From the Director

I am pleased to present the current issue of Advances, a quarterly e-brief update of the Frederick Seitz Materials Research Laboratory (FSMRL) at the University of Illinois. In this issue, we feature new advances in materials characterization at the nanoscale, carbon nanotube technology, and assembly of 3D photonic crystals with embedded waveguides.

The primary mission of the FSMRL is to foster interdisciplinary research at the forefront of materials science. Our laboratory brings together world-class faculty, graduate students, and post-doctoral researchers with expertise in condensed matter physics, chemistry, and materials science. We house several multi-investigator programs in the broadly defined areas of computational, nanoscale, quantum, and soft materials.

These programs derive great benefit from our central facilities for materials fabrication and characterization, which

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Measurement technique probes surface structure of gold nanocrystals

Gold nanocrystals make surprisingly good catalysts, however uncovering the key to their chemical reactivity has been difficult. Now, a team of scientists led by FSMRL researchers Jianmin Zuo (MatSE) and Ralph Nuzzo (Chemistry) that includes graduate students Weiwei Huang, Laurent Menard, and Jing Tao, and undergraduate student, Ruoshi Sun, have demonstrated a sensitive probe that can identify and characterize the atomic structure of gold and other nanocrystalline materials. Their work will appear on the cover of the April issue of the journal Nature Materials.

To probe the nanocrystals, Zuo and colleagues used a technique they developed called nano-area coherent electron diffraction. This technique works by illuminating a single gold nanocrystal (about 3 nm in diameter) with a coherent electron beam about 40 nm in diameter. The electron beam is scattered by the atoms in the nanocrystal, resulting in a complicated diffraction pattern that describes the structural arrangement and behavior of the atoms, and the number and lengths of chemical bonds in the nanocrystal.

Their study reveals that the bond lengths on the surface of a gold nanocrystal are very different from those inside a bulk crystal. The differences arise as a result of the surface atoms being contracted. The force behind the contraction is attributed to the smoothing of surface electron density and a resulting electrostatic force that pulls the surface ions toward the remaining bonds. Surprisingly, they find that the contraction depends on the crystal facets. Atoms on facets with fewer bonds dominate, and lead to a much smaller contraction on other facets. This behavior is markedly different from bulk crystalline surfaces, and represents a new pattern of structural dynamics for nanocrystalline materials. Zuo’s technique is emerging as an essential tool for understanding the special properties of nanomaterials.

This research is partially supported by DOE/BES Materials Sciences and Engineering Division through the FSMRL Materials Research Clusters (MRC) on Strongly Driven Transformations in Materials and Programming Function via Soft Materials.

Bending light through waveguides in colloidal crystals

FSMRL researcher Paul Braun (MatSE) and his group members, Stephanie Rinne and Florencio Garcia-Santamaria, are the first to achieve optical waveguiding of near-infrared light through features embedded in self-assembled, three-dimensional photonic crystals. Applications for the optically active crystals include low-loss waveguides, low-threshold lasers and on-chip optical circuitry. Their work appeared on the cover of Nature Photonics in January 2008. Braun and his team created these waveguides by coupling colloidal assembly and multi-photon polymerization, which is simpler and less expensive than conventional fabrication techniques, especially for large-area photonic crystals.

His research is partially supported by DOE/BES Materials Sciences and Engineering Division through the FSMRL Materials Research Cluster (MRC) on Programming Function via Soft Materials.

The FSMRL gratefully acknowledges financial support from the DOE/BES Division of Materials Sciences and Engineering.
are widely recognized as amongst the finest mid-scale facilities in the nation.

Each quarter, Advances introduces the researchers involved in the FSMRL and highlights their recent accomplishments. Together, we are transforming fundamental scientific discoveries into technological advances in the areas of photonics, flexible electronics, superconductor devices, and energy materials (e.g., catalysts, fuel cells, and photovoltaics).

I hope that you enjoy learning more about the Frederick Seitz Materials Research Laboratory and our impact on the scientific community and society as a whole.

Jennifer A. Lewis
FSMRL Director

Cahill leads MURI team

David Cahill (MatSE) and his colleagues received a Multidisciplinary University Research Initiative (MURI) Award from the Air Force Office of Scientific Research (AFOSR). Their project will focus on “Passive and Active Control of Heat Transfer at Interfaces”, working to develop new materials and new understanding of ultralow thermal conductivity, controllable interface conduction, enhanced radiative heat transport in the near-field, and highly coherent far-field radiation. The group will work to integrate these advances into proof-of-principle demonstrations of passive and active control of heat transfer, e.g. thermal diodes and thermal regulators.

New kind of transistor radios show capability of nanotubes

FSMRL researcher John Rogers (MatSE) led a team that has built the world’s first all-nanotube transistor radios. The radios, in which nanotube devices provide all of the active functionality in the devices, represent important first steps toward the practical implementation of carbon-nanotube materials into high-speed analog electronics and other related applications. Their work, which describes the design, fabrication and performance of the nanotube-transistor radios, appeared in the February 5, 2008 issue of the Proceedings of the National Academy of Sciences (PNAS). In addition to Rogers, the research team included FSMRL staff member Tony Banks, who oversees our Micro/Nanofabrication Facility, as well as radio frequency (RF) electronics engineers at Northrop Grumman Electronics Systems in Linthicum, Md.

For high-speed analog electronics, benchmarking studies comparing nanotubes against silicon indicate significant advantages in comparably scaled devices, together with capabilities that might complement compound semiconductors. Practical nanotube devices and circuits are now possible, thanks to a novel growth technique previously developed by Rogers and colleagues at the University of Illinois, Lehigh and Purdue universities, and described last year in the journal Nature Nanotechnology. The growth technique produces linear, horizontally aligned arrays of hundreds of thousands of carbon nanotubes that function collectively as a thin-film semiconductor material in which charge moves independently through each of the nanotubes. The arrays can be integrated into electronic devices and circuits by conventional chip-processing techniques.

Their results suggested that analog RF represented one promising area of application, leading to the creation of the nanotube transistor radios. They utilized a heterodyne receiver design consisting of four capacitively coupled stages: an active resonant antenna, two RF amplifiers, and an audio amplifier, all based on nanotube devices. The headphones plugged directly into the output of a nanotube transistor. Each radio incorporated seven nanotube transistors in all. For one test, the researchers tuned into WBAL-AM (1090) in Baltimore to pick up a traffic report. While merely a demonstration, the nanotube radios serve as an important milestone toward building the technology into a form that would be commercially competitive with entrenched approaches.

This research is partially supported by DOE/BES Materials Sciences and Engineering Division through the FSMRL Materials Research Cluster (MRC) on Programming Function via Soft Materials.

Other Highlights

John Rogers (MatSE) has been elected as a member of the inaugural class of Materials Research Society (MRS) Fellows. His citation reads “For unique contributions, ranging from the synthesis and characterization of novel materials, to development of unconventional fabrication strategies, to engineering design and testing of electronic devices in commercially realistic applications.”

Jennifer Lewis (MatSE) has been elected as an American Physical Society (APS) Fellow. Her citation reads “For seminal contributions to the fields of colloidal science and directed assembly of materials”.

Ken Schweizer (MatSE) is the recipient of the Tau Beta Pi Daniel C. Drucker Eminent Faculty award from the College of Engineering at UIUC.