CNM Users Meeting 2009

CNM Users Meeting Focus Session
"Nanostructured Materials for Solar Energy Utilization"
October 6, 2009

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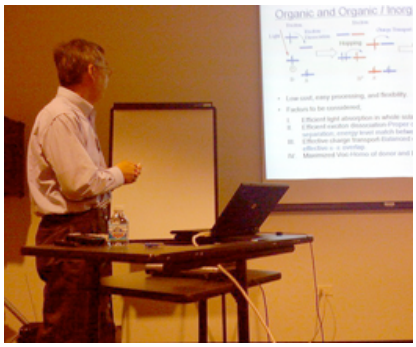
Sponsors: Plextronics, Inc.
Argonne-Northwestern Solar Energy Research (ANSER) Center

Many essential physical processes involved in solar energy conversion operate on nanometer length scales. Nanostructured materials provide promising pathways to improving the performance of next-generation photovoltaic, thermoelectric, and photocatalytic devices. Technological advances in these important fields require both a thorough understanding of the photophysics and electrical properties in solar energy systems, as well as rational control over the assembly of optoelectronically active nanomaterials. This full-day workshop provided a forum for presentation and discussion of current research advances in this important topical area. The collection of speakers included some of the leading researchers and pioneers in the fields of organic optoelectronics, semiconductor photophysics, and nanomaterials for photovoltaics. All major sectors of research (academic, national laboratory, and industrial) were represented, providing a diverse perspective.

Prof. Rakesh Agrawal (Purdue) kicked off the workshop presenting his group's efforts to develop solution-processible inorganic solar cells. They have developed an innovative method of using copper indium gallium disulfide (CIGS) nanocrystals as building blocks for fabrication of bulk CIGSSe thin films. The nanocrystal ink solution is applied directly on various substrates to form a thin film coating and then consolidated into large crystalline chalcopyrite domains by a brief thermal treatment under Se vapor. They are also working to adapt the CIGS method to Cu_2ZnSnS_4 (CZTS) nanocrystals and the associated PV devices. In the second presentation of the morning, Prof. Angus Rockett (UIUC) provided an informative and thought-provoking summary of the issues and prospects for photovoltaic devices based on nanomaterials. He pointed out where there were fundamental limitations with various technologies and where opportunities for advancement exist. This talk served as perfect groundwork to which the rest of the speakers could respond with their various approaches to understanding and working around the inherent property limitations.

The second morning session shifted to organic and hybrid organic-inorganic nanomaterials for photovoltaics. Dr. Garry Rumbles (NREL) focused on the process of exciton dissociation in conjugated polymers. He discussed the present low device performance efficiency, how it might be increased, and how performance compares with more conventional photovoltaic devices. He

then shifted to describe the use of time-resolved microwave conductivity using pulsed laser excitation as a tool for probing both the production and loss of free carriers resulting from exciton dissociation. In addition to traditional organic blends, he presented data on new donor polymers and dendrimers, as well as new acceptors such as single-wall carbon nanotubes (SWNTs) and colloidal quantum dots. Dr. Michael Pellin (Argonne) presented work using atomic layer deposition (ALD) to fabricate interdigitated morphologies for advanced dye-sensitized solar cells. ALD is a synthetic method capable of functionalizing nanoporous substrates with conformal, nanometer-scale-layered, transparent conducting oxides and semiconducting materials. They designed and fabricated a new photoelectrode architecture consisting of concentric conducting and semiconducting nanotubes for use in dye-sensitized and other types of solar cells. The cells exhibit both high photon absorption due to the high surface area of the nanoporous substrates and high current densities due to the radial collection of electrons. The industrial perspective on organic photovoltaics was presented by Dr. Christine McGuiness (Plextronics). Plextronics is among the select group of institutions exploring the scalability of organic technology from laboratory cells to modules. She reported on performance of their laboratory-scale organic photovoltaic device as well as the largest organic photovoltaic module to be certified by NREL. In lab-scale devices, their Plexcore inks have demonstrated NREL-certified power conversion efficiency of 5.98%. The technology has been scaled-up to larger area modules, which were certified by NREL as having 2.38% total area efficiency (4.95% active area efficiency). Dr. McGuiness also presented a formalized approach to ascertaining the lifetime performance in organic solar cells.



Following interesting discussions over the lunch break, Prof. Tobin Marks (Northwestern) kicked off the afternoon sessions with a summary of his group's work investigating interfacial layers in organic photovoltaic devices. He presented their ability to fabricate tailored interfaces to selectively modulate charge transport, facilitating transport of the desired charges while blocking that of the complementary charges. He also showed how these approaches can stabilize and control interfacial defect densities. This work aims not only to understand the interfacial processes, but also to replace materials used in devices with those having greater sustainability and superior performance. Working with collaborators at Solarmer, Prof. Luping Yu (Univ. of Chicago) has recently reported a new world record in organic solar cell efficiency based on novel polymeric materials designed and synthesized in his laboratory. These polymers are designed to have an energy band gap well tailored to harvest solar energy. The quinoidal structures provide these polymers with high rigidity and relatively high charge carrier mobility. A detailed structural variation led them to discover several polymers exhibiting a power conversion efficiency of 7.5%.

The final session of the workshop included two groundbreaking researchers in energy conversion research: Dr. Art Nozik (NREL) and Prof. Michael Wasielewski (Northwestern). Dr. Nozik's presentation was on the controversial topic of multiple exciton generation in semiconductor quantum dots. Using time-resolved ultrafast spectroscopy they observed efficient multiple exciton generation in PbSe, PbS, PbTe, and Si colloidal nanocrystals at threshold photon energies of 2-3 times the HOMO-LUMO transition. Recently, controversy has arisen regarding the reproducibility of reported MEG efficiencies in InAs and CdSe quantum dots. They addressed this controversy for lead chalcogenides with detailed studies, and find reproducible multiple exciton generation depending upon surface chemistry and dynamical conditions of the colloid. They also studied multiple exciton generation in close-packed arrays where the crystals are electronically coupled and thus exhibit good carrier mobility. Prof. Wasielewski finished off the day with beautiful examples of using advanced characterization techniques to probe photodriven charge separation and transport in self-organized donor-acceptor molecular assemblies. He prepared a series of donor-acceptor triad building blocks consisting of a PDI acceptor, an aminopyrene primary donor, and a diaminobenzene secondary donor. Small angle scattering at the APS was used to determine these self-assemble into helical hexamers in solution. Time-resolved EPR spectroscopy was used to measure the average distance between the photogenerated radical ions within the hexamer. This result showed that nonbonded secondary charge transport within ordered π-stacked donors and/or acceptors can be kinetically competitive with charge recombination within the covalent building block, making these materials of interest as photoactive nanostructured assemblies for artificial photosynthesis and organic photovoltaics.

In order to fully realize the potential of solar energy on a global scale, basic research into the processes underlying photovoltaic energy conversion is needed. The speakers at this workshop capture a cross-section of the research in this area, and specifically how nanomaterials are central to many of the most exciting future technologies. Argonne National Laboratory and the Center for Nanoscale Materials aim to have major impact in developing novel materials and processes for next-generation technologies and were thrilled to host such a stimulating forum on solar energy. We anticipate many new discussions and collaborations to emerge from this event.