SERI Photovoltaic Subcontract Reports: Abstracts and Document Control Information

1 January - 31 July, 1991

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Photovoltaic Energy Program

National Renewable Energy Laboratory
A Division of Midwest Research Institute
Operated for the U.S. Department of Energy
Under Contract No. DE-AC02-83CH10093

On September 16, 1991, the Solar Energy Research Institute was designated a national laboratory, and its name was changed to the National Renewable Energy Laboratory.

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SERI Photovoltaic Subcontract Reports: Abstracts and Document Control Information

1 January - 31 July, 1991

Photovoltaic Energy Program

National Renewable Energy Laboratory
(formerly the Solar Energy Research Institute)
1617 Cole Boulevard
Golden, Colorado 80401-3393
A Division of Midwest Research Institute
Operated for the U.S. Department of Energy
under Contract No. DE-AC02-83CH10093

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PREFACE

This report contains the document control information and abstracts for SERI Photovoltaic (PV) Program publications resulting from SERI's subcontracted PV research. The information is presented for reports published or distributed from January 1 through July 31, 1991. In the past, copies of the subcontractor reports were distributed to a broad spectrum of researchers in the field of photovoltaics at a considerable cost to the program. In an attempt to reduce costs and ensure that all researchers receive those current publications that are of specific interest to them, this report will outline these publications, organized by technology, on a regular basis. A list of additional publications and sources is included herein to provide the photovoltaic community with other sources of information. All of the documents represented here are available from the National Technical Information Service (NTIS) and can be purchased using the NTIS order form at the end of this document. Further information on a given subcontracted program may be obtained from the SERI technical monitor identified on each Document Control Page.

The SERI Photovoltaic Program is sponsored by the U.S. Department of Energy under contract No. DE-AC02-83CH10093. The Solar Energy Research Institute is operated by Midwest Research Institute for the U.S. Department of Energy.

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Document Control Page	1. SERI Report No. SERI/TP-214-4141	2. NTIS Accession No. DE91002132	3. Recipient's Accession No.
4. Title and Subtitle Optimization of Transparent and Reflecting Electrodes for Amorphous Silicon Solar Cells		5. Publication Date February 1991	
		6.	
7. Author(s) Roy G. Gordon, Jianhua Hu, Joshua Musher, Carmen Giunta		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address Department of Chemistry Harvard University Cambridge, Massachusetts 02138		10. Project/Task/Work Unit No. PV140201	
		11. Contract (C) or Grant (G) No. (C) XG-0-19121-1 (G)	
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401		13. Type of Report & Period Covered Technical report	
		14.	
15. Supplementary Notes SERI technical monitor: W. Luft, (303) 231-1823			
16. Abstract (Limit: 200 words) Textured fluorine-doped zinc oxide films with high light-trapping efficiency, high electrical conductivity, and high transparency were grown by chemical vapor deposition at atmospheric pressure. Growth rates were moderately high, so that a film with high enough conductivity for solar cells were grown in about 2 minutes. Growth temperatures for high-quality material were about 450° C, which is compatible with glass or metal substrates, but too high for back contacts to amorphous silicon. Amorphous silicon solar cells grown on the textured zinc oxide showed very high quantum efficiencies, confirming the light-trapping ability of the texture and the extremely low optical absorption in the new material.			
17. Document Analysis a. Descriptors photovoltaics ; solar cells ; amorphous silicon b. Identifiers/Open-Ended Terms c. UC Categories 271			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161		19. No. of Pages 44	
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Document Control Page	1. SERI Report No. SERI/TP-214-4271	2. NTIS Accession No. DE91002138	3. Recipient's Accession No.
4. Title and Subtitle Research on Stable, High Efficiency Amorphous Silicon Multijunction Modules		5. Publication Date April 1991	
		6.	
7. Author(s) A. Catalano, R. Arya, M. Bennett, B. Fieselmann, Y. Li, J. Morris, J. Newton, R. Podlesny, S. Wiedeman, L. Yang		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address Solarex Thin Film Division 826 Newtown-Yardley Road Newtown, Pennsylvania 18940		10. Project/Task/Work Unit No. PV140201	
		11. Contract (C) or Grant (G) No. (C) ZM-0-19033-1 (G)	
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401		13. Type of Report & Period Covered Technical report	
		14.	
15. Supplementary Notes SERI technical monitor: W. Luft, (303) 231-1823			
16. Abstract (Limit: 200 words) This research effort seeks to develop modules with a stabilized performance of 8.8% aperture area conversion efficiency after 600 hours light exposure (AM1.5) at 50°C in modules with aperture areas over 900 cm ² . Good progress toward this goal has been obtained with the demonstration of 9.3% initial performance in a submodule incorporating devices with relatively thin middle junction i-layer thickness of 6000Å. Devices with this design are expected to lose about 15% of their initial performance after 1000 hours of exposure. Achieving long-term stabilized efficiencies of 12% or more requires substantial improvements in materials and devices. Our analysis has shown that substantial optical losses occur at both front and rear contacts which we hope to address with ZnO films prepared by CVD and sputtering processes now under development. Further progress in doped layers and alloys are also needed. Fundamental studies of the relationship between material structure and processes (particularly the effect of hydrogen dilution) are reported here.			
17. Document Analysis a. Descriptors photovoltaics ; solar cells ; amorphous silicon ; thin film ; multijunction modules b. Identifiers/Open-Ended Terms c. UC Categories 271			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161		19. No. of Pages 68	
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Document Control Page	1. SERI Report No. SERI/TP-214-4292	2. NTIS Accession No. DE91002159	3. Recipient's Accession No.
4. Title and Subtitle Research on Stable, High-Efficiency Amorphous Silicon Multijunction Modules		5. Publication Date April 1991	
		6.	
7. Author(s) P.K. Bhat, S. Brown, R. Hollingsworth, D.S. Shen, J. del Cueto, E. Iwanicko, C. Marshall, C. DeHart, D. Mentor, A. Benson, C. Matovich, J. Sandwisch		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address Glasstech Solar, Inc. Golden, Colorado		10. Project/Task/Work Unit No. PV141101	
		11. Contract (C) or Grant (G) No. (C) ZM-0-19033-3 (G)	
		13. Type of Report & Period Covered Technical report	
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401		14.	
15. Supplementary Notes SERI technical monitor: W. Luft, (303) 231-1823			
16. Abstract (Limit: 200 words) This report describes a contract to produce multijunction modules based entirely on amorphous silicon alloys, the modules having an aperture area of at least 900 cm ² and a stable, reproducible conversion efficiency of at least 6.5% after 600 hours of light exposure (air mass 1.5) at 50° C. The work focussed on (1) producing opto-electronic-grade amorphous silicon material for band gaps of about 1.7 and 1.9 eV by changing the hydrogen content in the film bonded to the silicon, (2) studying and obtaining data on the light stability of single-junction p-i-n solar cells with gaps of about 1.7 and 1.9 eV, and (3) analyzing losses in a silicon/silicon multijunction cell. We report new results on an indium tin oxide (ITO)/silver back contact and the deposition of granular tin oxide by atmospheric-pressure chemical vapor deposition. Progress toward module fabrication at the end of six months has been good, with the demonstration of 5.4% initial efficiency in a silicon/silicon multijunction submodule with an aperture area of 4620 cm ² and incorporating devices with 2nd-junction i-layer thicknesses of about 3500 Å. We also demonstrated a single-junction silicon submodule with an aperture area of 4620 cm ² , a thickness of about 3500 Å, and an initial efficiency of 6.5%.			
17. Document Analysis a. Descriptors photovoltaics ; solar cells ; amorphous state ; silicon b. Identifiers/Open-Ended Terms c. UC Categories 271			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161		19. No. of Pages 69	
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Document Control Page	1. SERI Report No. SERI/TP-214-4409	2. NTIS Accession No. DE91002169	3. Recipient's Accession No.
4. Title and Subtitle Scanning Tunneling Microscopy Studies of the Surfaces of a-Si:H and a-SiGe:H Films			5. Publication Date June 1991
			6.
7. Author(s) A. Gallagher, R. Ostrom, D. Tannenbaum			8. Performing Organization Rept. No.
9. Performing Organization Name and Address National Institute of Standards and Technology Boulder, Colorado			10. Project/Task/Work Unit No. PV141101
			11. Contract (C) or Grant (G) No. (C) DB-4-04078-1 (G)
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401-3393			13. Type of Report & Period Covered Technical report, 1 December 1989 - 31 January 1991
			14.
15. Supplementary Notes SERI technical monitor: W. Luft, (303) 231-1452			
16. Abstract (Limit: 200 words) <p>This report describes the experimental complexities encountered in using scanning tunneling microscopy (STM) probing for the atomic structure of the surface of freshly grown, hydrogenated-amorphous semiconductors. The report also contains a speculative microscopic film-growth model that explains differences between the disorder in a-Si:H and a-SiGe:H films grown by chemical vapor deposition (CVD). The model is derived from prior results obtained in the chemical analysis of GeH₄ plasmas, combined with surface-reaction and thermodynamic considerations. The neutral radical fragments of silane, disilane, and germane dissociation in discharges, which dominate the vapor and film-growth reactions, were deduced from a detailed analysis of prior data; these fragments are also reported.</p>			
17. Document Analysis a. Descriptors photovoltaics ; solar cells ; amorphous state ; silicon ; microscopes ; film growth b. Identifiers/Open-Ended Terms c. UC Categories 271			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161			19. No. of Pages 29
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Document Control Page	1. SERI Report No. SERI/TP-214-4394	2. NTIS Accession No. DE91002191	3. Recipient's Accession No.
4. Title and Subtitle Structure of Amorphous Silicon and Germanium Alloy Films			5. Publication Date July 1991
			6.
7. Author(s) R. E. Norberg, P.A. Fedders			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Department of Physics Washington University St. Louis, Missouri			10. Project/Task/Work Unit No. PV141101
			11. Contract (C) or Grant (G) No. (C) XB-7-06055-1 (G)
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401-3393			13. Type of Report & Period Covered Technical report, 15 January 1990 - 14 January 1991
			14.
15. Supplementary Notes SERI technical monitor: W. Luft, (303) 231-1452			
16. Abstract (Limit: 200 words) This report describes a research project to improve our understanding of the structure of amorphous silicon and germanium alloy films. This is accomplished by means of theoretical and experimental correlations of the results of nuclear magnetic resonance (NMR), electron spin resonance, transmission electron microscopy, and other measurements. The work focussed on examining the significant rearrangements of hydrogen taking place under various deposition and post-deposition conditions. A CMX 300/200 dual-solenoid pulsed Fourier transform NMR spectroradiometer was used to study hydrogenated and deuterated amorphous silicon and amorphous germanium films. The studies revealed the presence of, and changes in, tightly and weakly bonded hydrogen, molecular hydrogen, and rotating silyl and hydrogen molecules trapped on nanovoid surfaces. Theoretical calculations reveal serious errors in many computer simulations of amorphous solid and liquid silicon.			
17. Document Analysis a. Descriptors photovoltaics ; solar cells ; amorphous state ; silicon ; germanium ; alloys ; film growth b. Identifiers/Open-Ended Terms c. UC Categories 271			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161			19. No. of Pages 31
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4. Title and Subtitle High Efficiency Copper Ternary Thin Film Solar Cells			5. Publication Date April 1991
			6.
7. Author(s) Bulent M. Basol and Vijay K. Kapur			8. Performing Organization Rept. No.
9. Performing Organization Name and Address International Solar Electric Technology 8635 Aviation Blvd. Inglewood, California 90301			10. Project/Task/Work Unit No. PV140301
			11. Contract (C) or Grant (G) No. (C) XL-7-06031-6 (G)
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401			13. Type of Report & Period Covered Technical report
			14.
15. Supplementary Notes SERI technical monitor: R. Mitchell (303) 231-1379			
16. Abstract (Limit: 200 words) This report describes work to develop a high efficiency, thin film CuInSe ₂ solar cell using a potentially low-cost process. The technique used in this development program is a two-stage process. The two-stage process involves depositing the metallic elements of the CuInSe ₂ compound (i.e., Cu and In) on a substrate in the form of stacked layers, and then selenizing this stacked metallic film in an atmosphere containing Se. Early results showed that the electrodeposition/ selenization technique could yield CuInSe ₂ films with good electrical and optical properties on small-area substrates. This report concentrates on the later half of the research effort; this portion was directed toward developing a two-stage process using evaporated Cu-In layers. The selenization technique has the potential of yielding solar cells with efficiencies in excess of 15 percent.			
17. Document Analysis a. Descriptors photovoltaics, solar cells, thin films, copper indium diselenide, high efficiency b. Identifiers/Open-Ended Terms c. UC Categories 273			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161			19. No. of Pages 26
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4. Title and Subtitle Fundamentals of Polycrystalline Thin Film Materials and Devices		5. Publication Date January 1991	
		6.	
7. Author(s) Bill N. Baron, Robert W. Birkmire, James E. Phillips, William N. Shafarman, Steven S. Hegedus, Brian E. McCandless		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address Institute of Energy Conversion University of Delaware Newark, Delaware		10. Project/Task/Work Unit No. PV140301	
		11. Contract (C) or Grant (G) No. (C) XL-9-19032-1 (G)	
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401		13. Type of Report & Period Covered Technical report	
		14.	
15. Supplementary Notes SERI technical monitor: H. S. Ullal, (303) 231-1841			
16. Abstract (Limit: 200 words) This report presents the results of a one-year research program on polycrystalline thin-film solar cells. The research was conducted to better understand the limitations and potential of solar cells using CuInSe_2 and CdTe by systematically investigating the fundamental relationships linking material processing, material properties, and device behavior. By selenizing Cu and In layers, we fabricated device-quality CuInSe_2 thin films and demonstrated a CuInSe_2 solar cell with 7% efficiency. We added Ga, to increase the band gap of CuInSe_2 devices to increase the open-circuit voltage to 0.55 V. We fabricated and analyzed $\text{Cu(InGa)Se}_2/\text{CuInSe}_2$ devices to demonstrate the potential for combining the benefits of higher V_{oc} while retaining the current-generating capacity of CuInSe_2 . We fabricated an innovative superstrate device design with more than 5% efficiency, as well as a bifacial spectral-response technique for determining the electron diffusion length and optical absorption coefficient of CuInSe_2 in an operational cell. The diffusion length was found to be greater than 1 μm . We qualitatively modeled the effect of reducing heat treatments in hydrogen and oxidizing treatments in air on the I-V behavior of CuInSe_2 devices. We also investigated post-deposition heat treatments and chemical processing and used them to fabricate a 9.6%-efficient CdTe/CdS solar cell using physical vapor deposition.			
17. Document Analysis a. Descriptors photovoltaics ; solar cells ; polycrystalline thin films ; copper indium diselenide ; cadmium sulfide ; cadmium telluride b. Identifiers/Open-Ended Terms c. UC Categories 273			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161		19. No. of Pages 98	
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Document Control Page	1. SERI Report No. SERI/TP-210-4319	2. NTIS Accession No. DE91002190	3. Recipient's Accession No.
4. Title and Subtitle Novel Ways of Depositing ZnTe Films by a Solution Growth Technique		5. Publication Date June 1991	
		6.	
7. Author(s) Robert W. Birkmire		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address Institute of Energy Conversion University of Delaware Newark, Delaware		10. Project/Task/Work Unit No. PV121104	
		11. Contract (C) or Grant (G) No. (C) XM-0-18110-1 (G)	
12. Sponsoring Organization Name and Address Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401-3393		13. Type of Report & Period Covered Technical report, 1 January 1990 - 1 January 1991	
		14.	
15. Supplementary Notes SERI technical monitor: T. Basso, (303) 231-7035			
16. Abstract (Limit: 200 words) <p>This report describes a research program to develop a method for depositing thin (< 50 nm) ZnTe films to form a transparent back contact to CdTe solar cells. We investigated several approaches to growing ZnTe films from aqueous solution, including electrodepositing the films, forming the films from the CdTe surface by an exchange reaction, and forming the films from a chemical solution. Methods to dope the ZnTe films with Cu were another integral part of the program. Of the three approaches, only the electrochemical method was successful. In this approach, the films were deposited from an aqueous bath containing ZnCl₂ and TeO₂ with the substrate externally short-circuited to a Zn counter electrode to form a galvanic cell. Controlling both the pH and Te⁴⁺ ion concentration in the solution were critical for forming the single-phase ZnTe films. A copper complex was added to the bath to control the ZnTe conductivity and dope the films p-type. CdTe/CdS solar cells were developed incorporating the ZnTe:Cu as the primary contact to the CdTe. These cells have exhibited efficiencies of ~9%.</p>			
17. Document Analysis a. Descriptors photovoltaics ; solar cells ; polycrystalline thin films ; film growth ; deposition b. Identifiers/Open-Ended Terms c. UC Categories 273			
18. Availability Statement National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161		19. No. of Pages 29	
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ADDITIONAL PUBLICATIONS AND SOURCES

The following publications were produced under the DOE Photovoltaics Program or are widely available publications in which substantial DOE-supported work is reported. Those that are available from the National Technical Information Service (NTIS) can be purchased with the NTIS order form provided hereafter.

Annual Report, Photovoltaic Measurements and Performance Branch, FY 1988. (January 1989). SERI/PR-213-3590. 160 pp. Available NTIS: Order No. DE89009500.

Annual Report, Photovoltaic Measurements and Performance Branch, FY 1989. (May 1990). SERI/TP-213-3712. 226 pp. Available NTIS: Order No. DE90000324.

Annual Report, Photovoltaic Program Branch, FY 1988. (March 1989). SERI/PR-211-3483. 302 pp. Available NTIS: Order No. DE89000898.

Annual Report, Photovoltaic Program Branch, FY 1989. (March 1990). SERI/TP-211-3643. 279 pp. Available NTIS: Order No. DE90000318.

Annual Report, Photovoltaic Subcontract Program, FY 1990. (March 1991). SERI/TP-214-4135. 314 pp. Available NTIS: Order No. DE91002149.

Annual Report, Solid State Photovoltaic Research Branch, FY 1988. (July 1989). SERI/PR-212-3494. 265 pp. Available NTIS: Order No. DE89009463.

Annual Report, Solid State Photovoltaic Research Branch, FY 1989. (September 1990). SERI/TP-212-3675. 288 pp. Available NTIS: Order No. DE891002128.

Conference Record of the Twentieth IEEE Photovoltaic Specialists Conference - 1988; Las Vegas, Nevada; September 26-30, 1988. (1988). New York: The Institute of Electrical and Electronics Engineers, Inc.; 2 Volumes, 1664 pp. Available from IEEE, 345 E. 47th St., New York, NY 10017.

Current Abstracts: Photovoltaic Energy, Electricity from Sunlight. Prepared by the Office of Scientific and Technical Information for the Office of Conservation and Renewable Energy, U. S. Department of Energy. Nov.-Dec. 1989, PB89-933006. Available from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831.

Current Abstracts: Photovoltaic Energy, Electricity from Sunlight. Prepared by the Office of Scientific and Technical Information for the Office of Conservation and Renewable Energy, U. S. Department of Energy. Jan.-Feb. 1990, PB90-933001. Available from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831.

Luft, W. (1990). "Photovoltaic Applications for Silicon Carbon Films and Microcrystalline Silicon Films." Applied Physics Communications. Vol. 9, No. 4, pp. 329-357.

Mitchell, R. L.; Zweibel, K.; Ullal, H. S. (November 1990). Research on Polycrystalline Thin-Film Materials, Cells, and Modules. SERI/TP-211-4061. 7 pp. Available NTIS: Order No. DE91002124.

Moskowitz, P. D.; Zweibel, K.; Fthenakis, V. M. (1990). Health, Safety and Environmental Issues Relating to Cadmium Usage in Photovoltaic Energy Systems. SERI/TR-211-3621. 34 pp. Available NTIS: Order No. DE90000310.

Photovoltaic Energy Program Summary, Volume I: Overview, Fiscal Year 1989. (January 1990). DOE/CH10093-58. Golden, CO: Solar Energy Research Institute; 20 pp. Prepared for the U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, Washington, DC, by the Solar Energy Research Institute, Golden, Colorado. Available NTIS: Order No. DE89009473.

Photovoltaic Energy Program Summary, Volume II: Research Summaries Fiscal Year 1989. (January 1990). DOE/CH10093-59. Golden, CO: Solar Energy Research Institute; 157 pp. Prepared for the U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, Washington, DC, by the Solar Energy Research Institute, Golden, Colorado. Available NTIS: Order No. DE89009474.

Photovoltaics: Entering the 1990s. (November 1989). SERI/SP-220-3461. 42 pp. Produced by the Development and Communications Office. Available NTIS: Order No. DE89009509.

Photovoltaics Technical Information Guide: Second Edition. (August 1988). SERI/SP-320-3328. 118 pp. Available NTIS: Order No. DE88001184.

Riordan, C. J.; Hulstrom, R. L.; Cannon, T. W.; Stoffel, T. L.; Myers, D. R. (February 1989). Photovoltaic Advanced Research and Development Project, Solar Radiation Research, Annual Report, 1 October 1987 - 30 September 1988. SERI/PR-215-3445. 24 pp. Available NTIS: Order No. DE89000884.

SERI Photovoltaic Subcontract Reports: 1988 Abstracts and Document Control Information. (June 1990). SERI/TP-211-3893. 35 pp. Available NTIS: Order No. DE90000357.

SERI Photovoltaic Subcontract Reports: 1989 Abstracts and Document Control Information. (April 1990). SERI/TP-211-3678. 57 pp. Available NTIS: Order No. DE90000336.

SERI Preprints for the 21st IEEE Photovoltaic Specialists Conference. (May 1990). SERI/TP-210-3833. 65 pp. Available NTIS: Order No. DE90000341.

Ullal, H. S.; Zweibel, K.; Surek, T. (1990). Recent Technological Advances in Thin Film Solar Cells. SERI/TP-211-3679. 5 pp. Prepared for the World Renewable Energy Congress, Reading, United Kingdom, 23-28 September 1990. Available NTIS: Order No. DE90000223.

Ullal, H. S.; Zweibel, K. (December 1989). Progress in Thin Film Solar Photovoltaic Technologies. SERI/TP-211-3604. 12 pp. Prepared for the 9th Miami International Congress on Energy and Environment, Miami Beach, Florida, 11-13 December 1989. Available NTIS: Order No. DE89009513.

Ullal, H. S.; Zweibel, K.; Mitchell, R. L. (November 1989). U.S. Polycrystalline Thin Film Solar Cell Program. SERI/TP-211-3595. 6 pp. Prepared for the Materials Research Society 1989 Fall Meeting, 27 November - 2 December 1989, Boston, Massachusetts. Available NTIS: Order No. DE89009506.

Ullal, H. S.; Zweibel, K.; Sabisky, E. S.; Surek, T. (August 1988). Solar Photovoltaic Technology: The Thin Film Option. SERI/TP-211-3390. 10 pp. Presented at the AIChE Summer National Meeting, Denver, Colorado, 21-24 August 1988. Available NTIS: Order No. DE88001195.

U.S. Photovoltaic Patents: 1951-1987. (September 1988). SERI/SP-210-3357. 616 pp. Available NTIS: Order No. DE88001178.

Zweibel, K.; Mitchell, R. L. (1989). CuInSe₂ and CdTe: Scale-Up For Manufacturing. SERI/TP-211-3571. 108 pp. Available NTIS: Order No. DE89000831.

Zweibel, K. (May 1989). Thin Film Photovoltaics. SERI/TP-211-3501. 7 pp. Prepared for the 24th Intersociety Energy Conversion Engineering Conference, Washington, D.C., 6-11 August 1989. Available NTIS: Order No. DE89009425.

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