2009 CNM Users Meeting, October 5-7, 2009

The Center for Nanoscale Materials (CNM) hosted its first stand-alone users meeting this year to better serve its active and robust user community. The CNM Users Executive Committee planned exciting and popular plenary and science sessions, topical focus sessions, and a poster session. The new CNM Scanning Probe Microscopy (SPM) Building was dedicated during a "virtual" ceremony, and other events included a two-day vendor exhibit, a variety of short courses, and a banquet. (full program). Highly successful focus sessions were held on the topics of “Nanostructured Materials for Solar Energy Utilization” and “Materials and Fabrication for Nano-Electro-Mechanical Systems (NEMS)”.

The student invited talk was presented by Ryan Smith of University of Wisconsin at Madison titled “Imaging and Structural Analysis of Ferroelectric Domains written by Piezoresponse Force Microscopy”. The Best Student Poster Prize went to Sevda Avci of Northern Illinois University for "Matching Effect and Dynamic Phases of Vortex Matter in BSCCO Nanoribbons with a Periodic Array of Holes”.

Fully-subscribed short courses were held on the following CNM user capabilities:

- Confocal Raman Spectroscopy
- Electron Beam Lithography
- Focused Ion Beam Nanofabrication
- Nanocarbon Synthesis, Fabrication & Applications
- Nanoimprint Lithography
- Optical Lithography & RIE
- Orientation to the CNM Nanoscience Computing Facility

CNM SPM Building Dedication

Plenary by Andreas Heinrich

Poster Session & Vendor Exhibit

Focus Session: Nanostructured Materials for Solar Energy Utilization

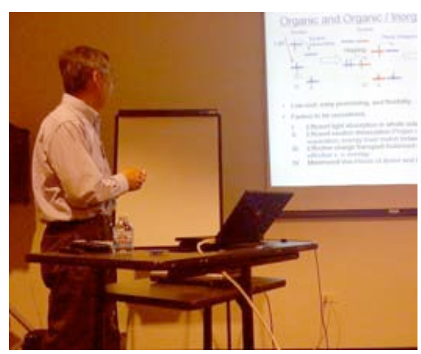
Organizers: Seth Darling (CNM) and Charles Black, (Center for Functional Nanomaterials, Brookhaven National Laboratory)

Sponsors: Plextronics, Inc. and 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. 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. Dr. Michael Pellin (Argonne) presented work using atomic layer deposition (ALD) to fabricate interdigitated morphologies for advanced dye-sensitized solar cells. 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. An 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.



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. 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. A detailed structural variation led them to discover several polymers exhibiting a power conversion efficiency of 7.5%.

The final session 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. 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. 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. His group's materials are 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 captured 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 excited to host such a stimulating forum on solar energy.

Focus Session: Materials and Fabrication for Nano-Electro-Mechanical Systems (NEMS)
Organizers: Daniel López (CNM) and Vladimir Aksyuk (Center for Nanoscale Science and Technology, NIST)

Many Nano-Electro-Mechanical System (NEMS) devices are currently being developed for unique applications in sensing, telecommunications, signal processing, data storage, and more. As characteristic device dimensions shrink to the nanoscale, novel fundamental and technological challenges need to be addressed before the full potential of these devices can be demonstrated. Examples of these challenges are: development of extremely precise mechanisms of nanofabrication, advancements in nano-metrology, and sensing and manipulation of short-range quantum forces. This full-day focus session provided an opportunity to identify the most challenging aspect of fabrication of NEMS devices and to evaluate putative solutions to them. The focus session consisted of a number of short presentations by leading experts in the area of nano-mechanical systems and general discussions with all the participants.

A variety of NEMS-enabled novel applications were discussed in detail by several speakers. Prof. Vinayak Dravid (Northwestern University) described his work with nano/micro-cantilevers for sensing and imaging. His group utilizes MOSFET-embedded cantilevers for measuring the signal transduction of molecular binding induced surface stress into nanomechanical motion of microcantilevers, thereby providing a new label- and optics-free all-electronic detection and sensing approach. His presentation covered the core philosophy of integrating advances in microelectronics and nanofabrication with biology for development of sensing, diagnostics and imaging systems.

Dr. J. Provine (Stanford University) presented his work on nano-fabricated freestanding 2-D photonic crystals (PC) that can be used as broadband mirrors with high reflectivity. By controlling the structure and geometrical dimensions, PC slabs can support guided resonances that couple to external radiation in ways that profoundly change the optical properties. Dr. John Moreland (NIST) provided an informative summary of state-of-the-art magnetic MEMS and presented an innovative "nano-magnetic manipulator" consisting of a micro-fluidic device integrated onto MRAM structures. This unique structure would create novel mechanisms to control NEMS devices inside fluids and would advance the fields of molecular electronics, single molecule DNA chip and single molecule manipulation.

The dynamics of NEMS devices in fluidics was discussed in detail by Prof. Kamil Ekinci (Boston University). Immersed in liquids, a NEMS resonator loses most of its vibrational energy to the fluid and, as a consequence, the quality factor (Q) of the resonator decreases significantly. Reductions in Q factor result in a reduction in the NEMS sensitivity limiting seriously their use for sensing. In order to solve this serious problem, he is studying NEMS resonators with textured surfaces with reduced dissipation in water. Nanomechanical single electron shuttles are an example of another novel use of NEMS devices. Chulki Kim (University of Wisconsin) presented experimental results of self-excitations in nanomechanical single electron transistors. The novelty of this structure allowed him to observe Coulomb blockade in suspended nanometer-size metallic islands.

Several experts described the challenges associated with using novel materials for NEMS fabrication. Prof. Mehran Mehregany (Case Western Reserve University, OH) presented his group's work on poly-SiC based NEMS. He showed his novel approach toward high-temperature computing with all-mechanical logic based on SiC NEMS switches. SiC is an attractive material platform for high temperature applications due its excellent mechanical properties, broad media compatibility and compatibility with nanoscale fabrication processes. Dr. Rachel Cannara (NIST) is exploring the origins of nanoscale friction for technologically relevant materials. Her work considers the use of diamond as an alternative to silicon for applications where adhesion and wear are unavoidable. Dr. Ani Sumant (CNM) reported on opportunities and challenges for ultrananocrystalline diamond (UNCD) as a structural material for NEMS. He presented the science performed to understand key aspects of UNCD film synthesis and the first UNCD based MEMS switch monolithically integrated with CMOS controlling electronics. Lastly, a comprehensive description of the use of diamond-coated nanoprobes for tip-based nanofabrication was given by Dr. Patrick Fletcher (University of Illinois at Urbana-Champaign).

These talks described current challenges in the use and design of NEMS devices and presented innovative solutions to overcome current limitations of this promising technology. This focus session generated considerable interest among the participants resulting in novel collaborations between research groups.