

STEVEN S. HEGEDUS

Professor, Electrical and Computer Engineering
Senior Scientist, Institute of Energy Conversion
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EDUCATION

- Ph.D. Electrical and Computer Engineering, University of Delaware, 1990.
Dissertation title: "Characterization of Midgap States by Capacitance Techniques in Amorphous Silicon and Amorphous Silicon Germanium p-i-n Solar Cells."
- M.E.E. Electrical Engineering, Cornell University, 1981.
Thesis title: "Modeling and Analysis of Polycrystalline GaAs Schottky Barrier Solar Cells."
- B.S.E.E. Electrical Engineering, Case Western Reserve University, 1977.

EXPERIENCE – 35+ years in Photovoltaic R&D and Education

2018-present Professor, Dept Electrical and Computer Engineering (ECE), University of Delaware

Graduated 3 PhD students and 1 MS student in 2018. Currently supporting 4 PhD students. Have supervised, supported, and graduated 12 PhD and 9 MS students from Electrical and Computer Engineer (ECE) since my secondary appointment in 2005. Currently teaching ELEG 628 Solar Electric Technology and Applications ELEG (for 20 years). Co-teaching newly developed course ELEG 457/657 Design and Operation of Renewable Microgrids (first year). Coteaching ELEG 298 Sophomore Circuit Design Challenges. Secondary appointment as Senior Scientist at Institute of Energy Conversion (IEC). Developing two new solar test bed facilities at IEC to further research at IEC and ECE: a 5 kW test bed for bifacial modules with residential smart inverter, charge controller and battery (funded by an external gift); and a hardware-in-loop (HIL) test bed for evaluating cyber security of power electronics like solar inverters (funded by 3 year Department of Energy (DOE) award). Both involve ECE grad students and/or faculty. Participating in two UD studies funded by State of Delaware: 1) apply LiDAR imaging to evaluate solar rooftop potential at UD and local urban areas; 2) Identify critical issues limiting Community Solar projects and propose viable approach for DE. Developing a new focus in power systems/grid integration as member of ECE Undergraduate Curriculum Committee. Serving on ECE Strategic Planning Committee and COE Educational Activities Committee. Served on 5 PhD committees (3 ECE, 1 MSEG, 1 ENEP).

2013-present Senior Scientist, Institute of Energy Conversion (IEC), University of Delaware
PI of \$1.2M DOE 3 year award "Rapid patterning and advanced device structures for low cost manufacturable Si IBC solar cells" (ending 2/2020) and \$600K DOE

3 year sub-award “Faster than real time simulation and demonstration of high penetration distributed energy resources” (ending 11/2022). Completed work as PI of \$3.8M DOE award involving consortium of other university and industry partners (ended 2015). Co-PI on proposal to DOE for PV-Agriculture project with professor in CAN (rejected). Developed team at UD to pursue microgrid applications. Received funding from State of Delaware (DNREC) to evaluate microgrids. Managing the Solar Cell Characterization and Accelerated Life Testing (ALT) Facility at IEC. Discussion with Sustainability Office of Caribbean Island Nations for funded collaboration with Biden School professor to analyze microgrid applications. Collaborated with administrators and facilities at STAR to build a microgrid. Wrote Unidel proposal for MG funding (rejected). Assisting STAR personnel in defining and evaluating PV projects and test bed for STAR.

2007-2013 Scientist, Institute of Energy Conversion, University of Delaware

Principal investigator on 3 DOE and 1 DARPA contracts: 1) DOE FPACE award “Low cost back contact heterojunction solar cells on thin c-Si wafers: Integrating laser and thin film processing for improved manufacturability” (2012-2015, \$1.2 M) to fabricate IBC-SHJ on kerfless Si wafers with laser fired contacts and patterning; 2) Subcontract to Air Products from DOE “Enhanced growth rate of amorphous and nanocrystalline Si single and tandem solar cells” (2009-2012, \$1.1M); 3) Subcontract to Konarka from DOE “Characterization of degradation modes in OPV cells and modules” (2008-2010, \$230K); and 4) Subcontract to SiOnyx on DARPA program to develop heterojunction solar cells on very thin (50 μm) Si wafers with ‘black’ laser texture surface.

Manager of the Solar Cell Characterization Facility at IEC including hiring, training and assisting in the calibration and troubleshooting of optoelectronic measurements. Create the Accelerated Life Test (ALT) Lab at IEC using customized environmental chambers for solar cell degradation studies. Collaborate with industry groups on ALT for encapsulated Cu(InGa)Se₂ and organic module stability. Applied Laser Beam Induced Current (LBIC) to evaluate uniformity of thin film solar cells and minimodules. Supervised 10+ graduate students from various departments. Taught graduate class on PV technology and applications for > 10 years. Edited second edition of “Handbook of PV Science and Engineering” for Wiley and Sons. Consulting with US PV industry. Has secondary appointment in ECE and Fellow in Center for Energy and Environmental Policy. Wrote invited paper comparing outdoor performance of crystalline Si vs thin film PV modules. Gave invited webinars and talks.

1993 - 2007 Associate Scientist, Institute of Energy Conversion, University of Delaware

Responsible for optimization, analysis and characterization of thin film a-Si and CdTe solar cells. Developed lumped circuit model and applied to a-Si p-i-n JV data to obtain fundamental transport properties of the i-layer. Extended model to analyze state-of-the-art a-Si/a-SiGe multijunction solar cells. Developed analysis of QE to quantify optical enhancement due to light trapping in a-Si solar cells. Characterized JV behavior of contacts and junctions between transparent conductive oxides and a-SiC or $\mu\text{c-Si}$ doped layers. Developed novel method to

characterize SnO₂/p contact in a-Si p-i-n solar cells. Designed and operated multichamber environmental stress test system to evaluate stability of CdTe solar cells under controlled electrical bias, atmosphere, and thermal stress. Developed comprehensive loss analysis for CdTe solar cells including new treatment of voltage-dependent photocurrent. Develop and apply bifacial QE and JV analysis to CdTe devices. Collaborate with CdTe industry on improving stability. Represent IEC on a-Si and CdTe Thin Film Partnership Teams. Developing approaches for thin Si bottom cell for tandem application. Maintain and critically evaluate IEC's solar simulator, and spectral response equipment. Wrote paper on solar cell characterization that has >550 citations (as of 2017). Direct and train technicians, visiting scientists, post-docs, graduate and undergraduate students. Supervised one Ph.D. and two Master's degree students. Obtained several contracts with new industry partners. Advised UD student team designing and building all-solar house for DOE competition. Teaching graduate course on "Solar Energy Technology and Applications." Co-editor and co-author of "Handbook of PV Science and Engineering," published by Wiley and Sons, UK, in 2002, the most comprehensive book on PV. Consulting editor of "Progress in Photovoltaics." Appointed Fellow in UD's Center for Energy and Environmental Policy in 2005.

1982-1993

Research Associate III Institute of Energy Conversion, University of Delaware
Studied photoresponse of CdS/CuInSe₂ heterojunctions. Characterized and analyzed a-Si devices from new photoCVD process leading to first 10% efficient a-Si cell by university group in U.S. Became co-principal investigator of photoCVD a-Si program. Developed several optoelectronic techniques to characterize devices, including sub-bandgap QE, to study light-induced defects. Detailed study of midgap density of states in a-SiGe p-i-n cells by capacitance lead to Ph.D. dissertation in 1990. Analyzed mechanisms determining V_{oc}. Studied CdS/CdTe devices, used QE measurements to identify S interdiffusion and formation of CdTe(S) alloy. Engineer in one of the earliest demonstrations of PV for demand side management study, providing technical assistance in assembling data acquisition and control system in PV powered solar house.

1977 - 1982

Semiconductor Device Engineer
IBM Corp., Endicott, New York

Responsible for modeling, testing, design and diagnostics of analog and digital integrated circuit devices. Designed and tested a new stress-independent integrated Hall effect sensor.

ACHIEVEMENTS

- Lead the first US university effort to fabricate a 10% a-Si solar cell (1988, publication 16)
- One of the earliest demonstrations of PV for residential demand side management (1994, publication 38)
- Lead the Multijunction Device Team for DOE National Thin Film Partnership (1992-2000, publications 35, 40, 48)

- Developed methodology to separate contact and junction degradation in a-Si and CdTe solar cells (2000, publications 56, 58)
- Developed comprehensive approach to characterize performance losses in thin film solar cells (2004, publication 70, cited > 700 times)
- Identified transient degradation and recovery in CdTe solar cells (2005 publication 72)
- Conducted accelerated degradation studies and device analysis on all commercially relevant thin film solar cells: a-Si, CdTe, organic, CIGS
- Editor of highly-cited book “*Handbook of Photovoltaic Science and Engineering*” (with Antonio Luque, Wiley and Sons 1st and 2nd Eds 2003, 2011)
- Principal Investigator of two DOE-funded multi-institution programs to fabricate Si Integrated Back Contact Heterojunction (IBC-HJ) Cells using lasers (2012, 2017)
- First demonstration of laser fired contacts on IBC-HJ cells (2014, publication 113)
- Establishing microgrid and solar inverter cyber security test facilities and team to provide new focus for ECE Dept and for IEC.

SYNERGISTIC ACTIVITIES

- 2021: Advising MEGR Solar Decathlon student design team
- 2020: Advised ECE Senior Design team on solar powered emergency medical back-up power system
- 2017-present: Serve on State DNREC Renewable Energy Task Force
- 2016: Co-chaired UDEI Solar Fuels Workshop, co-wrote white paper to DOE
- 2014-17: Regular guest lecture on Photovoltaics to CIEG 402, CIEG 465
- 2015-16: Executive Committee of Delaware Chapter of Sierra Club
- 2011-12: Lead team of UD graduate students designing and building Mobile Solar Demonstration Cart for K-12 education and training on solar energy
- 2002-12: Faculty advisor, UD Students for the Environment
- 1995-present: make presentations on solar electricity to local churches, schools, community groups; assist them in evaluating bids from solar contractors
- 1992-99: Team Leader, National Center Photovoltaics Thin Film R&D Industry Partnership Program

PROFESSIONAL MEMBERSHIPS

- Lifetime member, American Solar Energy Society
- Lifetime member, American Physical Society
- Senior Member, IEEE

PROFESSIONAL TRAINING

- 2016: Basic Training for HOMER Hybrid Microgrid Software Optimization
- 2013: 60 hr on-line class “Solar Electric Design and Installation of Grid Connected Systems” from industry-leading trainers Solar Energy International

PROFESSIONAL SERVICE

- 2020: Review ORAU proposals for new faculty
- 2019: Reviewer for IEEE Photovoltaics Specialists Conference Area 4
- 2018: External reviewer for 2 international PhD students (IIT-India, UNSW-Australia)
- 2017: Presentation on Solar Technology and Careers to IEEE Young Professionals (Philadelphia)
- 2012-present: Tutorial Instructor at five IEEE Photovoltaics Specialists Conference:
 - *Thin Film Solar Cells* (2012-2014, 2017);
 - *Fundamentals of PV Science and Technology* (2015-2016)
- 2009: Chair of Program Area 5 (Thin Film Si), 34rd IEEE Photovoltaics Specialists Conference, Philadelphia.
- 2003-2010: Hosted UD IEEE Student chapter several times for presentation and lab tour
- 2003-present: Consulting Editor of *Progress in Photovoltaics*
- 2015-present: Reviewer for IEEE J of Photovoltaics and other journals.

PATENTS

“Processes for fabricating all back contact heterojunction solar cells” Robert Birkmire, Steven Hegedus, Ujjwal Das. US2010319769A1, awarded Dec 2010.

BOOKS and CHAPTERS

- *Handbook of Photovoltaic Science and Engineering*, published John Wiley and Sons (2nd Edition 2011). A. Luque and S. Hegedus, editors.
- “Achievements and Challenges of Solar Electricity from Photovoltaics” S. Hegedus, A. Luque, in *Handbook of Photovoltaic Science and Engineering*, published John Wiley and Sons (2nd Edition 2011). A. Luque and S. Hegedus, editors.
- “Amorphous Silicon Solar Cells” E. Schiff, S. Hegedus, X. Deng, in *Handbook of Photovoltaic Science and Engineering*, published John Wiley and Sons (2nd Edition 2011). A. Luque and S. Hegedus, editors.

INVITED PUBLICATIONS

1. “Introduction to the Thin Film Photovoltaic Symposium Commemorating the 25th Anniversary of the Institute of Energy Conversion at the University of Delaware, USA,” Robert W. Birkmire and Steven S. Hegedus, *Progress in Photovoltaics* **5**(5), 305 (1997).
2. “Summary of 4 1/2 Years of Research Experience of the US Amorphous Silicon Research Teams,” B. von Roedern, E. Schiff, J.D. Cohen, S. Wagner and Steven S. Hegedus, *Progress in Photovoltaics: Res. Appl* **5**(5), 345 (1997).
3. “Substrates, Contacts and Monolithic Integration,” Steven S. Hegedus, Scot Albright, Frank Jeffrey, T.J. McMahon and S. Wiedeman, *Progress in Photovoltaics* **5**(5), 365 (1997).

4. "Thin-Film Solar Cells: Device Measurements and Analysis," Steven S. Hegedus, and William N. Shafarman, *Progress in Photovoltaics* **12**(3), 155 (2004). **>800 citations**
5. "Thin Film Solar Modules: The Low Cost, High Throughput and Versatile Alternative to Si Wafers," S. Hegedus, *Progress in Photovoltaic* **14**, 393 (2006)
6. "Review of photovoltaic module energy yield (kWh/kW): comparison of crystalline Si and thin film technologies" Steven Hegedus, *Wiley WIRE Energy Environ* 2012. doi: 10.1002/wene.61

REGULAR PUBLICATIONS (over 55 publications in IEEE journals and conference proceedings)

7. "The Photoresponse of CdS/CuInSe₂ Thin-Film Heterojunction Solar Cells," Steven S. Hegedus, *IEEE Trans. Electron Devices* Ed. **31**, 629 (1984).
8. "Transport Properties of LPCVD a-Si:H Solar Cells," S.S. Hegedus, *J. Noncryst. Sol.* **66**, 369 (1984).
9. "CVD Amorphous Silicon Solar Cells," S.S. Hegedus, R.E. Rocheleau, and B.N. Baron, *Proc. 17th IEEE PVSC*, 239 (1984).
10. "Properties of Intrinsic a-Si Films Deposited from Higher Order Silanes by CVD," R.E. Rocheleau, S.S. Hegedus, and B.N. Baron, *Proc. Mater. Res. Conf.* **49**, 15 (1985).
11. "Quantum Efficiency of Amorphous Alloy Solar Cells," V.L. Dalal, M. Leonard, J. Booker, A. Vaseashta, and S. Hegedus, *Proc. 18th IEEE PVSC*, 837 (1986).
12. "Electronic and Optical Properties of a-(SiGe):H Alloys," V. Dalal, M. Leonard, J. Booker, and S.S. Hegedus, *Proc. 18th IEEE PVSC*, 1500 (1986).
13. "Properties of a-Si:H and a-SiGe:H Films Deposited from Photo-Assisted CVD," R. Rocheleau, S. Jackson, S.S. Hegedus, and B. Baron, *Proc. Mater. Res. Soc. Conf.* **70**, 37 (1986).
14. "Density of Midgap States and Urbach Edge in Chemically Vapor Deposited Hydrogenated Amorphous Silicon Films," Steven S. Hegedus, R. E. Rocheleau, J.M. Cebulka, and B.N. Baron, *J. Appl. Phys.* **60**(3), 1046 (1986).
15. "Laboratory Safety Procedures for Processing II-VII and Related Compounds for Thin Film Photovoltaics," Steven S. Hegedus, J.D. Meakin, B.N. Baron, and J.A. Miller, *Solar Cells* **19**, 225 (1987).
16. "Measurement of the Built-in Potential in Amorphous Silicon p-i-n Solar Cells," Steven S. Hegedus, Martin Schmidt and Neil Salzman, *Proc. 19th IEEE PVSC*, 210 (1987).
17. "Analysis of a Transparent Cu/ITO Contact and Heat Treatments on CdTe/CdS Solar Cells," R.W. Birkmire, S.S. Hegedus, B.E. McCandless, J.E. Phillips, and W.N. Shafarman, *Proc. 19th IEEE PVSC*, 967 (1987).

18. "Novel Photochemical Vapor Deposition Reactor for Amorphous Silicon Solar Cell Deposition," Richard E. Rocheleau, Steven S. Hegedus, Wayne A. Buchanan, and Scott C. Jackson, *Appl. Phys. Lett.* **51**(2), 133 (1987).
19. "Performance and Analysis of Amorphous Silicon *p-i-n* Solar Cells Made by Chemical-Vapor Deposition from Disilane," Steven S. Hegedus, R.E. Rocheleau, W. Buchanan, and B.N. Baron, *J. Appl. Phys.* **61**(1), 381 (1987).
20. "Effects of Impurities on Film Quality and Device Performance in a-Si:H Deposited by Photo-Assisted CVD," Richard E. Rocheleau, Steven S. Hegedus, Wayne Buchanan, and Robert Tullman, *Proc. 19th IEEE PVSC*, 699 (1987).
21. "Low Bandgap Amorphous Silicon-Germanium Alloys for Thin Film Solar Cells Using a Novel Photo-CVD Reactor," Steven S. Hegedus, R.M. Tullman, H.S. Lin, J.M. Cebulka, W.A. Buchanan, R. Dozier, and R.E. Rocheleau, *Proc. 19th IEEE PVSC*, 867 (1987).
22. "Photo-assisted CVD of a-Si:H Solar Cells and a-SiGe:H Films," S. S. Hegedus, R.E. Rocheleau, R.M. Tullman, D.E. Albright, N. Saxena, W.A. Buchanan, K.E. Schubert, and R. Dozier, *Proc. 20th IEEE PVSC*, 129 (1988).
23. "The Relation of Dark and Illuminated Diode Parameters to the Open-circuit Voltage of Amorphous Silicon *p-i-n* Solar Cells," Steven S. Hegedus, Neil Salzman, and Edward Fagen, *J. Appl. Phys.* **63**(10), 5126 (1988).
24. "Light-induced Degradation in Undoped Hydrogenated Amorphous Silicon Films Studied by the Surface Photovoltage Technique: A Comparison of Lifetime Versus Space-charge Effects," Steven S. Hegedus, Hong-sheng Lin, and A.R. Moore, *J. Appl. Phys.* **64**(3), 1215 (1988).
25. "Amorphous Silicon-Germanium Deposited by Photo-CVD: Effect of Hydrogen Dilution and Substrate Temperature," R.E. Rocheleau, R.M. Tullman, D.E. Albright and S.S. Hegedus, *Mater. Res. Society Symposium* **118**, 653 (1988).
26. "The Open Circuit Voltage of Amorphous Silicon *p-i-n* Solar Cells," Steven S. Hegedus, *Proc. 20th IEEE PVSC*, 102, (1988).
27. "Characterization of Defects in a-Si:H Solar Cells Using Sub-band Gap Photocurrent Spectroscopy," Steven S. Hegedus and James M. Cebulka, *Proc. 20th IEEE PVSC*, 186 (1988).
28. "Midgap Defects in a-SiGe:H Devices from Capacitance Measurements," Steven S. Hegedus and Theodore X. Zhou, *Proc. Mater. Res. Society Spring Meeting* **149**, 533 (1989).
29. "Stable High Efficiency Amorphous Silicon Based Solar Cells," B.N. Baron, C.M. Fortmann, S.S. Hegedus, W.A. Buchanan, D.E. Albright, N. Saxena, and T.W.F. Russell, *Proc. 9th Euro. Communities PV Solar Energy Conf.*, 56 (1989).
30. "Design Considerations for Low Band Gap a-SiGe:H Alloy Solar Cells," S.S. Hegedus, C.M. Fortmann, and W.A. Buchanan, *J. Non-Crystalline Solids* **115**, 21 (1989).
31. "Capacitance Studies of a-SiGe:H *p-i-n* Solar Cells," Steven S. Hegedus, *Proc. 21st IEEE PVSC*, 1544 (1990).

32. "Steady-state Mobility-lifetimes and Photoconductivity in a-SiGe:H Thin Films," S.S. Hegedus and J.M. Cebulka, *J. Appl. Phys.* **67**(8), 3885 (1990).
33. "Influence of CdS Window Layers on Thin Film CdS/CdTe Solar Cell Performance," B.E. McCandless and S.S. Hegedus, *Proc. 22nd IEEE PVSC*, 967 (1991).
34. "Hydrogen Content and the Goal of Stable Efficient Amorphous-Silicon-Based Solar Cells," C.M. Fortmann, S.S. Hegedus, T.X. Zhou and B.N. Baron, *Solar Cells* **30**, 255 (1991).
35. "Polycrystalline Heterojunction Solar Cells: Device Perspective," J.E. Phillips, W.N. Shafarman, R.W. Birkmire, S.S. Hegedus, and B.E. McCandless, *AIP Conf. Proc.* **268**, 206 (1992).
36. "Polycrystalline Heterojunction Solar Cells: Processing Perspective," R.W. Birkmire, S.S. Hegedus, B.E. McCandless, J.E. Phillips, TWF Russell, W.N. Shafarman, S.Verma, and S. Yamanaka, *AIP Conf. Proc.* **268**, 212 (1992).
37. "Effects of Processing on CdTe/CdS Materials and Devices," R. W. Birkmire, B.E. McCandless, and S.S. Hegedus, *Int. J. Solar Energy* **12**, 145 (1992).
38. "Midgap States in a-Si:H and a-SiGe:H p-i-n Solar Cells and Schottky Junctions by Capacitance Techniques," Steven S. Hegedus and E. A. Fagen, *J. Appl. Phys.* **71**(12), 5941 (1992).
39. "Characterization of a-Si:H and a-SiGe:H p-i-n and Schottky Junctions by Admittance Circuit Modeling," Steven S. Hegedus and Edward A. Fagen, *IEEE Trans. on Elect. Dev.* **39**(10), 2368 (1992).
40. "Understanding Graded a-SiGe Solar Cells Using Bifacial Photocurrent Collection," Steven Hegedus and Wayne Buchanan, *Proc. 23rd IEEE PVSC*, 991 (1993).
41. "Recent Progress in Amorphous Silicon PV Technology," W. Luft, H.M. Branz, V.L. Dalal, S.S. Hegedus, and E.A. Schiff, *AIP Conf. Proc.* **306**, 31 (1994).
42. "Parametric Analysis of a-Si Solar Cells from Current Voltage Measurements," Steven S. Hegedus and James E. Phillips, *Proc. IEEE First WCPEC and 24th IEEE PVSC*, 654 (1994).
43. "Built-in Potentials via Electroabsorption Measurements in a-Si:H p-i-n Solar Cells: A Critical Assessment," Q. Wang, E.A. Schiff, and S.S. Hegedus, *Mater. Res. Society Symp. Proc.* **336**, 365 (1994).
44. "Photovoltaics as a Demand-side Management Technology: An Analysis of Peak-shaving and Direct Load Control Options," John Byrne, Steven Hegedus, and Young-Doo Wang, *Progress. in Photovoltaics* **2**, 235 (1994).
45. "Current Transport in Amorphous Silicon n/p Junctions and their Application as "tunnel" Junctions in Tandem Solar Cells," Steven S. Hegedus, Frank Kampas, and Jianping Xi, *Appl. Phys. Lett.* **67**(6), 813 (1995).
46. "Progress in Amorphous Silicon PV Technology: An Update," W. Luft, H.M. Branz, V.L. Dalal, S.S. Hegedus, and E.A. Schiff, *Amer. Inst. Physics Conf. Proc.* **353**, 81 (1995).

47. "Transparent Conducting Oxides (TCO's) for n-i-p and p-i-n Amorphous Silicon Solar Cells," Steven S. Hegedus, Wayne A. Buchanan, Erten Eser, James E. Phillips, and William N. Shafarman, *Amer. Inst. Physics Conf. Proc.* **353**, 465 (1995).
48. "Effect of Textured Tin Oxide and Zinc Oxide Substrates on the Current Generation in Amorphous Silicon Solar Cells," S. Hegedus, W. Buchanan, X. Liu, & R. Gordon, *Proc. 25th IEEE PVSC*, 1129 (1996).
49. "Analysis of Optical Enhancement in a-Si n-i-p Solar Cells Using a Detachable Back Reflector," Steven S. Hegedus & Xunming Deng, *Proc. 25th IEEE PVSC*, 1061 (1996).
50. "Progress Report on the Amorphous Silicon Teaming Activities," B. von Roedern, K. Zweibel, E. Schiff, J.D. Cohen, S. Wagner, S.S. Hegedus and T. Peterson, Proc. 14th NREL/SNL PV Program Review Meeting, *Amer. Inst. Physics Conf. Proc.* (1996).
51. "Analysis and Optimization of High Efficiency Multijunction a-Si:H Solar Cells," Richard E. Rocheleau, Moe Tun, and Steven S. Hegedus, *Proc. 26th IEEE PVSC*, 703 (1997).
52. "Improving Performance of Superstrate p-i-n a-Si Solar Cells by Optimization of n/TCO/Metal Back Contacts," Steven S. Hegedus, Wayne A. Buchanan, and Erten Eser, *Proc. 26th IEEE PVSC*, 603 (1997).
53. "Optical losses in Amorphous Silicon Solar Cells Due to Back Reflectors," B. L. Sopori, J. Madjdpour, B. V. Roedern, W. Chen, and S. S. Hegedus, *Proc. Mater. Res. Society Symp.* (1997).
54. "Current-Voltage Analysis of a-Si and a-SiGe Solar Cells Including Voltage-dependent Photocurrent Collection," Steven S. Hegedus, *Progress in Photovoltaics* **5**(3), 151 (1997).
55. "Preparation and Characterization of Micro-Crystalline Hydrogenated Silicon Carbide p-Layers," Erten Eser, Steven S. Hegedus, and Wayne A. Buchanan, *Amer. Inst. Physics Conf. Proc.* **462**, 254 (1998).
56. "Optical Modeling of a-Si Solar Cells," B. Sopori, J. Madjdpour, Y. Zhang, W. Chen, S.S. Hegedus, *Proc. MRS Spring Meeting* **557**, 755 (1999).
57. "Infrared Electroabsorption Spectra in Amorphous Silicon Solar Cells," J.H. Lyou, Eric A. Schiff, Steven S. Hegedus, S. Guha and J. Yang, *Proc. MRS Spring Symp.* **557**, 457 (1999).
58. "A New Method to Characterize TCO/P Contact Resistance in a-Si Solar Cells," Steven S. Hegedus, Michael Gibson, Gautam Ganguly and Rejeewa Arya, *Mat. Res. Soc. Symp. Proc.* **557**, 737 (1999).
59. "Characterization of the SnO₂/p and ZnO/p Contact Resistance and Junction Properties in a-Si p-i-n Solar Cells and Modules," Steven S. Hegedus, Ruhi Kaplan, Gautam Ganguly and George S. Wood, *Proc. 28th IEEE PVSC*, 728 (2000).
60. "Interfacial Optical Spectra in Amorphous Silicon Based *pin* Solar Cells," Kai Zhu, J.H. Lyou, E.A. Schiff, R.S. Crandall, G. Ganguly and S.S. Hegedus, *Proc. 28th IEEE PVSC*, 725 (2000).

61. "Analysis of Stress-Induced Degradation in CdS/CdTe Solar Cells," Steven S. Hegedus, Brian E. McCandless, and Robert W. Birkmire, *Proc. 28th IEEE PVSC*, 535 (2000).
62. "Initial and Stressed Performance of CdTe Solar Cells: Effect of Contact Processing," S. S. Hegedus, B. E. McCandless and R.W. Birkmire, *Proc. NCPV Prog. Rev. Mtg.*, 119 (2001).
63. "Thin Si p-layers Containing Boron Doped Micro-crystalline Si and a-SiO_x Phases," E. Eser, W. Buchanan and S. Hegedus, *Proc. NCPV Prog. Rev. Mtg.*, 183 (2001).
64. "Effect of Plasma and Thermal Annealing on Optical and Electronic Properties of SnO₂ Substrates Used for a-Si Solar Cells," Steven S. Hegedus, *J. Appl. Phys.* **92**(1), 620 (2002).
65. "Optical Design and Analysis of Textured a-Si Solar Cells," Steven Hegedus, Bhushan Sopori, P.D. Paulson, *Proc. 29th IEEE PVSC*, 1122 (2002).
66. "Analysis of Quantum Efficiency and Optical Enhancement in Amorphous Si p-i-n Solar Cells," Steven S. Hegedus and Ruhi Kaplan, *Prog. Progress in Photovoltaics: Res. and Appl.* **10**, 257 (2002).
67. "Correlation of Surface Phases with Electrical Behavior in Thin-film CdTe Devices," B.E. McCandless, S.S. Hegedus, R.W. Birkmire, D. Cunningham, *Thin Solid Films* **431**, 249 (2002).
68. "Role of Process Chemistry and Stability on CdTe-based Solar Cell Performance," by B. McCandless, K. Dobson, S. Hegedus, and P. Paulson, *Proc. NCPV Rev. Mtg.*, 401 (2003).
69. "Photoconductive CdS: How Does it Affect CdTe/CdS Solar Cell Performance?" S. Hegedus, D. Ryan, K. Dobson, B. McCandless, D. Desai, *Proc. MRS Symp.* **763**, 447 (2003).
70. "Status, Trends, Challenges, and the Bright Future of Solar Electricity from Photovoltaics," S. Hegedus, A. Luque, *Handbook of Photovoltaic Science and Engineering, Chapter 1* (A. Luque and S.S. Hegedus, eds.), Wiley and Sons, Chichester, UK, 1 (2003).
71. "Correlation of Surface Phases with Electrical Behavior in Thin-Film CdTe Devices," B.E. McCandless, S.S. Hegedus, R.W. Birkmire and D. Cunningham, *Thin Solid Films* **431-432**, 249 (2003).
72. "Improved Fill Factors in Amorphous Silicon Solar Cells on Zinc Oxide by Insertion of a Germanium Layer to Block Impurity Incorporation," G. Ganguly, D.E. Carlson, S.S. Hegedus, D. Ryan, R.G. Gordon, D. Pang, R.C. Reedy, *Appl. Phys. Lett.* **85**(3), 479 (2004).
73. "Accurate Determination of Optical Constants of Textured SnO₂ Using Low Incidence Angle Spectroscopic Ellipsometry," P.D. Paulson and Steven S. Hegedus, *Journal of Applied Physics* **96**(10), 5469 (2004).
74. "Transient Degradation and Recovery of CdS/CdTe Solar Cells," Steven Hegedus, Darshini Desai, Dan Ryan and Brian McCandless, *Proc. 31st IEEE PVSC*, 319 (2005).

75. "Real BOS and System Costs of Off-grid PV Installations in the US: 1987-2004," Steven Hegedus and Nozumi Okubo, *Proc. 31st IEEE PVSC*, 1651 (2005).
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