEE Photovoltaics Specialists Conference*, Anaheim, CA, September, 1997.
- [5] Witt, C.E., Mitchell, R.L., Thomas, H.P., Symko, M.I., King, R., and Ruby, D.S., "Manufacturing Improvements in the Photovoltaic Manufacturing Technology (PVMaT) Project," *Proceedings of the 2nd World Conference on Photovoltaic Solar Energy Conversion*, Vienna, Austria, July, 1998.
- [6] Thomas, H.P., Kroposki, B., McNutt, P., Witt, C.E., Bower, W., Bonn, R., and Hund, T.D., "Progress in Photovoltaic System Component Improvements," *Proceedings of the 2nd World Conference on Photovoltaic Solar Energy Conversion*, Vienna, Austria, July, 1998.