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Bibliography of Work on the Heterogenous Photocatalytic Removal of Hazardous Compounds from Water and Air Update Number 2 To October 1996

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Summary

The Solar Industrial Program, funded by the United States Department of Energy, has developed processes that destroy hazardous substances in or remove them from water and air. This work was done by the National Renewable Energy Laboratory in Golden, CO, and Sandia National Laboratory in Albuquerque, NM, and by their subcontractors at universities and small or large businesses. The processes of interest in this report are based on the application of heterogeneous photocatalysts, principally titanium dioxide or modifications thereof, but work on other heterogeneous catalysts is included in this compilation.

This report continues bibliographies that were published in May, 1994, and October, 1995. The author compiles published work on the photocatalytic oxidation and reduction of organic or inorganic compounds in air or water. The previous reports included 663 and 574 citations, respectively. This update contains an additional 518 references. These were published during the period from June 1995 to October 1996, or are references from prior years that were not included in the previous reports. The work generally focuses on removing hazardous contaminants from air or water to meet environmental or health regulations. This report also references work on properties of semiconductor photocatalysts and applications of photocatalytic chemistry in organic synthesis. This report follows the same organization as the previous publications. The first part provides citations for work done in a few broad categories that are generic to the process. Three tables provide references to work on specific substances. The first table lists organic compounds that are included in various lists of hazardous substances identified by the United States Environmental Protection Agency (EPA). The second table lists compounds not included in those categories, but which have been treated in a photocatalytic process. The third table covers inorganic compounds that are on EPA lists of hazardous materials or that have been treated by a photocatalytic process. A short update on companies that are active in providing products or services based on photocatalytic processes is provided.

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1.0 Introduction

This update in combination with the previous reports[1,2] provides a comprehensive bibliography of work available in the open literature for scientists and engineers interested in the use of heterogeneous photocatalytic oxidation or reduction processes in environmental remediation, process emission control, indoor air quality, or other applications. The combined bibliographies include more than 1700 citations to work published between 1970 and the third quarter of 1996. The literature cited includes United States and foreign patents. Information was compiled by manually scanning the literature and searching commercial databases. This update includes about 150 citations to work done prior to 1995 that were not included in the earlier reports. Some citations have doubtless been missed and topics covered in certain papers may not have been identified and covered in every appropriate category. The author is grateful to the many people who have sent references and reprints of their work. Coverage is limited to heterogeneous processes except in a few cases where review material for homogeneous processes is relevant to heterogeneous photocatalytic chemistry. The author invites readers to send references to relevant work that appeared before 1996 that has been missed to the mail or e-mail address included in Section 5.1 of this report.

The photocatalytic oxidation of organic compounds in water has received the most attention but there is a rapidly increasing amount of work on the oxidation of volatile organic or inorganic compounds in the gas phase. Photocatalytic reduction of both organic compounds and metal-containing ions is also receiving increasing attention.

It is widely observed that intermediates and by-products are often formed that persist in the treated stream. These can include acids, oxygenated compounds, and carbon monoxide. The nature of the intermediates is increasingly being used to reveal details of the chemical mechanism of the photocatalytic process. The net process involves oxidizing the organic compound to an intermediate stage of oxygen content or to

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[1]Blake, Daniel M. (1994). ***Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds from Water and Air.*** NREL/TP-430-6084. Golden, CO: National Renewable Energy Laboratory. 75 pp. [DE94006906] Available from the National Technical Information Service, Springfield, VA 22161.

[2]Blake, Daniel M. ***(1995). Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds from Water and Air. Update Number 1, to June,*** 1995. NREL/TP473-20300. Golden, CO: National Renewable Energy Laboratory. 102 pp. [DE95013148] Available from the National Technical Information Service, Springfield, VA 22161.

carbon dioxide, water, and a mineral acid (if a heteroatom such as nitrogen or chlorine is present). Other oxidizing agents may be substituted for oxygen. Certain metal ions can be modified or removed from water when the ions replace oxygen as the electron acceptor in the process and sacrificial electron donor compounds are provided.

Reference to test work on more than 270 compounds is included in the tables in Section 3. The most-studied compounds are phenol derivatives, BTEX (benzene, toluene, ethyl benzene, and xylene) components found in fuel spills, and chlorinated solvents such as trichloroethylene and chloroform. Test work reports that a significant number of pesticides, dye compounds, and surfactants can be completely oxidized (mineralized), and a variety of bacteria and viruses have been killed by irradiation with near-ultraviolet light in the presence of titanium dioxide. The breadth of work attests to the very wide range of applications that are being evaluated for the technology.

The section on companies active in the field notes only additions and changes that have occurred since the last report.2 The high level of participation of Japanese companies in the Second International Conference on TiO_2 Photocatalytic Purification and Treatment of Water and Air[3] and the numerous patents assigned to Japanese companies indicate a high level of activity in that country. However, the author has little information on the individual companies that may be active in this field in Japan.

The following sections discuss reviews written on various aspects of the technology, work in developing and testing photocatalysts and oxidants, engineering issues, other topics, patents, and companies active in bringing photocatalytic processes or services to the marketplace. These sections, which include information that can apply to a range of applications, are followed by tables listing references to work performed on specific substances. References to work on systems in which the compound to be treated is carried in the gas phase are indicated by the suffix "g" in the citation number.

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[3] Al-Ekabi, Hussain, ***Abstracts of the Second International Conference on TiO_2 Photocatalytic Purification and Treatment of Water and Air,*** Cincinnati, OH, October 26-29, 1996, Science and Technology Integration, Inc., London, ON.

2.0 Generic Information

This section refers to work that pertains to the field of photocatalytic processes.

2.1 Reviews and Articles

Reviews describe many aspects of photocatalytic chemistry and technology. This section also includes reviews written in the years prior to 1995 that were not cited in the previous reports. Reviews covering the broad topics given can be found in the following:

Semiconductors and supports - 120, 362, 368, 369, 370, 371, 396, 495, and 506; methodology for comparing reaction systems - 396,424, and 446; mechanisms/activity - 165, 173, 174, 179, 231, 277, 365, 366, 367, 368, 398, 425, 435, and 439; nanocrystalline semiconductors - 165,231, and 233; photoelectrochemical systems - 113 and 115; photocatalysis - 46, 47, 104, 105, 106, 107, 113, 114, 115, 119, 121, 127, 132, 146, 157, 173,231, 365,366, 367, 368, 372, and 506; solar processes - 112,355, and 461g; companies active in the field - 16; adsorption - 78; disinfection - 17, 167, 269, 330g, and 489; water treatment - 30, 269, and 297; indoor air quality - 17, 324, 326, 330g, 438g, and 450g; environmental applications - 112, 144, 145, 166, 173, 174, 179,250, 386,412, and 461g; energy storage - 193; preparation and applications of semiconductor thin films - 232,233, and 250; organic synthesis - 372; intercalation compounds - 350; oxidation of phenols - 414 and 435; comparison of advanced oxidation processes - 109, 269, and 406; issues and questions in application of photocatalysis - 355, 412, and 494; reactors - 259; problems of immobilization of catalyst - 45; photocatalytic ammonia synthesis - 52 and 84; activation of oxygen - 103; charge injection into semiconductor particles - 110, 111, 116, 117, and 118; and activating TiO_2 with visible light - 217.

2.2 Photocatalysts

The nature of the photocatalyst determines the rate and efficiency of the process. The anatase form of titanium dioxide has the desirable properties of being chemically stable, readily available, and active as a catalyst for oxidation processes. The 3.2 eV band gap matches the output of a wide variety of readily available lamps but is not ideal for solar applications. The photoefficiency for reaction of hazardous molecules is generally rather low, particularly for the aqueous-phase processes. Considerable work has

been directed toward modifying TiO_2 and testing other semiconductors to identify ways to increase process efficiency and to improve the overlap of the absorption spectrum of the photocatalyst with the solar spectrum. This work is broken down into a few broad categories and covered in the references cited.

2.2.1 Modified Titanium Dioxide

Titanium dioxide and modified forms, including different commercially available forms, heat treated materials, and materials prepared by a range of techniques:

sol-gel - 2, 3, 13, 14, 21, 91, 164, 212, 239, 241, 253, 254, 311, 316, 336, 343g, 388, 397g, 429, 492, and 508; controlled hydrolysis of $TiCl_4$ - 423; heat treatment - 65, 164, and 252; colloidal or quantized particles - 51, 67, 68, 96, 102, 291, 337, 407, 419, 420, 421, and 453; xerogel/aerogel - 2, 3, 246, 317, and 470; flame synthesis - 77 and 381; or catalysts from different vendors - 35, 51, 285, 334, 389, 413, 424, and 446; spray pyrolysis - 44 and 77; impregnation - 44 and 67; co-precipitation - 44 and 67; microemulsion - 68; reduction - 183; rutile - 432g; potassium pillared layered titanate - 3 18 and 3 19; cysteine - 387; and surface modification - 462.

2.2.2 Hydrophobic Surface Treatment

No new work was identified in this area

2.2.3 Dye Sensitized Titanium Dioxide

Sensitizers have been used in conjunction with titanium dioxide to improve the response to visible light:

ruthenium complexes - 38, 99, 235, 364, and 476; vanadium(+5) complexes - 41; cobalt(+2) complexes - 3 1; nickel(+2) complexes - 31; copper(+2) complexes - 3 1; cobalt(+3) complexes - 40; metal phthalocyanine - 43 and 266; organic dyes - 38, 266, and 278; poly-(10-substituted-2-(9-enthral) ethylmethacrylates) - 122; polypyrrole - 507; or erythrosin B - 234.

2.2.4 Metal Ion Doping of Titanium Dioxide or Mixed Oxides

Other metal ions have been introduced into the titanium dioxide lattice to modify the properties. They are covered in the following:

Al - 13; Si - 2, 3, 13, 14, 21, 33, 55, 139, and 329g; V - 39, 190, 407, and 423; Cr - 195, 200, 370,407, and 423; Fe - 44, 51, 96, 340, 342,407, and 423; Co - 39; Cu - 69; Ga - 182, 185, 187, and 474g; Zr - 139; Nb - 182, 185, 187, and 474g; Mo - 92; Ce - 55; or W - 92, 299, and 329g.

2.2.5 Metallized Titanium Dioxide

Noble metals have been deposited on the titanium dioxide surface to enhance catalytic activity:

Ni - 73, 172, 180, 181,378, and 380; Rh - 98, 172, 178, 180, and 181; Pd - 146, 156,218, and 398; Pt - 22, 32, 73g, 74g, 76g, 89, 98, 140g, 172, 175, 176, 178, 180, 181, 191, 192, 194, 197, 201, 278, 287g, 298, 310, 316, 370, 371, 376, 378,380, 398, 457, 486, 510, and 514; Ag - 198, 199, 226, and 251; Au - 32 and 198; Pt/Rh - 199; Ag/Rh - 199; or Pt/Pd - 199.

2.2.6 Other Semiconductors

A wide range of other semiconductors and other materials have been tested for photocatalytic activity. In general they have been found to be less active than titanium dioxide. Relevant work is cited in the following:

Al_2O_3 - 60g and 237; V_2O_5 - 196g and 375g; Fe_2O_3 - 60g, 158, 159, 160, 200, and 402; ZnO - 9, 22, 99, 196g, 200, 202, 237, 375g, 393,402, and 426; Zn - or CdS - 265,402, and 486; Pt/CdS - 486; ZnTe - 298; ZrO_2 - 133, 196g, 200, 339, and 375g; $ZrTiO_4$ - 75, 339, and 241; MoS_2 - 298; SnO_2 - 33, 99, 122, 133, 196g, 230, 375g, and 475; Sb_2O_4 - 196g, 200, and 375g; Sn/SbO_2 - 375g; CeO_2 - 196g, 200, and 375g; WO_3 - 123, 196g, 200,202, and 375g; Nb_2O_5 - 26; fly ash - 160; furnace slag or core sands - 70; polyaniline - 59; poly(p-phenylene) - 472g; polythiocyanogen - 472g; muscovite - 160; or natural minerals - 134 and 158.

2.2.7 Immobilized Photocatalysts

Most experimental work on aqueous systems has used fine particles of photocatalyst suspended in the liquid phase. In a waste treatment application it would be simpler if the catalyst were immobilized in the photoreactor so the material would not have to be separated from the treated fluid in a subsequent process step. Most work on the treatment of gases has used immobilized catalyst. Titanium dioxide has been affixed to a variety of surfaces:

glass (including fibers) - 18, 21, 57, 97, 120, 141, 148g, 239, 252, 254, 255g, 307, 308, 311, 316, 327,328, 331, 357, 358, 359, 383, 397, 427, 428, 429, 467, 473g, 477, 492, 502, and 514; silica - 49, 67, 326g, 405g, 458g, 463,471, 498, and 514; metal - 97, 163, 164, 331, 514, and 518; clays - 67 and 120; polymer - 6, 7, 15, 120, 262, 265, 331, 459g, 464,482, and 483; thin films - 23, 120, 255g, 343g, 397g, 403,441, 442,443, and 493; internal light guide - 444; zeolite - 21, 53, 120, 254, 325, 458g, 471,498, 501,512, and 515; alumina - 458g and 498; carbon - 215, 216, 220g, 292, 458g, and 471; paper - 305 and 306g; Ambersorb - 514; PHOTOPERM™ - 39, 41, and 42; metal oxides and ceramics - 120, 147, 405g, and 459g; vesicles and micelles - 120; or silica coating on TiO_2 films - 441,442, and 443.

2.3 Hydrogen Peroxide and Other Oxidants

Oxygen is the most commonly used oxidant, but other oxidants have been found to improve rates of reaction with a variety of organic substrates under some conditions. This work is covered in the following:

hydrogen peroxide - 9, 29, 35, 48, 206, 364, 373, 5 11, and 517; superoxide - 373; peroxydisulfate - 35, 303, and 313; chlorite - 303; chlorate - 303; bromate - 303 and 312; periodate - 303; or ozone - 26, 48, 304, 379, and 499.

2.4 Engineering Issues

In recent years the success of laboratory work has led to interest in applying the technology to environmental remediation and treatment of process waste streams. Literature now discusses scale-up of the process and resolution of engineering problems. Progress has been significant and many companies are now providing turn-key systems for treating contaminated water and air.

2.4.1 Reactor and System Design

A number of papers address topics relevant to the design of reactors for photocatalytic processes:

photochemical reactors - 251, 252, 300, 301, and 310; non-concentrating reactor - 345 and 460g; parabolic trough - 50, 79, and 313; compound parabolic concentrator - 79; kinetic modeling - 300, 301, 405g, 497, and 513; fixed bed - 91 and 343; filtration - 491 and 508; controlled periodic illumination - 100, 416, 417, and 436; light scattering model - 4, 149; flat plate reactor - 28;

ceramic monolith - 405g; effectiveness factors for reactions in a planar membrane - 94; mass transfer limitations - 95 and 25 1; photocatalytic membrane reactor - 214; fiber optic cable reactor - 358 and 359; or field tests - 392g.

2.4.2 Systems Analysis

As the technology for the photocatalytic treatment of contaminated air or water has progressed, some work on economic evaluation has appeared in the literature. However, there was limited new information during the last year:

process waste water - 379; or photon costs from lamps and sunlight - 48.

2.5 Miscellaneous Topics

This category includes papers of interest that do not fall into the preceding headings:

actinometry - 210; adsorption - 22, 292, 302, 320, 344g, 405g, 426g, and 443g; combined photocatalytic and biological treatment - 48; effect of applied voltage bias on photocatalytic reactions - 477,478, and 479; non-aqueous solvent systems - 131, 135, 137, 228, 234, 235, 377, 396, 431, 436, and 486; application in chemical analysis - 1, 262,445, and 457; polymer aging - 6, 7, and 152; photo initiators - 40; "inert" ion effect - 29, 51, 285, and 290; dissolved metal ion effect - 56, 66, 159, 290, 463, 511, and 517; comparison with other advanced oxidation processes - 51, 81, 364, 366, 379, and 418; purification of water for recycle in semiconductor fabs - 63; purification of drinking water - 64; photoelectrode - 71; organic synthesis - 108, 114, 119, 124, 125, 126, 127, 128, 132, 136, 228, 356, 377, 396, 486, and 496; surface science of TiO_2 - 150, 286g, and 287g; quantum yield as a function of particle size and light intensity - 15 1, 420, and 42 1; photoconductivity/electrical conductivity - 177, 184, 185, 186, 187, 196g, and 201; self cleaning surface - 357,437, and 459; mixed waste - 418; or treatment of photographic processing effluents - 422.

2.6 Patents

The number of patents for aspects of photocatalytic technology has increased rapidly in the last decade. They cover a range of aqueous and gas-phase applications. The general topic of the patents are described in the following:

process for oxidation of hydrocarbons - 229; parts having photocatalytic function - 168, 169, 240, 241, 242, and 258; catalyst formulation - 15, 171, 238, 240, 241, 242, 244g, 258, 263,268, 308, 327, 331, 336, 353, 360, 381, 399, 447, 449g, 454, 455, 467, 468, 470, 490, and 515; thin silica coating - 441; odor control - 335g; water treatment - 308, 347, 466, 505, and 514; water treatment system - 58, 142, 205, 270, and 447; painted bodies - 204 and 456; photocatalytic tiles - 222; photocatalyst on paper supports - 451 and 452; photocatalyst on flexible supports - 223; membrane for water purification - 279; regeneration of adsorbents - 24g and 449g; metals removal from water - 245; method for activity measurement - 348; removal of chlorinated compounds from air (includes scrubber) - 309g; removal of air pollutants (includes catalysts on exterior walls of buildings) - 24g, 25g, 141g, 143g, 148g, 215g, 238g, 242g, 258g, 308g, 449g, and 467; method for cleaning solid surface - 332; additive to enhance degradation of plastics in the environment - 352; deodorizing agents - 242 and 401; process for killing cells or disinfection - 93, 205, 354, and 448; methanol synthesis - 353; method for preparing hydrocarbons - 390; ethylene oxidation to preserve fruit and vegetables - 400; pigment additive - 55; slurry reactor configuration - 72; catalyst cleaning - 499; or plasma reactor - 500.

2.7. Companies Active in the Field

Research and development (R&D) and market assessment activity is underway at many companies in the United States but there is little change in the list of companies that have started business lines that use photocatalytic processes?

The assets, in the field of photocatalytic oxidation, of IT Corporation, NEPCCO, and PHOTOX Corporation have been acquired by a new company, Zentox Corporation:

Zentox Corporation
Mr. J. Sandy Reese, President
2140 N.E. 36th Avenue
Ocala, FL 34470
Telephone: (352) 867-9706 Fax: (352) 867-1320
Products: Advanced oxidation, ozone treatment, electrocoagulation, low temperature distillation, and photocatalytic oxidation systems for groundwater remediation, industrial water treatment, and treatment of contaminated vapor streams for industrial, environmental, consumer, and medical applications.

Universal Air Technology, Inc.
Sanjeev K. Hingorani, Ph.D.
Sid Martin Biotechnology Development Institute
12085 Research Drive
Alachua, FL 32615
Telephone: (904)418-0661 Fax: (904) 462-0875

Products: Stand-alone and HVAC duct integrated products for indoor air disinfection using photocatalytic technology.

3.0 Compounds Studied

The tables in this section have the same format as in the first two reports. No compounds have been removed from the tables but new compounds have been added to the second table to incorporate new work. The list of the compounds included in various lists of priority pollutants, air toxics, and the toxic release inventory compiled by the EPA[4] provided the starting point for these tables. Table 1 lists compounds in the EPA categories; Table 2 lists organic compounds that are not in EPA lists; and Table 3 covers inorganic compounds in EPA lists or that have been treated by a photocatalytic process. The inorganic compounds are arranged by element unless a significant number of citations referred to work on a specific ion or compound. Formulas of compounds, when given, are not in the standard format because the software used to prepare the tables does not support subscripts. A few broad categories are included in Table 2 that reflect new applications: bacteria, algae, and virus; coal or carbon; adsorbable organic halides (AOX); color or chemical oxygen demand (COD); and oil or petroleum, for example. In these tables the citation suffix "g" indicates a gas-phase study. The treatability of compounds that have not been tested can usually be inferred from results for related compounds in the tables.

[4]"Notice of the Second Priority List of Hazardous Substances Commonly Found at Super-fund Sites," *Environmental Reporter,* October 28, 1988, 1255-1260.

Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory

Substance	Formula	Halo-gen	Het. Atom	Reference
1,1,1-Trichloroethane	CHCl2CH2Cl	Cl		206,392g
1,1,2,2-Tetrachloroethane	CHCl2CHCl2	Cl		206
1,1,2-Trichloroethane	CHCl2CH2Cl	Cl		206
1,1,2-Trichloro-1,2,2-trifluoroethane	CCl2FCClF2	Cl,F		
1,1 -Dichloroethane	CH3CHCl2	Cl		206
1,1 -Dimethyl hydrazine	(CH3)2NNH2		N	
1,2,3-Trichloropropane	CH2ClCHClCH2Cl	Cl		
1,2,4-Trichlorobenzene	C6H3Cl3	Cl		
1,2,4-Trimethylbenzene	C6H3(CH3)3			
1,2-Butylene oxide	H2COCHCH2CH3			
1,2-Dibromoethane	BrCH2CH2Br	Br		
1,2-Dibromo-3-chloropropane (DBCP)	CH2BrCHBrCH2Cl	Br,Cl		
1,2-Dichlorobenzene	C6H4Cl2	Cl		
1,2-Dichloroethane	ClCH2CH2Cl	Cl		206,257g
1,2-Dichloroethylene	ClHC:CHCl	Cl		206,392g
1,2-Dichloropropane	CH3CHClCH2Cl	Cl		
1,2-Dinitrotoluene	C6H3CH3(NO2)2		N	
1,2-Diphenylhydrazine	C12H12N2		N	
1,2-Trans-dichloroethene	C2H2Cl2	Cl		
1,3,5-Trinitrobenzene	C6H3(NO2)3		N	87,408
1,3-Butadiene	H2C:CHHC:CH2			
1,3-Dichlorobenzene	C6H4Cl	Cl		
1,3-Dichloropropene	CHCl:CHCH2Cl	Cl		
1,4-Dichlorobenzene	C6H4Cl2	Cl		292
1,4-Dioxane	OCH2CH2OCH2CH2			
1-Amino-2-methylanthraquinone	C6H4[C(O)]2C6H2NH2CH3			
1-Bromo-4-phenyoxybenzene	p-BrC6H4OC6H5	Br		
2,2,4-Trimethylpentane	(CH3)3C5H9			
2,3,7,8-Tetrachlorodibenzo-p-dioxin	C12H4C14O2	Cl		
2,4,5-Trichlorophenoxyacetic acid	C6H2Cl3OCH2CO2H	Cl		333
2,4,5-TP acid (silvex)	Cl3C6H2OCH(CH3)COOH	Cl		
2,4,5-Trichlorophenol	C6H2Cl3OH	Cl		26,82,208
2,4,6-Trichlorophenol	C6H2Cl3OH	Cl		82,208
2,4,6-Trinitrotoluene	CH3C6H2(NO2)3			48,87,408,408,409,410,411
2,4 Diaminoanisole	(NH2)2C6H3OCH3		N	
2,4-Dichlorophenoxyacetic acid (2,4-D)	Cl2C6H3OCH2COOH	Cl		81,294,333,364,389,440
2,4-Diaminoanisole sulfate	(NH2)2C6H3OCH3.H2SO4		N	
2,4-Dichlorophenol	Cl2C6H3OH	Cl		82,247,511
2,4-Dimethylphenol	(CH3)2C6H3OH			465

Substance	Formula	Halo-gen	Het. Atom	Reference
2,4-Dinitrophenol	C6H3OH(NO2)2		N	
2,4-Dinitrotoluene	C6H3CH3(NO2)2			87
2,4-Toluene diamine	CH3(NH2)2C6H3		N	
2,6-Dinitrotoluene	C6H3CH3(NO2)2		N	87
2,6-Xylidine	(CH3)2C6H3NH2		N	
2-Acetylaminofluorene	CH3C(O)NHC6H3CH2C6H4	F	N	
2-Aminoanthraquinone	C6H4(CO)2C6H3NH2		N	
2-Butanone	CH3COCH2CH3			
2-Chloroacetophenone	C6H5COCH2Cl	Cl		
2-Chloroethyl vinyl ether	CH2ClCH2OCHCH2	Cl		
2-Chlorophenol	C6H4OHCl	Cl		59,82,267
2-Ethoxyethanol	H3CCH2OCH2CH2CH2OH			
2-Methoxyethanol	MeOCH2CH2OH			
2-Methylnaphthalene	C10H7CH3			
2-Nitrophenol	NO2C6H4OH		N	413,414
2-Nitropropane	CH3CHNO2CH3		N	
2-Pentanone, 4-Methyl	CH3(CH2)2COCH3			
2-Phenylphenol	C6H5C6H4OH			
3,3'-Dichlorobenzidine	C6H3ClNH2C6H3ClNH2	Cl	N	
3,3'-Dimethoxybenzidine	[C6H3(OCH3)NH2]2		N	
3,3'-Dimethylbenzidine (o-Tolidine)	[C6H3(CH3)NH2]2		N	
4,4'-Dichlorodiphenyldichloroethylene	(ClC6H4)2CCCl2	Cl		
4,4'-Diaminodiphenyl ether	NH2(C6H4)2NH2		N	
4,4'-Isopropylidenediphenol	(CH3)2C(C6H4OH)2			
4,4'-Methylenebis(N,N-dimethyl) benzenamine	C17H22N2		N	
4,4'-Methylenedianiline	H2NC6H4CH2C6H4NH2		N	
4,4'-Methylene-bis-(2-chloroaniline)	CH2(C6H4ClNH2)2	Cl	N	
4,4'-Thiodianiline	C12H12N2S		S,N	
4,6-Dinitro-o-cresol	CH3C6H2(NO2)2OH		N	
4,6-Dinitro-2-methylphenol	C7H6N2O5		N	
4-Aminoazobenzene	C6H5NNC6H4NH2		N	
4-Aminobiphenyl	C6H5C6H4NH2		N	
4-Chloroaniline	ClC6H4NH2	Cl		
4-Chlorophenyl phenyl ether	p-ClC6H4OC6H5	Cl		
4-Dimethylaminoazobenzene	(CH3)2C6H3NH2		N	
4-Methylphenol	p-CH3C6H4OH			
4-Nitrobiphenyl	C6H5C6H4NO2		N	
4-Nitrophenol	NO2C6H4OH		N	85,86,299,413,414
5-Nitro-o-anisidine	NO2C6H3(NH2)(OCH3)		N	
Acenaphthene	C10H6(CH2)2			
Acenaphthylene	C12H8			
Acetaldehyde	CH3CHO			158,305g,306g,343g,344g,

Substance	Formula	Halo-gen	Het. Atom	Reference
				397g,405g,432g,450g
Acetamide	CH3CNOH2		N	293
Acetone	CH3COCH3			282g,329g
Acetonitrile	CH3CN		N	282g,283,283g,284g
Acetophenone	CH3C(O)C6H5			
Acrolein	CH2CHCHO			
Acrylamide	CH2CHCONH2		N	
Acrylic acid	H2C:CHCOOH			
Acrylonitrile	H2C:CHCN		N	
Aldrin	C12H8Cl6	Cl		
Ally1 chloride	H2C=CHCH2Cl	Cl		
Aniline	C6H5NH2		N	
Anthracene	C6H4(CH)2C6H4			134
Aramite	(CH3)3CC6H4OCH2CH(CH3)-SO3C2H4Cl	Cl	S	
Atrazine	C18H14ClN5	Cl	N	41,42,313,383
Benzal chloride	C6H5CHCl2	Cl		
Benzamide	C6H5CONH2		N	81
Benzene	C6H6			140g,224g,282g,429
Benzidine	NH2(C6H4)2NH2		N	
Benzoic acid	C6H5COOH			160
Benzoic trichloride	C6H5CCl3	Cl		
Benzoyl chloride	C6H5COCl	Cl		
Benzoyl peroxide	(C6H5CO)2O2			
Benzo(a)anthracene	C22H14			
Benzo(a)pyrene	C20H12			
Benzo(b)fluoranthene	C20H12			
Benzo(g,h,i) perylene	C22H12			
Benzyl alcohol	C6H5CH2OH			
Benzyl chloride	C6H5CH2Cl	Cl		
BHC (Benzenehexachloride)	C6H6Cl6	Cl		
Biphenyl	C6H5C6H5			
Bis(2-Chloroethoxy)methane	CH2(2-ClC2H5O)2	Cl		
Bis(2-chloroethyl) ether	ClCH2CH2OCH2CH2Cl	Cl		
Bis(2-chloro-1-methylethyl) ether	[ClCH2(CH3)CH]2O	Cl		
Bis(2-ethylhexyl) adipate	(C7H13)2C4H8(CO2)2			
Bis(2-ethylhexyl)phthalate	(C4H9CH(CH2))2OOC			
Bis(chloromethyl)ether	(CH2Cl)O(CH2Cl)	Cl		
Bromochloromethane	BrCH2Cl	Br,Cl		
Bromodichloromethane	CHCl2Br	Cl,Br		
Bromoethane	C2H5Br	Br		
Bromoform (Tribromomethane)	CHBr3	Br		43
Bromomethane (Methyl bromide)	CH3Br	Br		

Substance	Formula	Halo-gen	Het. Atom	Reference
Butyl acrylate	CH2:CHCOOC4H9			
Butylbenzyl phthalate	C4H9OOCC6H4COOC7H7			
Butyraldehyde	CH3(CH2)2CHO			
Calcium cyanamide	NCNCa		N	
Caprolactam	CH2(CH2)4NHCO		N	
Captan (N-Trichloromethylmercapto-tetrahydrophthalimide)	C9H8Cl3NO2S	Cl	N,S	
Carbaryl [1 -Naphthalenol, methylcarbamate]	C 1 0H7OOCNHCH3		N	
Carbon disulfide	cs2		S	
Carbon tetrachloride	cc14	Cl		206,282g,404g,513
Carbonyl sulfide	c o s			
Catechol	C6H4(OH)2			302
Chloramben (Benzoic acid, 3-amino-2, 5-dichloro-)	C6H(CO2H)(NH2)Cl2	Cl	N	
Chlordane	C10H6Cl8	Cl		
Chloroacetic acid	CH2ClCOOH	Cl		101
Chlorobenzene	C6H5Cl	Cl		
Chlorobenzilate (Benzeneacetic acid, 4-chloro-alpha-(4-chlorophenyl)-)	(C6H4Cl)2C(OH)COOC2H5	Cl		
Chlorodibenzodioxins, various	Cl 2O2H8-xClx	Cl		
Chlorodibenzofurans	Cl 2OH8-xClx	Cl		
Chlorodibromomethane	ClBr2CH	Br,Cl		
Chlorodifluoromethane	CHClF2	Cl,F		
Chloroethane	C2H5Cl	Cl		
Chloroform	CHC13	Cl		206,276,282g,300,301,404g
Chloromethane	CH3Cl	Cl		
Chloromethyl methyl ether	C2H5ClO	Cl		
Chloroprene	H2C:CHCCl:CH2	Cl		
Chlorothalonil (1,3-Benzendedicarboni-trile, 2,4,5,6-tetrachloro-)	C6Cl4(CN)2		N	254
Chrysene	C18H12			
cis- 1 ,2-Dichloroethylene	ClHC:CHCl	Cl		
cis- 1,3-Dichloropropene	CHCl:CHCH2Cl	Cl		
o-,m-,p-Cresols	CH3C6H4OH			
Cumene	C6H5CH(CH3)2			
Cumene hydroperoxide	C6H5C(CH3)2OOH			
Cupferron (Benzeneamine, N-hydroxy-N-nitrose, ammonium salt)	C6H5N(NO)ONH4		N	
Cyclohexane	C6H12			323,413
Cyclohexanone	C6H10O			
Cyclonite (RDX)	(CH2)4(NNO2)4		N	48
Decabromodiphenyl oxide	(C6Br5)2O	Br		

Substance	Formula	Halo-gen	Het. Atom	Reference
Dialate [Carbamothioic acid, bis (1 -methylethyl)-, S-(2,3-dichloro-2-propenyl) ester]	(CH3)2CH]2NCOSCH2CClCHCl	Cl	N,S	
Diaminotoluene (mixed isomers)	CH3C6H3(NH2)2		N	
Diazomethane	CH2N2		N	
Dibenzofuran	C12H8O			
Dibenzo(a,h)anthracene	C22H14			
Dibromochloropropane	CH2BrCHBrCH2Cl	Br,Cl		
Dibutyl phthalate	C6H4(COOC4H9)2			
Dichlorobenzene (mixed isomers)	C6H4Cl2	Cl		
Dichlorobromomethane	CHBrCl2	Cl,Br		
Dichlorodifluoromethane	CCl2F2	Cl,F		
Dichlorvos (Phosphoric acid, 2 dichloroethenyl dimethyl ester)	(CH3O)2P(O)OCH:CCl2	Cl	P	427,428,517
Dicofol ,4,4'-Dichloro-alpha-trichloro-methylbenzhydrol	C14H9Cl5O	Cl		
Dieldrin/aldrin	C12H10OPCl6	Cl	P	
Diepoxybutane .	C4H6O2			
Diethanolamine	(HOCH2CH2)2NH		N	
Diethyl phthalate	C6H4(CO2C2H5)2			
Diethyl sulfate	(C2H5)2SO4		S	
Dimethyl aminoazobenzene	C6H5NNC6H4N(CH3)2		N	
Dimethyl for-man-tide (DMF)	HCON(CH3)2		N	293
Dimethyl phthalate	C6H4(COOCH3)2			
Dimethyl sulfate	(CH3)2SO4		S	
Dimethylcarbamyl chloride	(CH3)2NCOCl	Cl	N	
Disulfoton	(C2H5O)2P(S)SCH2CH2SCH2CH3		P,S	
Di-n-butyl phthalate	C6H4(COOC4H9)2			
Di-n-octyl phthalate	C6H4(CO2)(n-C8H17)2			
Di-(2-ethylhexy) phtbalate (DEHP)	C6H4[COOCH2CH(C2H5)C4H9]2			
Endosulfan	C9H6Cl603S	Cl		
Endrin aldehyde/ endrin	(C12H8OCl6)	Cl		
Epichlorohydrin	CH2OCHCH2Cl	Cl		
Ethyl acrylate	CH2:CHCOOC2H5			
Ethyl chloroformate	ClCOOC2H5	Cl		
Ethylbenzene	C6H5C2H5			
Ethylene	H2C:CH2			493g
Ethylene glycol	CH2OHCH2OH			
Ethylene oxide	CH2CH2O			
Ethylene thiourea	NHCH2CH2NHCS		N,S	
Ethyleneimine (Aziridine)	CH2NHCH2		N	
Fluometuron [Urea, N,N-dimethyl-N'-[3-(trifluoromethyl)phenyl]-]	C10H11F3N2O	F	N	

Substance	Formula	Halo-gen	Het. Atom	Reference
Fluoranthene	C16H10			
Fluorene	C6H4CH2C6H4			
Fluorotrichloromethane	CCl3F	Cl,F		
Formaldehyde	HCHO			344g,405g
Heptachlor/heptachlor epoxide	C10H7Cl7	Cl		
Heptane	CH3(CH2)5CH3			
Hexachlorobenzene	C6Cl6	Cl		
Hexachlorobutadiene	Cl2C:CClCCl:CCl2	Cl		
Hexachlorocyclopentadiene	C5Cl6	Cl		
Hexachloroethane	Cl3CCCl3	Cl		
Hexachloronaphthalene	C10H2Cl6	Cl		
Hexamethylphosphoramide	[(N(CH3)2]3PO		P,N	
Hexamethylene- 1,6-diisocyanate	OCN(CH2)6NCO		N	
Hexane	CH3(CH2)4CH3			
Hydroquinone	C6H4(OH)2			57
Indeno(1,2,3-cd)pyrene	C22H12			
Isophorone	C(O)CHC(CH3)CH2C(CH3)2CH2			
Isopropyl alcohol	(CH3)2CHOH			55,101,207,228,271,274g,282g 339,374,413
Lindane (gamma-BenzenehexacNoride)	C6H6Cl6	Cl		161,280
Malachite Green	C23H25ClN2	Cl	N	
Malathion	(CH3O)2P(S)SCH(CO2C2H5)-CH2CO2C2H5		P,S	
Maleic anhydride	HC:CHC(O)OC(O)			
Maneb (Carbamodithioic acid, 1,2-ethanediylbis-,manga.nese complex)	SSCNCH2CH2NHCSS)Mn		N,S	
Mechlorethamine	CH3N(CH2CH2Cl)2	Cl	N	
Melamine	H2NCNC(NH2)NC(NH2)N		N	
Methanol	CH3OH			207,228,274g,282g,283,283g, 344g,374,376,378,380,482, 483,510
Methoxychlor	Cl3CCH(C6H4OCH3)2	Cl		
Methyl acrylate	CH2:CHCOOCH3			
Methyl butyl ketone	CH3COC4H9			
Methyl ethyl ketone	CH3COCH2CH3			513
Methyl iodide	CH3I	I		
Methyl isobutyl ketone	(CH3)2CHCOCH3			
Methyl isocyanate	CH3NCO		N	
Methyl methacrylate	CH2:C(CH3)COOCH3			
Methyl tert-butyl ether	(CH3)3COCH			
Methylene bromide	CH2Br2	Br		
Methylene chloride	CH2Cl2	Cl		206,282g,283,283g,404g
Methylenebis(phenylisocyanate) (MBI)	CH2(C6H4NCO)2		N	

Substance	Formula	Halo-gen	Het. Atom	Reference
Methylhydrazine	CH3NHNH2		N	
Michler's ketone	CO[C6H4N(CH3)2]2		N	
Mirex	C10Cl12	Cl		
Mustard gas	S(CH3CH2Cl)2	Cl	S	
m-Nitroaniline	NO2C6H4NH2		N	
N,N-Dimethylaniline	C6H5N(CH3)2		N	
Naphthalene	C10H8			158,160
Naphthylamine (alpha-, beta-)	C10H7NH2		N	
Nitrilotriacetic acid	N(CH2COOH)3		N	
Nitrobenzene	C6H5NO2		N	81,87,356
Nitrofen [Benzene, 2,4-dichloro-1-(4-nitrophenoxy)-]	C12H7C12NO3	Cl	N	
Nitrogen mustard (2-Chloro-N-(2-cNoroethyl)-N-methylethanamine)	(ClCH2CH2)2NCH3	Cl	N	
Nitroglycerin	CH2NO3CHNO3CH2NO3		N	329g
Nitrophenol	NO2C6H4OH		N	
n-Butyl alcohol	CH3(CH2)2CH2OH			
n-Dioctyl phthalate	(C8H17OOC)2C6H4			
N-Nitrosodiethylamine	C4H10N2O		N	
N-Nitrosodimethylamine	(CH3)2N2O		N	
N-Nitrosodiphenylamine	(C6H5)2NNO		N	
N-Nitrosodi-n-butylamine	ONN(n-C4H9)2		N	
N-Nitrosodi-n-propylamine	ONN(n-C3H7)2		N	
N-Nitrosomethylvinylamine	ONN(CH3)(C2H3)		N	
N-Nitrosomorpholine	ONNC4H8O		N	
N-Nitrosonomicotine			N	
N-Nitrosopiperidine	C5H10NHNO		N	
N-Nitroso-N-ethylurea	C(O)(NH2)N(NO)C2H5		N	
N-Nitroso-N-methylurea	C(O)(NH2)N(NO)(CH3)		N	
n-Pentane	CH3(CH2)3CH3			
Octachloronaphthalene	C10Cl8	Cl		
Octane	CH3(CH2)6CH3			
Oxirane	H2COCH2			
o-Anisidine	CH3OC6H4NH2		N	
o-Anisidine hydrochloride	CH3OC6H4NH2.HCl	Cl	N	
o-Nitroaniline	NO2C6H4NH2		N	
o-Toluidine	CH3C6H4NH2		N	
o-Toluidine hydrochloride	CH3C6H4NH2.HCl	Cl		
Parathion (DNTP)	(C2H5O)2P(S)OC6H4NO2		P,S	427,428,517
PCBs (Aroclor 1260,1254,1248, and 1242)	C12ClxH10-x	Cl		70,209,351
Pentachlorobenzene	C6Cl5H	Cl		
Pentachlorophenol	C6Cl5OH	Cl		208,280,359
Peracetic acid	CH3COOOH			

Substance	Formula	Halo-gen	Het. Atom	Reference
Phenanthrene	C4H10			
Phenol	C6H5OH			28,29,56,57,67,68,79,91,102, 276,311,318,319,349,382,413, 414,424,446,464,488,492
Phenol,2-methyl	CH3C6H4OH			
Phosgene	COCl2	Cl		225g,328g
Phthalic anhydride	C6H4(CO)2O			
Picric acid	C6H2(NO2)3OH		N	
Polybrominatedbiphenyls	C12BrxH10-x	Br,Cl		
Propane sultone	C3H6SO2		S	
Propionaldehyde	C2H5CHO			458g
Propiolactone, beta-	OCH2CH2CO			
Propoxur [Phenol, 2-(1-methylethoxy)-methylcarbamate]	C1		N	294
Propylene oxide	CH2OCHCH3			
Propylene (Propene)	CH3CH:CH2			
Propyleneimine	CH3HCNHCH2		N	
Pyrene	C16H10			
p-Anisidine	CH3OC6H4NH2		N	10
p-Chloro-m-cresol	C6H3CH3OHCl	Cl		
p-Cresidine	CH3C6H3(NH2)OCH3		N	
p-Nitrosodiphenylamine	(C6H5)2NNO		N	
p-Phenylenediamine	C6H4(NH2)2		N	
Quinoline	C9H7N		N	61
Quinone	C6H4O2			
Quintozene (Pentachloronitrobenzene)	C6Cl5NO2	Cl	N	
Safrole	C3H5C6H3O2CH2			
set-Butyl alcohol	CH3CH2CHOHCH3			
Sevin (carbaryl)	C			
Sodium Alizarinsulfonate	SO3C6H3(CO)2C6H2(OH)2Na		N.S	
Styrene	C6H5CH:CH2			
Styrene oxide	C6H5CHOCH2			
Terephthalic acid	C6H4(COOH)2			
tert-Butyl alcohol	(CH3)3COH			282g
tert-Butylformate	(CH3)3COC(O)H			
Tetrachloroethylene	Cl2C:CCl2	Cl		162,206,282g,392g,463,504g,
Tetrachlorvinphos	C	Cl	P	248
Tetrahydrofuran	CH2CH2CH2CH2O			
Thioacetamide	CH3CSNH2		S,N	
Thiourea	(NH2)2CS		S,N	

Substance	Formula	Halo-gen	Het. Atom	Reference
Toluene	C6H5CH3			49g,53g,60g,224g,340,404g,
Toluene diisocyanate	CH3C6H3(NCO)2		N	
Total xylenes	C6H4(CH3)2			
Toxaphene	C10H10Cl8	Cl		
Triaziquone	C12H13N3O2		N	
Trichlorfon	(CH3O)2P(O)CH(OH)CCl3	Cl	P	
Trichloroethylene	CHCl:CCl2	Cl		39g,41,42,206,213g,225g,255g 257g,275,276,282g,283,283g, 292,328g,392g,404g,463, 493g,504g,505,5 13
Triethylamine	N(C2H5)3		N	
Trifluralin	F3C(NO2)2C6H2N(C3H7)2	F	N	
Trinitrophenylmethylnitramine	(NO2)3C6H2N(NO2)CH3		N	
Tris(2,3-dibromopropyl) phosphate	(CH2BrCHBrCH2O)3PO	Br	P	
Urethane (ethyl carbamate)	CO(NH2)OC2H5		N	
Vinyl acetate	CH3COOCH:CH2			
Vinyl bromide	CH2CHBr	Br		
Vinyl chloride	CH2:CHCl	Cl		
Vinylidene chloride	CH2:CCl2	Cl		
Xylene (mixed isomers)	C6H4(CH3)2			49g,322g,496
Zineb	Zn(CS2NHCH2)2		S,N	

Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Halo-gen	Het. Atom	Reference
1,1,1,2-Tetrachloroethane	Cl3CCH2Cl	Cl		
1,3,5,7-Tetramethylcyclotertrasiloxane			Si	441,442,443
1,1,1-Trifluoro-2,2,2-trichloroethane	F3CCCL3	F,Cl		282g
1,1,1-TrifluorobromocNoroethane	C2HF3ClBr	F		
1,1,3-Trichloropropene	Cl2CCHCH2Cl	Cl		404g
1,1-Difluoro-1,2,2-trichloroethane	ClF2CCHCl2	F,Cl		
1,1-Difluoro-1,2-dichloroethane	FClCCClH2	F,Cl		
1,1-Difluoroethylene	CH2CF2	F		
1,1-Dimethyl-3-phenylurea	C6H5NHC(O)N(CH3)2		N	393
1,1-Diphenylethylene	(C6H5)CCH2			125
1,2-Dimethoxybenzene	(CH3O)2C6H4			8,9,12,373
1,2-Bis(2-chloroethoxy)ethane	(ClC2H4)2C2H4	Cl		
1,2-, 1,3-, or 1,4-Dinitrobenzene	(NO2)2C6H4		N	87
1,2,4,5-Tetramethylbenzene	(CH3)4C6H2			
1,3-Dimethoxybenzene	(CH3O)2C6H4			12
1,3-Diphenylisobenzofuran	(C6H5)2C6H2OC6H4			237
1,4-Dinitrobenzene	(NO2)C6H4		N	296
1,4-Napthoquinone	C10H6O2			160
1,4-Pentanediole	CH3CH(OH)(CH2)3OH			133
1-Benzylnicotinamide	(C6H5)CH2(C5H3N)C(O)NH2		N	
1-Bromodecane	BrC	Br		
1-Bromododecane	BrC12H25	Br		
1-Butanol	CH3(CH2)3OH			101,374
1-Dodecanol	CH3(CH2)			
1-Hexene	C6H12			
1-(Methoxyphenyl)-2-propanol	(CH3OC6H4)(CH3)CHOH			
1-Phenylethanol	CH3CH(C6H5)OH			485
1-Propanol	n-C3H7OH			101,374,376,378,380
1-Nitronaphthalene	C10H7NO2		N	296
2,2-Dichloropropionic acid	CH3CCl2CO2H	Cl		59
2,3-, 2,4- or 3,4-Difluorophenol	F2C6H3OH	F		
Tris-(2,4-dichlorophenoxy)ethyl-phosphite	C2H5P[OC6H3Cl2]3	Cl	P	
2,6-Dichlorophenol	C6H3Cl2OH	Cl		52.315
2,7-Dichlorodibenzo-p-dioxin	Cl2C12H6O2	Cl		
2-, 3-, or 4-Chlorobenzoic acid				80
2-, 3-, or 4-Fluorophenol	FC6H4OH	F		
2-,3-, or 4-Nitrotoluene	N02C6H4CH3		N	87

Substance	Formula	Halo-gen	Het. Atom	Reference
2,3-Benzofuran	C8H6O			11
2,3- and 2,5-Dichlorophenol	Cl2C6H3OH	Cl		82,208,291,315
2,3-Dihydrobenzofuran	C8H8O			377
2,4-Dimethoxybenzene	(CH3O)2C6H4			8,12
2,5-Dinitrophenol	(NO2)2C6H3OH	Cl	N	
2,6-Dichloroindophenol	C8H2N(OH)Cl2			
2,5-Furandimethanol	C4H2O(CH2OH)2			
2,4,6-Trinitrobenzoic acid	(NO2)3C6H2CO2H		N	408
2-Chloroaniline	ClC6H4NH2	Cl	N	
2-Chlorobiphenyl	ClC6H4C6H5	Cl		513
2-Chlorodibenzo-p-dioxin	ClC12H7O2	Cl		
2-Chloroethylethylsulfide	(ClC2H4)C2H5S	Cl	S	130
2-Chloroethylmethylsulfide	(ClC2H4)CH3S	Cl	S	130
2-Coumaranone	C8H6O2			11
2-Furoic Acid	(CH2)3CHOCO2H			
2-Hydroxypyridine	HOC5H4N		N	
2-Hydroxytetrahydropyran	HOC5H9O			
2-Methyl- 1 ,4-hydroquinone	CH3C6H3(OH)2			100
2-Naphthol	C10H7OH			160
2-Tolualdehyde	CH3C6H4CHO			60g
2,2'-Dihydroxybiphenyl	C12H8(OH)2			54
3,3,3-Trifluoropropene	CH2CHCF3			
3,3'-Dichlorobiphenyl	(ClC6H4)2	Cl		
3,4,5-Trichlorophenol	Cl3C6H2OH	Cl		82
3,4-Dichlorophenol	3,4-Cl2C6H3OH	Cl		82
3-Aminoanisole	CH3OC6H4NH3		N	10
3-Chloroanisole	CH3OC6H4Cl	Cl		10
3-Chlorophenol	m-ClC6H4OH	Cl		59,81,82
3-Chlorosalicylic acid	C7H5ClO3	Cl		
3-Chlorotoluene	CH3C6H4Cl	Cl		496
3-Fluoroanisole	CH3OC6H4F	F		10
3-Fluorotoluene	CH3C6H4F	F		496
3-hydroxyanisole	CH3OC6H4OH			10
3-Methyl-2-oxobutanoic acid	(CH3)CHC(O)CO2H			486
3-Nitroanisole	CH3OC6H4NO2			10
3-Nitrotoluene	CH3C6H4NO2	N		496
4-Acetobenzaldehyde	CH3C(O)C6H4CHO			228
4-Aminoanisole	CH3OC6H4NH2		N	10
4-Chloroanisole	CH3OC6H4Cl	Cl		10
4-Chlorotoluene	CH3C6H4Cl	Cl		496
4-Fluoroanisole	CH3OC6H4F	F		10
4-Fluorotoluene	CH3C6H4F	F		496
4-Hydroxyanisole	CH3OC6H4OH			10

Substance	Formula	Halo-gen	Het. Atom	Reference
4-Nitroanisole	CH3OC6H4NO2		N	10
4-Bromophenol	BrC6H4OH	Br		
4-t-Butyltoluene	p-(t-C4H9)C6H4CH3			496
4-Chloro-3-nitro-benzotrifluoride	C6HCl(NO2)F3	F,Cl	N	
4-Chlorophenol	ClC6H4OH	Cl		59,81,82,85,157g,303,358,359, 434,435,478,485,487,498
4-Chlorophenylisocyanate	ClC6H4NCO	Cl	N	
4-Fluorophenol	FC6H4OH	F		
4-Hydroxyacetophenone	HOC6H4C(O)CH3			
4-Hydroxybenzyl Alcohol	p-HO(C6H4)CH2OH			
4-Hydroxybiphenyl	C12H9OH			54
4-Iodophenol	IC6H4OH			
4-Methoxybenzyl(3-phenylpropyl)-ether	CH3OC6H4CH2O(CH2)3C6H5			377
4-Methoxyphenol	CH3C6H4OH			
4-Nitroaniline	NO2C6H4NH2		N	
4-Nitrobenzaldehyde	NO2C6H4CHO		N	228
4-Nitrocatechol	(NO2)C6H3(OH)2		N	
4-Nitrophenylethylphosphinate	(NO2)C6H4(C2H5)PO2		N,P	
4-Nitrophenylisopropylphosphinate	(NO2C6H5)(C3H7)HPO3		N,P	
4-Nitrophenyldiethylphosphate	(NO2C6H5)(C2H5)2PO4		N,P	
4-Nitrotoluene	CH3C6H4NO2		N	296,496
4-Phenylbutylamine	C6H5(CH2)4NH2		N	128
4-Picoline	CH3C5H4N		N	340
4-Thiophenyl- 1 -butanol .	C6H5S(CH2)4OH		S	
4-Trifluoromethylphenol	CF3C6H4OH	F		
4,4'-Dihydroxybiphenyl	C12H8(OH)2			54
5-Bromouracil	BrC4H(NH)2(O)2	Br	N	5
5-Chlorouracil	ClC4H(NH)2(O)2	Cl	N	5
5-Fluorouracil	FC4H(NH)2(O)2	F		5
5-Hydroxypentanoic acid	HO(CH2)4CO2H			
6-Methoxytetralin	CH3OC8H5O			377
5-Methylresorcinol	CH3C6H5O2			382
12-Nitrododecanoic acid	NO2C 11 H22CO2H		N	296
12-phenyldodecanesulfonate, sodium salt	C6H5(CH2)12SO3H			
Acenapthane	C10H16(CH2)2			
Acetic Acid	CH3CO2H			90,239,344g,405g
Acetophenone	CH3COC6H5			160,485,498
Acetylene	C2H2			
Acid orange 7	Na,O3SC6H4N2C10H6OH		N,S	477,478,479,481
Adipic acid	C5H11CO2H			
Aldicarb	CH3SC(CH3)2CHN(O)C(O) NHCH3		N,S	

Substance	Formula	Halo-gen	Het. Atom	Reference
p-Alkylphenol (various)	R(C6H4)OH			
Ally1 alcohol	C3H5OH			
Alochlor				
p-Aminophenol	NH2(C6H4)OH			
Anthraquinone-Zsulfonic acid	HO3SC14H7O2			
AOX or Haloform Precursors				
Asulam				304
Azobenzenes (various)	XC6H4NNC6H4X			
Azobisformamidoacetic acid				
Bacteria/Algae/Virus				36,147,167,273,281,305,307, 330g.347,430,473,489
Basagran				256
Benzaldehyde	C6H5C(O)H			160,228
Benzophenone	(C6H5)2CO			
Benzoquinone	C6H4O2			
Benzyldodecyldimethylamonium chloride	(C6H5CH2)(C12H25)(CH3)2N,Cl	Cl		
Benzyl ethers	C6H5CH2O-R R=CH3, n-C6H13, t-C4H9, (CH2)3C6H5, CH2C6H5			377
Benzyltetradecyldimethylamonium chloride	(C6H5CH2)(C14H27)(CH3)2N,Cl	Cl		
Biomass				
Biphthalate	(C6H4)(CO2H)CO2)(-1)			
Bromobenzene	BrC6H5	Br		485
Butane	C4H10			
But- 1 -ene	CH2CHCH2CH3			19
But-2-ene, trans	CH3CHCHCH3			
Butylamine	n-C4H7NH2		N	62
tButylazine			N	415
n-Butyltin chloride	C4H9SnCl3		Sn	338
But- 1 -yne	CHCCH2CH3			19
Butyric acid	C3H7CO2H			
Carbetamide			N	361
Carbon dioxide (reduction)	CO2			18,20,31,156,271,298,320g, 466,503
Carbon monoxide	CO			175g, 182g, 186g,188g, 189g, 474
Carbon tetrabromide	CBr4	Br		243g,286g,287g
Catechol	C6H4(OH)2			57
C 12-Betaine	(C12H25)(CH3)2NCO2		N	202,203
C 12-Amidobetaine				202

Substance	Formula	Halo-gen	Het. Atom	Reference
Cetyldimethylbenzylamonium chloride	CH3(CH2)15(CH3)2-(C6H5CH2)N,Cl		N	
Cetylpyridinium chloride	N-[CH3(CH2)15](C5H5N),Cl		N	92,334
Cetyltrimethylammonium bromide	CH3(CH2)15(CH3)3N,Cl		N	202
Chloroacetaldehyde	CH2ClC(O)H	Cl		
Chlorobenzoic acids, o-, m-, or p-	Cl(C6H4)CO2H	Cl		
Chlorofluorocarbons, various		F,C		
Chloral hydrate	Cl3CO(OH)2	Cl		
Chloranil, o- and p-	C6Cl4O2	Cl		
Chloroethylammonium chloride	ClH3N,Cl	Cl	N	
Chlorpyrifos		Cl	S,N	
Ciba Orange RI				
Citric acid	HO2CCH2C(OH)(CO2H)CH2CO2I			48,101
Coal or Carbon				
Color and/or COD (in wastewater)				34
Congo Red	C32H22O6N6S2Na2			
Cresol violet	C16H8NO(NH2),Cl		N	
Creosote phenolics				
Cyanuric acid	C3N3(OH)3		N	
Cyclododecanol	C12H23OH			
Cyclohexanedicarboxylic acids	C6H10(CO2H)2			
Cyclohexanol	C6H11OH			323
Cyclohexene	C6H10			
Cyclohexene oxide	C6H10O			
Cyclooctatetraene .	C8H8			135
Cyclopentane	C5H10			73g,74g,370g
Cyclophosphamide	OPONHC3H6[N(C2H4Cl)2]		P,N	
Cynnamyl alcohol	C6H4C2H2OH			
DDT	(ClC6H4)2CHCCl3	Cl		333
Decalin	C10H18			
Decarnethyltetrasiloxane	(CH3)10Si4O3		Si	
Decanoic acid	C9H19CO2H			
Decanol	HOC10H21			
Desipramine	(C6H4)2(CH2)2N(CH2)3NHCH3			
Diazinon	[(CH3)2CHC4N2H(CH3)O]-PS(OC2H5)2		N,P,S	304
Dibenzo-p-dioxines, various	XnC12H(8-n)O2	Cl		516
Dibromomethane	CH2Br2	Br		
Dimethylacetamide	CH3C(O)N(CH3)2		N	293
Dichloroacetic acid	Cl2CHCO2H	Cl		51,253,285,345,358
Dichloroacetyl Chloride	Cl2CHCOCl	Cl		225g,328g
Dimethylamine	(CH3)2NH		N	
Dimethylphenols (Xylenols)	(CH3)2C6H3OH			465

Substance	Formula	Halo-gen	Het. Atom	Reference
Dimethylsulfide	CH3)2S		S	
Dimethyl-2,2-dichlorovinyl phosphate	CH3)2(Cl2CCH)PO4	Cl	P	
Diphenylacetylene	C6H5)2C2			207
Diphenylmethane	C6H5)2CH2			
Diphenylsulfide	(C6H5)2S		S	
Direct blue 1	(Na,O3S)C16H6(NH2)(OH)-(OCH3)N2]2		N,S	
Diquat				256
Disinfection by-products				394,514
Disperse red 74				509
Diuron	C6H3Cl2NHC(O)N(CH3)2		N	256
Dodecane	C12H26			
Dodecyl sulfate	(C12H25)2SO4			
Dodecylbenzenesulfonate	12H25)C6H4SO3(-1)		S	92,202,334
Dodecyldecaoxyethylenephosphates			P	
Dodecylpyridinium chloride	12H25)C5H5NH,Cl	Cl		12,203
Doxycycline				
Dyes, unidentified				96,226,227
Eosin				
Ethambutol			N	
Ethane	2H6			
Ethanol	2H5OH			2,101,228,264,274g,329g, 74,405g
Ethylacetate	H3CO2C2H5			
Ethylenediaminetetraacetic acid	)2CCH2)4N2C2H4			8,101,342,484
2-, 3-, or 4-Ethylphenol	C2H5)C6H4OH			
Fenitrothion	9H12NO5PS		SP	49
Fluorescein	20H 1205			
Folicur			N	
Formamide	IC(O)NH2		N	'93
Formic Acid	ICO2H			8,90,101,163,214,251,252, 44g,416,444
Fullerenes	60,C70, and C84			236
Fulvic acid				
Glucose	6H11O6			18
Glycerol	3H5(OH)3			
HCFC or HFC		Cl,F		
Heparin				
Heptanal	6H13CHO			228
Hexafluorobenzene	6F6	F		
Hexafluoropropene	F2CFCF3	F		
HMX	(CH2)4(NNO2)4		N	48
Hexanol	6H13OH			

Substance	Formula	Halo-gen	Het. Atom	Reference
Humic Acids				34,37,480
Hydroxybenzoic acid (various)	HOC6H4(OH)CO2H			
Hydroxycarboxylic acids, alpha	RCH(OH)CO2H			
Hydroxyethylcellulose				
Imidazole	C3H4N2		N	346
Indole	C8H6NH		N	
Isobutane	C4H10			88g
Isobutanol	CH3CH(CH3)CH2OH			
Isobutene	C4H8			
Isobutyric Acid	CH3CH(CH3)CO2H			101
Isonicotinaldehyde	C5H4NCHO		N	228
Isoprene	CH2C(CH3)CHCH2			
Isosorbide dinitrate	C6O2H8(ONO2)2		N	
Iso-octane	(CH3)2CH(CH2)4CH3			282g
L-Lysine	NH2(CH2)4CH(NH2)CO2H			101
Lactic acid	C3H6O3			
Landfill leachate				35
Kraft lignin				
Malachite green oxalate	(C6H5)[C6H4N(CH3)2][C6H4N-(CH3)2]C,(C2O4H)2.H2C2O4		N	153,154
Maleic acid	HO2CCHCHCO2H			
Malic acid	HO2CCH2CH(OH)CO2H			97
Malonic acid	CH2(CO2H)2			219
Methane	CH4			
Methanethiol	CH3SH		S	450g
Methylcyclohexane	CH3C6H			
Methyl orange	Na,O3SC6H4N2C6H4N(CH3)2		N,S	
alpha-Methylstyrene	C6H5(CH3)CCH2			396
Methyl viologen	(CH3C5H4N)2,Cl2	Cl	N	
Methylene blue	(CH3)2NC6H3NSC6H3N(CH3)2,(	Cl	N,S	26,272
Methylvinylketone	CH3COC2H3			
Mixed waste				418
Molasses				402
Monocrotophos			P	428,428,517
Monuron	ClC6H4NHCON(CH3)2	Cl	N	27
Morpholine	C4H8ONH		N	90
m-Phenoxytoluene	m-C6H5O-C6H4CH3			
N-Benzyldiphenylamine	(C6H5CH2)(C6H5)2N		N	108,129
N-Dodecanoyl-N-(2-hydroxyethyl)amide	CH3(CH2)10C(O)NH(CH2)2OH		N	202,203
N-Dodecanoyl-N,N-bis(2-hydroxyethyl)-amide	CH3(CH2)10C(O)N[(CH2)2OH]2		N	203
N-Hydroxysuccinimide	C2H4(C(O))2NOH		N	346
N,N,N',N'-Tetraethyloxonine			N	

Substance	Formula	Halo-gen	Het. Atom	Reference
Naphthol	C10H7OH			
Naphthol blue black	(C6H5N2)C12H2(OH)(NH2)-(SO3Na)2		N,S	337,475,477
Nicotine	C5H4NC4H7NCH3		N	305
Nile Blue A	C16NO(NH2)N(C2H5)2,SO4		N,S	
Nitrocellulose			N	
p-Nitrotoluenesulfonic acid	(CH3)(NO2)C6H3SO3H		N,S	
Nitrotoluene, various	NO2C6H4CH3		N	
Nonylphenolethoxylate	C9H17C6H4OC2H5			
n-Octanol	C8H17OH			436,502
octanal	C7H15CHO			228
Octaphenylcyclotetrasiloxane	(C6H5)8(SiO2)4		Si	314
Oil/Petroleum				170
Oxalic acid	C2O4H2			101,159,200,342,358,423
PCB -polyhydroxy		Cl		315
Pendimethalin				195
Pentaethyleneglycol n-dodecyl ether	(HO)(CH2CH2O)5(C12H23)			202
Pentafluorophenol	C6F5OH			
n-Pentyl amine	n-C5H 11 NH2		N	
Permethrin				
Pesticides - unspecified				221
Phenacylstyrylthioether	PhCH2SCH2C(C6H5)CH2		S	138
Phenosafranin	C6H5N2C12H4(NH2(CH3)2		N	
p-Phenylenediamine	H2NC6H4NH2		N	288,289,291
Phenylmercaptotetrazole				484
Phorate	(C2H5O)P(S)SCH2SC2H5		P,S	427,428,5 17
Phthaldialdehyde	C6H4(CHO)2			160
Phthalan				377
Phthalic acid	C6H4(CO2H)2			160
Picoline	CH3C5H4N		N	
Piperidene	C5H10NH		N	52
Polyethoxylene alkyl ethers	R2(OC2H4)n			
Polyethylene	(CH2CH2)n			
Poly(methylphenylsiloxane)	[(C6H5)(CH3)SiO]n		Si	314
Polypropylene	[(CH3)CHCH2]n			
Polyvinylalcohol	(C2H3OH)n			
Polyvinylchloride	(CH2CHCl)n	Cl		152
Proline	C4H8NCO2H		N	
Prometon				
Prometryn				
Propane	C3H8			194
Propionamide	CH3CH2C(O)NH2		N	293
Propionic acid	C2H5CO2H			101

Substance	Formula	Halo-gen	Het. Atom	Reference
Propylene	C3H6			375g
Propylene glycol dinitrate	CH3CH(NO3)CH2(NO3)		N	
Propyne	CH3CCH			
Propyzamide			N	471
Pyridine	C5H5N		N	62,224g
Pyrocatechol	o-C6H4(OH)2			
Pyrrole	C4H5N		N	
Quinoline acid yellow				260
Reactive Dyes				
Red Dye 79			N,S	
Resorcinol	C6H6O2			382
Rhodamine B	CH3OC(O)(C6H4)C13H6O(NH2)2		N	
Rhodamine 6G	C2H5OC(O)C6H4C13H4(CH3)2-[N(C2H5)]2,Cl	Cl	N	14
Rhodamine 6ZH				
Rose Bengal	Na2,O2CC6Cl4C13H2OI4O2	Cl,I		
S-Dodecyl thioether carboxylates			S	
S-Ethyl-N,N-dipropyl thiocarbamate (EPTC)	(C2H5)SC(O)N(C3H7)2		N,S	
S-Ethyl-N,N-diisopropylthiocarbamate (Butylate)	(C2H5)SC(O)N(i-C3H7)2		N,S	
S-Ethyl-4-hexahydro- 1 -H-azepine-1-carbothionate (molinate)			N,S	
S-Propyl-N-cyclohexyl thiocarbamate (cycloate)	(C3H7)SC(O)NH(C6H11)		N,S	
S-Propyl-N,N-dipropyl tbiocarbamate (vernolate)	(C3H7)SC(O)(NC3H7)2		N,S	
Salicylaldehyde	C7H6O2			
Salicylic acid	C7H6O3			48,91,102,246,469
Simazine	(C2H5)Cl(NHC2H5)C3N3		N	
Sodium chloroacetate	CH3CO2Na	Cl		
Sodium dodecylbenzene sulfonate	C 12H25C6H4SO3Na		S	
Stearic acid	CH3(CH2)16CO2H			429
S tilbene	C6H5CHCHC6H5			131
Succinic acid	HO2CCH2CH2CO2H			
Sucrose	C12H22O11			
Sulfones	RS(O)2R'		S	
Surfactants - unspecified				295
Tetrachlorvinphos	CHClCH(2,4,5-Cl3C6H2)(CH3)PO4	Cl	P	
Tetrafluoroethylene	C2F4	F		
Tetralin	C10H12			377
Tetramethylenediamine	NH2(CH2)4NH2		N	
Tetrabutylammonium phosphate	[(n-C4H9)4N]4,PO4		P	

Substance	Formula	Halo-gen	Het. Atom	Reference
Tetradecyldimethylbenzylammonium-chloride	CH3(CH2)13(CH3)2(C6H5CH2)-NC1		N	202.203
Theophylline	C7H8N4O2.H2O		N	
Thioethers	RSR'		S	
Thiobencarb				
Thymine	C5H6N2O2		N	
Thionine	C12NS(NH2),O2CCH3		S,N	
p-Toluenesulfonic acid	CH3(C6H4)SO3H		S	
s-Triazines			N	38
Trichloroacetic acid	Cl3CCO2H	Cl		433
Trietazine			N	
Triethanolamine	N(CH2CH2OH)3		N	
Trifluoroacetic acid	CF3CO2H	F		
Trihydrazinotriazine			N	
Trihydroxybenzene	(HO)3C6H3			
Trimethylamine	(CH3)3N		N	
Trinitrophenol	(NO2)3C6H2OH			
Triphenylacetic acid	(C6H5)3CCO2H			
Triphenylbismuthine	(C6H5)3Bi		Bi	431
Triphenylphosphine	(C6H5)3P		P	431
Triphenylstibine	(C6H5)3Sb		Sb	431
Tri-(p-Tolyl)arsine	(CH3C6H4)3As		As	431
Triton X- 100	C8H17C6H4(OCH2CH2)xOH			92,334
Umbelliferone	C9H6O3			
Uracil	HNC(O)NHC(O)CHCH		N	5
Urea	C(O)(NH2)2		N	

Table 3. Inorganic Substances Included in EPA Lists of Hazardous Substances and/or Treated by a Photocatalytic Process

Substance/Element	Formula/Symbol	Reference
Actinides	Th,Pa,U,Np,Pu	18
Aluminum (fume or dust)	Al	
Aluminum oxide	41203	
Ammonia	NH3	61g,321g,472g
Ammonium nitrate (soln)	NH4NO3	
Ammonium sulfate (soln)	NH4)2SO4	
Antimony	Sb	
Arsenic	As	
Asbestos	Mg,Si	
Azide ion	N3(-)	
Barium	Ba	
Beryllium	Be	
Bismuth	Bi	
Boron	B	
Cadmium	Cd	
Chlorine	21	
Chlorine dioxide	2102	
Chromium	Cr	154
Cobalt	co	
Copper	cu	101,197,198
Cyanide and Complexes	CN(- 1) and M(CN)x	2,3,218,384,385
Cyanate ion	CNO(- 1)	
Gold	Au	197
Halide ion	X(1-), X = F, Cl, Br, or I	33,137,484
Hydrazine	H2NNH2	
Hydrogen sulfide	H2S	
Hypophosphorus acid	H2PO2	48
Iridium	Ir	197
Iron	Fe	
Lead	Pb	387
Manganese	Mn	
Mercury	Hg	
Molybdenum	Mo	
Nickel	Ni	197
Nitrates/nitrites	NO3(-1),NO2(-1)	388

Substance	Formula	Reference
Nitrogen oxides	NOX	18,25g,143g,216g,220g, 243g,244g,261g,262g, 449g,459g,460g,461g, 472,501,512
Nitrogen	N2	
Oxalate ion	C2O4(2-)	
Oxygen	O2	
Ozone	O3	
Palladium	Pd	197,199,264
Phosphorus	P	
Platinum	Pt	98,197,199,264,444
Radium	Ra	
Radon	Rn	
Rhodium	Rh	98,197,199,264
Selenium	Se	
Silicon	Si	
Silver	Ag	197,198,199,211,290
Strontium	Sr	
Sulfate radical	SO4(1-)	
Sulfite	SO3(1-)	
Sulfur	S	
Sulfur oxides	SOx	449g
Sulfuric acid	H2SO4	
Thallium	Tl	
Thiocyanate	SCN(1-)	33
Thiosulfate	S2O3(2-)	48,198,484
Thorium	Th	
Tin	Sn	
Tritium	H.(T)	
Tungsten	W	
Vanadium	V	
Zinc	Zn	

4.0 Conclusions

The level of activity in this field remains high. The potential to develop new technology for environmental remediation is still a major driving force for R&D activity. However, it is clear that many companies see potential markets for VOC removal in indoor air quality applications. The application of photocatalytic chemistry for the disinfection of water and air has been the subject of sporadic reports over the last 9 years. The potential impact of this application is very large and it is drawing increased attention. In the work to date no clear mechanism for the killing of micro-organisms has been established. The magnitude of the contribution of a photocatalytic effect versus the effect of heat, light, or extraneous agents such as hydrogen peroxide or transition metal ions is often difficult to determine.

In research, more attention is being paid to the detection and identification of intermediates and by-products that can be formed during the photocatalytic process, both in aqueous and gas phase systems. Defining intermediates helps researchers understand the chemical mechanisms of the processes and is necessary to insure that potentially harmful substances are not left in the processed stream. Key areas of work identified in the last report continue to be important. Few studies include mass balances for the reactions and kinetic models that can be used to size treatment systems are still rare. As systems are deployed in the field, it is increasingly important that the issues of catalyst lifetime and regeneration be addressed. Related to this is the need to identify those components of an air or water stream that can inhibit or kill activity. All of these are important to the design of efficient and economical treatment systems. Questions concerning the economic viability of photocatalytic processes are being raised more often. The significance of simple mineralization of one more organic compound without regard to the amount of energy or time that it took is questioned by those who want to see the process efficiency improved. This may be taken as a sign that the field is maturing. There are entrepreneurs and companies that would like to capitalize on the scientific foundation that has been developed for photocatalytic chemistry.

5.0 Bibliography

1. Abdullah, M. I., and E. Eek. "Automatic Photocatalytic Method for the Determination of Dissolved Organic Compounds (DOC) in Natural Waters." *Water Res. 30,* no. 8 (1996): 1813-22.

2. Ahrned, Mohamed S., and Yosry A. Attia. "Aerogel Materials for Photocatalytic Detoxification of Cyanide Wastes in Water." *J. Non-Cryst. Solids* 186 (1995): 402-7.

3. Ahmed, Mohamed Sayed."TiO_2-SiO_2 Aerogel Catalyst for Photodegradation of Cyanide in an Industrial Waste *Stream," Cerarn. Trans.* 55, Sol-Gel Science and Technology (1995): *353-63.*

4. Alfano, Orlando M., Maria I. Cabrera, and Alberto E. Cassano. "Modeling of Light Scattering in Photochemical Reactors." *Chem. Eng. Sci. 49,* no. 24B (1994): 5327-46.

5. Aliskandarani, M., C. Dupuy-Maillard, M. Petit-Ramel, H. Brun, B. Pouyet, and J. P. Percherancier. "Water Purification by Photodegradation on TiO_2 of Uracil and Halogenouracils." *Vecteur Environ. 29,* no. 2 (1996): 57-64.

6. Allen, Norman S., and Hassan Katami. "Comparison of Various Thermal and Photoaging Conditions on the Oxidation of Titanium Dioxide Pigmented Linear Low Density Polyethylene Films." *Polym. Degrad. Stab. 52,* no. 3 (1996): 31 l-20.

7. Allen, Norman S., and Hassan Katami. "Influence of Titanium Dioxide Pigments on Thermal and Photochemical Oxidation and Stabilization of Polyolefin Films.", 537-54. Adv. Chem. Ser., 249. Washington, DC: American Chemical Society, 1996.

8. Amalric, L., C. Guillard, and P. Pichat. "The GC-MS Identification of Some Aliphatic Intermediates from the TiO_2 Photocatalytic Degradation of Dimethoxybenzenes in Water." *Res. Chem. Intermed.* 21, no. 1 (1995): 33-46.

9. Amalric, L., C. Guillard, and P. Pichat. "Use of Catalase and Superoxide Dismutase to Assess the Roles of Hydrogen Peroxide and Superoxide in the TiO_2 or ZnO Photocatalytic Destruction of 1,2-Dimethoxybenzene in Water." *Res. Chem. Intermed. 20,* no. 6 (1994): 579-94.

10. Amalric, Laurence, Chantal Guillard, Emanuelle Blanc-Brude, and Pierre Pichat. "Correlation Between the Photocatalytic Degradability Over TiO_2 in Water of Meta and Para Substituted Methoxybenzenes and Their Electron Density, Hydrophobicity and Polarizability Properties." *Water Res. 30,* no. 5 (1996): 1137-42.

11. Amalric, Laurence, Chantal Guillard, and Pierre Pichat. "The Photodegradation of 2,3-Benzofuran and Its Intermediates, 2-Coumaranone and Salicylaldehyde, in TiO_2 Aqueous Suspensions." *J. Photochem. Photobiol., A 85,* no. 3 (1995): 257-62.

12. Amalric, Laurence, Chantal Guillard, Nick Serpone, and Pierre Pichat. "Water Treatment: Degradation of Dimethoxybenzenes by the Titanium Dioxide-UV Combination." *J. Environ. Sci. Health, Part A* A28, no. 6 (1993): 1393-408.

13. Anderson, Carl Alan. "Improved Heterogeneous Photocatalysts of Titanium Dioxide/Silicon Dioxide and Titanium Dioxide/Aluminum Oxide Prepared by Sol-Gel Methods." Ph.D. diss., Univ. of Texas, 1995.

14. Anderson, Carl, and Allen J. Bard. "An Improved Photocatalyst of TiO_2/SiO_2 Prepared by a Sol-Gel Synthesis." *J. Phys. Chem. 99,* no. 24 (1995): 9882-5.

15. Ando, Tsuneo, and Shuzo Oohara, inventors. "Synthetic Resin Compositions and Their Laminates." Goyo Shiko Kk, Japan, assignee. Japan Patent, 07316342 A2. 1996. *124:204458 CA.*

16. Anonymous. *Product Profile & Applications - Purifics Environmental Technologies, Inc.* London, Ontario, Canada: Purifics, Inc., 1995.

17. Anonymous. "Titanium Dioxide Catalysts Break Down Pollutants." *Chem. Eng. News 74,* no. 3 (1996): 23-4.

18. Anpo, Masakazu. "Approach to Photocatalysis at the Molecular Level. Design of Photocatalysts, Detection of Intermediate Species, and Reaction Mechanisms." *Sol. Energy Mater. Sol. Cells 38,* no. l-4 (1995): 221-38.

19. Anpo, Masakazu, Masanori Tomonari, and Marye Anne Fox. "In *Situ* Photoluminescence of Titania as a Probe of Photocatalytic Reactions." *J. Phys. Chem. 93,* no. 21 (1989): 7300-2.

20. Anpo, Masakazu, Hirorni Yamashita, Yuichi Ichihashi, and Shaw Ehara. "Photocatalytic Reduction of CO_2 with H_2O on Various Titanium Oxide Catalysts." *J. Electroanal. Chem.* 396, no. l-2 (1995): 21-6.

21. Anpo, Masakazu, Hiromi Yamashita, Shin-ichi Kawasaki, and Yuichi Ichihashi. "Photocatalytic Reduction of CO, with H_2O on Titanium Oxide Catalysts." *Sekiyu Gakkaishi 38,* no. 5 (1995): 300-10.

22. Anpo, Masakuzu, Katsuichi Chiba, Masanori Tomonari, Salvatore Coluccia, Michael Che, and Marye Anne Fox. "Photocatalysis on Native and Platinum-Loaded TiO_2 and ZnO Catalysts - Origins of Different Reactivities on Wet and Dry Metal Oxides." *Bull. Chem. Soc. Jpn. 64* (1991): 543-51.

23. Aoki, Akihiko, and Gyoichi Nogami. "Fabrication of Anatase Thin Films from Peroxo-Polytitanic Acid by Spray Pyrolysis." *J. Electrochem. Soc.* 143, no. 9 (1996): L191-L192.

24. Aragai, Kazuteru, Tetsuhiro Terano, Satoshi Nishikata, Masahiro Myarnoto, and Takeo Takahashi, inventors. "Apparatus for Removing Air Pollutants by Adsorption Using Photocatalyst." Fuji Electric Co. Ltd., Japan, assignee. Japan Patent, 07284634 A2. 1995. *124:96051 CA.*

25. Aragai, Kazuteru, Tetsuhiro Terano, Satoshi Nishikata, Masahiro Myamoto, and Takeo Takahashi, inventors. "Apparatus for Removing Hazardous Gas From Air Using Solar Cells and Near UV Irradiation." Fuji Electric Co. Ltd., Japan, assignee. Japan Patent, 08071370 A2. 1996. *124:324278 CA.*

26. Artem'ev, Yu M., M. A. Artem'eva, M. G. Vinogradov, and T. I. Ilika. "Photocatalytic Destruction of Methylene Blue and 2,4,5-Trichlorophenol in Ozonizing TiO_2 and Nb_2O_5 Aqueous Suspensions." *Zh. Prikl. Khim. 67,* no. 9 (1994): 1542-6.

27. Augugliaro, V., L. Cavallero, G. Marci, L. Palmisano, and E. Pramauro. "Influence of Operational Variables on the Photodegradation Kinetics of Monuron in Aqueous Titanium Dioxide Dispersions." *Stud. Surf. Sci. Catal.* 82, (New Developments in Selective Oxidation II) (1994): 713-20.

28. Augugliaro, V., V. Loddo, G. Marci, L. Palmisano, and M. Schiavello. "Performance of a Continuous Flat Reactor for Phenol Degradation in Heterogeneous Photocatalytic System." *Chem. Biochem. Eng. Q. 9,* no. 3 (1995): 133-9.

29. Augugliaro, Vincenzo, Vittorio Loddo, Leonardo Palmisano, and Mario Schiavello. "Heterogeneous Photocatalytic Systems: Influence of Some Operational Variables on Actual Photons Absorbed by Aqueous Dispersions of TiO_2." *Sol. Energy Mater. Sol. Cells* 38, no. l-4 (1995): 411-19.

30. Bahnemann, D., J. Cunningham, M. A. Fox, E. Pelizzetti, P. Pichat, and N. Serpone. "Photocatalytic Treatment of Waters." *Aquat. Surf. Photochem.,* eds. R. G. Zepp, G. R. Helz, and D. G. Crosby, 261-3 16, Boca Raton, FL: Lewis Publishers, 1994.

31. Bala, Manju, and Sangeeta Dube. "Use of Imines and Their Complexes as Photosensitizers in Photoreduction of *CO,." Asian J. Chem. 7,* no. 4 (1995): 886-8.

32. Bamwenda, Gratian R., Susumu Tsubota, Toshiko Nakamura, and Masatake Haruta. "Photoassisted Hydrogen Production From Water-Ethanol Solution: a Comparison of Activities of Au-TiO, and Pt-TiO_2." *J. Photochem. Photobiol. A: Chem. 89* (1995): 177-89.

33. Bedja, Idriss, and Prashant V. Kamat. "Capped Semiconductor Colloids. Synthesis and Photoelectrochemical Behavior of TiO_2 Capped SnO_2 Nanocrystallites." *J. Phys. Chem. 99,* no. 22 (1995): 9182-8.

34. Bekbolet, M. "Destructive Removal of Humic Acids in Aqueous Media by Photocatalytic Oxidation With Illuminated Titanium Dioxide." *J. Environ. Sci. Health, Part A: Environ. Sci. Eng. Toxic Hazard. Subst. Control* A31, no. 4 (1996): 845-58.

35. Bekbolet, M., M. Lindner, D. Weichgrebe, and D. W. Bahnemann. "Photocatalytic Detoxification with the Thin-Film Fixed-Bed Reactor (TFFBR): Clean-Up of Highly Polluted Landfill Effluents Using a Novel TiO_2-Photocatalyst." *Sol. Energy 56,* no. 5 (1996): 455-69.

36. Bekbolet, Miray, and Claudia V. Araz. "Inactivation of Escherichia Coli by Photocatalytic Oxidation." *Chemosphere 32,* no. 5 (1996): 959-65.

37. Bekbolet, Miray, and Golhan Ozkosemen. "A Preliminary Investigation on the Photocatalytic Degradation of a Model Humic Acid." *Water Sci. Technol. 33,* no. 6, Hazard Assessment and Control of Environmental Contaminants in Water (1996): 189-94.

38. Bellmann, E., J. Lobedank, H. Ross, and J. Bendig. "Sensitized Photocatalytic Oxidation of S-Triazine Herbicides." *J. Inf. Rec.* 23, no. l-2, 14th Conference Photochemistry Section of the Society of German Chemists, 1995, Pt. 2 (1996): 43-45.

39. Bellobono, Ignazio Renato. "Advanced Oxidation and Integral Degradation of Trichloroethene in Air by Photocatalytic Membranes Immobilizing Titanium Dioxide and Promoting Photocatalysts." *Life Chem. Rep.* Volume Date 1995, 13, no. l-2 (1995): 63-70.

40. Bellobono, Ignazio Renato. "Influence of Photocatalytic Systems in Photochemical Production of Composite Membranes and Reinforced Plastics." *Adv. Sci. Technol. (1995), 7(Advanced Structural Fiber Composites), 249-256.*

41. Bellobono, Ignazio Renato, and Barbara Barni. "Photosynthetic Membranes. Part 41. Pilot Plant Scale Photodegradation of Trichloroethene and Atrazine in Aqueous Solutions by Photocatalytic Membranes Immobilizing Titanium Dioxide." *Adv. Sci. Technol. (1995), 3D(Ceramics: Charting the Future), 2 771-2 778.*

42. Bellobono, Ignazio Renato, Barbara Bami, and Franco Gianturco. "Pre-Industrial Experience in Advanced Oxidation and Integral Photodegradation of Organics in Potable Waters and Waste Waters by PHOTOPERM™ Membranes Immobilizing Titanium Dioxide and Promoting Photocatalysts." *J. Membr. Sci.* 102, no. l-3 (1995): 139-47.

43. Better-ton, Eric A., Robert G. Arnold, Ronald J. Kuhler, and Gregory A. Santo. "Reductive Dehalogenation of Bromoform in Aqueous Solution." *Environ. Health Perspect. Suppl.* 103, Suppl. 5 (1995): 89-91.

44. Bickley, Roger I., Laurence T. Hogg, Teresita Gonzalez-Carreno, and Leonardo Palmisano. "A Comparative Study of the Photocatalytic Activities of Iron-Titanium(IV) Oxide Photocatalysts Prepared by Various Methods; Spray Pyrolysis, Impregnation and Co-Precipitation." *Stud. Surf. Sci. Catal.* 91, Preparation of Catalysts VI: 589-96.

45. Bideau, M., B. Claudel, C. Dubien, L. Faure, and H. Kazouan. "On the "Immobilization" of Titanium Dioxide in the Photocatalytic Oxidation of Spent Waters." *J. Photochem. Photobiol., A* 91, no. 2 (1995): 137-44.

46. Blake, Daniel M. *Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds From Water and Air,* NREL/TP-430-6084; DE94006906. Golden, CO: National Renewable Energy Laboratory, May 1994.

47. Blake, Daniel M. *Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds From Water and Air Update Number 1, to June, 1995,* NREL/TP-473-20300; DE95013148. Golden, CO: National Renewable Energy Labor-tory, October 1995.

48. Blake, Daniel, Edward Wolfrum, James Boulter, Prairie Michael, Steven Showalter, Philip Rodacy, Pam Leslie, and Bertha Stange. *Photocatalytic Oxidation and Reduction Chemistry and a New Process for Treatment of Pink Water and Related Contaminated Water,* NREL/TP-430-21580. Golden, CO: National Renewable Energy Laboratory, November 1996.

49. Blanco, J., P. Avila, A. Bahamonde, E. Alvarez, B. Sanchez, and M. Romero. "Photocatalytic Destruction of Toluene and Xylene at Gas Phase on a Titania Based Monolithic Catalyst." *Catal. Today 29,* no. l-4 (1996): 437-42.

50. Blanco, Julian, Sixto Malato, Christoph Richter, Francisco Carmona, and Francisco Martinez. "Wastewater Treatment by Solar Photocatalysis." *Ing. Quim. Madrid 27,* no. 316 (1995): 125-33.

51. Bockelmann, D., M. Lindner, and D. Bahnemann. "From Nano-Sized Particles to Commercial Products: the Search for Novel Photocatalysts." *NATO ASI Ser., Ser. 3 (1996), 12(Fine Particles Science and Technology), 675-689.*

52. Boucher, David L., Julian A. Davies, Jimmie G. Edwards, and Abdelkader Mennad. "An Investigation of the Putative Photosynthesis of Ammonia on Iron-Doped Titania and Other Metal Oxides." *J. Photochem. Photobiol., A 88,* no. 1 (1995): 53-64.

53. Bouquet-Somrani, Christine, Annie Finiels, Patrick Geneste, Patrick Graffin, Alain Guida, Martine Klaver, Jean-Louis Olive, and Ahmed Saaedan. "Photocatalytic Oxidation of Substituted Toluenes with Irradiated TiO_2 Semiconductor. Effect of Zeolite." *Catal. Lett. 33,* no. 3,4 (1995): 395-400.

54. Bouquet-Somrani, Christine, Annie Finiels, Patrick Graffin, and Jean-Louis Olive. "Photocatalytic Degradation of Hydroxylated Biphenyl Compounds." *Appl. Catal., B 8,* no. 1 (1996): 101-6.

55. Brand, John R., Roger A. Baldwin, and Thomas Ian Brownbridge, inventors. "Durable Coated Pigmentary Titanium Dioxide." Kerr-McGee Chemical Corp., USA, assignee. Europe Patent, 654509 Al. 1995. *123:231422 CA.*

56. Brezova, Vlasta, Alzbeta Blazkova, Eva Borosova, Michal Ceppan, and Radim Fiala. "The Influence of Dissolved Metal Ions on the Photocatalytic Degradation of Phenol in Aqueous TiO_2 Suspensions." *J. Mol. Catal. A: Chem. 98,* no. 2 (1995): 109-16.

57. Brezova, Vlasta, Alzbeta Blazkova, Mirko Breznan, Peter Kottas, and Michal Ceppan. "Phenol Degradation on Glass Fibers with Immobilized Titanium Dioxide Particles." *Collect. Czech. Chem. Commun. 60,* no. 5 (1995): 788-94.

58. Butters, Brian Edward, and Anthony Leonard Powell, inventors. "Method and System for Photocatalytic Decontamination of Wastewaters." Purifics Environmental Technologies, Inc., Can., assignee. World Patent, 9523766 Al. 1995. *123:295642 CA.*

59. Campanella, L., G. Crescentini, and S. Militemo. "Photobiodegradation of Chlorinated Water Pollutants by a Combined TiO_2 - Polyaniline - Enzyme Catalytic System." *Proc. SPIE-Int. Soc. Opt. Eng. 2504,* Environmental Monitoring and Hazardous Waste Site Remediation, 1995 (1995): 577-86.

60. Casado, Juan, Jean Marie Herrmann, and Pierre Pichat. "Phototransformation of o-Xylene Over Atmospheric Solid Aerosols in the Presence of Molecular Oxygen and Water." *Phys.-Chem. Behav. Atmos. Pollut., [Proc. Eur. Symp.], 5th* (1990): 283-8.

61. Cermenati, Laura, Chantal Guillard, Pierre Pichat, and Angelo Albini. "Study of the Active Species Involved in the TiO_2 Photocatalytic Detoxification of Water Via Comparison With the Photo-Fenton Process and Use of an Enzyme." *Book of Abstracts, 211th ACS National Meeting, New Orleans, LA, March 24-28* (1996): PHYS-267.

62. Chen, Ciping, Daohu Lu, and Guangzhi Xu. "Radical Intermediates Generated in Photocatalytic Oxidation of Some Organic Compounds Containing Nitrogen Atoms." *Bopuxue Zazhi* 11, no. 2 (1994): 141-7.

63. Chen, G., and F. Shadman. "Removal of Process-Generated Organic Impurities From Recycled Water in Semiconductor Fabs." *Proc. SPIE-Int. Soc. Opt. Eng. 2725,* Metrology, Inspection, and Process Control for Microlithography X (1996): 300-307.

64. Chen, Paris H., Chiu-Yang Chen, and Christina H. Jenq. "TiO_2 Photocatalysis to Remove the Trace Organic in Drinking Water." *Water Supply* 13, no. 3/4, IWSA International Specialized Conference on Advanced Treatment and Integrated Water System Management into the 21st Century (1995): 29-34.

65. Chen, Shifu, Mengyue Zhao, and Yaowu Tao. "Influence of the Different Preparation Conditions on the Photocatalytic Activity of TiO_2." *Huaxue Gongye Yu Gongcheng* 12, no. 2 (1995): l-8.

66. Chen, Shifu, Mengyue Zhao, Yuewu Tao, and Guosheng Peng. "Study on the Photocatalytic Degradation of Organophosphorus Pesticides." *Huanjing Kexue* 16, no. 5 (1995): 61-3.

67. Cheng, Soofin, Shi-Jane Tsai, and Yi-Fen Lee. "Photocatalytic Decomposition of Phenol Over Titanium Oxide of Various Structures." *Catal. Today 26,* no. 1 (1995): 87-96.

68. Chhabra, V., V. Pillai, B. K. Mishra, A. Morrone, and D. 0. Shah. "Synthesis, Characterization, and Properties of Microemulsion-Mediated Nanophase TiO_2 Particles." *Langmuir* 11, no. 9 (1995): 3307-11.

69. Chiang, Hui-Jean, Jyh Mimg Shyuu, and Chong Mou Wang. "Photodegradation of Chlorinated Organic Wastes With n-TiO_2 Promoted by p-CuO." *J. Chin. Chem. Soc. 43,* no. 1 (1996): 21-7.

70. Chiarenzelli, J., R. Scrudato, M. Wunderlich, D. Rafferty, K. Jensen, G. Oenga, R. Roberts, and J. Pagano. "Photodecomposition of PCBs Absorbed on Sediment and Industrial Waste: Implications for Photocatalytic Treatment of Contaminated Solids." *Chemosphere* 31, no. 5 (1995): 3259-72.

71. Chojnowski, Fabien, Paul Clechet, Jean Rene Martin, Jean Marie Herrmann, and Pierre Pichat. "Hydrogen Production by Water Photoelectrolysis With a Powder Semiconductor Anode." *Chem. Phys. Lett. 84,* no. 3 (1981): 555-9.

72. Cooper, Gerald, Matthew A. Ratcliff, and Jeffrey G. Sczechowksi, inventors. "Photocatalytic Slurry Reactor Having Turbulence Generating Means." Photo-Catalytics, Inc., assignee. United States Patent, 5116582. 1992.

73. Courbon, H., J. M. Herrmann, and P. Pichat. "Metal Content and Temperature Effects on the Photocatalytic Isotopic Exchange Between Cyclopentane and Deuterium Over Pt on Ni/TiO_2 in the Normal SMSI State." *J. Catal. 95* (1985): 539.

74. Courbon, H., J. M. Herrmann, and P. Pichat. "Photocatalytic Isotopic Exchange Between Cyclopentane and Deuterium Over a Bifunctional Platinum/Titanium Dioxide Catalyst." *J. Catal. 72,* no. 1 (1981): 129-38.

75. Courbon, Henri, Jean Disdier, Jean Marie Herrmann, Pierre Pichat, and Jose Antonio Navio. "Surface Characterization of Zirconium Titanate ($ZrTiO_4$) Powder by Measurements of Electrical Photoconductance and Photoassisted Oxygen Isotope Exchange." *Catal. Lett. 20,* no. 3-4 (1993): 251-8.

76. Courbon, Henri, Jean Marie Herrmann, and Pierre Pichat. "Effect of Platinum Deposits on Oxygen Adsorption and Oxygen Isotope Exchange over Variously Pretreated, Ultraviolet-Illuminated Powder Titanium Dioxide." *J. Phys. Chem. 88,* no. 22 (1984): 5210-14.

77. Cui, Hua. "The Low Temperature Synthesis and Characterization of Co_9S_8, Ni_3S_2, and Zinc Sulfide and Study of the Photocatalytic Property of Titanium Dioxide." Ph.D. diss., Brown univ., 1995.

78. Cunningham, Joseph, Ghassan Al-Sayyed, and Somkiat Srijaranal. "Adsorption of Model Pollutants Onto TiO_2 Particles in Relation to Photoremediation of Contaminated Water." *Aquat. Surf. Photochem.,* eds. George R. Helz, Richard G. Zepp, and Donald G. Crosby, 317-48, Boca Raton, Fla.: Lewis, 1994.

79. Curco, D., S. Malato, J. Blanco, J. Gimenez, and P. Marco. "Photocatalytic Degradation of Phenol: Comparison Between Pilot-Plant-Scale and Laboratory Results." *Sol. Energy 56,* no. 5 (1996): 387-400.

80. D'Oliveira, J. C., W. D. W. Jayatilake, K. Tennakone, J. M. Herrmann, and P. Pichat. "Heterogeneous Photocatalysis As a Method of Water Decontamination: Degradation of 2-, 3- and 4-Chlorobenzoic Acids Over Illuminated Titania at Room Temperature." *Stud. Surf. Sci. Catal.* 75, no. New Frontiers in Catalysis, Pt. C (1993): 2167-71.

81. D'Oliveira, Jean Christophe, Chantal Guillard, Catherine Maillard, and Pierre Pichat. "Photocatalytic Destruction of Hazardous Chlorine- or Nitrogen-Containing Aromatics in Water." *J. Environ. Sci. Health, Part A A28,* no. 4 (1993): 941-62.

82. D'Oliveira, Jean-Christophe, Claudio Minero, Ezio Pelizzetti, and Pierre Pichat. "Photodegradation of Dichlorophenols and Trichlorophenols in Titania Aqueous Suspensions: Kinetic Effects of the Positions of the Chlorine Atoms and Identification of the Intermediates." *J. Photochem. Photobiol., A 72,* no. 3 (1993): 261-7.

83. Dabestani, Reza, Xuelin Wang, Allen J. Bard, Alan Campion, Mar-ye Anne Fox, Stephen E. Webber, and J. M. White. "Photoinduced Oxidation of Bromide to Bromine on Irradiated Platinized Titanium Dioxide Powders and Platinized Titanium Dioxide Particles Supported on Nafion Films." *J. Phys. Chem. 90,* no. 12 (1986): 2729-32.

84. Davies, Julian A., David L. Boucher, and Jimmie G. Edwards. "The Question of Artificial Photosynthesis of Ammonia on Heterogeneous Catalysts." *Adv. Photochem.* 19 (1995): 235-3 10.

85. Dieckmann, Melissa S., Kimberly A. Gray, and Prashant V. Kamat. "The Sensitized Photocatalysis of a Mixed Reactant System of 4-Chlorophenol and 4-Nitrophenol." *Crit. Issues Water Wastewater Treat., Proc. Natl. Conf. Environ. Eng.,* eds. Joseph N. Edwards Marc Ryan, 726-32, New York, NY: American Society of Civil Engineers, 1994.

86. Dieckmann, Melissa S., and Kimberly A. Gray. "A Comparison of the Degradation of 4-Nitrophenol Via Direct and Sensitized Photocatalysis in TiO_2 Slurries." *Water Res. 30,* no. 5 (1996): 1169-83.

87. Diller, Ralf, Matthias Brandt, Iris Fomefett, Ulrike Siebers, and Detlef Bahnemann. "Photocatalytic Degradation of Trinitrotoluene and Other Nitroaromatic Compounds." *Chemosphere 30,* no. 12 (1995): 2333-41.

88. Disdier, Jean, Jean Marie Herrmann, and Pierre Pichat. "A Photoconductivity Study of the Interactions Between Titanium Dioxide, Oxygen and Isobutane Under Ultraviolet Irradiation" *Rev. Port. Quim.* 19, no. l-4 (1977): 91-4.

89. Disdier, Jean, Jean Marie Herrmann, and Pierre Pichat. "Platinum/Titanium Dioxide Catalysts. A Photoconductivity Study of Electron Transfer From the Ultraviolet-Illuminated Support to the Metal and of the Influence of Hydrogen." *J. Chem. Soc., Faraday Trans. 1* 79, no. 3 (1983): 651-60.

90. Doherty, Stephen, Chantal Guillard, and Pierre Pichat. "Kinetics and Products of the Photocatalytic Degradation of Morpholine (Tetrahydro-2H-1,4-Oxazine) in TiO_2 Aqueous Suspensions." *J. Chem. Soc., Faraday Trans.* 91, no. 12 (1995): 1853-9.

91. Dorion, C., 0. Zahraa, and M. Bouchy. "Fixed Bed Photocatalytic Reactor for Wastewater Treatment." *Recents Prog. Genie Procedes 9,* no. *38, Genie des Procedes dans la Chaine des Polymeres et dans la Chaine Catalytique* (1995): 105-10.

92. Dube, Sangeeta, and N. Nageswara Rao. "Rate Parameter Independence on the Organic Reactant: a Study of Adsorption and Photocatalytic Oxidation of Surfactants Using MO,-TiO_2 (M = Mo or W) Catalysts." *J. Photochem. Photobiol., A 93,* no. 1 (1996): 71-7.

93. Dum, Joseph E., inventor. "Titanium Dioxide Photocatalyst and Pulsed Light Synergism in Deactivation of Contaminants in Food Systems." Purepulse Technologies, Inc., USA, assignee. World Patent, 9609776 Al. 1996. *125:32362 CA.*

94. Edwards, Morgan E., Carlos M. Villa, Charles G. Jr. Hill, and Thomas W. Chapman. "Effectiveness Factors for Photocatalytic Reactions Occurring in Planar Membranes." *Ind. Eng. Chem. Res. 35,* no. 3 (1996): 712-20.

95. Edwards, Morgan Eugene. "Kinetics and Intraparticle Mass Transfer Limitations in Photocatalytic Systems." Ph.D. diss., Univ. Wisconsin, 1994.

96. Fang, Jing-huai, Xiang-yang Zhang, Tong Lu, and Zu-hong Lu. "Sensitized Photocatalytic Oxidation of Dyes." *Gaodeng Xuexiao Huaxue Xuebao* 16, no. 11, Suppl. (1995): 226-9.

97. Femandez, A., G. Lassaletta, V. M. Jimenez, A. Justo, A. R. Gonzalez-Elipe, J.-M. Herrmann, H. Tahiri, and Y. Ait-Ichou. "Preparation and Characterization of TiO_2 Photocatalysts Supported on Various Rigid Supports (Glass, Quartz and Stainless Steel). Comparative Studies of Photocatalytic Activity in Water Purification." *Appl. Catal., B 7,* no. l-2 (1995): 49-63.

98. Femandez, A., G. Munuera, A. R. Gonzalez-Elipe, J. P. Espinosa, J. M. Herrmann, P. Pichat, and C. Leclercq. "Photoassisted Deposition of Rhodium on Platinum/Titania Samples As a Method of Preparing Bimetallic Catalysts." *Appl. Catal. 57,* no. 2 (1990): 191-202.

99. Fessenden, Richard W., and Prashant V. Kamat. "Rate Constants for Charge Injection From Excited Sensitizer into SnO_2, ZnO, and TiO_2 Semiconductor Nanocrystallites." *J. Phys. Chem. 99,* no. 34 (1995): 12902-6.

100. Foster, Nancy S., Carl A. Koval, Jeffrey G. Sczechowski, and Richard D. Noble. "Investigation of Controlled Periodic Illumination Effects on Photo-Oxidation Processes at Titanium Dioxide Films Using Rotating Ring-Disk Photoelectrochemistry." *J. Electroanal. Chem. 406,* no. l-2 (1996): 213-17.

101. Foster, Nancy S., Alice N. Lancaster, Richard D. Noble, and Carl A. Koval. "Effect of Organics on the Photodeposition of Copper in Titanium Dioxide Aqueous Suspensions." *Ind. Eng. Chem. Res. 34,* no. 11 (1995): 3865-71.

102. Fotou, George P., and Sotiris E. Pratsinis. "Photocatalysis of Phenol and Salicylic Acid by Nanostructured Titania Powders." *Polym. Mater. Sci. Eng. 73* (1995): 287-8.

103. Fox, M. A. "Activation of Oxygen by Photoinduced Electron Transfer." *Photoinduced Electron Transfer* Pt. D, (1988): l-27.

104. Fox, M. A. *Augmentation for Research Training: Surface-Mediated Photocatalysis,* ARO-29548.8-CH-AAS. 1994. AD-A281591.

105. Fox, M. A. *Surface Mediated Photocatalysis,* ARO-21263.4-CH. 1987. AD-A188882.

106. Fox, M. A. *Surface Mediated Photocatalysis,* ARO-25169.13-CH. 1991. AD-A233 748.

107. Fox, M. A. *Surface-Mediated Photocatalysis,* ARO-28298.4-CH. 1992. AD-A249906.

108. Fox, M. A., M. T. Dulay, and K. Krosley. "Comparison of Oxidative and Excited State Cyclizations of N-Benzyldiphenylamines to N-Benzylcarbazoles." *Curr. Sep.* 13, no. 4 (1995): 120.

109. Fox, Marye Anne. "A Comparison of the Mechanisms of Photo-oxidative Degradation of Organic Molecules on Irradiated Semiconductor Powders and in Aerated Supercritical Water." *Sol. Energy Mater. Sol. Cells 38,* no. l-4 (1995): 381-90.

110. Fox, Marye Anne. "Charge Injection into Semiconductor Particles. Importance in Photocatalysis." *Chim. Ind. (Milan) 68,* no. 10 (1986): 59-64.

111. Fox, Marye Anne. "Charge Injection into Semiconductor Particles - Importance in Photocatalysis." *NATO ASI Ser., Ser. C, Homogeneous Heterog. Photocatal.* 174 (1986): *363-83.*

112. Fox, Mar-ye Anne. "Photocatalysis: Decontamination With Sunlight." *CHEMTECH 22,* no. 11 (1992): 680-5.

113. Fox, Marye Anne. "Photocatalysis on Modified Semiconductor Surfaces and on Bipolar Photoelectrodes." New *J. Chem.* 11, no. 2 (1987): 129-33.

114. Fox, Marye Anne. "Photocatalytic Oxidation of Organic Substrates." *NATO ASI Ser., Ser. C, Photocatal. Environ. 237* (1988): 445-67.

115. Fox, Marye Anne. "Photodetoxification Via Photoelectrochemical Oxidation on Irradiated Titanium Dioxide Particles." *Electroorg. Synth., [Manuel M. Baizer Meml.Symp.]* (1991): 181-6.

116. Fox, Marye Anne. "Photoinduced Electron Transfer." *Photochem. Photobiol. 52,* no. 3 (1990): 617-27.

117. Fox, Marye Anne. "Photoinduced Electron Transfer in Arranged Media and on Semiconductor Surfaces." *Pure Appl. Chem.* 60, no. 7 (1988): 1013-16.

118. Fox, Marye Anne. "Photoinduced Electron Transfer on Irradiated Semiconductor Surfaces." *Adv. Electron Transfer Chem.* 1, (1991): l-53.

119. Fox, Marye Anne. "Selective Formation of Organic Compounds by Photoelectrosynthesis at Semiconductor Particles." *Electrochemistry I,* 71-99. Top. Curr. Chem., 1987.

120. Fox, Marye Anne. "Semiconductor Particles Included Within Supports." *Res. Chem. Intermed.* 15, no. 2 (1991): 153-64.

121. Fox, Marye Anne. "The Role of Hydroxyl Radicals in the Photocatalyzed Detoxification of Organic Pollutants: Pulse Radiolysis and Time-Resolved Diffuse Reflectance Measurements." *Photocatalytic Purification and Treatment of Water and Air,* eds. David F. Ollis, and Hussain Al-Ekabi, 163-7, Trace Met. Environ., ed. Jerome 0. Nriagu, New York: Elsevier, 1994.

122. Fox, Marye Anne, and Phillip F. Britt. "Photosensitization of Semiconductor Electrodes by Adsorbed Polymeric Thin Films." *New J. Chem.* 16, no. l-2 (1992): 113-20.

123. Fox, Marye Anne, Raul Cardona, and Elizabeth Gaillard. "Photoactivation of Metal Oxide Surfaces: Photocatalyzed Oxidation of Alcohols by Heteropolytungstates." *J. Am. Chem. Soc.* 109, no. 21 (1987): 6347-54.

124. Fox, Marye Anne, and C. C. Chen. "Mechanistic Features of the Semiconductor Photocatalyzed Olefin-to-Carbonyl Oxidative Cleavage." *J. Am. Chem. Soc.* 103, no. 22 (198 1): 6757-9.

125. Fox, Marye Anne, and Chia Chung Chen. "Electronic Effects in the Semiconductor-Photocatalyzed Oxidative Cleavage of Olefins." *Tetrahedron Lett. 24,* no. 6 (1983): 547-50.

126. Fox, Marye Anne, and Chia Chung Chen. "Oxidative Cyclization of the Dianion of 1,3-Diphenylpropan-2-one." *J. Chem. Soc., Chem. Commun.,* no. 1 (1985): 23-4.

127. Fox, Mat-ye Anne, Chia Chung Chen, Koon Ha Park, and Janet N. Younathan. "Controlled Organic Redox Reactivity on Irradiated Semiconductor Surfaces." *Org. Phototransform. Nonhomogeneous Media,* 69-78, ACS Symp. Ser., Washington, DC: American Chemical Society, 1985.

128. Fox, Marye Anne, and Ming Jang Chen. "Photocatalytic Formylation of Primary and Secondary Amines on Irradiated Semiconductor Powders." *J. Am. Chem. Soc.* 105, no. 13 (1983): 4497-9.

129. Fox, Marye Anne, Maria T. Dulay, and Kevin Krosley. "Comparison of Oxidative and Excited State Cyclizations of N-Benzyldiphenylarnines to N-Benzylcarbazoles." *J. Am. Chem. Soc.* 116, no. 24 (1994): 10992-g.

130. Fox, Marye Anne, Young Soo Kim, A. A. Abdel-Wahab, and Maria Dulay. "Photocatalytic Decontamination of Sulfur-Containing Alkyl Halides on Irradiated Semiconductor Suspensions." *Catal. Lett. 5,* no. 4-6 (1990): 369-76.

131. Fox, Marye Anne, Barbara Lindig, and Chia Chung Chen. "Transients Generated Upon Photolysis of Colloidal Titanium Dioxide in Acetonitrile Containing Organic Redox Couples." *J. Am. Chem. Soc.* 104, no. 21 (1982): 5828-9.

132. Fox, Marye Anne, Harou Ogawa, and Jennifer Muzyka "Selective Organic Redox Reactions on Irradiated Semiconductor Particles." *Photoelectrochem. Electrosynthesis Semicond. Mater.,* 9-15, Proc.- Electrochem. Soc., New York: Electrochemical Society, 1988.

133. Fox, Marye Anne, Haruo Ogawa, and Pierre Pichat. "Regioselectivity in the Semiconductor-Mediated Photooxidation of 1,4-Pentanediol." *J. Org. Chem. 54,* no. 16 (1989): 3847-52.

134. Fox, Mar-ye Anne, and Susan Olive. "Photooxidation of Anthracene on Atmospheric Particulate Matter." *Science (Washington, D. C.) 205,* no. 4406 (1979): 582-3.

135. Fox, Mar-ye Anne, and Robert C. Owen. "Carbanion Photooxidation at Semiconductor Surfaces." *Photoeff. Semicond.-Electrolyte Interfaces, 337-42,* ACS Symp. Ser., no. 146. Washington, DC: American Chemical Society, 198 1.

136. Fox, Marye Anne, and Robert C. Owen. "Mediated Photochemical Oxidative Dimerization." *J. Am. Chem. Soc.* 102, no. 21 (1980): 6559-61.

137. Fox, Mar-ye Anne, and Thomas L. Pettit. "Use of Organic Molecules As Mechanistic Probes for Semiconductor-Mediated Photoelectrochemical Oxidations: Bromide Oxidation." *J. Org. Chem. 50,* no. 25 (1985): 5013-15.

138. Fox, Marye Anne, and Carol A. Triebel. "A New Pathway for Cleavage of Some Phenacyl and Styryl Thioethers." *J. Org. Chem. 48,* no. 6 (1983): 835-40.

139. Fu, Xianzhi, Louis A. Clark, Qing Yang, and Marc A. Anderson. "Enhanced Photocatalytic Performance of Titania-Based Binary Metal Oxides: TiO_2/SiO_2 and TiO_2/ZrO_2." *Environ. Sci. Technol. 30,* no. 2 (1996): 647-53.

140. Fu, Xianzhi, Walter A. Zeltner, and Marc A. Anderson. "The Gas-Phase Photocatalytic Mineralization of Benzene on Porous Titania-Based Catalysts." *Appl. Catal., B 6,* no. 3 (1995): 209-24.

141. Fujii, Toshiaki, inventor. "Photoelectron-Induced Photoionization Electrostatic Air Filters in Semiconductor Device Processing." Ebara Sogo Kenkyusho Kk, Japan, and Ebara Mfg, assignees. Japan Patent, 07057981 A2. 1995. *123:100010 CA.*

142. Fujii, Toshiaki, Yasuhiro Mitsui, Kazuhiko Sakamoto, and Hiroaki Tada, inventors. "Process for Treating (Waste)Water Containing Organics by Photocatalyst." Ebara Sogo Kenkyusho Kk, Japan, Ebara Mfg, and Nippon Sheet Glass Co. Ltd., assignees. Japan Patent, 08071573 A2. 1996. *124:324910 CA.*

143. Fujii, Toshiaki, Kazuhiko Sakamoto, and Hiroaki Tada, inventors. "Method and Apparatus for Removing Hazardous Gases." Ebara Sogo Kenkyusho Kk, Japan, and Nippon Sheet Glass Co. Ltd., assignees. Japan Patent, 08010576 A2. 1996. *124:210518 CA.*

144. Fujishima, Akira "Environment Cleaning by Photocatalysts." *Taiyo Enerugi* 21, no. 6 (1995): 5-l 1.

145. Fujishima, Akira. "Photoexcited TiO_2 Surfaces-New Trends in Photocatalytic Reactions." *Oyo Butsuri 64,* no. 8 (1995): 803-7.

146. Fujishima, Akira. "Recent Progress in Photoelectrochemistry." *Gaodeng Xuexiao Huaxue Xuebao* 16, no. 11, Suppl. (1995): 7-12.

147. Fujishima, Akira, and Kazuhito Hashimoto. "Photocatalytic Ceramic Tile." *Kagaku to Kogyo,* no. 1996 (Tokyo): 49(6), 764-67.

148. Fujishima, Akira, Kazuhito Hashimoto, Tomakazu Iyoda, and Shigemichi Fukayama, inventors. "Titanium Oxide Photocatalyst Structure and Its Manufacture for Air Purification." Kanagawa Academy of Science and Technology, Japan, assignee. World Patent, 9613327 Al. 1995. *125:40700 CA.*

149. Funayama, Hitoshi, and Takuo Sugawara. "Local Light Intensity Distribution in a Titanium-Dioxide Suspended Photoreactor." *Akita Kogyo Koto Senmon Gakko Kenkyu Kiyo 30* (1994): 119-22.

150. Gamble, Lara, Linda S. Jung, and Charles T. Campbell. "Decomposition and Protonation of Surface Ethoxys on TiO_2(1 10)." *Surface Science 348* (1996): 1-16.

151. Gerischer, H. "Photocatalysis in Aqueous Solution With Small TiO_2 Particles and the Dependence of the Quantum Yield on Particle Size and Light Intensity." *Electrochim. Acta* 40, no. 10 (1995): 1277-81.

152. Gesenhues, U. "Contribution of TiO_2 to the Durability and the Degradation of Organic Coatings." *Double Liaison--Phys., Chim. Econ. Peint. Adhes. 43,* no. 479-480 (1996): 32-41,X-XVIII.

153. Giglio, Kimberly D., David B. Green, and Ben Hutchinson. "Photocatalytic Destruction of an Organic Dye Using TiO_2 and Solar Energy: a General Chemistry Experiment. [Erratum to Document Cited in CA123:8735]." *J. Chem. Educ. 72,* no. 7 (1995): 625.

154. Giglio, Kimberly D., David B. Green, and Ben Hutchinson. "Photocatalytic Destruction of an Organic Dye Using TiO_2 and Solar Energy: a General Chemistry Experiment." *J. Chem. Educ. 72,* no. 4 (1995): 352-4.

155. Gimenez, J., M. A. Aguado, and S. Cervera-March. "Photocatalytic Reduction of Chromium(VI) With Titania Powders in a Flow System. Kinetics and Catalyst Activity." *J. Mol. Catal. A: Chem.* 105, no. l-2 (1996): 67-77.

156. Goren, Z., I. Willner, A. J. Nelson, and A. J. Frank. "Selective Photoreduction of CO_2/HCO_3^- to Formate by Aqueous Suspensions and Colloids of Pd-TiO_2." *J. Phys. Chem.* 94 (1990): 3784-90.

157. Gray, K. A., P. Kamat, U. Stafford, and M. Dieckmann. "Mechanistic Studies of Chloro- and Nitrophenolic Degradation on Semiconductor Surfaces." *Aquat. Surf. Photochem.,* eds. George R. Helz, Richard G. Zepp, and Donald G. Crosby, 399-408, Boca Raton, Fla.: Lewis Publishers, 1994.

158. Guillard, Chantal, Laurence Amalric, Jean-Christophe D'Oliveira, Herve Delprat, Can Hoang-Van, and Pierre Pichat. "Heterogeneous Photocatalysis: Use in Water Treatment and Involvement in Atmospheric Chemistry." *Aquat. Surf. Photochem., eds.* George R. Helz, Richard G. Zepp, and Donald G. Crosby, 369-86, Boca Raton, Fla.: Lewis Publishers, 1994.

159. Guillard, Chantal, Hoang-Van Can, Pierre Pichat, and Frederique Marme. "Laboratory Study of the Respective Roles of Ferric Oxide and Released or Added Ferric Ions in the Photodegradation of Oxalic Acid in Aerated Liquid Water." *J. Photochem. Photobiol., A* 89, no. 3 (1995): 221-7.

160. Guillard, Chantal, Herve Delprat, Hoang Van Can, and Pierre Pichat. "Laboratory Study of the Rates and Products of the Phototransformations of Naphthalene Adsorbed on Samples of Titanium Dioxide, Ferric Oxide, Muscovite, and Fly Ash." *J. Atmos. Chem.* 16, no. 1 (1993): 47-59.

161. Guillard, Chantal, Gaspard Huber, Can Hoang-Van, and Pierre Pichat. "Use of the TiO_2-UV System to Detoxify Water Contaminated by Lindane (1 .Alpha., 2.Alpha., 3.Beta., 4.Alpha., 5.Alpha., 6.Beta.-Hexachlorocyclohexane)." *Soil Environ. (1995), 5(Contaminated Soil 95, Vol. 2):* 1233-34.

162. Gupta, Hani, and Shuzo Tanaka. "Photocatalytic Mineralization of Perchloroethylene Using Titanium Dioxide." *Water Sci. Technol.* 31, no. 9 (1995): 47-54.

163. Ha, Heung Yong, and Marc A. Anderson. "Photocatalytic Degradation of Formic Acid Via Metal-Supported Titania." *J. Environ. Eng.,* 122, no. 3 (1996): 217-21.

164. Ha, Heung Yong, and Marc A. Anderson. "Photodegradation of Organic Pollutants in Water Using Metal-Supported TiO_2 Catalysts Prepared by Sol-Gel Techniques." *Hwahak Konghak 34,* no. 3 (1996): 356-62.

165. Hagfeldt, Anders, and Michael Gratzel. "Light-Induced Redox Reactions in Nanocrystalline Systems." *Chem. Rev. 95,* no. 1 (1995): 49-68.

166. Hashimoto, Kazuhito, and Akira Fujishima. "New Application of Titanium Oxide Photocatalyst." *Gendai Kagaku 305* (1996): 23-28.

167. Hashimoto, Kazuhito, and Akira Fujishima. "New Ceramics Covered With Optically Active Titanium Oxide. Addition of Antibacterial and Decontamination Functions." Nyu *Seramikkusu 9,* no. 2 (1996): 55-61.

168. Hayakawa' Makoto, and Makoto Chikuni, inventors. "Parts Having Photocatalytic Function." Toto Ltd, Japan, assignee. Japan 08131841 A2. 1996. *125:149342 CA.*

169. Hayakawa' Makoto, Makoto Chikuni, and Toshiya Watanabe, inventors. "Photocatalytic Functional Material and Method of Production Thereof." Toto Ltd., Japan, assignee. World Patent, 9614932 Al. 1996. *125:71646 CA.*

170. Heller, Adam, and J. R. Brock. "Accelerated Photooxidative Dissolution of Oil Spills." *Aquat. Surf. Photochem.,* eds. George R. Helz, Richard G. Zepp, and Donald G. Crosby, 427-36, Boca Raton, Fla.: Lewis, 1994.

171. Heller, Ephraim, Adam Heller, and Michael V. Pishko, inventors. "Photocatalyst-Binder Composition." E. Heller and Co., USA, assignee. World Patent, 951175 1 Al. 1995. *123:212961 CA.*

172. Herrmann, J. M. "Electronic Effects in Strong Metal-Support Interactions on Titania Deposited Metal Catalysts." *J. Catal. 89,* no. 2 (1984): 404-12.

173. Herrmann, J.-M. "Heterogeneous Photocatalysis: an Emerging Discipline Involving Multiphase Systems." *Catal. Today 24,* no. l-2 (1995): 157-64.

174. Herrmann, J.-M. "Heterogeneous Photocatalysis: Concepts, Reaction Mechanisms and Potential Applications in Environmental Problems." *Trends Photochem. Photobiol. 3,* no. 2 (1994): 633-42.

175. Herrmann, J. M. "M/TiO_2 Catalysts Under SMSI Conditions : Electronic Effects During H_2 Chemisorption, H_2 + CO Interactions and Photocatalysis." *American Chemical Society Symposium Series,* eds. S. J. Tauster, R. T. K. Baker, and J. Dumesic, 200. Washington, DC: American Chemical Society, 1986.

176. Herrmann, J. M., J. Disdier, and P. Pichat. "Platinum/Titania Catalysts: Electronic and Photoelectronic Interactions Between the Metal and Its Support." *Stud. Surf. Sci. Catal.* 11, Met.-Support Met.-Addit. Eff. Catal. (1982): 27-35.

177. Herrmann, J. M., J. Disdier, and P. Pichat. "Study of the Electronic Interactions of Oxygen With UV Irradiated Titanium Dioxide by Photoconductivity Measurements. Consequences for Photocatalytic Oxidations." *Proc. Int. Vac. Congr., 7th 2,* (1977): 951-4.

178. Herrmann, J. M., J. Disdier, P. Pichat, and C. Leclercq. "Photo-Assisted Deposition of Noble Metals : Investigation of a New Route for Metallic and Bimetallic Catalyst Preparation. ", eds., G. G. Poncelet, P. Grange, P. A. Jacobs, and B. Delmon, 285. Studies in Surf. Sci. and Catal., 31. Amsterdam: Elsevier, 1987.

179. Herrmann, J. M., C. Guillard, and P. Pichat. "Heterogeneous Photocatalysis: an Emerging Technology for Water Treatment." *Catal. Today 17,* no. 1-2 (1993): 7-20.

180. Herrmann, J. M., and P. Pichat. "Electronic Interactions in Platinum-, Rhodium-, and Nickel/Titanium Dioxide Catalysts." *Geterog. Katal.* 5th, Pt. 2, (1983): 389-94.

181. Herrmann, J. M., and P. Pichat. "Evidence by Electrical Conductivity Measurements for Hydrogen Spillover on Platinum-, Rhodium-, and Nickel-Titania Catalysts. Consequences for Bifunctional Photocatalysis." *Stud. Surf. Sci. Catal.* 17, Spillover Adsorbed Species (1983): 77-87.

182. Herrmann, J. M., P. Vergnon, and S. J. Teichner. "Effect of Gallium or Niobium Doping of Titanium Dioxide (Anatase) on Its Catalytic Activity in the Oxidation of Carbon Monoxide." *React. Kinet. Catal. Lett.* 2, no. 3 (1975): 199-205.

183. Herrmann, J. M., P. Vergnon, and S. J. Teichner. "Electrical Conductivity Study of the Nature of Faults Created in Titanium Dioxide (Anatase) by Various Reducing Treatments." *Bull. Soc. Chim. Fr.*, no. 8 (1972): 3034-41.

184. Herrmann, Jean M. "Electrical Conductivity and Structure Defects of n Type Semiconductor Oxides. I. General Relation Between Electrical Conductivity and Oxygen Pressure for Different Defect Species." *J. Chim. Phys. Phys.-Chim. Biol. 73,* no. 5 (1976): 474-8.

185. Herrmann, Jean M., Philippe De Montgolfier, and Pierre Vergnon. "Electrical Conductivity and Structure Defects of n Type Semiconductor Oxides. II. Application to Pure and Gallium or Niobium Doped Titania (Anatase)." *J. Chim. Phys. Phys.-Chim. Biol. 73,* no. 5 (1976): 479-84.

186. Herrmann, Jean M., Henri Latreille, Pierre Vergnon, Jean Veron, and Stanislas Jean Teichner. "Evidence for the Formation of an Active Oxygen Species in the Catalytic Oxidation of Carbon Monoxide by Electrical Conductivity Measurements of Titanium Dioxide (Anatase)." *J. Chim. Phys. Physicochim. Biol.* 71, no. 6 (1974): 943-8.

187. Herrmann, Jean M., Pierre Vergnon, and Stanislas J. Teichner. "Effect of Titanium Dioxide (Anatase) Doping on Electrical Conductivity Variations as a Function of Oxygen *Pressure." C. R. Acad. Sci., Ser. C 279,* no. 3 (1974): 83-5.

188. Herrmann, Jean M., Pierre Vergnon, and Stanislas J. Teichner. "Influence of the Morphology and the Size of Titanium Dioxide (Anatase) Particles on the Catalytic Oxidation of Carbon Monoxide." *J. Catal. 37,* no. 1 (1975): 57-67.

189. Herrmann, Jean M., Pierre Vergnon, and Stanislas J. Teichner. "Relation Between the Rate of Catalytic Oxidation of Carbon Monoxide in Contact With Titanium Dioxide (Anatase) and the Electrical Conductivity of This Oxide Measured During the Reaction." *C. R. Acad. Sci., Ser. C 278,* no. 9 (1974): 561-4.

190. Herrmann, Jean M., Pierre Vergnon, and Stanislas J. Teichner. "Structure Defects in Vanadium-Doped Titanium Dioxide." *Bull. Soc. Chim. Fr.,* no. 7-8, Pt. 1 (1976): 1056-8.

191. Herrmann, Jean Marie. "Effect of Temperature on the Photocatalytic Regime in Endergonic Reactions." *Actas Simp. Iberoam. Catal., 9th* 1, (1984): 668-74.

192. Herrmann, Jean Marie. "Thermodynamic Considerations of Strong Metal-Support Interaction in a Real Platinum/Titania Catalyst." *J. Catal. 118,* no. 1 (1989): 43-52.

193. Herrmann, Jean Marie J., Henri Courbon, Jean Disdier, Marie Noelle Mozzanega, and Pierre Pichat. "Use of Heterogeneous Photocatalysis for the Chemical Storage of Light Energy for Energy and Raw Material Economy." 6 *Sov.-Fr. Seminar Po Katalizu. Sb. Dokl., M. (1983): 4-8.*

194. Herrmann, Jean Marie, Henri Courbon, and Pierre Pichat. "Regioselective Isotopic Exchange Between Propane and Deuterium over Illuminated Platinum-Titania Catalyst Below Room Temperature." *J. Catal.* 108, no. 2 (1987): 426-32.

195. Herrmann, Jean Marie, Jean Disdier, and Pierre Pichat. "Effect of Chromium Doping on the Electrical and Catalytic Properties of Powder Titania Under UV and Visible Illumination." *Chem. Phys. Lett.* 108, no. 6 (1984): 618-22.

196. Herrmann, Jean Marie, Jean Disdier, and Pierre Pichat. "Oxygen Species Ionosorbed on Powder Photocatalyst Oxides From Room-Temperature Photoconductivity as a Function of Oxygen Pressure." *J. Chem. Soc., Faraday Trans. 1 77,* no. 11 (1981): 2815-26.

197. Herrmann, Jean Marie, Jean Disdier, and Pierre Pichat. "Photoassisted Platinum Deposition on TiO_2 Powder Using Various Platinum Complexes." *J. Phys. Chem. 90,* no. 22 (1986): 6028-34.

198. Herrmann, Jean Marie, Jean Disdier, and Pierre Pichat. "Photocatalytic Deposition of Silver on Powder Titania: Consequences for the Recovery of Silver." *J. Catal.* 113, no. 1 (1988): 72-81.

199. Herrmann, Jean Marie, Jean Disdier, Pierre Pichat, Asuncion Femandez, Agustin Gonzalez-Elipe, Guillermo Munuera, and Christiane Leclercq. "Titania-Supported Bimetallic Catalyst Synthesis by Photocatalytic Codeposition at Ambient Temperature: Preparation and Characterization of Platinum-Rhodium, Silver-Rhodium, and Platinum-Palladium Couples." *J. Catal. 132,* no. 2 (1991): 490-7.

200. Herrmann, Jean Marie, Marie Noelle Mozzanega, and Pierre Pichat. "Oxidation of Oxalic Acid in Aqueous Suspensions of Semiconductors Illuminated With UV or Visible Light." *J. Photochem. 22,* no. 4 (1983): 333-43.

201. Herrmann, Jean Marie, and Pierre Pichat. "Metal-Support Interactions: *an in Situ* Electrical Conductivity Study of Platinum/Titania Catalysts." *J. Catal. 78,* no. 2 (1982): 425-35.

202. Hidaka, Hisao, Kayo Nohara, Satoshi Horikoshi, Nobuyuki Tanaka, Toshiya Watanabe, Jincai Zhao, and Nick Serpone. "Photodegradation of Surfactants. XVIII. Total Organic Carbon Measurements in the TiO_2-Assisted Photomineralization of Surfactants." *Nihon Yukagakkaishi 45,* no. 1 (1996): 21-8.

203. Hidaka, Hisao, Kayo Nohara, Jincai Zhao, Ezio Pelizzetti, and Nick Serpone. "Photodegradation of Surfactants XIV. Formation of NH,' and NO_3^- Ions for the Photocatalyzed Mineralization of Nitrogen-Containing Cationic, Non-Ionic and Amphoteric Surfactants." *J. Photochem. Photobiol., A* 91, no. 2 (1995): 145-52.

204. Hiramatsu, Takashi, Kazunobu Oota, and Yasuaki Hayamizu, inventors. "Painted Bodies and Their Preparation." Sekisui Jushi Kk, Japan, assignee. Japan Patent, 08117683 A2. 1996. *125:99933 CA.*

205. Hirayama, Shoji, inventor. "Method and Apparatus for Bacterial-Containing Wastewater Treatment." Hirayama Shoji, Japan, assignee. Japan Patent, 07284764 A2. 1995. *124:96510 CA.*

206. Hisanaga, Teruaki, Kenji Harada, and Keiichi Tanaka. "Photocatalytic Degradation of Organochlorine Compounds in Suspended TiO_2." *J. Photochem. and Photobiol. A: Chem.* *54* (1990): 113-8.

207. Hoang-Van, Can, Pierre Pichat, and Marie-Noeelle Mozzanega. "Room-Temperature Hydrogen Transfer From Liquid Methanol or 2-Propanol to Diphenylacetylene over Group VIII Metal/TiO_2 Photocatalysts." *J. Mol. Catal. 92,* no. 2 (1994): 187-99.

208. Hsieh, Yung-Hsu, and Ting-Shan Chia. "Investigation and Study on the Photocatalytic Degradation of Polychlorophenols in Aqueous Solution." *Hazard. Ind. Wastes 27th* (1995): *383-92.*

209. Huang, I.-Wei, Chia-Swee Hong, and Brian Bush. "Photocatalytic Degradation of PCBs in TiO_2 Aqueous Suspensions." *Chemosphere 32,* no. 9 (1996): 1869-81.

210. Huang, Jiansheng, Huiling Ding, William S. Dodson, and Yuzhuo Li. "Application of TiO_2 Sol for UV Radiation Measurements." *Anal. Chim. Acta* 311 (1995): 115-22.

211. Huang, Min, Erwin Tso, Abhaya K. Datye, Michael R. Prairie, and Bertha M. Stange. "Removal of Silver in Photographic Processing Waste by TiO_2-Based Photocatalysis." *Environ. Sci. Technol. 30,* no. 10 (1996): 3084-88.

212. Huang, *Y.,* and *C.* J. Chu. *High Efficiency TiO_2* Photocatalysts by the Sol-Gel Process, ARO-34492.1-CH-SAH. 1995. AD-A303985.

213. Hung, Chung-Hsuang Jeremy. "Gas-Phase Photocatalytic Degradation of Trichloroethylene and Formation of Reaction Products on Immobilized Titanium Dioxide (Chlorination)." Ph.D. diss., Purdue Univ., 1995.

214. Hyun, Sang-Hoon, and Kee-Hong Lee. "Oxidation of Organic Compounds Through the Electrochemical Reaction Using TiO_2 Photocatalytic Membranes." *Memburein 6,* no. 2 (1996): 101-8.

215. Ibusuki, Akitsugu, Hiroshi Takeuchi, Takeo Takahashi, Kazuteru Aragai, Masahiro Myamoto, Satoshi Nishikata, and Tetsuhiro Terano, inventors. "Apparatus for Removing Hazardous Gases from Air." Kogyo Gijutsuin, Japan, and Fuji Electric Co. Ltd., assignees. Japan 07108138 A2. 1995. *123:121889 CA.*

216. Ibusuki, Takashi. "Removal of Low Concentration NOx from Ambient Air by Photocatalysis." *Jidosha Gijutsu 50,* no. 7 (1996): 34-36.

217. Ichihashi, Yuichi, Hiromi Yamashita, and Masakazu Anpo. "Recent Trends in the Environmental Photocatalysis Using Titanium Oxide-Based Photocatalysts an a New Approach to Utilization of Visible Light in Photocatalysis." *Kino Zairyo* 16, no. 7 (1996): 12-22.

218. Ike&, Katsuyoshi, Hideki Sakai, Ryo Baba, Kazuhito Hashimoto, and Akira Fujishima. 'Microscopic Observation of Photocatalytic Reaction Using Microelectrode: Spatial Resolution for Reaction Products Distribution." *Chem. Lett.* no. 11 (1995): 979-80.

219. Inel, Yueksel, and Ayse Neren Oekte. "Photocatalytic Degradation of Malonic Acid in Aqueous Suspensions of Titanium Dioxide: an Initial Kinetic Investigation of CO_2 Photogeneration." *J. Photochem. Photobiol., A 96,* no. l-3 (1996): 175-80.

220. Ishihara, Shigehisa, and Takeshi Furutsuka. "Removal of NOx or Its Conversion into Harmless Gases by Charcoals and Composites of Metal Oxides." *Prepr. Pap. - Am. Chem. Soc., Div. Fuel Chem.* 41, no. 1 (1996): 289-92.

221. Itou, Yoshihisa, and Hidezou Oogaki. "Photolysis of Pesticides." *Tochigi-Ken Kogai Kenkyusho Nenpo 19 (1995): 55-65.*

222. Iwane, Nobuo, Teruo Aoe, and Osamu Ikemoto, inventors. "Photocatalytic Tiles." Teikoku Kako Co. Ltd., Japan, assignee. Japan Patent, 08105178 A2. 1996. *125:99932 CA.*

223. Jacoby, William A., and Daniel M. Blake, inventors. "Photocatalytic Reactor With Flexible Supports." Midwest Research Institute, Kansas City, MO, assignee. United States 5449443. 1995.

224. Jacoby, William A., Daniel M. Blake, John A. Fennell, James E. Boulter, LeAnn M. Vargo, Marya C. George, and Suzanne K. Dolberg. "Heterogeneous Photocatalysis for Control of Volatile Organic Compounds in Indoor *Air." J. Air and Waste Management Assoc. 46* (1996): 891-98.

225. Jacoby, William A., Daniel M. Blake, Richard D. Noble, and Carl A. Koval. "Kinetics of Oxidation of Trichloroethylene in Air Via Heterogeneous Photocatalysis." *J. Catal.* 157, no. 1 (1995): 87-96.

226. Jiang, Weichuan, and Xiangping Tan. "Study on the Photodegradation of Dyes in Aqueous Solution Over a Ag-Loaded TiO_2 Catalyst." *Huanjing Kexue* 16, no. 2 (1995): 15-8.

227. Jiang, Weichuan, Qiquan Wang, and Chuanming Yu. "Study of Semiconductor Photocatalytic Degradation on Disperse Dyes Solution." *Shanghai Huanjing Kexue* 14, no. 5 (1995): 8-10.

228. Joyce-Pruden, Cheryl, Jeffrey K. Pross, and Yuzhuo Li. "Photoinduced Reduction of Aldehydes on Titanium Dioxide." *J. Org. Chem. 57,* no. 19 (1992): 5087-91.

229. Juillet, Francois, Stanislas Teichner, and Marc Formenti, inventors. "Process for the Photocatalytic Oxidation of Hydrocarbons into Aldehydes and Ketones." Agence Nationale de Valortiation de la Reserche, assignee. United States Patent, 3,781,194. 1973.

230. Kabir-ud-Din, Robert C. Owen, and Marye Anne Fox. "Behavior of Some N-Type Unmodified and Chemically Modified Metal Oxide Electrodes in Nonaqueous Solvents." *J. Phys. Chem. 85,* no. 12 (1981): 1679-82.

231. Kamat, Prashant K. "Native and Surface Modified Semiconductor Nanoclusters.", 273-343. Progress in Inorganic Chemistry, ed. Kenneth D. Karlin, Molecular Level Artificial Photosynthetic Materials. New York, NY: John Wiley and Sons, Inc., 1997.

232. Kamat, Prashant V. "Tailoring Nanostructured Thin Films." *CHEMTECH 25,* no. 6 (1995): *22-28.*

233. Kamat, Prashant V., Idriss Bedja., and K. Vinodgopal. "Photoinduced Charge Transfer Processes in Semiconductor Heterostructures. Capped vs. Coupled Systems." *NATO ASI Ser., Ser. 3 (1996), 12(Fine Particles Science and Technology), 303-316.*

234. Kamat, Prashant V., and Marye Anne Fox. "Photosensitization of Titanium Dioxide Colloids by Erythrosin B in Acetonitrile." *Chem. Phys. Lett.* 102, no. 4 (1983): 379-84.

235. Kamat, Prashant V., and Marye Anne Fox. "Time-Resolved Photoelectrochemistry. A Laser-Induced Coulostatic Flash Study of N-Titanium Dioxide in Acetonitrile." *J. Phys. Chem. 87,* no. 1 (1983): 59-63.

236. Kamat, Prashant V., and Genevieve Sauve. "Photophysical and Charge Transfer Processes of C,." *Proc. - Electrochem. Soc.* 95-10, Proceedings of the Symposium on Recent Advances in the Chemistry and Physics of Fullerenes and Related Materials, 1995 (1995): 431-40.

237. Kamat, Prashant V., and K. Vinodgopal. "The Role of Support Material in the Photodegradation of Colored Organic Compounds." *Aquat. Surf. Photochem., eds.* George R. Helz, Richard G. Zepp, and Donald G. Crosby, 443-50, Boca Raton, Fla.: Lewis Publishers, 1994.

238. Kamya, Tsuneo, Kazuo Yamamoto, and Takashi Fujii, inventors. "Photocatalyst Carrier and Titanium Oxide Photocatalyst for Purification Waste Gases and Wastewater." Toho Titanium Co. Ltd., Japan, assignee. Japan Patent, 07213913 A2. 1995. *123:321067 CA.*

239. Kato, K., Y. Torii, H. Taoda, T. Kato, Y. Butsugan, and K. Niihara. "TiO_2 Coating Photocatalysts With Nanostructure and Preferred Orientation Showing Excellent Activity for Decomposition of Aqueous Acetic Acid." *J. Mater. Sci. Lett.* 15, no. 10 (1996): 913-15.

240. Kato, Kazumi, and Hiroshi Taoda, inventors. "Titanium Oxide Thin Film Photocatalyst and Its Manufacture." Kogyo Gijutsuin, Japan, assignee. Japan 07100378 A2. 1995. *123:44261 CA.*

241. Kato, Kazumi, and Hiroshi Togeda, inventors. "Porous Thin Film Photocatalysts Containing Titanium Oxide and Manufacture Thereof." Kogyo Gijutsuin, Japan, assignee. Japan Patent, 08099041 A2. 1996. *125:66102 CA.*

242. Kato, Kenji, and Takuya Murayama, inventors. "Supporting Titanium Oxide Particles on Base Materials for Formation of Photocatalyst Layers." Matsushita Seiko Kk, Japan, assignee. Japan Patent, 08117596 A2. 1996. *125:66174 CA.*

243. Kaviratna, P. D., and C. H. F. Peden. "Photocatalytic Destruction of Automobile Exhaust Emissions." *Prepr.- Am. Chem. Soc., Div. Pet. Chem.* 41, no. 1 (1996): 51-3.

244. Kawagoe, Hiroshi, Shuichi Sugano, Akira Kato, and Hiroshi Myadera, inventors. "Coating Materials Removing Nitrogen Oxides and Application Thereof." Hitachi Ltd., Japan, assignee. Japan Patent, 07331120 A2. 1996. *124:205184 CA.*

245. Kawashima, Koichi, Ryuji Masuda, Wataru Takahashi, Masayuki Murabayashi, and Kiminori Ito, inventors. "Photocatalyst for Removal of Heavy Metal Ions in Wastewater and Apparatus for Removal of Heavy Metal Ions From Wastewater." Nippon Muki Kk, Japan, assignee. Japan Patent, 07144136 A2. 1995. *123:151976 CA.*

246. Kelly, Sean, Wu-Mian Shen, and Micha Tomkiewicz. "Role of Surface Area and Crystallite Size in the Photocatalytic Activity of TiO_2 Aerogels." *Proc.- Electrochem. Soc.* 95-8, no. Proceedings of the Symposium on Nanstructured Materials in Electrochemistry, 1995 (1995): 137-42.

247. Kemp, Terence J., Patrick R. Unwin, and Laszlo Vincze. "Photogenerated Chloride Ion Concentration Near the Surface of UV-Irradiated Titanium Dioxide in the Presence of Aqueous 2,4-Dichlorophenol Probed Using an Ultramicroelectrode." *J. Chem. Soc., Faraday Trans.* 91, no. 21 (1995): 3893-6.

248. Kerzhentsev, M., C. Guillard, J. M. Herrmann, and P. Pichat. "Titanium Dioxide-Photosensitized Degradation of the Insecticide Tetrachlorvinphos ((z)-2-Chloro-1-(2,4,5-Trichlorophenyl)Ethenyl Dimethyl Phosphate)." *Photocatalytic Purification and Treatment of Water and Air,* eds. David F. Ollis, and Hussain Al-Ekabi, 601-6, Trace Met. Environ., ed. Jerome 0. Nriagu, New York, NY: Elsevier, 1994.

249. Kerzhentsev, Mikhail, Chantal Guillard, Jean-Marie Herrmann, and Pierre Pichat. "Photocatalytic Pollutant Removal in Water at Room Temperature: Case Study of the Total Degradation of the Insecticide Fenitrothion (Phosphorothioic Acid O,O-Dimethyl-O-(3-Methyl-4-Nitro-Phenyl) Ester)." *Catal. Today 27,* no. 1-2 (1996): 215-20.

250. Kikuchi, Yoshihiko, Kazuhito Hashimoto, and Akira Fujishima. "Photocatalysts in Action." *Kagaku Kogyo 46,* no. 12 (1995): 937-42.

251. Kim, Dong Hyun, and Marc A. Anderson. "Solution Factors Affecting the Photocatalytic and Photoelectrocatalytic Degradation of Formic Acid Using Supported TiO_2 Thin Films." *J. Photochem. Photobiol., A 94,* no. 2-3 (1996): 221-9.

252. Kim, Dong Hyun, Marc A. Anderson, and Walter A. Zeltner. "Effects of Firing Temperature on Photocatalytic and Photoelectrocatalytic *Properties* of TiO_2." *J. Environ. Eng.* 121, no. 8 (1995): 590-4.

253. Kim, Dong-Hyung, Tai-Kyu Lee, Kwang-Bok Kim, and Seung-Won Lee. "The Photocatalytic Activity of TiO_2 Powder Prepared by Sol-Gel Method." *Han'Guk Chaelyo Hakhoechi 6,* no. 3 (1996): 282-90.

254. Kim, Jong-Hyan, Chun-Dong Nam, and Byung-Kwan Kim. "Photocatalytic Degradation of Chlorothalonil Using TiO_2 Supported in Matrixes." *Kongop Hwahak 7,* no. 4 (1996): 750-756.

255. Kim, Jong-Soon, Kiminori Itoh, and Masayuki Murabayashi. "Photocatalytic Degradation of Trichloroethylene on TiO_2 Sol-Gel Thin Films in Gas Phase: Effect of Humidity on Reaction Rates, and *Analyses* of Products." *Yokohama Kokuritsu Daigaku Kankyo Kagaku Kenkyu Senta Kiyo 22,* no. 1 (1996): 17-21.

256. Kinkennon, Amy E., David B. Green, and Ben Hutchinson. "The Use of Simulated Concentrated Natural Solar Radiation for the TiO_2-Mediated Photodecomposition of Basagran, Diquat, and Diuron." *Chemosphere 3* 1, no. 7 (1995): 3663-71.

257. Kittrell, J. R., and C. W. Quinlan. "Air Stripping Photocatalytic Oxidation - A Winning Team for Groundwater Remediation." *Environmental Protection* (September 1995): 15-22.

258. Kiuchi, Masato, Hiroyuki Kojima, Kyoshi Ogata, and Osamu Imai, inventors. "Photocatalytic TiO_2-Coated Material and Fabrication Thereof." Kogyo Gijutsu Incho, Japan, and Nitsushin Denki Kk, assignees. Japan Patent, 08134630 A2. 1996. *125:127572 CA.0*

259. Kobayakawa, Koichi, Yuichi Sato, and Akira Fujishima. "Removal of Organic Contaminants in Water by TiO_2 Fixed Photoreactors. Current Topics of Photocatalysis." *Kino Zairyo* 15, no. 4 (1995): 5-10.

260. Koehler, Terrence L., Robert R. Hudgins, and William A. Anderson. "Using Photocatalytic Degradation as a Demonstration of an Advanced Oxidation Process." *Can. Chem. News 48,* no. 3 (1996): 15-16.

261. Koesters, M., F. Krueckel, S. Lopp, and D. Hesse. "On the Use of Photocatalysts in Flue *Gas* Cleaning." *IChemE Res. Event--Eur. Con. Young Res. Chem. Eng., lst, 348-50,* Rugby, UK: Inst. Chem. Eng., 1995.

262. Komazaki, Y., H. Shimizu, S. Tanaka, J. Miyai, and T. Inomata. "The Measurement of NOx in Flue Gases by Using a Diffusion Scrubber Coated With Photocatalyst and Ion Chromatography." *Kankyo Kagaku 5,* no. 2 (1995): 468-9.

263. Kosaka, Yoshiomi, inventor. "Photocatalysts and Method for Applying the Catalysts." Matsushita Seiko Kk, Japan, assignee. Japan 07060132 A2. 1995. *123:40329 CA.*

264. Kriek, R. J., W. J. Engelbrecht, and J. J. Cruywagen. "Separation and Recovery of Some Platinum Group Metals (PGMs) by Means of Selective Photocatalytic Reduction." *J. S. Afr. Inst. Min. Metall. 95,* no. 2 (1995): 75-81.

265. Krishnan, M., James R. White, Marye Anne Fox, and Allen J. Bard. "Integrated Chemical Systems: Photocatalysis at Semiconductors Incorporated into Polymer (Nafion)/Mediator Systems." *J. Am. Chem. Soc.* 105, no. 23 (1983): 7002-3.

266. Kruggel, M., and Israel G. "Photocatalytical Detoxification of Water Pollutants." *J. Inf. Rec.* 23, no. l-2, 14th Conference Photochemistry Section of the Society of German Chemists, 1995, Pt. 2 (1996): 47-51.

267. Ku, Young, Ren-Ming Leu, and Kuen-Chyr Lee. "The Effect of Dissolved Oxygens on the Treatment of 2-Chlorophenol in Aqueous Solution by the UV/TiO_2 Process." *Zhongguo Huanjing Gongcheng Xuekan 6,* no. 1 (1996): 43-9.

268. Kumai, Hiroshi, Hidejiro Kudo, Masanori Tomonari, and Takeshi Zedo, inventors. "Manufacture of Compositions for Titanium Oxide Coatings for Photocatalysis." Korukooto Kk, Japan, and Ishihara Sangyo Kaisha, assignees. Japan Patent, 08164334 A2. 1996. *125:199852 CA.*

269. Kuo, Jih-Fen, and Scott 0. Smith. "Disinfection." *Water Environ. Res. 68,* no. 4 (1996): 503- 10.

270. Kuroda, Hiroshi, and Takashi Ashimura, inventors. "Preparation of Semiconductive Photocatalysts and Treatment of Wastewater Containing Organic Compounds." Fuji Chitan Kogyo Kk, Japan, assignee. Japan Patent, 07275702 A2. 1995. *124:96502 CA.*

271. Kuwabata, Susumu, Hiroyuki Uchida, Akihiro Ogawa, Shigeki Hirao, and Hiroshi Yoneyama. "Selective Photoreduction of Carbon Dioxide to Methanol on Titanium Dioxide Photocatalysts in Propylene Carbonate Solution." *J. Chem. Soc., Chem. Commun.,* no. 8 (1995): 829-30.

272. Lakshmi, S., R. Renganathan, and S. Fujita. "Study on TiO_2-Mediated Photocatalytic Degradation of Methylene Blue." *J. Photochem. Photobiol., A 88,* no. 2-3 (1995): 163-7.

273. Larsen, Craig S., and Andrew P. Kruzic. "Photocatalyst Assisted Ultraviolet Disinfection of Municipal Wastewater Secondary Effluent." *Proc. Water Environ. Fed. Annu. Conf. Expo., 68th,* 271-82, Alexandria' Va: Water Environment Federation, 1995.

274. Larson, Sheldon A., Jason A. Widegren, and John L. Falconer. "Transient Studies of 2-Propanol Photocatalytic Oxidation on Titania." *J. Catal.* 157, no. 2 (1995): 611-25.

275. Lee, Tai K., Dong H. Kim, Sug H. Cho, and Chungmoo Auh. "Solar Detoxification of Trichloroethylene in Waste Water With Slurry Batchtype Photoreactor." *Solar Energy* 12, no. 3 (1992): 10-20.

276. Lee, Tai K., Dong H. Kim, Kyung N. Kim, and P. Chungmoo Auh. "Heterogeneous Photocatalytic Decomposition of Organics in Water Phase." *Solar Energy* 15, no. 2 (1995): 65-76.

277. Lepore, Giuseppe Piettro. "Primary Events Governing Photocatalytic Activity of Different Titanium Dioxide Archetypes." Ph.D. diss., Univ. of Calgary, 1995.

278. Levy, Boris, and Tongguang Zhang. "Field Assisted Charge Transport in Chemically and Dye Sensitized AgX and Pt-TiO_2 -Dye Particulate Heterojunctions." *ICPS' 94: Phys. Chem. Imaging Syst., IS&T's 47th Annu. Conf.*, 313-17, Springfield, Va: IS&T--The Society for Imaging Science and Technology, 1994.

279. Lewis, David Frank, Graeme John Baird, David Macdonald Bonnick, and Howard Matthew Colquhoun, inventors. "Membrane for Water Purification by Photocatalysis." North West Water Group Plc, UK, assignee. World Patent, 9604069 Al. 1996. *124:352165 CA.*

280. Li, Tian, and Yanling Qiu. "Photocatalytic Oxidation of Benzene Hexachloride and Pentachlorophenol in Aqueous Solution." *Huanjing Kexue 17,* no. 1 (1996): 24-26.

281. Li, X. Z., M. Zhang, and H. Chua "Disinfection of Municipal Wastewater by Sensitized Photooxidation." *Water Sci. Technol. 33,* no. 3, High-Performance Low-Cost Environmental and Sanitation Control Systems (1996): 111-18.

282. Lichtin, N. N., M. Avudaithai, E. Berman, and A. Grayfer. "TiO_2-Photocatalyzed Oxidative Degradation of Binary Mixtures of Vaporized Organic Compounds." *Sol. Energy 56,* no. 5 (1996): 377-85.

283. Lichtin, Norman N., and Muthusami Avudaithai. "TiO_2-Photocatalyzed Oxidative Degradation of CH_3CN, CH_3OH, C_2HCl_3, and CH_2Cl_2 Supplied as Vapors and in Aqueous Solution Under Similar Conditions." *Environ. Sci. Technol. 30,* no. 6 (1996): 2014-20.

284. Lichtin, Norman N., Muthusamy Avudaithi, and Elliot Berman. "Photocatalytic Oxidative Decomposition of CH_3CN Vapor." *Proc., Annu. Meet. - Air Waste Manage. Assoc.* 87th, Vol. 6B, Air Pollution Sources & Control (1994): 1-16 Paper 94-FA149.05.

285. Lindner, Martin, Detlef Bahnemann, Bernd Hirthe, and Wolf Dieter Griebler. "Novel Catalysts for Photocatalytic Wastewater Treatment." *WLB, Wasser, Luft Boden 38,* no. 1 1/12 (1994): 38-40.

286. Linsebigler, Amy, Guangquan Lu, and John T. Jr. Yates. "CO Photooxidation on TiO_2(110)." *J. Phys. Chem.* 100, no. 16 (1996): 6631-6.

287. Linsebigler, Amy, Camelia Rusu, and John T. Jr. Yates. "Absence of Platinum Enhancement of a Photoreaction on TiO_2-CO Photooxidation on Pt/TiO_2(110)." *J. Am. Chem. Soc.* 118, no. 22 (1996): 5284-89.

288. Liu, Chun-yan, and Xin-min Ren. "Photocatalytic Oxidation of N-Substituted P-Phenylenediarnines in TiO_2 Dispersion." *J. Photogr. Sci. 43,* no. 5 (1995): 160-5.

289. Liu, Chun-yan, and Xin-min Ren. "The Photocatalytic Oxidation of the Derivatives of P-Phenylenediamine." *Cuihua Xuebao* 16, no. 4 (1995): 274-9.

290. Liu, Chun-yan, Chuan-yi Wang, and Xin-min Ren. "Photocatalytic Reaction of Phenylmercaptotetrazole on TiO_2 Dispersion." *IS&T's Annu. Con., Final Program Adv. Print. Pap., 48th*, 252-4, Springfield, Va.: IS&T--The Society for Imaging Science and Technology, 1995.

291. Liu, Chun-Yan, Ling Zang, Si-Hai Chen, and Xin-Min Ren. "Photophysical Properties of Semiconductor Particles and Photocatalytic Degradation of Organic Pollutants." *ICPS' 94: Phys. Chem. Imaging Syst., IS&T's 47th Annu. Conf.*, 187-9, Springfield, Va.: IS&T--The Society for Imaging Science and Technology, 1994.

292. Liu, Junbiao, John C. Crittenden, David W. Hand, and David L. Per-ram. "Regeneration of Adsorbents Using Heterogeneous Photocatalytic Oxidation." *J. Environ. Eng.* 122, no. 8 (1996): 707-13.

293. Lu, Daohui, Dewen Chen, and Guangzhi Xu. "Photocatalytic Decomposition of Amides on the Surface of Silver-Modified TiO_2 Particles." *Bopuxue Zazhi* 12, no. 6 (1995): 627-34.

294. Lu, Ming-Chun, Gwo-Dong Roam, Jong-Nan Chen, and C. P. Huang. "Photocatalytic Mineralization of Toxic Chemicals With Illuminated TiO_2." *Chem. Eng. Commun.* 139 (1995): 1-13.

295. Maezawa, Akinori, Nobuo Terai, Shigeo Uchida, and Masahiko Yano. "Photooxidation Treatment of Surfactant-Containing Wastewater Using a Titania Catalyst." *Kagaku Kogaku* 60, no. 8 (1996): 569-70.

296. Mahdavi, Farah, Thomas C. Bruton, and Yuzhuo Li. "Photoinduced Reduction of Nitro Compounds on Semiconductor Particles." *J. Org. Chem. 58,* no. 3 (1993): 744-6.

297. Malati, M. A. "The Photocatalyzed Removal of Pollutants From Water." *Environ. Technol.* 16, no. 11 (1995): 1093-9.

298. Malati, Mounir A. "Mitigation of CO_2 Greenhouse Effect. Combined Disposal and Utilization by Photocatalysis." *Energy Convers. Manage. 37,* no. 6-8 (1996): 1345-50.

299. Marci, Giuseppe, Leonardo Palmisano, Antonino Sclafani, Maria Venezia, Renzo Campostrini, Giovanni Carturan, Cristina Martin, Vicente Rives, and Gabriel Solana. "Influence of Tungsten Oxide on Structural and Surface Properties of Sol-Gel Prepared TiO_2 Employed for 4-Nitrophenol Photodegradation." *J. Chem. Soc., Faraday Trans. 92,* no. 5 (1996): 819-29.

300. Martin, Carlos A., Miguel A. Baltanas, and Alberto E. Cassano. "Photocatalytic Reactors. 3. Kinetics of the Decomposition of Chloroform Including Absorbed Radiation Effects." *Environ. Sci. Technol. 30,* no. 7 (1996): 2355-64.

301. Martin, Carlos A., Miguel A. Baltanas, and Alberto E. Cassano. "Photocatalytic Reactors. II. Quantum Efficiencies Allowing for Scattering Effects. An Experimental Approximation." *J. Photochem. Photobiol., A 94,* no. 2-3 (1996): 173-89.

302. Martin, Scot T., Janet M. Kesselman, David S. Park, Nathan S. Lewis, and Michael R. Hoffmann. "Surface Structures of 4-Chlorocatechol Adsorbed on Titanium Dioxide." *Environ. Sci. Technol. 30,* no. 8 (1996): 2535-42.

303. Martin, Scott T., Albert T. Lee, and Michael R. Hoffmann. "Chemical Mechanism of Inorganic Oxidants in the TiO_2/UV Process: Increased Rates of Degradation of Chlorinated Hydrocarbons." *Environ. Sci. Technol. 29,* no. 10 (1995): 2567-73.

304. Mas, D., T. Hisanaga, K. Tanaka' and P. Pichat. "Photocatalytic Degradation of the Pesticides Asulam and Diazinon in Titanium Dioxide Aqueous Suspensions." *Trends Photochem. Photobiol. 3,* no. 2 (1994): 467-79.

305. Matsubara, Hirokazu, Makoto Takada, and Shinichi Koyama. "Research on Application of Photoactive TiO_2 to Paper." *Kinoshi Kenkyu Kaishi, 34* (1996): 36-9.

306. Matsubara, Hirokazu, Makoto Takada, Shinichi Koyama, Kazuhito Hashimoto, and Akira Fujishima. "Photoactive TiO_2 Containing Paper: Preparation and Its Photocatalytic Activity Under Weak UV Light Illumination." *Chem. Lett.,* no. 9 (1995): 767-8.

307. Matsunaga, Tadashi, and Mina Okochi. "TiO_2 Mediated Photochemical Disinfection of Escherichia Coli Using Optical Fibers." *Environ. Sci. Technol. 29,* no. 2 (1995): 501-5.

308. Matsutani, Hiroshi, inventor. "Immobilized Photocatalyst for Purification of Wastewater and Waste Gases." Kurita Water Ind Ltd., Japan, assignee. Japan Patent, 08024666 A2. 1996. *124:210896 CA.*

309. Matsutani, Hiroshi, inventor. "Photooxidative Decomposition of Organic Chlorine Compounds in Air." Kurita Water Ind Ltd, Japan, assignee. Japan Patent' 08173765 A2. 1996. *125:176190 CA.*

310. Matsutani, Hiroshi, and Shinichi Takasaki. "Photocatalytic Decomposition Rate of TOC With Suspended Platinum Loaded TiO_2 in Internal Radiation-Type Cylindrical Reactors." *Mizu Kankyo Gakkaishi 19,* no. 3 (1996): 236-42.

311. Mikula, M., V. Brezova, M. Ceppan, L. Pach, and L'. Karpinsky. "Comparison of Photocatalytic Activity of Sol-Gel TiO_2 and P25 TiO_2 Particles Supported on Commercial Fiberglass Fabric." *J. Mater. Sci. Lett.* 14, no. 9 (1995): 615-16.

312. Mills, Andrew, Ahmed Belghazi, and Derek Rodman. "Semiconductor Photocatalysis: The Removal of Bromate From Potable Water." *BHR Group Conf. Ser. Publ. (1995), 17(3rd International Conference on Water and Waste Water Treatment, 1995), 3-11.*

313. Minero, C., E. Pelizzetti, S. Malato, and J. Blanco. "Large Solar Plant Photocatalytic Water Decontamination: Degradation of Atrazine." *Sol. Energy 56,* no. 5 (1996): 411-19.

314. Minero, Claudio, Valter Maurino, and Ezio Pelizzetti. "Photocatalytic Degradation of Free and Chemically Bound Silicones on Irradiated Titanium Dioxide." *Langmuir* 11, no. 11 (1995): 4440-4.

315. Minero, Claudio, Ezio Pelizzetti, Pierre Pichat, Michela Sega, and Marco Vincenti. "Formation of Condensation Products in Advanced Oxidation Technologies: The Photocatalytic Degradation of Dichlorophenols on TiO_2." *Environ. Sci. Technol. 29,* no. 9 (1995): 2226-34.

316. Mita, Keisuke. "Preparation of Pt-TiO_2 Supported on Silica-Coated Glass Flake as Efficient Photocatalyst." *Kagaku to Kogyo Osaka 70,* no. 3 (1996): 133-6.

317. Mohs, C. R., and K. J. Klabunde. "Preparation of Small Particles of Titanium(IV) Oxide." *NATO ASI Ser., Ser. E* 260(Nanophase Materials) (1994): 121-4.

318. Morawski, A. W., J. Grzechulska, and K. Kalucki. "A New Method for Preparation of Potassium-Pillared Layered Titanate Applied in Photocatalysis." *J. Phys. Chem. Solids 57,* no. 6-8, Proceedings of the 8th International Symposium on Intercalation Compounds, 1995 (1996): 1011-17.

319. Morawski, Antoni W., Joanna Grzechulska, Maria Tomaszewska, Kyzysztof Karakulski, and Kazimierz Kalucki. "Photocatalytic Decay of Phenol in Water in the Presence of Modified TiO_2." *Gaz, Woda Tech. Sanit. 69,* no. 3 (1995): 89-90.

320. Morterra, Claudio, Anna Chiorino, Flora Boccuzzi, and Emilia Fisicaro. "A Spectroscopic Study of Anatase Properties. 4. The Adsorption of Carbon Dioxide." *Z. Physikalische Chem. Neue Folge 124 (1981): 211-22.*

321. Mozzanega, Henri, Jean Marie Herrmann, and Pierre Pichat. "Ammonia Oxidation over UV-Irradiated Titanium Dioxide at Room Temperature." *J. Phys. Chem. 83,* no. 17 (1979): 225 l-5.

322. Mozzanega, Marie Noelle, Jean Marie Herrmann, and Pierre Pichat. "Oxidation of Alkyltoluenes to Alkylbenzaldehydes by Contact With UV Irradiated Titanium Dioxide." *Tetrahedron Lett.,* no. 34 (1977): 2965-6.

323. Mu, Wei, Jean Marie Herrmann, and Pierre Pichat. "Room Temperature Photocatalytic Oxidation of Liquid Cyclohexane into Cyclohexanone over Pure and Modified Titanium(IV) Oxide." *Catal. Lett. 3,* no. 1 (1989): 73-84.

324. Mune, Toshiyasu. "Photocatalytic Titanium Oxide Deodorant Addible to Organic Substances." *Konbatekku 24,* no. 3 (1996): 26-28.

325. Mune, Toshiyasu, and Makoto Sato. "Development of Photocatalytic Deodorant (GYT) Addable to Organic Substances." *Kino Zairyo* 16, no. 9 (1996): 12-21.

326. Mune, Toshiyasu, Makoto Sato, Hitoshi Kawahara, Tsuneo Ando, Suzo Ohhara, Yoshinori Tanigami, and Soi Cho. "Deodorants Miscible With Organic Substances." *Kogyo Zairyo* 44, no. 8 (1996): 114-18.

327. Murabayashi, Masayuki, Kiminori Ito, Koichi Kawashima, Ryuji Masuda, and Wataru Takahashi, inventors. "Photocatalyst for Catalytic Decomposition of Hazardous Substances in Waste Solutions and Its Apparatus." Murabayashi Masayuki, Japan, Ito Kiminori, and Nippon Muki *Kk,* assignees. Japan *07096202* A2. 1995. *123:121808 CA.*

328. Murabayashi, Masayuki, Kiminori Itoh, and Jong-Soon Kim. "Gas-Phase Photocatalytic Degradation of Organic Chlorocompounds." *Yokohama Kokuritsu Daigaku Kankyo Kagaku Kenkyu Senta Kiyo 21,* no. 1 (1995): 29-36.

329. Muradov, Nazim Z., Ali T-Raissi, Donald Muzzey, Charles R. Painter, and Michael R. Kemme. "Selective Photocatalytic Destruction of Airborne VOCs." *Sol. Energy 56,* no. 5 (1996): 445-53.

330. Murakami, Hajime, and Tasaka Ishida. "Titanium Oxide Deodorizer Filter." *Kogyo Zairyo* 44, no. 6 (1996): 57-61.

331. Murasawa, Sadao, Hajime Murakami, Yasuro Fukui, Mitsuru Watanabe, Akira Fujishima, and Kazuhito Minamikosug Hashimoto, inventors. "Photocatalyst Composite and Process for Producing the Same." Ishihara Sangyo Kaisha, Ltd., Japan, assignee. Europe 633064 Al. 1995. *123:127421 CA.*

332. Murasawa, Sadao, and Shigure Teramoto, inventors. "Method of Cleaning Solid Surface." Ishihara Sangyo Kaisha, Japan, assignee. Japan Patent, 07051646 A2. 1995. *123:35820 CA.*

333. Mursyidi, Achmad, Sri Noegrohati, and Ibnu Gholib Gandjar. "Photodegradation of Organochlorine Compounds Catalyzed by Titanium Dioxide." *Maj. Farm. Indones. 5,* no. 2 (1994): 44-51.

334. Nageswara Rao, N., and Sangeeta Dube. "Photocatalytic Degradation of Mixed Surfactants and Some Commercial Soap/Detergent Products Using Suspended TiO_2 Catalysts." *J. Mol. Catal. A: Chem.* 104, no. 3 (1996): L197-9.

335. Naito, Akira, inventor. "Deodorizing Apparatus Especially for Smoking Odor." Mitsubishi Electric Corp, Japan, assignee. Japan Patent, 0725 1028 A2. 1995. *124:36496 CA.*

336. Nakamura, Shinya, and Koji Suzuki, inventors. "Photocatalyst Functional Body." Nakamura Shinya, Japan, and Suzuki Koji, assignees. Japan Patent, 08187433 A2. 1996. *125:208277 CA.*

337. Nasr, Chouhaid, K. Vinodgopal, Luke Fisher, Surat Hotchandani, A. K. Chattopadhyay, and Prashant V. Kamat. "Environmental Photochemistry on Semiconductor Surfaces. Visible Light Induced Degradation of a Textile Diazo Dye, Naphthol Blue Black, on TiO_2 Nanoparticles." *J. Phys. Chem.* 100, no. 20 (1996): 8436-42.

338. Navio, J. A., C. Cerrillos, F. J. Marchena, F. Pablos, and M. A. Pradera. "Photoassisted Degradation of N-Butyltin Chlorides in Air-Equilibrated Aqueous TiO_2 Suspension." *Langmuir* 12, no. 8 (1996): 2007-14.

339. Navio, J. A., and G. Colon. "Heterogeneous Photocatalytic Oxidation of Liquid Isopropanol by TiO_2, ZrO_2 and $ZrTiO_4$ Powders." *Stud. Surf. Sci. Catal. 82,* no. New Developments in Selective Oxidation II (1994): 72 l-8.

340. Navio, J. A., M. Garcia Gomez, M. A. Pradera Adrian, and J. Fuentes Mota. "Partial or Complete Heterogeneous Photocatalytic Oxidation of Neat Toluene and 4-Picoline in Liquid Organic Oxygenated Dispersions Containing Pure or Iron-Doped Titania Photocatalysts." *J. Mol. Catal. A: Chem.* 104, no. 3 (1996): 329-39.

341. Navio, J. A., F. J. Marchena, M. Macias, P. J. Sanchez-Soto, and P. Pichat. "Thermal olution of (Zirconium, Titanium) Dioxide Gels Synthesized at Different Basic pH." *J. Therm. Anal. 40,* no. 3 (1993): 1095-102.

342. Navio, Jose A., Gerardo Colon, Marta I. Litter, and Gladi N. Bianco. "Synthesis, Characterization and Photocatalytic Properties of Iron-Doped Titania Semiconductors Prepared From TiO_2 and Iron(III) Acetylacetonate." *J. Mol. Catal. A: Chem.* 106, no. 3 *(1996): 267-76.*

343. Negishi, Nobuaki, Tomokazu Iyoda, Kazuhito Hashimoto, and Akira Fujishima. "Preparation of Transparent TiO_2 Thin Film Photocatalyst and Its Photocatalytic Activity." *Chem. Lett.*, no. 9 (1995): 841-2.

344. Nimlos, Mark R., Edward J. Wolfrum, Matthew L. Brewer, John A. Fennell, and Gayle Bintner. "Gas-Phase Heterogeneous Photocatalytic Oxidation of Ethanol: Pathways and Kinetic Modeling." *Environ. Sci. Technol. 30,* no. 10 (1996): 3102-10.

345. Nogueira, Raquel F. P., and Wilson F. Jardim. "TiO_2-Fixed-Bed Reactor for Water Decontamination Using Solar Light." *Sol. Energy 56,* no. 5 (1996): 471-77.

346. Nohara, K., H. Hidaka, E. Pelizzetti, and N. Serpone. "Dependence on Chemical Structure of the Production of NH,+ and/or NO_3^- Ions During the Photocatalyzed Oxidation of Nitrogen-Containing Substances at the Titania/Water Interface." *Catal. Lett. 36,* no. 1,2 (1996): 115-l 8.

347. Nomura, Eiji, and Tokuo Suita, inventors. "Photocatalyst and Process for Purifying Water." Ishihara Sangyo Kaisha, Ltd., Japan, assignee. Europe Patent' 634363 Al. 1995. *123:40630 CA.*

348. Norimoto, Keiichiro, Eiichi Kojima, and Tosha Watabe, inventors. "Activity Measurement of Photocatalyst Thin Film and Film for Measurement." Toto Ltd., Japan, assignee. Japan Patent, 07191011 A2. 1995. *123:301406 CA.*

349. O'Shea,, Kevin E., and Claudia Cardona "The Reactivity of Phenol in Irradiated Aqueous Suspensions of TiO_2. Mechanistic Changes As a Function of Solution pH." *J. Photochem. Photobiol., A* 91, no. 1 (1995): 67-72.

350. Ogawa, . Makoto, and Kazuyuki Kuroda. "Photofunctions of Intercalation Compounds." *Chem. Rev. 95,* no. 2 (1995): 399-438.

351. Ogawa, Shunjiro, Kazuhiro Nozawa, Yukiko Hanasaki, and Teruhisa Hirayama. "Photocatalytic Decomposition of Polychlorinated Biphenyl (PCB) Coated on Titanium Dioxide As a Catalyst." *Jpn. J. Toxicol. Environ. Health 42,* no. 1 (1996): 44-52.

352. Oohara, Shuzo, and Hiroshi Kawahara, inventors. "Photodegradable and Biodegradable Polymer Moldings." Goyo Shiko Kk, Japan, assignee. Japan Patent, 08001806 A2. 1996. *124:234483 CA.*

353. Oozora, Hiroyuki, and Kazuto Kobayashi, inventors. "Composite Material With Photocatalytic Activity." Mitsubishi Heavy Ind Ltd., Japan, assignee. Japan Patent, 07163886 A2. 1995. *124:189362 CA.*

354. Ozaki, Yukinori, Ju Kawai, and Takemi Oketa, inventors. "Apparatus for Purification of Bath Water With Photocatalyst." Matsushita Electric Ind Co. Ltd., Japan, assignee. Japan Patent, 08089725 A2. 1996. *1241352185 CA.*

355. Parent, Yves, Daniel Blake, Kim Magrini-Bair, Carol Lyons, Craig Turchi, Andy Watt, Ed Wolfrum, and Michael Prairie. "Solar Photocatalytic Processes for the Purification of Water: State of Development and Barriers to Commercialization." *Solar Energy 56,* no. 5 (1996): 429-37.

356. Park, Koon Ha' Huyn Sang Joo, Kyung 11 Ahn, and Kun Jun. "One Step Synthesis of 4-Ethoxy- 1,2,3,4-Tetrahydroquinoline From Nitroarene and Ethanol: a TiO_2 Mediated Photocatalytic Reaction." *Tetrahedron Lett. 36,* no. 33 (1995): 5943-6.

357. Paz, Y., Z. Luo, L. Rabenberg, and A. Heller. "Photooxidative Self-Cleaning Transparent Titanium Dioxide Films on Glass." *J. Mater. Res.* 10, no. 11 (1995): 2842-8.

358. Peill, Nicola J., and Michael R. Hoffmann. "Chemical and Physical Characterization of a TiO_2-Coated Fiber Optic Cable Reactor." *Environ. Sci. Technol. 30,* no. 9 (1996): 2806-12.

359. Peill, Nicola J., and Michael R. Hoffmann. "Development and Optimization of a TiO_2-Coated Fiber-Optic Cable Reactor: Photocatalytic Degradation of 4-Chlorophenol." *Environ. Sci. Technol. 29,* no. 12 (1995): 2974-81.

360. Penth, Bemd, inventor. "Sol-Gel Process for the Formation of Ceramic Bonding Interlayers and Coatings, and Use of the Coatings." Germany, assignee. World Patent, 9600198 Al. 1996. *124:183677 CA.*

361. Percherancier, J. P., R. Chapelon, and B. Pouyet. "Semiconductor-Sensitized Photodegradation of Pesticides in Water: the Case of Carbetamide." *J. Photochem. Photobiol., A 87,* no. 3 (1995): 261-6.

362. Peshev, O., and J. M. Herrmann. "Dispersed Nonmetals in Thermal and Photocatalytic Reactions." *Izv. Khim.* 13, no. 1 (1980): 97-107.

363. Pettit, Thomas L., and Marye Anne Fox. "Photoassisted Oxygenation of Olefins: an Exchanged Zeolite As a Heterogeneous Photosensitizer." *J. Phys. Chem. 90,* no. 7 (1986): 1353-4.

364. Pichat, P., J. C. D'Oliveira, J. F. Maffre, and D. Mas. "Destruction of 2,4-Dichlorophenoxyethanoic Acid (2,4-D) in Water by Titanium Dioxide-UV, Hydrogen Peroxide-UV or Direct Photolysis." *Photocatalytic Purification and Treatment of Water and Air,* eds. David F. Ollis, and Hussain Al-Ekabi, 683-8, Trace Met. Environ., ed. Jerome 0. Nriagu, New York, NY: Elsevier, 1994.

365. Pichat, P., and M. A. Fox. "Photocatalysis on Semiconductors." *Photoinduced Electron Transfer Pt.* D, (1988): 241-302.

366. Pichat, P., C. Guillard, C. Maillard, L. Amalric, and J. C. D'Oliveira. "Titanium Dioxide Photocatalytic Destruction of Water Aromatic Pollutants: Intermediates; Properties-Degradability Correlation; Effects of Inorganic Ions and Titanium Dioxide Surface Area; Comparisons With Hydrogen Peroxide Processes." *Photocatalytic Purification and Treatment of Water and Air,* eds. David F. Ollis, and Hussain Al-Ekabi, 207-23, Trace Met. Environ., ed. Jerome 0. Nriagu, New York, NY: Elsevier, 1994.

367. Pichat, P., and J. M. Herrmann. "Adsorption/Desorption. Related Mobility and Reactivity in Photocatalysis." *Photocatalysis - Fundamentals and Applications,* eds. *N.* Serpone, and E. Pelizzetti, 217-50. New York, NY: John Wiley and Sons, 1989.

368. Pichat, P., J. M. Herrmann, H. Courbon, J. Disdier, and M. N. Mozzanega. "Photocatalytic Oxidation of Various Compounds over Titanium Dioxide and Other Semiconductor Oxides; Mechanistic Considerations." Can. *J. Chem. Eng. 60,* no. 1 (1982): 27-32.

369. Pichat, P., J. M. Herrmann, J. Disdier, H. Courbon, and M. N. Moxxanega "Modification on the TiO_2 Electron Density by Ion Doping or Metal Deposit and Consequences for Photo-Assisted Reactions." *Catalysis on the Energy Scene, Proc. 9th Canad. Symp. Catal.*, eds. S. Kaliaguine, and A. Mahay, 319, Amsterdam: Elsevier, 1984.

370. Pichat, P., J. M. Herrmann, J. Disdier, M. N. Mozzanega, and H. Courbon. "Modification of the Anatase Electron Density by Ion Doping or Metal Deposit and Consequences for Photoassisted Reactions." *Stud. Surf. Sci. Catal.* 19, Catal. Energy Scene (1984): 319-26.

371. Pichat, P., J. M. Herrmann, B. Jenny, J. Disdier, H. Courbon, M. N. Mozzanega, and N. Jaffrezic. "Pt/TiO_2 Catalysts : Characterization and Use in Photocatalytic Reactions." *Adv. in Catal. Sci. Techn.*, ed. T. S. R. Prasad Rao, 741. New York, NY: Wiley Eastern Ltd., 1985.

372. Pichat, Pierre. "Partial or Complete Heterogeneous Photocatalytic Oxidation of Organic Compounds in Liquid Organic or Aqueous Phases." *Catal. Today* 19, no. 2 (1994): 313-33.

373. Pichat, Pierre, Chantal Guillard, Laurence Amalric, Ann-Christel Renard, and Olivier Plaidy. "Assessment of the Importance of the Role of H_2O_2 and O_2^- in the Photocatalytic Degradation of 1,2-Dimethoxybenzene." *Sol. Energy Mater. Sol. Cells 38,* no. l-4 (1995): 391-9.

374. Pichat, Pierre, Jean Marie Herrmann, Jean Disdier, Henri Courbon, and Marie Noelle Mozzanega. "Photocatalytic Hydrogen Production from Aliphatic Alcohols over a Bifunctional Platinum on Titanium Dioxide Catalyst." Nouv. *J. Chim. 5,* no. 12 (1981): 627-36.

375. Pichat, Pierre, Jean Marie Herrmann, Jean Disdier, and Marie Noelle Mozzanega. "Photocatalytic Oxidation of Propene over Various Oxides at 320 K. Selectivity." *J. Phys. Chem. 83,* no. 24 (1979): 3122-6.

376. Pichat, Pierre, Marie Noelle Mozzanega, Jean Disdier, and Jean Marie Herrmann. "Platinum Content and Temperature Effects on the Photocatalytic Hydrogen Production from Aliphatic Alcohols over Platinum/Titanium Dioxide." *Nouv. J. Chim. 6,* no. 11 (1982): 559-64.

377. Pincock, James A., Alexandra L. Pincock, and Marye Anne Fox. "Controlled Oxidation of Benzyl Ethers on Irradiated Semiconductor Powders." *Tetrahedron 41,* no. 19 (1985): 4107-17.

378. Prahov, L. T., J. Disdier, J. M. Herrmann, and P. Pichat. "Room Temperature Hydrogen Production From Aliphatic Alcohols Over UV-Illuminated Powder Nickel/Titanium Dioxide Catalysts." *Int. J. Hydrogen Energy 9,* no. 5 (1984): 397-403.

379. Prairie, M. R., B. M. Stange, S. K. Showalter, and K. A. Magrini. *Destruction of Trace Organics in Otherwise Ultra Pure Water,* SAND94-3170-UC-1303. Sandia National Laboratories, Albuquerque, NM, December 1995.

380. Prakhov, L., Jean Marie Herrmann, and Pierre Pichat. "Effects of Nickel Deposits on Powder Titanium Dioxide for Photocatalytic Hydrogen Production from Aliphatic Alcohols at Room Temperature." *Geterog. Katal.* 5th, *Pt. 2,* (1983): 267-72.

381. Pratsinis, Sotiris Emmanuel, Srinivas Vemury, George P. Fotou, and Andreas Gutsch, inventors. "Flame Hydrolysis Process for Manufacturing Ceramic Powders, Especially Titania Powder for Use As Photooxidation Catalyst, and Photooxidation Reactions Using the Catalyst." University of Cincinnati, USA, assignee. World Patent, 9606803 Al. 1996. *124:347458 CA.*

382. Preis, S., and J. Kallas. "Photocatalytic Oxidation Against Phenolic Compounds in Wastewaters From Oil Shale Treatment." *IChemE Res. Event--Eur. Conf. Young Res. Chem. Eng., lst,* 550-2, Rugby, UK: Inst. Chem. Eng., 1995.

383. Pugh, Kathleen C., Douglas J. Kiserow, Jack M. Sullivan, and John H. Jr. Grinstead. "Photocatalytic Destruction of Atrazine Using TiO_2 Mesh." *ACS Symp. Ser. 607;* no. Emerging Technologies in Hazardous Waste Management 5 (1995): 174-94.

384. Rader, W. Scott' Ljiljana Solujic, Emil B. Milosavljevic, James L. Hendrix, and John H. Nelson. "Photocatalytic Detoxification of Cyanide and Metal Cyano-Species From Precious-Metal Mill Effluents." *Environ. Pollut. 90,* no. 3 (1995): 33 l-4.

385. Rader, Willard Scott. "Photocatalytic Detoxification of Cyanide and Metal Cyano Species (Mercury, Copper, Zinc)." Ph.D. diss., Univ. of Nevada, 1996.

386. Rajeshwar, K. "Photoelectrochemistry and the Environment." *J. Appl. Electrochem. 25* (1995): 1067-82.

387. Rajh, Tijana, Agnes E. Ostafin, Olga I. Micic, David M. Tiede, and Marion C. Thurnauer. "Surface Modification of Small Particle TiO_2 Colloids With Cysteine for Enhanced Photochemical Reduction: An EPR Study." *J. Phys. Chem.* 100, no. 11 (1996): 4538-45.

388. Ranjit, K. T., B. Vuiswanathan, and T. K. Varadarajan. "Photocatalytic Reduction of Nitrite and Nitrate Ions Over TiO_2 Semiconductors." *J. Mater. Sci. Lett.* 15, no. 10 (1996): 874-77.

389. Rao, N. Nageswara, and Sangeeta Dube. "Application of Indian Commercial TiO_2 Powder for Destruction of Organic Pollutants: Photocatalytic Degradation of 2,4-Dichlorophenoxyacetic Acid (2,4-D) Using Suspended and Supported TiO_2 Catalysts." *Indian J. Chem. Technol. 2,* no. 5 (1995): 241-8.

390. Rasputina, Tatyana M., and Umirzak Utebaev, inventors. "Method of Preparing Cl-5 Hydrocarbons." USSR, assignee. Russia Patent, 2043321 Cl. 1995. *124:316495 CA.*

391. Read, Harry W., Xianzhi Fu, Louis A. Clark, Marc A. Anderson, and Tim Jarosch. "Field Trials of a TiO_2 Pellet-Based Photocatalytic Reactor for Off-Gas Treatment at a Soil Vapor Extraction Well." *J. Soil Contam. 5,* no. 2 (1996): 187-202.

392. Ren, Pengcheng, Zhongke Tan, and Wenxiu Luo. "Studies of Thin Layer Photoelectric Crystal." *Gongneng Cailiao 26,* no. 2 (1995): 138-40.

393. Richard, Claire, and Stephane Bengana. "pH Effect in the Photocatalytic Transformation of a Phenyl-Urea Herbicide." *Chemosphere 33,* no. 4 (1996): 63541.

394. Richardson, Susan D., Alfred D. Jr. Thruston, Timothy W. Collette, Kathleen S. Patterson, Benjamin W. Jr. Lykins, and John C. Ireland. "Identification of TiO_2/UV Disinfection Byproducts in Drinking Water." *Environ. Sci. Technol. 30,* no. 11 (1996): 3327-34.

395. Riegel, Georg. "The Photocatalytic Efficiency of Titanium Dioxide Particles." Ph.D. diss., Univ. of Western Ontario, 1994.

396. Sackett, Debra D., and Marye Anne Fox. "Effect of Cosolvent Additives on Relative Rates of Photooxidation on Semiconductor Surfaces." *J. Phys. Org. Chem.* 1, no. 2 (1988): 103-14.

397. Saitoh, Tokuyoshi, and Shigemichi Fukayama. "Photoactive TiO_2 Thin Films." *Zairyo Gijutsu 14,* no. 5 (1996): 133-37.

398. Sakai, Hideki. "Mechanism of Photocatalytic Reactions at Surface of Oxide Semiconductors." *Zairyo Gijutsu* 14, no. 5 (1996): 138-43.

399. Sakai, Tooru, Kenji Murakami, Koji Ishikawa, and Kenichi Sasama, inventors. "Metal Oxide Photocatalysts and Their Manufacture." Nhk Spring Co. Ltd., Japan, assignee. Japan Patent, 08126845 A2. 1996. *125:127573 CA.*

400. Sakura, Makoto, and Shuji Okudaira, inventors. "Photocatalysts Decomposing Ethylene in Preservation of Fruits and Vegetables." Nitsuki Yunibaasaru Kk, Japan, assignee. Japan *07088367 A2.* 1995. *123:31771 CA.*

401. Sakura, Makoto, and Shuji Okudaira, inventors. "Poison-Resistant Deodorization Photocatalysts." Nitsuki Yunibaasaru Kk, Japan, assignee. Japan 07171403 A2. 1995. *123:174162 CA.*

402. Santosh, and B. Bhushan. "Photocatalytic Conversion of Molasses - a Waste Product of Sugar Industry." *Proc. Natl. Acad. Sci., India, Sect. A* Volume Date 1995, 65, no. 2 (1995): 147-50.

403. Sasase, M., K. Miyake, I. Takano, and S. Isobe. "Photocurrent Performance of TiO_x Films Prepared by Ar+ Ion Beam-Assisted Reactive Deposition Method." *Thin Solid Films 269,* no. l-2 (1995): 3640.

404. Sauer, Michael L., Michael A. Hale, and David F. Ollis. "Heterogeneous Photocatalytic Oxidation of Dilute Toluene-Chlorocarbon *Mixtures* in Air." *J. Photochem. Photobiol., A* 88, no. 2-3 (1995): 169-78.

405. Sauer, Michael L., and David F. Ollis. "Photocatalyzed Oxidation of Ethanol and Acetaldehvde in Humidified *Air." J. Catal.* 158, no. 2 (1996): 570-82.

406. Sawyer, Donald T., Andrzej Sobkowiak, and Takayuki Matsushita "Metal [ML,; M = Fe, Cu, Co, Mn] Hydroperoxide - Induced Activation of Dioxygen for the Oxygenation of Hydrocarbons: Oxygenated Fenton Chemistry." *Acc. Chem. Res. 29,* no. 9 (1996): 409-16.

407. Schiavello, M., V. Augugliaro, L. Palmisano, A. Sclafani, and A. M. Venezia. "Comments on the Paper "Spectroscopic, Photoconductivity, and Photocatalytic Studies of TiO_2 Colloids: Naked and With the Lattice Doped With Cr^{3+}, Fe^{3+}, and V^{5+} Cations"." *Langmuir* 11, no. 8 (1995): 3278.

408. Schmelling, Daniel C., and Kimberly A. Gray. "Photocatalytic Transformation and Mineralization of 2,4,6-Trinitrotoluene *(TNT)* in TiO_2 Slurries." *Water Res. 29,* no. 12 (1995): 2651-62.

409. Schmelling, Daniel C., and Kimberly A. Gray. "Photocatalytic Transformations and Degradation of 2,4,6-Trinitrotoluene *(TNT)* in TiO_2 Slurries." *Crit. Issues Water Wastewater Treat., Proc. Natl. Conf. Environ. Eng.,* eds. Joseph N. Ryan, and Marc Edwards, 751-5, New York, NY: American Society of Civil Engineers, 1994.

410. Schmelling, Daniel C., Kimberly A. Gray, and Prashant V. Katnat. "Role of Reduction in the Photocatalytic Degradation of TNT." *Environ. Sci. Technol. 30,* no. 8 (1996): 2547-55.

411. Schrnelling, Daniel Carothers. "The Photocatalytic Behavior of 2,4,6-Trinitrotoluene in Titanium Dioxide Systems: Photochemical, Electrochemical and Radiolytic Investigations (Contamination, Groundwater)." Ph.D. diss., Univ. of Notre Dame, 1996.

412. Schwinkendorf, William E., John McFee, M. Devarakonda, Lisette Lambregts Nenninger, Frances S. Fadullon, Terry L. Donaldson, and Kathryn Dickerson. *Alternatives to Incineration - Technical Area Status Report,* DOE/MWIP-26. U.S. Department of Energy, April 1995.

413. Sclafani, A., and J. M. Herrmann. "Comparison of the Photoelectronic and Photocatalytic Activities of Various Anatase and Rutile Forms of Titania in Pure Liquid Organic Phases and in Aqueous Solutions." *J. Phys. Chem. 100,* no. 32 (1996): 13655-61.

414. Sclafani, Antonino, Leonardo Palmisano, and Mario Schiavello. "Phenol and Nitrophenol Photodegradation Using Aqueous TiO_2 Dispersions." *Aquat. Surf. Photochem., eds.* George R. Helz, Richard G. Zepp, and Donald G. Crosby, 419-25, Boca Raton, Fla: Lewis, 1994.

415. Scrano, L., S. A. Bufo, and M. Mansour. "Photocatalytic Degradation of Terbutylazine in Soil on Titanium Dioxide." *Proc. Int. Workshop 'Environ. Behav. Pestic. Regul. Aspects", 5th,* ed. A. Copin, 285-90, Rixensart, Belg.: Eur. Study Serv., 1994.

416. Sczechowski, Jeffrey G. "Increasing the Photoefficiency in Heterogeneous Photocatalysis Through Controlled Periodic Illumination." Ph.D. diss., Univ. of Colorado, 1994.

417. Sczechowski, Jefrey G., Carl A. Koval, and Richard D. Noble. "A Taylor Vortex Reactor for Heterogeneous Photocatalysis." *Chem. Eng. Sci. 50,* no. 20 (1995): 3163-73.

418. Sen Gupta, Supriya K., Ron G. Peori, and Steve L. Wickware. "Destruction of Organic Contaminants in Industrial Wastewater." *Ind. Water Treat. 27,* no. 5 (1995): 17-24.

419. Serpone, N., D. Lawless, and R. Khairutdinov. "Size Effects on the Photophysical Properties of Colloidal Anatase TiO_2 Particles: Size Quantization Versus Direct Transitions in This Indirect Semiconductor?" *J. Phys. Chem. 99,* no. 45 (1995): 16646-54.

420. Serpone, N., D. Lawless, R. Khairutdinov, and Ezio Pelizzetti. "Subnanosecond Relaxation Dynamics in TiO_2 Colloidal Sols (Particle Sizes Rp = 1 .O- 13.4 Nm). Relevance to Heterogeneous Photocatalysis." *J. Phys. Chem. 99,* no. 45 (1995): 16655-61.

421. Serpone, N., D. Lawless, and E. Pelizzetti. "Subnanosecond Characteristics and Photophysics of Nano-Sized TiO_2 Particulates From Rpart = 10 A to 134 A: Meaning for Heterogeneous Photocatalysis." *NATO ASI Ser., Ser. 3 (1996),12(Fine Particles Science and Technology), 657-673.*

422. Serpone, Nick. "Heterogeneous Photocatalytic Technology for the Detoxification of Photographic Processing Effluents." *IS&T's Annu. Con.., Final Program Adv. Print. Pap., 48th,* 186-9 , Springfield, Va: IS&T--The Society for Imaging Science and Technology, 1995.

423. Serpone, Nick, Darren Lawless, Jean Disdier, and Jean-Marie Herrmann. "Spectroscopic, Photoconductivity, and Photocatalytic Studies of TiO_2 Colloids: Naked and With the Lattice Doped With Cr^{+3}, Fe^{+3}, and V^{+5} Cations." *Langmuir* 10 (1994): 643-52.

424. Serpone, Nick, Genevieve Sauve, Ralf Koch, Halima Tahiri, Pierre Pichat, Paola Piccinini, Ezio Pelizzetti, and Hisao Hidaka. "Standardization Protocol of Process Efficiencies and Activation Parameters in Heterogeneous Photocatalysis: Relative Photonic Efficiencies." *J. Photochem. Photobiol., A 94,* no. 2-3 (1996): 191-203.

425. Serpone, Nick, Rita Terzian, Darren Lawless, and Jean-Marie Herrmann. "Light-Induced Electron Transfer in Inorganic Systems in Homogeneous and Heterogeneous Phases." *Adv. Electron Transfer Chem. 3, (1993): 33-166.*

426. Shapira, Y., S. M. Cox, and David Lichtman. "Chemisorption, Photodesorption and Conductivity Measurements on ZnO Surfaces." *Surface Sci. 54* (1976): 43-59.

427. Shen, Shifu, Mengyue Zhao, and Yaowu Tao. "Study on the Photocatalytic Degradation of Organophosphorus Pesticides Using Thin Films of TiO_2 Under Sunlight." *Taiyangneng Xuebao* 16, no. 3 (1995): 234-9.

428. Shifu, Chen, Zhao Mengyue, and Tao Yaowu. "Photocatalytic Degradation of Organophosphorus Pesticides Using TiO_2 Supported on Fiberglass." *Microchem. J. 54,* no. 1 (1996): 54-58.

429. Sitkiewitz, Steve, and Adam Heller. "Photocatalytic Oxidation of Benzene and Stearic Acid on Sol-Gel Derived TiO_2 Thin Films Attached to Glass." New *J. Chem. 20,* no. 2 (1996): 23341.

430. Sjogren, Jon Charles. "Inactivation of Phage MS2 by Titanium Dioxide Photocatalysis (Viral Disinfection)." Ph.D. diss., Univ. of Arizona, 1996.

431. Somasundaram, Narayanan, and Chockalingam Srinivasan. "Photocatalyzed Oxidation of Triphenyl Derivatives of P, As, Sb and Bi and Reduction of Their Oxides." *J. Org. Chem.* 61, no. 8 (1996): 2895-6.

432. Sopyan, Iis, Mitsuru Watanabe, Sadao Murasawa, Kazuhito Hashimoto, and Akira Fujishima. "Efficient TiO_2 Powder and Film Photocatalysts with Rutile Crystal Structure." *Chem. Lett.* no. 1 (1996): 69-70.

433. Spangenberg, D., U. Moeller, and K. Kleinermanns. "Photooxidation of Exhaust Pollutants. IV. Photocatalytic and Thermal Decomposition of Trichloroacetic Acid: Degradation Efficiencies and Products." *Chemosphere 33,* no. 1 (1996): 43-49.

434. Stafford, Ulick. "Photocatalytic Oxidation of a Model Halogenated Aromatic Compound: a Mechanistic Study (Chlorophenol, Titanium Dioxide)." Ph.D. diss., Univ. of Notre Dame, 1994.

435. Stafford, Ulick, Kimberly A. Gray, and Prashant V. Kamat. "Photocatalytic Degradation of Organic Contaminants: Halophenols and Related Model Compounds." *Heterog. Chem. Rev.* 3, no. 2 (1996): 77-104.

436. Stewart, Gina, and Marye Anne Fox. "The Effect of Dark Recovery Time on the Photoefficiency of Heterogeneous Photocatalysis by TiO_2 Suspended in Nonaqueous Media" *Res. Chem. Intermed.* 21, no. 8/9 (1995): 933-8.

437. Strauss, Stephen. "A Self-Cleaning World." *Technology Review* (February/March, 1996): 234.

438. Sugawara, Takuo. "Application of Photocatalysts for Amenities." *Petrotech,* 19, no. 3 (1996): 199-203.

439. Sun, Lizhong. "Quantum Yields and Mechanism in Titanium Dioxide Mediated Photocatalysis (Titanium Dioxide)." Ph.D. diss., Univ. of West. Ontario , 1994.

440. Sun, Yunfu, and Joseph J. Pignatello. "Evidence for a Surface Dual Hole-Radical Mechanism in the Titanium Dioxide Photocatalytic Oxidation of 2,4-D." *Environ. Sci. Technol. 29,* no. 8 (1995): 2065-72.

441. Tada, Hiroaki, inventor. "Coating Process for Thin Film Silica on (Composite) Oxide Semiconductor Material Substrates." Nippon Itagarasu Tekuno Risaac, Japan, assignee. Japan Patent, 08165113 A2. 1996. *125:198659 CA.*

442. Tada, Hiroaki. "Layer-by-Layer Construction of SiO_x Film on Oxide Semiconductors." *Langmuir* 11, no. 9 (1995): 32814.

443. Tada, Hiroaki. "Photoinduced Oxidation of Methylsiloxane Monolayers Chemisorbed on TiO_2." *Langmuir* 12, no. 4 (1996): 966-71.

444. Tada, Hiroaki, and Hisao Honda. "Photocatalytic Activity of TiO_2 Film Coated on Internal Lightguide." *J. Electrochem. Soc.* 142, no. 10 (1995): 3438-43.

445. Tagawa, Y., T. Iyoda, K. Hashimoto, and A. Fujishima. "TiO_2-Coated Surface Acoustic Wave Devices." *Gaodeng Xuexiao Huaxue Xuebao* 16, no. 11, Suppl. (1995): 2724.

446. Tahiri, Halima, Nick Serpone, and Raymond Le van Mao. "Application of Concept of Relative Photonic Efficiencies and Surface Characterization of a New Titania Photocatalyst Designed for Environmental Remediation." *J. Photochem. Photobiol., A 93,* no. 2-3 (1996): 199-203.

447. Takagi, Sadanobu, inventor. "Fixation of Photooxidation Catalyst and Wastewater Treatment Using It." Kansai Paint Co. Ltd., Japan, assignee. Japan Patent, 08155308 A2. 1996. *125:127574 CA.*

448. Takahama, Koichi, Minoru Inoe, Toshiji Sako, Naoharu Nakagawa, and Kazuo Seto, inventors. "Bactericidal Inorganic Silicate-Based Coatings of Low Baking Temperature." Matsushita Electric Works Ltd., Japan, assignee. Japan Patent' 08067835 A2. 1996. *125:36022 CA.*

449. Takahashi, Takeo, Kazuteru Aragai, Masahiro Myamoto, and Satoshi Nishikata, inventors. "Hazardous Gas Removing Apparatus for Tunnels." Fuji Electric Co. Ltd., Japan, assignee. Japan Patent, 08117560 *A2.* 1996. *125:66161 CA.*

450. Takaoka, Kazuchiyo, and Isao Ebihara. "Application of Photocatalytic Reaction to Deodorizing Sheets." *Kagaku Kogyo 46,* no. 12 (1995): 966-72.

451. Takaoka, Kazucho, and Yasuhiro Aizawa, inventors. "Paper Carrying Titanium Oxide With Photolytic Characteristics." Mitsubishi Paper Mills Ltd, Japan, assignee. Japan Patent, 08173805 *A2.* 1996. *125:181103 CA.*

452. Takaoka, Kazucho, Yasuhiro Aizawa, and Michihiko Sato, inventors. "Manufacture of Titanium Oxide-Carrying Sheets Having Excellent Photocatalytic Deodorization and Weather Resistance." Mitsubishi Paper Mills Ltd, Japan, assignee. Japan Patent, 08173762 A2. 1996. *125:203522 CA.*

453. Takaoka, Yoichi, and Hitoshi Ando. "Development of Ultra Fine TiO_2 Particles for Photocatalysis." *Hyomen Kagaku* 16, no. 3 (1995): 209-12.

454. Takaoka, Yoichi, Yoshio Hirobe, Masanori Tomonari, and Yoshiki Kinoshita, inventors. "Titanium Oxide Photocatalyst and Method of Producing the Same." Ishihara Sangyo Kaisha, Ltd., Japan, assignee. Europe Patent, 666107 A2. 1995. *123:241818 CA.*

455. Takaoka, Yoichi, Masanori Tomonari, and Yoshiki Kinoshita, inventors. "Vanadium-Titania Photocatalyst." Ishihara Sangyo Kaisha, Japan, assignee. Japan Patent, 07275704 *A2.* 1995. *124:101729 CA.*

456. Takatani, Kazuki, inventor. "Formation of Titanium Dioxide Films." Shinto Paint Co. Ltd., Japan, assignee. Japan Patent, 08091839 A2. 1996. *125:62461 CA.*

457. Takeda, Kazuhiko, and Kitao Fujiwara. "Characteristics on the Determination of Dissolved Organic Nitrogen Compounds in Natural Waters Using Titanium Dioxide and Platinized Titanium Dioxide Mediated Photocatalytic Degradation." *Water Res. 30,* no. 2 (1996): 323-30.

458. Takeda, Norihiko, Tsukasa Torimoto, Srinivasan Sampath, Susumu Kuwabata, and Hiroshi Yoneyama. "Effect of Inert Supports for Titanium Dioxide Loading on Enhancement of Photodecomposition Rate of Gaseous Propionaldehyde." *J. Phys. Chem. 99,* no. 24 (1995): 9986-91.

459. Takeuchi, Koji. "Air Cleaning Materials Functioning by Natural Energy." *Kogyo Zairyo* 44, no. 8 (1996): 106-9.

460. Takeuchi, Koji. "Air-Purifying Sheets for Cleaner *Streets." Look Japan* (December 1995): *24-5.*

461. Takeuchi, Koji, and Shuzo Kutsuna. "Removal of Chemical Substances from the Atmosphere by Photocatalysis." *Shigen to Kankyo 5,* no. 1 (1996): 43-50.

462. Takiyama, Marcia Matiko Kondo. "Surface Modification and Immobilization of the Photocatalyst Titanium Dioxide (Pollutants)." Ph.D. diss., Univ. of Delaware, 1996.

463. Taoda, Hiroshi, Eiji Watanabe, and Kazumi Kato. "Photocatalytic Treatment of Halogenated Organic Compounds Using Film Catalyst." *Yosui to Haisui 38,* no. 4 (1996): *290-6.*

464. Tennakone, K., C. T. K. Tilakaratne, and I. R. M. Kottegoda. "Photocatalytic Degradation of Organic Contaminants in Water With TiO_2 Supported on Polythene Films." *J. Photochem. Photobiol., A 87,* no. 2 (1995): 177-9.

465. Terzian, Rita, and Nick Serpone. "Heterogeneous Photocatalyzed Oxidation of Creosote Components: Mineralization of Xylenols by Illuminated TiO_2 in Oxygenated Aqueous Media." *J. Photochem. Photobiol., A 89,* no. 2 (1995): 163-75.

466. Thanpi, K. Ravindranathan, John Kiwi, and Michael Gratzel. "Methanation and Photomethanation of Carbon Dioxide at Room Temperature and Atmospheric Temperature." *Nature 327* (1987): 506.

467. Togeda, Hiroshi, and Kazumi Kato, inventors. "Photocatalytic Filters and Their Manufacture." Kogyo Gijutsuin, Japan, assignee. Japan Patent, 08103631 A2. 1996. *125:66172 CA.*

468. Togeda, Hiroshi, and Kazumi Kato, inventors. "Porous Photocatalysts and Their Preparation." Kogyo Gijutsuin, Japan, assignee. Japan Patent, 08196903 A2. 1996. *125:234285 CA.*

469. Tomkiewicz, Micha, Geula Dagan, and Zhu Zhu. "Morphology and Photocatalytic Activity of TiO_2 Aerogels." *Res. Chem. Intermed. 20,* no. 7 (1994): 701-10.

470. Tomonari, Masanori, Satoyuki Hirota, and Yoshiki Kinoshita, inventors. "Photocatalysts and Their Manufacture for Air Deodorization." Ishihara Sangyo Kaisha, Japan, assignee. Japan Patent, 08182934 A2. 1996. *125:229476 CA.*

471. Torimoto, Tsukasa, Shigeyoshi Ito, Susumu Kuwabata, and Hiroshi Yoneyama. "Effects of Adsorbents Used As Supports for Titanium Dioxide Loading on Photocatalytic Degradation of Propyzamide." *Environ. Sci. Technol. 30,* no. 4 (1996): 1275-81.

472. Toth, Zoltan, Peter Penzeli, and Eniko Posan. "Heterogeneous Photocatalytic Reduction of NO in the Presence of Conjugated Polymers." *React. Kinet. Catal. Lett. 56,* no. 1 (1995): 185-90.

473. Trivedik, Dhara. "Photocatalytic Disinfection of Airborne Microorganisms." Ph.D. *diss.,* University of Florida, 1994.

474. Vergnon, P., J. M. Herrmann, and S. J. Teichner. "Effect of Particle Sizes and Doping on the Catalytic Activity of Highly Dispersed Titanium Dioxide." *Zh. Fiz. Khim. 52,* no. 12 (1978): 30214.

475. Vinodgopal, K., Idriss Bedja, and Prashant V. Kamat. "Nanostructured Semiconductor Films for Photocatalysis. Photoelectrochemical Behavior of SnO_2/TiO_2 Composite Systems and Its Role in Photocatalytic Degradation of a Textile *Azo* Dye." *Chem. Mater. 8,* no. 8 (1996): 2180-2187.

476. Vinodgopal, K., Xiao Hua, Robin L. Dahlgren, A. G. Lappin, L. K. Patterson, and Prashant V. Kamat. "Photochemistry of $Ru(Bpy)_2(Dcbpy)(+2)$ on Al_2O_3 and TiO_2 Surfaces. An Insight into the Mechanism of Photosensitization." *J. Phys. Chem. 99,* no. 27 (1995): 10883-89.

477. Vinodgopal, K., and Prashant V. Kamat. "Combine Electrochemistry With Photocatalysis." *CHEMTECH 26,* no. 4 (1996): 18-22.

478. Vinodgopal, K., and Prashant V. Kamat. "Electrochemically Assisted Photocatalysis Using Nanocrystalline Semiconductor Thin Films." *Sol. Energy Mater. Sol. Cells 38,* no. 14 (1995): 401-10.

479. Vinodgopal, K., and Prashant V. Kamat. "Enhanced Rates of Photocatalytic Degradation of an Azo Dye Using SnO_2/TiO_2 Coupled Semiconductor Thin Films." *Environ. Sci. Technol.* 29, no. 3 (1995): 841-5.

480. Vinodgopal, K., and Prashant V. Kamat. "Photosensitization of Semiconductor Colloids by Humic Substances." *Aquat. Surf. Photochem.,* eds. George R. Helz, Richard G. Zepp, and Donald G. Crosby, 43742, Boca Raton, Fla.: Lewis, 1994.

481. Vinodgopal, K., Darrel E. Wynkoop, and Prashant V. Kamat. "Environmental Photochemistry on Semiconductor Surfaces: Photosensitized Degradation of a Textile Azo Dye, Acid Orange 7, on TiO_2 Particles Using Visible Light." *Environ. Sci. Technol. 30,* no. 5 (1996): 1660-6.

482. Wahl, A., M. Ulmann, A. Carroy, B. Jermann, M. Dolata, P. Kedzierzawski, C. Chatelain, A. Monnier, and J. Augustynski. "Photoelectrochemical Studies Pertaining to the Activity of TiO_2 Towards Photodegradation of Organic Compounds." *J. Electroanal. Chem. 396,* no. l-2 (1995): 41-51.

483. Wahl, Axel, Mar-tine Ulmann, Annick Carroy, and Jan Augustynski. "Highly Selective Photo-Oxidation Reactions at Nanocrystalline TiO_2 Film Electrodes." *J. Chem. Soc., Chem. Commun. (1994): 2277-8.*

484. Wang, Chunyi, Chunyan Liu, and Xinmin Ren. "Photocatalytic Degradation of Phenylmercaptotetrazole in Aqueous TiO_2 Suspensions." *Huaxue Wuli Xuebao 9,* no. 1 (1996): 18-23.

485. Wang, Hai, Dewen Chen, Shuhua Wang, and Guangzhi Xu. "Photocatalytic Decomposition of Aromatic Compounds on the Surface of Titanium Dioxide Colloid." *Huaxue Wuli Xuebao 8,* no. 2 (1995): 146-53.

486. Wang, Han-Hui, Jia-Yong Yu, Ji-Ping Huang, Guo-Zhu Gui, Shi-Yan Yang, Wen-Hua Sun, and Jin-Xia Liu. "Photocatalytic Asymmetric Synthesis of L-Alpha.-Valine From 3-Methyl-2-oxobutanoic Acid With Chiral Rh(I) Complexes and Powdery Semiconductors." *Ganguang Kexue Yu Guang Huaxue 13,* no. 1 (1995): 48-52.

487. Wang, Kuo-Hua, Kuo-Shu Huang, and Yung-Hsu Hsieh. "Study on the Photocatalytic Degradation of Monochlorophenol Pollutants by Titanium Dioxide in Aqueous Solution." *Hazard. Ind. Wastes 27th (1995): 342-5 1.*

488. Wang, Yizhong, Chun Hu, and Hongxiao Tong. "Photocatalytic Oxidation of Phenol on TiO_2 Particle. 1. Product Distribution and Reaction Pathway." *Huanjing Kexue Xuebao* 15, no. 4 (1995): 472-9.

489. Watanabe, Toshiya. "Photocatalytic Sterilization and Its Application." *Kagaku Kogyo 46,* no. 12 (1995): 978-82.

490. Watanabe, Toshiya, Eiichi Kojima, Keiichiro Norimoto, Tamon Kimura, Mitsuyoshi Machida, Makoto Hayakawa, Atsushi Kitamura, Makoto Chikuni, Yoshimitsu Saeki, and et al., inventors. "Multifunctional Materials With Photocatalytic Functions and Method of Manufacturing Them." Toto Ltd., Japan, assignee. Canada Patent, 2155822 AA. 1995. *124:353 780 CA.*

491. Watts, Richard J., Sungho Kong, and Wendy Lee. "Sedimentation and Reuse of Titanium Dioxide: Application to Suspended-Photocatalyst Reactors." *J. Environ. Eng. (N.Y.)* 121, no. 10 (1995): 730-5.

492. Wei, Hongbin, and Xushi Yan. "Photocatalytic Oxidation of Phenol on Titanium Dioxide Film." *Shanghai Huanjing Kexue* 14, no. 10 (1995): 31-4.

493. Weinberger, B. R., and R. B. Garber. "Titanium Oxide Photocatalysts Produced by Reactive Magnetron Sputtering." *Appl. Phys. Lett. 66,* no. 18 (1995): 2409-l 1.

494. Wilson, Elizabeth. "TiO_2 Appears Inefficient for Water Treatment." *Chem. Eng. News 74,* no. 27 (1996): 29.

495. Wold, Aaron, Daniel Miller, Robert Kershaw, and K. Dwight. "Synthesis of Catalytic Materials by Spray Pyrolysis." *Prepr. - Am. Chem. Soc., Div. Pet. Chem. 40,* no. 1 (1995): 37-9.

496. Worsley, David, Andrew Mills, Keith Smith, and Michael G. Hutchings. "Acid Enhancement Effect in the Clean Oxidation of Toluenes Photocatalyzed by TiO_2." *J. Chem. Soc., Chem. Commun.,* no. 11 (1995): 1119-20.

497. Wu, Nan-Min, and H. Ted Chang. "Modeling UV Photocatalysis of Organic Contaminants on Titanium Dioxide." *Proc. Ind. Waste Conf., 50th, 1995* (1996): 193-8.

498. Xu, Yiming, and Cooper H. Langford. "Enhanced Photoactivity of a Titanium(IV) Oxide Supported on ZSM5 and Zeolite A at Low Coverage." *J. Phys. Chem. 99,* no. 29 (1995): 11501-7.

499. Yamagata, Koji, inventor. "Cleaning and Regenerating Photooxidation Catalysts for Water Treatment." Raizaa Kogyo Kk, Japan, assignee. Japan Patent' 07185340 A2. 1995. *123:208376 CA.*

500. Yamanashi, Ichiro, Yoshinori Tatsukawa, and Takaaki Murata, inventors. "Plasma Chemical Reactors." Tokyo Shibaura Electric Co., Japan, assignee. Japan Patent, 07328425 A2. 1995. *124:179674 CA.*

501. Yamashita, Hiromi, Yuichi Ichihashi, Masakazu Anpo, Mitsuo Hashimoto, Catherine Louis, and Michel Che. "Photocatalytic Decompostion of NO at 275 K on Titanium Oxides Included Within Y-Zeolite Cavities: the Structure and Role of the Active Sites." *J. Phys. Chem.* 100, no. 40 (1996): 160414.

502. Yamashita, Hiromi, Yuichi Ichihashi, Masaru Harada, Gina Stewart' Marye Anne Fox, and Masakazu Anpo. "Photocatalytic Degradation of 1-Octanol on Anchored Titanium Oxide and on TiO_2 Powder Catalysts." *J. Catal.* 158, no. 1 (1996): 97-101.

503. Yamashita, Hiromi, Akira Shiga, Shin-ichi Kawasaki, Yuichi Ichihashi, Shaw Ehara, and Masakazu Anpo. "Photocatalytic Synthesis of CH_4 and CH_3OH From CO, and H_2O on Highly Dispersed Active Titanium Oxide Catalysts." *Energy Convers. Manage. 36,* no. 6-9 (1995): 617-20.

504. Yamazaki-Nishida, Suzuko, Xianzhi Fu, Marc A. Anderson, and Kenzi Hori. "Chlorinated Byproducts from the Photoassisted Catalytic Oxidation of Trichloroethylene and Tetrachloroethylene in the Gas Phase Using Porous TiO_2 Pellets." *J. Photochem. and Photobiol. A: Chem. 97 (1996): 175-79.*

505. Yamazaki, Norimune, and Katsuji Atisawa, inventors. "Oxidation-Reduction Using Photocatalysts Supporting Semiconductor Materials." Pentel Kk, Japan, assignee. Japan 07124464 A2. 1995. *123:127422 CA.*

506. Yasumori, Atsuo. "Sol-Gel Processing of TiO_2 As Photocatalyst." *Nyu Seramikkusu 8,* no. 2 (1995): 21-5.

507. Yildiz, Attila, Andrzej Sobczynski, A. J. Bard, A. Campion, M. A. Fox, T. E. Mallouk, S. E. Webber, and J. M. White. "Sensitized Polypyrrole-Coated Semiconducting Powders As Materials in Photosystems for Hydrogen Generation." *Langmuir 5,* no. 1 (1989): 148-9.

508. Yokota, Toshiyuki, and Hiroto Ohwada. "Photocatalytic Properties of TiO_2-Coated SiO_2 Particles Prepared by Metal Alkoxide Processing." *Kagaku Kogaku Ronbunshu 21,* no. 6 (1995): 103946.

509. Yu, Chuanming, and Weichuan Jiang. "Photocatalytic Degradation of Disperse Red Solution With Different Light Sources." *Zhejiang Gongye Daxue Xuebao 23,* no. 2 (1995): 130-5.

510. Zabidi, Noor A. M., Dale Tapp, and Timothy F. Thomas. "Kinetics of the Rapid Dark Reaction Between Methanol and Oxygen in the Presence of a "Photocatalyst"." *J. Phys. Chem. 99,* no. 40 (1995): 14733-7.

511. Zang, Ling, Chun-Yan Liu, and Xin-Min Ren. "Photochemistry of Semiconductor Particles Part 4. Effects of Surface Condition on the Photodegradation of 2,4-Dichlorophenol Catalyzed by TiO_2 Suspensions." *J. Chem. Soc., Faraday Trans. 91,* no. 5 (1995): 917-23.

512. Zhang, Shicheng, Takaomi Kobayashi, Yoshio Nosaka, and Nobuyuki Fujii. "Photocatalytic Property of Titanium Silicate Zeolite." *J. Mol. Catal. A: Chem. 106,* no. 1-2 (1996): 119-23.

513. Zhang, Yin, J. C. Crittenden, D. W. Hand, and D. L. Perram. "Destruction of Organic Compounds in Water Using Supported Photocatalysts." *J. Sol. Energy Eng.* 118, no. 2 (1996): 123-29.

514. Zhang, Yin, John C. Crittenden, David W. Hand, and David L. Perram, inventors. "Photocatalytic Oxidation of Organic Compounds in Drinking Water." Michigan Technology University, USA, assignee. United States 5501801 A. 1996. *124:269912 CA.*

515. Zhang, Zhenyu, and James R. Fehlner, inventors. "Molecular Sieve - Photoactive Semiconductor Membranes for Catalytic Treatment of Wastes." Inrad, USA, assignee. United States Patent, 5468699 A. 1995. *124:65696 CA.*

516. Zhang, Zhijun, Zhicheng Bao, Keou Wang, and Minghui Zheng. "Photolysis of Chlorinated Dibenzo-p-Dioxins with Titanium Dioxide As Catalyst." *Huanjing Huaxue* 15, no. 1 (1996): 47-51.

517. Zhao, Mengyue, Shifu Chen, and Yaowu Tao. "Photocatalytic Degradation of Organophosphorus Pesticides Using Thin Films of TiO_2." *J. Chem. Technol. Biotechnol.* 64, no. 4 (1995): 339-44.

518. Zhou, M., W-Y. Lin, N. R. de Tacconi, and K. Rajeshwar. "Metal/Semiconductor Electrocomposite Photoelectrodes: Behavior of Ni/TiO_2 Photoanodes and Comparison of Photoactivity of Anatase and Rutile Modifications." *J. Electroanal. Chem. 402,* no. l-2 (1996): 2214.

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