

Optics and Photonics for Advanced Energy Technology Abstracts

•Wednesday, June 24, 2009•

Wong Lobby

8:00 a.m.

Registration Open

Wong Lobby

8:30 a.m.–9:00 a.m.

Breakfast

WA • Welcome and Plenary Session I

Wong Auditorium

9:00 a.m.–10:00 a.m.

Rajeev J. Ram; MIT, USA, Presider

WA1 • 9:00 a.m.

Invited

Solar Photovoltaics Technology: The Revolution Begins, Lawrence L. Kazmerski; Natl. Ctr. for Photovoltaics, Natl. Renewable Energy Lab, USA. The prospects of solar-photovoltaic (PV) technologies are envisioned, arguing this electricity source is at a *tipping point* in the complex, worldwide energy outlook. The emphasis of this presentation is on R&D advances, providing insights into how PV has developed and where we can expect to be by mid-21st century.

Wong Lobby

10:00 a.m.–10:30 a.m.

Break

WB • Solid-State Lighting

Wong Auditorium

10:30 a.m.–12:25 p.m.

Marc Baldo; MIT, USA, Presider

WB1 • 10:30 a.m.

Invited

Energy Implications of Solid-State Lighting Technology, E. Fred Schubert, Jong Kyu Kim; Rensselaer Polytechnic Inst., USA. The efficient yet highly controllable generation of light can be accomplished by light-emitting diodes that can have a 20 times greater efficiency than incandescent light sources. Implications on energy, environment, and finances will be discussed.

WB2 • 10:55 a.m.

Invited

Advanced LEDs, Matthew A. Stough; Osram Sylvania, USA. Light Emitting Diodes (LEDs) are the new tungsten filament of the lighting world. Advances in the optical performance, geometric configuration, and availability of type place the LED at the forefront of modern lighting product designs.

WB3 • 11:20 a.m.

Invited

Solid-State Lighting Technology, Anil Duggal; GE Global Res., USA. In this talk the vision of LED and OLED based solid state lighting will be introduced and the technical efforts at GE aimed at enabling a low cost OLED lighting technology will be discussed.

WB4 • 11:45 a.m.

Invited

Flexible Solid-State Lighting, Brian D'Andrade, Alex Kattamis; Exponent Inc., USA. Steel foil tolerance to high temperature processing, dimensional stability, chemical resistance, low moisture and oxygen permeability are characteristics that in combination with top emission organic LEDs are needed for flexible solid state lighting sources.

WB5 • 12:10 p.m.

Ultrathin Metal Transparent Electrodes for Lighting and Photovoltaic Applications, Dhriti Sundar Ghosh¹, Danny Krautz¹, Stephanie Cheylan¹, Valerio Pruneri^{1,2}; ¹ICFO- Inst. of Photonic Sciences, Spain, ²ICREA- Inst. Catalana de Recerca i Estudis Avançats, Spain. Transparent electrodes based on ultrathin metal films are realized, whose transparency is high compared to ITO in UV and IR and similar in visible region. Performance of an OLED is demonstrated as a potential application.

Morss Hall

12:30 p.m.–1:30 p.m.

Lunch

WC • Poster Session I

Morss Hall

1:30 p.m.–2:30 p.m.

WC1

Array of Plasmonic Nanoparticles Enabling Light Coupling and Guiding in Solar Systems: A Theoretical Analysis, Shabnam Ghadarghadr, Hossein Mosallaei; Northeastern Univ., USA. This paper demonstrates a novel approach for enhancing energy coupling into thin-layered solar cells enabled by depositing non-periodic arrays of plasmonic nanoparticles. Theoretical models are developed to characterize the structure and determine novel physical performance.

WC2

Stochastic Resonance Enhanced Imaging for Defect Location in Silicon Solar Cells, Janice A. Hudgings, Kevin D. McCarthy; Alenas Imaging Inc., USA. We describe the use of stochastic resonance enhanced thermoreflectance imaging for characterizing and locating defects including shunts and microcracks in multicrystalline silicon solar cells.

WC3

Increasing Fused Silica Transmission for Solar Applications with Improved Optics Manufacturing Techniques, *Joseph Spilman, Alan Gould, Tobias Nitzsche, Jonathan Watson, Andrew Haefner, Robert Wiederhold, Jessica DeGroot Nelson; Optimax Systems Inc., USA.* Fused silica's broad transmission spectrum makes it desirable for solar concentrator optics. A four-phase project is underway to create an optical manufacturing process that ensures maximized optical transmission for fused silica.

WC4

Absorption Enhancement in Organic Photovoltaic Devices Based on Surface Plasmon-Polariton Effects, *Yifen Liu, Jaeyoun Kim; Iowa State Univ., USA.* We propose to enhance the photovoltaic effect using an Au grating electrode which induces surface plasmon-polaritons (SPPs) propagating along the active layer/bottom electrode interface and hence increases the interaction length without increasing the actual thickness.

WC5

Nanoscale Investigation of Colloidal Quantum Dot/Organic Semiconductor Interfaces, *Matthew J. Panzer, Polina O. Anikeeva, Jonathan E. Halpert, Mounqi G. Bawendi, Vladimir Bulovic; MIT, USA.* We examine several methods for preparing bilayers of colloidal quantum dots (QDs) and hole-transporting organic semiconductor thin films. Controlling the degree of interpenetration between these two materials at the nanoscale may enhance our understanding of QD-based optoelectronic device performance.

WC6

Colloidally-Synthesized Nanocrystal LEDs Using Metal Oxide Thin Films, *Vanessa Wood, Matthew Panzer, Jean-Michel Caruge, Jonathan Halpert, Mounqi Bawendi, Vladimir Bulovic; MIT, USA.* We present methods for integrating colloidally synthesized nanocrystals (NCs) and metal oxide thin films into functional, air-stable devices. We demonstrate metal oxide and NC light emitting devices and use them to study the mechanisms for electrical excitation of NCs.

WC7

Synchrotron-Based Investigation of Metal Impurity Diffusion in Silicon Solar Cell Materials, *David Fenning, Steve Hudelson, Joseph Sullivan, Sarah Bernardis, Mariana Bertoni, Bonna Newman, Tonio Buonassisi; MIT, USA.* This presentation details synchrotron-based diffusion experiments investigating the impact of high-temperature processing on the distribution of transition metal impurities in the bulk crystal and along grain boundaries in silicon solar cell materials.

WC8

Synchrotron-Based X-Ray Absorption Spectroscopy Applied to Novel Silicon Solar Cell Material, *Bonna Newman, Joseph Sullivan, Matthew Marcus, Sirine Fakra, Mark Winkler, Renee Sher, Tonio Buonassisi; MIT, USA.* After doping silicon well above the solubility limit with selenium atoms using femto-second laser pulses, we observe strong absorption of photons below the band gap of silicon. This enhanced absorption allows the possibility of increasing the photocurrent and the efficiency of silicon solar cells. We use synchrotron-based X-ray absorption spectroscopy to probe the chemical state of selenium to understand the material's unique absorption properties.

WC9

Earth-Abundant Materials for High-Efficiency Heterojunction Thin Film Solar Cells, *Yun Seog Lee, Mariana Bertoni, Tonio Buonassisi; MIT, USA.* We investigate materials for thin film solar cells that can meet tens of terawatts level deployment potential. As one of the candidates, cuprous oxide (Cu₂O) is synthesized and characterized optically and electronically.

WC10

Annealing of Dislocations in Multicrystalline Silicon Solar Cell Material, *Mariana Bertoni, Clémence Colin, Tonio Buonassisi; MIT, USA.* We propose and demonstrate a method to remove performance-limiting dislocations from multicrystalline silicon solar cell material. High temperature annealing procedures, inspired in the well known treatment of metals, show dislocation density reductions of >95%.

WC11

Monolithic Integration of Non-Nitride Green Light Emitting Devices on Si Substrates, *M. J. Mori, S. T. Boles, E. A. Fitzgerald; MIT, USA.* We present a novel pathway towards the development of high-efficiency AlInGaP, InGaP and AlInP light emitting devices. Virtual substrates with tunable lattice constants on Si or GaAs serve as a thermodynamically stable platform which has numerous advantages over existing nitride-based technology.

WD • Solar I

Wong Auditorium

2:30 p.m.–5:50 p.m.

Peter Peumans; Stanford Univ., USA, Presider

WD1 • 2:30 p.m.

Invited

Solar Economics, *Ardeth Barnhardt; Univ. of Arizona, USA.*
Abstract not available.

WD2 • 2:55 p.m. Invited

Organic Materials for Solar Photovoltaics, Mark E. Thompson¹, M. Dolores Perez¹, Carsten Borek¹, Peter I. Djurovich¹, Richard R. Lunt², Stephen R. Forrest²; ¹Univ. of Southern California, USA, ²Univ. of Michigan, USA. Metalloporphyrins and subphthalocyanines make excellent donor/acceptor materials in OPVs, some with high open circuit voltages (Voc). The properties of these devices and model for understanding the origin of Voc for OPVs will be presented.

WD3 • 3:20 p.m. Invited

Nanoporous "Black Silicon" by a Nanocatalyzed Etch: Photovoltaic Anti-Reflection and Simple Physics from a Graded-Density Surface Layer, Howard M. Branz, Hao-Chih Yuan, Vernon E. Yost, Paul Stradins, Matthew R. Page; Natl. Renewable Energy Lab, USA. We fabricate nanoporous "black-silicon" surfaces by a low-cost nanocatalyzed liquid etch and find an exponential decay of reflectance versus the wavelength-scaled density grade depth. Using this surface in place of conventional anti-reflection coating, we have fabricated confirmed 16.8%-efficient silicon solar cells.

WD4 • 3:45 p.m. Invited

What Photons Tell Us about Solar Cells: Imaging Diagnostic Techniques, Martin Kasemann¹, Johannes A. Giesecke¹, Wolfram Kwapiel¹, Bernhard Michl¹, Marco Seeland², Harald Hoppe², Wilhelm Warta¹; ¹Fraunhofer Inst. for Solar Energy Systems, Germany, ²Technical Univ. of Illmenau, Germany. We demonstrate that luminescence, heat radiation, dislocation luminescence, and junction-breakdown radiation allows to measure and detect local series resistances, hot-spots, junction breakdown, bulk-, surface-, grain-boundary recombination, degradation and contamination in silicon and/or polymer solar cells.

WD5 • 4:10 p.m. Invited

Light Management in Photovoltaic Modules, Dan Doble; Fraunhofer Ctr. for Sustainable Energy Systems, USA. In the future, it may be that the most significant innovations in anti-reflection will be those that can be manufactured on a massive scale at a significantly reduced cost.

WD6 • 4:35 p.m. Invited

Optical Aspects of Linear Fresnel Reflector Design, David Mills; Austra, Inc., USA. A Linear Fresnel Reflector Solar Collector uses long tracking reflector rows to overlay reflected images of the sun upon a linear downward-facing thermal receiver for the generation of steam.

WD7 • 5:00 p.m. Invited

Focusing on the Optics, Narkis Shatz¹, John Bortz¹, Roland Winston²; ¹Science Applications Intl. Corp., USA, ²Univ. of California at Merced, USA. The flux-transfer efficiency of nonimaging optical systems is limited by étendue conservation. For symmetric optical systems a more stringent limitation is imposed. A concentrating photovoltaic system comprises collection/concentration optics and a solar cell.

WD8 • 5:25 p.m. Invited

Beating the Optical Liouville Theorem, Roland Winston; Univ. of California at Merced, USA. It is well-known that conservation of phase-space volume or optical étendue leads to strict limits to concentration. Less well-known is the connection between entropy and étendue. Entropy has a logarithmic dependence on étendue in addition to the familiar linear dependence on heat. This trade-off permits, in principle, an exponential boost in concentration. Optical systems that make use of this possibility will be discussed.

WE • Reception & Dinner (Speaker)

MIT Faculty Club

6:00 p.m.–9:00 p.m.

Fred Leonberger; MIT, USA, *President*

WE1 • 7:05 p.m. Invited

Wall Street Perspective on the Alternative Energy Sector, Jeff Adams; Goldman Sachs, USA. A high level review of the trends and outlook for solar and LED technologies, and the investor environment, sentiment, and capital availability for energy companies.

•Thursday, June 25, 2009•

Wong Lobby

8:00 a.m.

Registration Open

Wong Lobby

8:30 a.m.–9:00 a.m.

Breakfast

ThA • Plenary Session II

Wong Auditorium

9:00 a.m.–9:45 a.m.

Tonio Buonassisi; MIT, USA, *Presider*

ThA1 • 9:00 a.m. **Invited**

Solar Energy Prospects, John Deutch; MIT, USA. Electro optical technology is the key element for transformation of sunlight to heat, electricity, or fuels. Successful innovation, requires integration into a system designed for a particular application. The criteria for success include cost, and environmental benefit, as well as technical performance. However the absence of clear government policies adds additional uncertainty to design choices and comparison between different approaches. Despite these challenges it is sure that solar will become a dominant source of energy in the future -- when and how much cannot be predicted today.

Wong Lobby

9:45 a.m.–10:15 a.m.

Break

ThB • Energy Development

Wong Auditorium

10:15 a.m.–12:50 p.m.

Alan Kost; Univ. of Arizona, USA, *Presider*

ThB1 • 10:15 a.m. **Invited**

Optical Current Sensors for Electric Power Grid Modernization, Allen H. Rose, Jim Blake; AREVA T&D Inc., USA. Optical current transducers will advance the modernization of the power grid, because of the economic cost, environmental cost, safety, reliability, and metrology performance improvements they make to the measurement of current at high voltages.

ThB2 • 10:40 a.m. **Invited**

Downhole Fluid Analysis: The Key to Unraveling Reservoir Complexities, Oliver Mullins; Schlumberger Technology Corp., USA. Downhole fluid analysis (DFA) utilizing visible and near-infrared molecular spectroscopy is transforming the way the subsurface oil reservoirs are characterized. DFA is the key enabling technology to

characterize the complexities of reservoir fluids and reservoir architecture greatly improving efficiency.

ThB3 • 11:05 a.m.

Trace Gas Analyzers Based on Tunable Diode Laser Absorption Spectroscopy (TDLAS) for Energy Production, Transmission, and Storage, Mickey B. Frish, David M. Sonnenfroh; Physical Sciences Inc., USA. This paper describes energy-related uses of TDLAS. Applications include improving the efficiency and quality of natural gas transmission, monitoring and verifying the fate of CO₂ at geological sequestration sites, and monitoring contaminants in hydrogen fuels.

ThB4 • 11:20 a.m. **Invited**

Optical Gas Sensing in Energy Applications, Alexis Mendez; MCH Engineering, LLC, USA. Optical gas sensing is an effective and practical tool for detection, assessment and localization of fugitive gas emissions, leaks and contaminants, such as hydrocarbons and SF₆ in chemical plants, refineries, power plants, and gas pipelines.

ThB5 • 11:45 a.m. **Invited**

Fiber-Optic Sensor for Advanced Wind Energy Generation: Structural Monitoring and Pitch Control, Kevin Hsu¹, Alan Turner¹, Alexis Mendez²; ¹Micron Optics, Inc., USA, ²MCH Engineering, LLC, USA. Fiber Bragg grating sensing systems are deployed to optimize design, operation and maintenance of wind turbines from manufacturing to in-service operation. The multi-channel sensing network can monitor composite blades with 1μstrain repeatability at 1KHz rate.

ThB6 • 12:10 p.m.

Tomographic Phase Imaging of Fuel Cell Systems, Laura Waller, Jungik Kim, Yang Shao-Horn, George Barbastathis; MIT, USA. We extend our optical phase tomographic system for monitoring water content of fuel cell membranes *in situ*. Using interferometry at two angles, we tomographically reconstruct smooth distributions using a custom modified filtered backprojection algorithm.

ThB7 • 12:35 p.m. **Invited**

New Opportunities for Direct Light-to-Fuel Energy Conversion, Yogesh Surendranath, Matthew W. Kanan and Daniel G. Nocera; MIT, USA. Recent discovery of a cobalt-phosphate water oxidation catalyst has opened new avenues for the development of efficient and robust water-splitting photoelectrodes. Insight into the catalyst's mechanism and properties that make it suitable for this application will be discussed.

Morss Hall

12:50 p.m.–1:45 p.m.

Lunch

ThC • Poster Session II

Morss Hall

1:45 p.m.–2:45 p.m.

ThC1

Photonic Crystal Fibre Sensor for High Temperature Energy Environment, Vittoria Finazzi¹, Joel Villatoro¹, Gianluca Coviello¹, Valerio Pruneri^{1,2}; ¹ICFO- Inst. of Photonic Sciences, Spain, ²ICREA – Inst. Catalana de Recerca i Estudis Avançats, Spain. We present an integrated sensor for high temperature environments based on a photonic crystal fibre. Being all-silica it can measure parameters, such as strain, gas concentration and temperature up to the material softening point (>1000°C).

ThC2

Advanced Fiber Optic Condition Monitoring System for the Entire Wind Turbine Life Cycle, Vahid Sotoudeh, Behzad Moslehi, Richard Black; Intelligent Fiber Optic Systems Corp., USA. IFOS demonstrates here its fiber-optic-based solution for wind turbine blade manufacturing monitoring and pre-installation inspection. The proposed sensing system is a wind turbine condition monitoring system (CMS) for blade, the gearbox, tower and generator monitoring.

ThC3

Guided-Resonance Induced Absorption Enhancement in Silicon Nanowire Arrays for Photovoltaic Application, Chenxi Lin, Michelle L. Povinelli; Ming Hsieh Dept. of Electrical Engineering, Univ. of Southern California, USA. We simulate the optical properties of silicon nanowire arrays using the transfer matrix method. Results reveal that guided resonances in nanowire arrays with proper size can greatly enhance the absorption of solar radiation.

ThC4

Metallic Nanolens and III-V Nano-Optical Metamaterials Lenses for Subwavelength Imaging and Optoelectronics Applications, Bernard Didier F. Casse, Wentao T. Lu, Yongjian Huang, Srinivas Sridhar; Northeastern Univ., USA. We report the experimental realization of a metallic nanolens for far-field subwavelength imaging and 3 innovative III-V nano-optical lenses based on negative-index phenomena for optoelectronics applications. This work was supported by AFRL and NSF.

ThC5

Photonic Crystals for Improving Organic Solar Cell Efficiency, David Duché^{1,2}, Ludovic Escoubas^{1,2}, Jean-Jacques Simon^{1,2}, Philippe Torchio^{1,2}, Judikael Le Rouzo^{1,2}, Wilfried Vervisch^{1,2}, François Flory^{2,3}, Antoine Labeyrie^{4,5}, Jean-Louis Roumiguères⁵; ¹IM2NP Lab, Univ. Paul Cézanne, France, ²CNRS, IM2NP (UMR 6242), Faculté des Sciences et Techniques de Saint Jérôme, France, ³École Centrale Marseille, IM2NP,

France, ⁴College de France, France, ⁵Irilab Co., France. An improvement of the organic solar cells efficiency is theoretically demonstrated by nanostructuring the active layer in the shape of a photonic crystal. An original process allowing polymers nanostructuration is presented.

ThC6

Towards Efficient Quantum Dot-Based Schottky Photovoltaic Cells, N. Zhao, T. P. Osedach, L. -y Chang, S. M. Geyer, M. Bawendi, V. Bulović; MIT, USA. Schottky photovoltaic cells (PVs) based on PbS quantum dot films have recently attracted much research interest due to their ability to harvest solar energy at infrared wavelengths. By engineering the device structure and fabrication methods, we explore several important aspects that determine the performance of PbS QD-based Pvs.

ThC7

Optimization of Thermophotovoltaic Systems Using Tungsten Photonic Crystal Structures, M. Araghchini, A. Yeng, M. Ghebrebrhan, Ivan Čelanović, J. Joannopoulos, G. S. Petrich, L. A. Kolodziejski; MIT, USA. Thermophotovoltaic (TPV) systems convert heat into electricity. A basic thermophotovoltaic system consists of a thermal emitter and a photovoltaic (PV) diode. Although TPV conversion systems have advantages such as no moving parts, long lifetime and low maintenance, they suffer from low efficiency. In order to achieve high TPV efficiencies it is necessary to better match the emitted spectrum to the sensitivity spectrum of the PV diode. In this work spectral control is done via selective emission using tungsten photonic crystal.

ThC8

Luminescent Solar Concentrators for Energy Harvesting in Displays, C. L. Mulder, H. Kim, C. Rotschild, M. A. Baldo; MIT, USA. We propose to use linearly polarized luminescent concentrators to harvest energy in displays. The concentrator employs aligned dye molecules that redirect absorbed photons to solar cells in the frame of the display.

ThC9

High Open-Circuit Voltage in Heterojunction Photovoltaics Using Printed Colloidal Quantum Dots as a Photosensitive Layer, Alexi C. Arango¹, Tim P. Osedach¹, Matthew J. Panzer¹, Vladimir Bulović¹, Scott M. Geyer², David C. Oertel², Mounqi G. Bawendi²; ¹Dept. of Electrical Engineering and Computer Science, MIT, USA, ²Dept. of Chemistry, MIT, USA. We have successfully printed a thin film of colloidal cadmium selenide (CdSe) quantum dots onto a transparent organic semiconductor, forming a unique solar cell that generates more voltage than previously expected for donor/acceptor photovoltaics.

ThC10

High Efficiency Organic Multilayer Photodetectors Based on Singlet Fission, Jiye Lee, Priya Jadhav, Marc Baldo; MIT, USA. We aim to enhance the efficiency of an organic multilayer photodetector employing exciton fission process. Our device consists of ultrathin pentacene-fullerene alternating layers. The quantum efficiency enhancement from singlet fission was about 35%.

ThC11

Solar Thermoelectric Generator for μ -Power Applications, Reja Amatyia, R. J. Ram; MIT, USA. Solar thermoelectric generator (STG) using cheap parabolic concentrator with high ZT modules can be a cost-effective alternative to solar photovoltaics for micro-power generation. Using novel thermoelectric materials, conversion efficiency of 5.5% can be achieved for a STG.

ThC12

Polychromatic Diffractive Concentrators for Ultra-High Efficiency Photovoltaic Cells, Rajesh Menon; MIT, USA. I will describe an approach to achieve energy-conversion efficiencies > 50% via a thin nanostructured optic that not only concentrates sunlight, but also separates and assigns the solar-spectral components to photovoltaic cells with matching bandgaps.

Location

2:30 p.m.–2:45 p.m.

Break

ThD • Solar II

Wong Auditorium

2:45 p.m.–5:20 p.m.

ThD • 2:45 p.m.

Vladimir Bulovic; MIT, USA, Presider

ThD1 • 2:45 p.m.

Invited

Thin Film PV: The Pathway to Grid Parity, Benny Buller, David Eaglesham; First Solar Inc., USA. First Solar is the global leader in PV module manufacturing, at <\$1.00/W. Grid parity will require a module cost/W 30% lower. This talk will outline the pathway to \$0.65/W and parity with fossil fuels.

ThD2 • 3:10 p.m.

Invited

A MEMS Wafer Expansion Approach to Microconcentrator Silicon Solar Cells, Peter Peumans; Stanford Univ., USA. We developed an approach to expand a wafered solar cell into an array of miniature solar cells placed accurately on a low-cost substrate with integrated wiring that is then mated to low-cost molded optics.

ThD3 • 3:35 p.m.

Invited

Thin Film PV Design and Broadening Applications, Sam Palmer¹, Jeff Chapin²; ¹Konarka Technologies Inc., USA, ²IDEO, USA. Abstract not available.

ThD4 • 4:00 p.m.

Invited

Luminescent Solar Concentrators, Marc Baldo; MIT, USA. Luminescent solar concentrators (LSCs) are planar waveguides containing an organic or inorganic dye and inorganic solar cells attached to the edges. Light is absorbed by the dye and reemitted into waveguide modes for collection by the solar cells.

ThD5 • 4:25 p.m.

Invited

Nanowires as Solar Cells and Nanoelectronic Power Sources, Charlie Lieber, Thomas Kempa; Harvard Univ., USA. Studies of single nanowire photovoltaic cells elucidate the benefits of “bottom-up” nanoscale design, lead to fundamental and breakthrough device performance insights, and open new opportunities for next generation solar cells.

ThD6 • 4:50 p.m.

Nanostructured Absorber and Emitter for Solar Thermo-Photovoltaics Exceeding the Shockley-Queisser Limit, Eden Rephaeli, Shanhui Fan; Stanford Univ., USA. We present a tungsten-based nanostructured absorber and emitter pair designed for solar thermo-photovoltaic (STPV) applications. The pair enables STPV systems with efficiencies exceeding the Shockley-Queisser limit.

ThD7 • 5:05 p.m.

A Silicon Metamaterial Demonstrating Low-Energy Carrier Generation and Multiplication, Zbigniew T. Kuznicki; Photonic Systems Lab, France. New PV conversion mechanisms were observed in nanostructured Si produced by amorphizing ion-implantation and subsequent thermal treatment. Intense physical transformations of usual c-Si lead to *Si-metamaterials* and a *multistage conversion cycle*.

ThE • Postdeadline Papers

Wong Auditorium

5:20 p.m.–6:00 p.m.

Fred Leonberger; MIT, USA, Presider