

XUNMING DENG

Curriculum Vitae

4/2002

Professor of Physics
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Education

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| Ph.D. | 1990 | University of Chicago | Physics |
| M.S. | 1987 | University of Chicago | Physics |
| B.S. | 1985 | University of Science and Technology of China | Physics |

Professional Experience

1996--present University of Toledo, Toledo, Ohio
Department of Physics and Astronomy
Full Professor, 2002—
Associate Professor, 1999—2002
Assistant Professor, 1996—1999

- Established an internationally recognized strong program in amorphous silicon (a-Si) photovoltaic (PV) materials research and device fabrication. My research group is currently the *only* academic group, in the world, which fabricates high-efficiency (NREL confirmed 12.5% initial, active-area efficiency) a-Si solar cell devices with advanced triple-junction structure.
- Written numerous proposals. Received 15 grant awards, as PI, with a total funding of \$3,105,620.
- Taught a variety of courses. Received one of the best teaching evaluations.
- Directed research of 5 undergraduates, 4 M.S. students, 2 Ph.D students, and 3 postdocs.
- Serving as Chairman of UT University Patent and Commercialization Committee, which is responsible for the intellectual properties of the University.
- Serving as the Team Leader for NREL National Amorphous Silicon Multijunction Device Research Team.

1990—1996 Energy Conversion Devices, Inc. (ECD), Troy, Michigan
Project Manager, Photovoltaic Development, 1995—1996
Senior Research Scientist, 1992—1995
Research Scientist, 1990—1992

- Created and managed ECD's *Photovoltaic Development Group* to conduct research on advanced a-Si based materials/devices with the objective of further improving the efficiency of triple-junction a-Si alloy solar cells. Developed new solar cell device designs and process techniques. Achieved world record for open circuit voltage for single-junction a-Si solar cells.
- Initiated and conducted extensive research programs to: 1) develop new amorphous and microcrystalline thin-film semiconductor materials using a variety of deposition techniques including RF and microwave PECVD deposition, RF and DC sputtering, LPCVD, and UV excimer laser ablation deposition techniques; and 2) develop and optimize non-semiconductor materials required for solar cell device research.
- Written numerous research proposals. Received 4 grant awards, as sole-PI, with a total funding of \$3,204,907.

1985--1990 University of Chicago, Graduate Research Assistant

- Did Ph.D. thesis under the advisory of Professor Hellmut Fritzsche in research on amorphous silicon based materials.

Honors and Awards

- Ranked **FIRST** in “Nation-wide University Entrance Examination of China, 1980” in Jiangxi province over more than 100,000 competitors in 1980.
- Received 2nd Prize in *Electronics Competition* in 1983 at The University of Science and Technology of China.
- Won CUSPEA (China-U.S. Physics Examination and Application) Candidacy, which led to the admission to the University of Chicago, 1985
- Ranked in **Group One**, i.e., the top-performing group, in the Ph.D. Qualifying Exam of the Physics Department at the University of Chicago, 1986
- Listed in Marquis *Who's Who in America* and *Who's Who in America, Science and Engineering*.
- Awarded Dean's Merit, College of Arts and Sciences, UT, 2001. Only 15 awards were given in 2001 in the Arts & Science College that has 19 academic departments.
- Received 2002 Outstanding Faculty Research Award, UT. Only four professors received such awards at UT in 2002.

List of Publications

(See <http://www.physics.utoledo.edu/~dengx/papers/papers.htm> for PDF files.)

- X. Deng and H. Fritzsche, “Light-induced Perturbation of the High-temperature Equilibrium in Phosphorus-doped a-Si:H”, *Physical Review B* **36**, 9378 (1987).
- X. Deng, H. Fritzsche, and R. Johanson, “Study of Artificial Interfaces in Undoped and Phosphorus Doped a-Si:H”, *J. of Non-Cryst. Solids* **114**, 684 (1989).
- X. Deng, “Strain-relief Spiral Buckling of a-Si:H films”, *Phil. Mag. Lett.*, **61**, 281 (1990).
- X. Deng, “Irreversible Changes in Doping Efficiency and Hydrogen Bonding in the Equilibrium State of a-Si:H”, *Phys. Rev. B* **43**, 4820 (1991).
- X. Deng, A. Hamed, H. Fritzsche and M.Q. Tran, “Metastable Defects in a-SiO_x:H and a-SiC_x:H”, in *Amorphous Silicon Technology--1991*, edited by A. Madan, Y. Hamakawa, M.J. Thompson, P.C. Taylor and P.G. LeComber (Materials Research Society, Pittsburgh, 1991), Vol. **219**, p.147.
- A. Hamed, H. Fritzsche, X. Deng, S. Kohler and R. Gupta, “Metastable Defect States and Equilibrium Temperatures in a-SiN_x:H, a-SiO_x:H and a-SiC_x:H”, *J. Non-Cryst. Solids*, **137&138**, 287 (1991).
- X. Deng, E. Mytilineou, R.T. Young and S. R. Ovshinsky, “Toward the Elimination of Light-induced Degradation of Amorphous Si by Fluorine Incorporation”, in *Amorphous Silicon Technology--1992*, edited by M.J. Thompson, Y. Hamakawa, P.G. LeComber, A. Madan and E. Schiff, (Materials Research Society, Pittsburgh, 1992), Vol. **258**, p.491.
- M. Izu, X. Deng, A. Krisko, K. Whelan, R. Young, H.C. Ovshinsky, K.L. Narasimhan and S.R. Ovshinsky, “Manufacturing of Triple-junction 4 ft² a-Si alloy PV Modules”, *Proceedings of 23rd IEEE Photovoltaic Specialist Conference*, 919 (1993).
- X. Deng, M. Izu, K.L. Narasimhan, and S.R. Ovshinsky, “Stability Test of 4 ft² Triple-junction a-Si Alloy PV Production Modules”, in *Amorphous Silicon Technology--1994*, edited by E. Schiff, M. Hack, A. Madan, M. Powell, and A. Matsuda, (Materials Research Society, Pittsburgh, 1994), Vol. **336**, p.699.
- S. Guha, J. Yang, A. Banerjee, T. Glatfelter, K. Hoffman, S.R. Ovshinsky, M. Izu, H.C. Ovshinsky and X. Deng, “Amorphous Silicon Alloy Photovoltaic Technology--from R&D to Production”, in *Amorphous Silicon Technology--1994*, edited by E. Schiff, M. Hack, A. Madan, M. Powell, and A. Matsuda, (Materials Research Society, Pittsburgh, 1994), Vol. **336**, p.645.
- X. Deng, K.L. Narasimhan, J. Evans, M. Izu and S.R. Ovshinsky, “Dependence of a-Si Solar Cell V_{oc} on Deposition Temperature”, in *IEEE First World Conference on Photovoltaic Energy Conversion*, p678 (1994).
- X. Deng and K.L. Narasimhan, “New Evaluation Technique for Thin-film Solar Cell Back-reflector Using Photothermal Deflection Spectroscopy”, in *IEEE First World Conference on Photovoltaic Energy Conversion*, p555 (1994).

- M. Izu, H.C. Ovshinsky, X. Deng, A.J. Krisko, K.L. Narasimhan, R. Crucet, T. Laarman, A. Myatt, and S.R. Ovshinsky, "Continuous Roll-to-roll Serpentine Deposition for High Throughput a-Si PV Manufacturing", in *IEEE First World Conference on Photovoltaic Energy Conversion*, p820 (1994).
- X. Deng, S.J. Jones, K.L. Narasimhan, J. Evans, and M. Izu, "c-Si(n⁺)/a-Si Alloy/Pd Schottky Barrier Device for the Effective Evaluation of a-Si Alloy Materials", in *Amorphous Silicon Technology--1995*, MRS Proc. Vol. **377**, p.803.
- S. Hegedus and X. Deng, "Analysis of Back Reflectors and Optical Enhancement for a-Si Solar Cells Using a Textured TCO/Glass/Ag Substrate", in *Conference Record of the Twenty Fifth IEEE Photovoltaic Specialists Conference--1996*, p.1061 (1996).
- M. Izu, X. Deng, H.C. Ovshinsky, R. Crucet, S.R. Ovshinsky and A. Polisan, "Production Start-up of 2 MW a-Si PV Manufacturing Line at Sovlux Plant", in *Conference Record of the Twenty Fifth IEEE Photovoltaic Specialists Conference--1996*, p.1327 (1996).
- L. Jiang, Q. Wang, E.A. Schiff, S. Guha, Y. Yang, and X. Deng, "Electroabsorption measurements and built-in potentials in amorphous silicon pin solar cells", *Appl. Phys. Lett.*, **69**, 3063 (1996).
- X. Deng, S.J. Jones, T. Liu, M. Izu, S.R. Ovshinsky and K. Hoffman, "VHF plasma deposition of high performance microcrystalline silicon p-layer materials", in *Amorphous and Microcrystalline Silicon Technology--1997*, edited by E.A. Schiff, M. Hack, S. Wagner, R. Schropp, and I. Shimizu (Materials Research Society, Pittsburgh, 1997), Vol. **467**, p.795.
- D. Han, K. Wang, C. Yeh, L. Yang, X. Deng and B. von Roedern, "Luminescence in amorphous silicon p-i-n diodes under double-injection dispersive-transport-controlled recombination", *Phys. Rev. B* **55**, 15619 (1997).
- X. Deng, S.J. Jones, T. Liu, M. Izu and S.R. Ovshinsky, "Improved μ c-Si p-layer and a-Si i-layer materials using VHF plasma deposition", in *Conference Record of the Twenty Sixth IEEE Photovoltaic Specialists Conference--1997*, p.591 (1997).
- S. Guha, J. Yang, A. Banerjee, K. Hoffman, S. Sugiyama, J. Call, S.J. Jones, X. Deng, J. Doehler, M. Izu and H.C. Ovshinsky, "Triple-junction amorphous silicon alloy PV manufacturing plant of 5MW annual capacity", in *Conference Record of the Twenty Sixth IEEE Photovoltaic Specialists Conference--1997*, p.607 (1997).
- S.J. Jones, X. Deng, T. Liu and M. Izu, "Preparation of a-Si:H and a-SiGe:H i-layers for nip solar cells at high deposition rates using a very high-frequency technique", in *Amorphous and Microcrystalline Silicon Technology--1998*, edited by H. Branz, M. Hack, R. Schropp, I. Shimizu and S. Wagner (Materials Research Society, Pittsburgh, 1998), Vol **507**, p113.
- X. Geng, L. Wu, K. Price, X. Deng, and D. Han, "Internal electric field profile of a-Si:H and a-SiGe p-i-n solar cells", in *Amorphous and Microcrystalline Silicon Technology--1998*, edited by H. Branz, M. Hack, R. Schropp, I. Shimizu and S. Wagner (Materials Research Society, Pittsburgh, 1998), Vol. **507**, p187.
- X. Deng, G. Miller, R. Wang, L. Xu and A.D. Compaan, "Study of sputter deposition of ITO films for a-Si:H n-i-p solar cells", in *Proc. of Second World Conference and Exhibition on Photovoltaic Solar Energy Conversion and 27th IEEE Photovoltaic Specialist Conference*, 700 (1998).
- X.B. Liao, J. Walker, and X. Deng, "Effect of buffer layers in narrow bandgap a-SiGe solar cells", in *Amorphous and Heterogeneous Silicon Thin Films—Fundamentals to Devices*, ed. By H. Branz, R.W. Collins, H. Okamoto, S. Guha, and R. Schropp, MRS Symp. Proc. **557**, 779 (1999).
- S.J. Jones, X. Deng, T. Liu and M. Izu, "Preparation of triple-junction a-Si:H nip based solar cells at deposition rates near 10 A/s using a very high frequency technique", in *Amorphous and Heterogeneous Silicon Thin Films—Fundamentals to Devices*, ed. By H. Branz, R.W. Collins, H. Okamoto, S. Guha, and R. Schropp, MRS Symp. Proc. **557**, 133 (1999).
- S.J. Jones, R. Crucet, X. Deng, J. Doehler, R. Kopf, A. Myatt and M. Izu, "Use of a gas jet technique to prepare microcrystalline silicon based solar cells at high i-layer deposition rates", in *Amorphous and Heterogeneous Silicon Thin Films—Fundamentals to Devices*, ed. By H. Branz, R.W. Collins, H. Okamoto, S. Guha, and R. Schropp, MRS Symp. Proc. **557**, 567 (1999).
- X. Deng and X.B. Liao, S. Han, H. Povolny and P. Agarwal, "Amorphous silicon and silicon germanium materials for high efficiency triple-junction solar cells", *Solar Energy Materials & Solar Cells*, **62**, 89 (2000).

- G. Yue, X. Deng, G. Ganguly and D. Han, "Electro- and Photo-Luminescence Spectra From a-Si and a-SiGe p-i-n Solar Cells", *J. of Non-Crystalline Solids*, **266-269**, 1119 (2000).
- H. Povolny, P. Agarwal, S. Han and X. Deng, "Comparison study of a-SiGe solar cells and materials deposited using different hydrogen dilution", in *Amorphous and Heterogenous Silicon Thin Films—2000*, ed. by H. Branz, R. Collins, S. Guha, H. Okamoto and M. Stutzmann, 2000.
- S.J. Jones, R. Crucet, X. Deng, and M. Izu, "Preparation of microcrystalline silicon based solar cells at high i-layer deposition rates using a gas jet technique", in *Amorphous and Heterogenous Silicon Thin Films—2000*, ed. by H. Branz, R. Collins, S. Guha, H. Okamoto and M. Stutzmann, 2000.
- S.J. Jones, T. Liu, X. Deng, D. Tsu and M. Izu, "Comparison of structural properties and solar cell performance of a-Si:H films prepared at various deposition rates using 13.56 and 70 MHz PECVD methods", in *Amorphous and Heterogenous Silicon Thin Films—2000*, MRS Proc, 2000.
- X. Deng, H. Povolny, S. Han and P. Agarwal, "Ultra-lightweight amorphous silicon solar cells deposited on 7.5 μ m thick stainless steel substrates", in *Proceedings of 28th IEEE Photovoltaic Specialist Conf.* (2000)
- S.J. Jones, T. Liu, X. Deng and M. Izu, "a-Si:H-based triple-junction cells prepared at i-layer deposition rates of 10 A/s using a 70 MHz PECVD technique", in *Proceedings of 28th IEEE PVSC* (2000)
- P. Agarwal, H. Povolny, S. Han and X. Deng, "Study of a-SiGe:H films and n-i-p devices used in high-efficiency triple-junction solar cells", *J. of Non-Cryst. Solids*, 2001.
- E.L. Miller, R.E. Rocheleau and X. Deng, "Design considerations for a hybrid amorphous silicon / photoelectrochemical multijunction cell for hydrogen production, in *Proc. of International Symposium on Solar Hydrogen Fuel Cells- 2001*, August 26-30, 2001, Cancun, Mexico.
- X. Deng, W. Wang, X. Liao, S. Han, H Povolny, X. Xiang, and W. Du, *Proc. of NREL NCPV Program Review Meeting*, 2001.
- W. Wang, H. Povolny, W. Du, X.B. Liao and X. Deng, "Improved Triple-Junction a-Si Solar Cells with Heavily Doped Thin Interface Layers at the Tunnel Junctions", to be published in *Proc. of IEEE 29th Photovoltaic Specialist Conference*, 2002.
- X. Liao, H. Povolny, P. Agarwal and X. Deng, "Raman and IR Study of Narrow Bandgap a-SiGe and μ c-SiGe Films Deposited Using Different Hydrogen Dilution", to be published in *Proc. of IEEE 29th Photovoltaic Specialist Conference*, 2002.
- X.B. Liao, W. Wang and X. Deng, "AMPS Modeling of Nanocrystalline Si p-Layer in a-Si NIP Solar Cells", to be published in *Proc. of IEEE 29th Photovoltaic Specialist Conference*, 2002.
- X. Deng and E. Schiff, "Amorphous Silicon Related Solar Cells", a chapter in *Handbook of Photovoltaic Engineering*, ed. A. Luque & S. Hegedus, to be published by John Wiley & Sons, Ltd. , 2002 (being reviewed by the Editors).

List of Other Publications

- M. Izu, X. Deng, A. Krisko, H.C. Ovshinsky, D. Tsu, K. Whelan, and R. Young, "Continuous Roll-to-roll a-Si Photovoltaic manufacturing Technology", in *Annual Report, Photovoltaic Subcontract Program, FY 1992*, (March 1993). NREL/TP-410-5335, p246. Available NTIS: Order No. DE93000092.
- M. Izu, S.R. Ovshinsky, X. Deng, A.J. Krisko, H.C. Ovshinsky, K.L. Narasimhan, and R. Young, "Continuous Roll-to-roll Amorphous Silicon Photovoltaic Manufacturing Technology", in *AIP Conference Proc.* **306**, edited by R. Noufi and H. Ullal (American Institute of Physics, New York, 1994), p.198.
- M. Izu, S.R. Ovshinsky, X. Deng, A.J. Krisko, H.C. Ovshinsky, K.L. Narasimhan, and R. Young "Continuous Roll-to-roll a-Si Photovoltaic Manufacturing Technology", in *Annual Report, NREL Photovoltaic Program, FY 1993*, (August 1994). NREL/TP-410-6285, p243. Available NTIS: Order No. DE94011880.
- M. Izu, X. Deng, H.C. Ovshinsky and S.R. Ovshinsky, "Roll-to-Roll RF PECVD Machine for a-Si Solar Cell Manufacturing", *Proc. of Annual Conference of Society of Vacuum Coaters*, April 2-7, 1995, Chicago, IL.
- X. Deng, M. Izu, S.J. Jones, K.L. Narasimhan, J. Evans, and S.R. Ovshinsky, "Development of High, Stable-efficiency Triple-junction a-Si Alloy Solar Cells", in *NREL Photovoltaic Program FY 1994 Annual Report*, (June 1995). NREL/TP-410-7993, p155. Available NTIS: Order No. DE95009244.

- M. Izu, S.R. Ovshinsky, X. Deng, A. Krisko, H.C. Ovshinsky, K.L. Narasimhan, S.J. Jones, “Continuous Roll-to-roll a-Si Photovoltaic Manufacturing Technology”, in *NREL Photovoltaic Program FY 1994 Annual Report*, (June 1995). NREL/TP-410-7993, p269. Available NTIS: Order No. DE95009244.
- M. Izu, S.R. Ovshinsky, X. Deng, H.C. Ovshinsky, S.J. Jones and J. Doehler, “Continuous Roll-to-Roll a-Si PV Module Manufacturing”, in *AIP Conference Proc. 353*, edited by H. S. Ullal, and C. E. Witt (American Institute of Physics, Woodbury, New York, 1996), p.290.
- X. Deng, S.J. Jones, T. Liu, M. Izu and S.R. Ovshinsky, “Development of High, Stable-efficiency Triple-junction a-Si Alloy Solar Cells”, in *NREL Photovoltaic Program FY 1995 Annual Report*, (June 1996). NREL/TP-410-21101, p167. Available NTIS: Order No. DE96007869.
- M. Izu, S.R. Ovshinsky, X. Deng, H.C. Ovshinsky, and S.J. Jones, “Continuous Roll-to-roll a-Si Photovoltaic Manufacturing Technology”, in *NREL Photovoltaic Program FY 1995 Annual Report*, (June 1996). NREL/TP-410-21101, p281. Available NTIS: Order No. DE96007869.
- X. Deng, “Development of High, Stable-efficiency Triple-junction a-Si Alloy Solar Cells”, *Phase I Annual Subcontract Report*, July 18, 1994-July 17, 1995, prepared under Subcontract No. ZAN-4-13318-11. (February 1996). NREL/TP-411-20687. Available NTIS: Order No. DE9696000530.
- X. Deng, M. Izu, S.J. Jones, T. Liu and S.R. Ovshinsky, “Development of High, Stable-efficiency Triple-junction a-Si Alloy Solar Cells”, in *NREL Photovoltaic Program FY 1996 Annual Report*, (August 1997). NREL/BK-210-21966, p199. Available NTIS: Distribution Code UC-1250.
- X. Deng, M. Izu, S.J. Jones, T. Liu, S.R. Ovshinsky, and B. Vier, “Development of High, Stable-efficiency Triple-junction a-Si Alloy Solar Cells”, *Phase II Annual Subcontract Progress Report*, prepared under Subcontract No. ZAN-4-13318-11, (October 1996)
- X. Deng, "Study of triple-junction amorphous silicon alloy solar cells", in *American Institute of Physics Conf. Proc. 462*, 297 (1998).
- X. Deng, S.J. Jones, T. Liu, M. Izu and S.R. Ovshinsky, “Development of High, Stable-efficiency Triple-junction a-Si Alloy Solar Cells”, in *NREL Photovoltaic Program FY 1997 Annual Report*, (June 1998). NREL/BK-210-23607, p235. Available NTIS.
- X. Deng, S.J. Jones, T. Liu and M. Izu, “Development of High, Stable-efficiency Triple-junction a-Si Alloy Solar Cells”, *Final Technical Report*, prepared under Subcontract No. ZAN-4-13318-11. (April 1998). NREL/SR-520-24580. Distribution Code: UC-1262.
- T. Smith, B. Friedmann, A. N. Witt, R. Wang, X. Deng and D. Furton, "Photoluminescence of carbonaceous grain mantle materials with silicon impurities", Proceedings of Laboratory Space Science Workshop, Harvard-Smithsonian Center for Astrophysics, April 1-3, 1998, p245.
- A.D. Compaan, X. Deng and R.G. Bohn, “High efficiency thin film CdTe and a-Si based solar cells”, Phase I Annual Technical Report, Dec. 1999. NREL/SR-520-27666.
- S. Huang, Y.L. Soo, Y.H. Kao, W.A. Anderson, and X. Deng, "Interfacial roughness in thin film silicon photovoltaic materials", American Physical Society March Meeting, Atlanta, Georgia, March, 1999.
- X. Deng, P. Agarwal, H. Povolny and S. Han, “Amorphous silicon germanium solar cells and thin films deposited using different hydrogen dilution”, in Procc of NCPV Program Review Meeting—2000, A13 (2000).
- A.D. Compaan, X. Deng and R.G. Bohn, “High efficiency thin film CdTe and a-Si based solar cells”, Phase II Annual Technical Report, 2001.

List of Issued Patents

- S.R. Ovshinsky, R. Young, W. Czubytyj and X. Deng, “Semiconductor with Ordered Clusters”, US Patent **5,103,284**. Filed: Feb. 8, 1991, Issued: Apr. 7, 1992.
- S.R. Ovshinsky, X. Deng and R. Young, “High Quality Photovoltaic Semiconductor Material and Laser Ablation Method of Fabricating Same”, US Patent **5,231,047**. Filed: Dec. 19, 1991. Issued July 27, 1993.
- S.R. Ovshinsky, S. Guha, C.C. Yang, X. Deng, S. Jones, "Semiconductor Having Large Volume Fraction of Intermediate Range Order Material", US Patent **8,766,219**, filed Dec. 12, 1996.