

Workshop on Efficient Conversion of Solar Energy to Electricity and Fuels: Critical Research Directions and Tutorial



Casey A. Cass/University of Colorado

August 13-15, 2008 • University of Colorado at Boulder

August 13th, 2008

5:00-8:00pm *Conference Registration*—Duane Physics Lawn/Quad (South of Duane Physics)

6:00-7:30pm *Reception*—Duane Physics Lawn/Quad (South of Duane Physics-White Tent)

Keynote Address

7:30-7:45pm *Welcoming Remarks*—Duane Physics Auditorium G1B30

7:45-9:00pm *'Global Energy Perspectives: Chemical Challenges and Sustainable Energy Conversion'* by **Nathan Lewis**, California Institute of Technology

Suggested Reading: Nathan S. Lewis "Powering the Planet" *MRS BULLETIN* • VOLUME 32 • OCTOBER 2007 • www.mrs.org/bulletin

August 14th, 2008

7:00am-noon *Conference Registration*—Duane Physics Lobby G1B30

Session One: Conversion of Solar Photons to Electricity—Duane Physics Auditorium G1B30

8:00-8:30am **Overview of FY09 Budget Marks for BES/DOE from House and Senate**

8:30-9:15am **Overview and Current Status of Photovoltaics**

'Production and Cost Trends in Photovoltaics'

John Benner, NREL

Suggested Reading: Gregory F. Nemet, Beyond the learning curve: factors influencing cost reductions in photovoltaics, *Energy Policy* 34 (2006) 3218–3232.

Suggested Reading: Conley, P. "Experience Curve as a Planning Tool" *IEEE Spectrum* 7 (6) pp 63-68, 1970.

9:15-10:00am **Sensitized Solar Cells**

'Science, technology, and the future of sensitized solar cells'

Arthur Frank, NREL

Suggested Reading: Michael Grätzel, Conversion of sunlight to electric power by nanocrystalline dye-sensitized solar cells, *Journal of Photochemistry and Photobiology A: Chemistry* 164 (2004) 3–14

Suggested Reading: Arthur J. Frank, Nikos Kopidakis, Jao van de Lagemaat, Electrons in nanostructured TiO₂ solar cells: transport, recombination and photovoltaic properties, *Coordination Chemistry Reviews* 248 (2004) 1165–1179

10:00-10:30am **Coffee Break**–Duane Physics Lobby G1B30

10:30-11:15am **Small Molecule Photovoltaics**

'Excitonic Semiconductors and Solar Cells'

Brian Gregg, NREL

Suggested Reading: Sophie E. Gledhill, Brian Scott, and Brian A. Gregg, Organic and nano-structured composite photovoltaics: An overview, *Journal of Materials Research* Vol. 20, No. 12, Dec **2005**

Suggested Reading: Brian A. Gregg, Si-Guang Chen, and Russell A. Cormier, Coulomb Forces and Doping in Organic Semiconductors *Chem. Mater.* **2004**, *16*, 4586-4599.

Suggested Reading: Brian A. Gregg, Excitonic Solar Cells, *J. Phys. Chem. B* **2003**, *107*, 4688-4698

11:15am-noon **Polymer Photovoltaics**

'Advancing Polymer-based Excitonic Solar Cells: The Role of Chemistry'

Garry Rumbles, NREL

Suggested Reading: Sariciftci, N. S.; Smilowitz, L.; Heeger, A. J.; Wudl, F., Photoinduced Electron Transfer from a Conducting Polymer to Buckminsterfullerene. *Science* **1992**, *258*, (5087), 1474-1476.

Suggested Reading: *MRS Bulletin* January **2005**. This is an excellent edition all round. Polymer–Fullerene Bulk Heterojunction Solar Cells, René A.J. Janssen, Jan C. Hummelen, and N. Serdar Sariciftci

Suggested Reading: Ohkita, H.; Cook, S.; Astuti, Y.; Duffy, W.; Tierney, S.; Zhang, W.; Heeney, M.; McCulloch, I.; Nelson, J.; Bradley, D. D. C.; Durrant, J. R., Charge Carrier Formation in Polythiophene/Fullerene Blend Films Studied by Transient Absorption Spectroscopy. *J. Am. Chem. Soc.* **2008**, *130*, (10), 3030-3042.

Suggested Reading: Dennler, G.; Scharber, M. C.; Ameri, T.; Denk, P.; Forberich, K.; Waldauf, C.; Brabec, C. J., Design Rules for Donors in Bulk-Heterojunction Tandem Solar Cells Towards 15 % Energy-Conversion Efficiency. *Advanced Materials* **2008**, *20*, (3), 579-583.

Speakers and Students Informal Discussion (Gamow Tower, top floor): Brown Bag Lunch

Session Two: Conversion of Solar Photons to Electricity and Fuels–Duane Physics Auditorium

1:30-2:15pm **The Hydrogen Economy**

'Frontiers, Opportunities and Challenges for a Hydrogen Economy'

John Turner, NREL

Suggested Reading: Michael Grätzel, Photoelectrochemical cells *NATURE* | VOL 414 | 15 NOVEMBER **2001** | www.nature.com

Suggested Reading: Nathan S. Lewis Frontiers of research in photoelectrochemical solar energy conversion, *Journal of Electroanalytical Chemistry* 508 (**2001**) 1–10

Suggested Reading: Krishnan Rajeshwar, Hydrogen generation at irradiated oxide semiconductor–solution interfaces, *J. Appl. Electrochem.* (**2007**) 37:765–787

2:15-3:00pm **Catalysis in Solar Fuel Production**

'Role of water oxidation in energy conversion'

Tom Meyer, University of North Carolina, Chapel Hill

Suggested Reading: Liu, F.; Concepcion, J. J.; Jurss, J. W.; Cardolaccia, T.; Templeton, J. L.; Meyer, T. J., Mechanisms of Water Oxidation from the Blue Dimer to Photosystem II. *Inorg. Chem.* **2008**, *47*, (6), 1727-1752.

Suggested Reading: Alstrum-Acevedo, J. H.; Brennaman, M. K.; Meyer, T. J., Chemical approaches to artificial photosynthesis. 2. *Inorg. Chem.* **2005**, *44*, (20), 6802-6827.

3:00-3:30pm **Coffee Break**–Duane Physics Lobby G1B30

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3:30-4:15pm **Overview and Current Status of Photoelectrochemistry**
'The Past, Present and Future of Photoelectrochemical Energy Conversion'
Bruce Parkinson, Colorado State University; University of Wyoming

Suggested Reading: Bak, T.; Nowotny, J.; Rekas, M.; Sorrell, C. C., Photo-electrochemical hydrogen generation from water using solar energy. Materials-related aspects. *International Journal Of Hydrogen Energy* **2002**, 27, (10), 991-1022.

4:15-5:00pm **Catalysis in Solar Fuel Production**
'Photochemical CO₂ Reduction: Current Status and Future Prospectus'
Etsuko Fujita, Brookhaven National Labs

Suggested Reading: Fujita, E., Muckerman, J.T. Catalytic Reactions Using Transition-Metal-Complexes Toward Solar Fuel Generation, *Bull. Jpn. Soc. Coord. Chem.* Vol.51 (2008)

Suggested Reading: Fujita, E., Photochemical carbon dioxide reduction with metal complexes. *Coordination Chemistry Reviews* **1999**, 186, 373-384.

7:00-9:00pm **Poster Session**—The Millennium Hotel (Grand Ballroom)

August 15th, 2008

Session Three: 3rd Generation Photoconversion and Time-Resolved Spectroscopy—Duane
Physics Auditorium G1B30

8:00-8:45am **Overview of BES Programs on Solar Photoconversion**
Mark Spitler, US Department of Energy

8:45-9:30am **Strategies for 3rd Generation Photoconverters**
'Quantum Dot Solar Cells: Applications to Third Generation Solar Photon Conversion'
Arthur Nozik, NREL

Suggested Reading: Nozik, A. J., Multiple exciton generation in semiconductor quantum dots. *Chemical Physics Letters* **2008**, 457, (1-3), 3-11.

9:30-10:15am **Amorphous, Nanocrystalline, and Quantum-Confined Thin Films**
'Thin Films for 3rd Generation Photovoltaic Applications'
Craig Taylor, Colorado School of Mines

Suggested Reading: *MRS Bulletin*, Vol. 33, No. 4, April **2008**, especially the article by D. Ginley, M. A. Green, and R. Collins "Solar Energy Conversion Toward 1 Terawatt"

Suggested Reading: G. R. Fleming and M. A. Ratner, *Physics Today*, July **2008**, pp. 28-33 "Grand Challenges in Basic Energy Science"

Suggested Reading: P. C. Taylor, *J. Non-Cryst. Solids*, Vol. 33, pp 839-850 (**2006**) "The Localization of Electrons in Amorphous Semiconductors: A Twenty-First Century Perspective"

10:15-10:45am **Coffee Break**—Duane Physics Lobby G1B30

10:45-11:30am **Spectroscopies for Characterizing Photoconversion Nanostructures and Assemblies**
'Femtosecond Dynamics and Multidimensional Spectroscopy'
David Jonas, University of Colorado at Boulder

Suggested Reading: Jonas, D. M., Two-dimensional femtosecond spectroscopy. *Annu. Rev. Phys. Chem.* **2003**, 54, 425-463.

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11:30am-12:15pm **Spectroscopies for Characterizing Photoconversion Nanostructures and Assemblies**

'Light-Harvesting and Energy Transfer in Conjugated Systems'

Valeria Kleiman, University of Florida

Suggested Reading: Peng, Z. H.; Melinger, J. S.; Kleiman, V., Light harvesting unsymmetrical conjugated dendrimers as photosynthetic mimics. *Photosynthesis Research* **2006**, 87, (1), 115-131.

Suggested Reading: Wells, N. P.; Boudouris, B. W.; Hillmyer, M. A.; Blank, D. A., Intramolecular exciton relaxation and migration dynamics in poly(3-hexylthiophene). *Journal Of Physical Chemistry C* **2007**, 111, (42), 15404-15414.

Suggested Reading: Lanzani, G.; Cerullo, G.; Polli, D.; Gambetta, A.; Zavelani-Rossi, M.; Gadermaier, C., Photophysics of conjugated polymers: the contribution of ultrafast spectroscopy. *Physica Status Solidi A-Applied Research* **2004**, 201, (6), 1116-1131.

Speakers and Students Informal Discussion (Gamow Tower, top floor): Brown Bag Lunch

Session Four: Novel Materials and Nanostructures—Duane Physics Auditorium G1B30

1:45-2:30pm **Organic/Inorganic Approaches to Photoconversion**

'Polymer Hybrid and All Inorganic Nanoparticle Photovoltaics'

Sue Carter, University of California, Santa Cruz

Suggested Reading: Gur, I.; Fromer, N. A.; Geier, M. L.; Alivisatos, A. P., Air-Stable All-Inorganic Nanocrystal Solar Cells Processed from Solution. *Science* **2005**, 310, (5747), 462-465.

Suggested Reading: *MRS Bulletin* January **2005**. Provides a good overview of organic solar cell technology.

Suggested Reading: *MRS Bulletin* March **2007**. Provides a good overview of inorganic and quantum dot solar cells.

2:30-3:15pm **Materials Science Related to Photoconversion**

'Molecular Approaches to Solar Energy Conversion at Sensitized Semiconductor Interfaces'

Gerald Meyer, Johns Hopkins University

Suggested Reading: Meyer, G. J., Molecular Approaches to Solar Energy Conversion with Coordination Compounds Anchored to Semiconductor Surfaces. *Inorg. Chem.* **2005**, 44, (20), 6852-6864.

3:15-3:45pm **Coffee Break** – Duane Physics Lobby G1B30

3:45-4:30pm **Conducting Oxides and Thin Film Technologies**

'Next Generation Transparent Conductive Oxides for Solar Cell Applications'

David Ginley and John Perkins, NREL

Suggested Reading: Elvira Fortunato, David Ginley, Hideo Hosono, and David C. Paine, Transparent Conducting Oxides for Photovoltaics, *MRS BULLETIN* • VOLUME 32 • MARCH **2007** • www.mrs.org/bulletin

4:30-5:15pm **High Efficiency Multi-junction Cells**

'The practice and promise of multijunction solar cells'

Jerry Olson, NREL

Suggested Reading: Henry, C. H., Limiting Efficiencies Of Ideal Single And Multiple Energy-Gap Terrestrial Solar-Cells. *Journal of Applied Physics* **1980**, 51, (8), 4494-4500.

Suggested Reading: Kurtz, S. R.; Faine, P.; Olson, J. M., Modeling Of 2-Junction, Series-Connected Tandem Solar-Cells Using Top-Cell Thickness As An Adjustable-Parameter. *Journal Of Applied Physics* **1990**, 68, (4), 1890-1895.

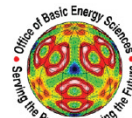
6:00-9:00pm **Conference Banquet** – The Millennium Hotel (Outdoor Pavilion)

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Map of relevant venues for the workshop:



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