2009 MRS Fall Meeting Communicates Cross-Disciplinary Research on Materials

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The 2009 Materials Research Society (MRS) Fall Meeting, chaired by **Kristi Anseth** (University of Colorado), **Li-Chyong Chen** (National Taiwan University), **Peter Gumbsch** (University of Karlsruhe), and **Ji-Cheng Zhao** (The Ohio State University), was held in Boston on November 30–December 4. Through 50 symposia, symposium organizers from around the world offered coverage of developments in the areas of energy and environment; information processing and sensing; materials across the macro- to nanoscales; nanoscience and technology; and health and biological materials. The Meeting—receiving over 6000 attendees—included oral and poster presentations, award talks, an international equipment and resource exhibit, information on government funding, and special outreach or educational opportunities, including tutorials, professional development for women in materials science and engineering, and how to improve on giving oral presentations. This year, the Meeting was preceded by the National Science Foundation-sponsored multidisciplinary workshop on third-generation solar technologies (see page 245).

Energy and the Environment

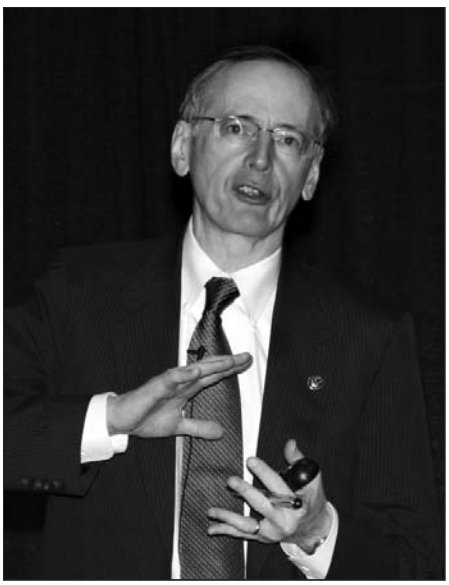
Many believe that research toward reducing dependence on fossil fuels with renewable energy sources and nuclear energy will begin to pay off within the next decade or two. The energy produced from renewable resources is primarily electrical energy; therefore, solving the problem of electrical energy storage is a critical issue in the transition to a renewable energy economy. Improved electrical energy storage systems, such as electrochemical capacitors (supercapacitors) and high-capacity batteries, are needed to move from "chemical" (fossil fuel) to "physical" (electrical) energy.

Presentations in Symposium U on Materials Challenges Facing Electrical Energy Storage were primarily dedicated to materials for electrochemical capacitors. P. Simon (Université Paul Sabatier, France) described materials that store energy using ion adsorption (electrochemical double layer capacitors) while K. Naoi (Tokyo Univ. of Agriculture & Technology), B. Dunn (Univ. of California, Los Angeles), and E. Frackowiak (Poznan Univ. of Technology, Poland) reported on pseudocapacitors that use fast surface redox reactions. Supercapacitors can complement or replace batteries in electrical energy storage and harvesting applications when high power delivery or uptake is needed. Combination of pseudo-capacitive nanomaterials, including oxides, nitrides, and polymers, with the latest generation of nanostructured Li electrodes (hybrid capacitors) can bring the energy density of supercapacitors closer to that of batteries. A notable improvement in material performance has been achieved due to recent advances in understanding charge storage mechanisms and the development of advanced nanostructured materials, such as carbide-derived carbons and nanotube films.

Research on non-traditional photovoltaic (PV) devices has expanded rapidly in the last few years, and Symposium R on Advanced Nanostructured Solar Cells demonstrated that healthy competition between organic bulk heterojunction solar cells (OPV) and dye-sensitized solar cells (DSC)—as well as a general awareness of the importance of nanostructured devices for energy conversion—continues to stimulate innovative research. The current state of the art in OPV research and development was reviewed by A. Heeger (Univ. of California, Santa Barbara), who also described new polymers that enhance light harvesting in the red part of the solar spectrum. M. Grätzel (École Polytechnique Fédérale de Lausanne) provided an overview with several exciting new results for DSCs. Impressive progress has been made in the development of large-area DSC modules with N. Koide (Sharp) reporting 8.2% AM 1.5 efficiency for a 242 cm^2 integrated module.

Tobin Marks Presents Von Hippel Address

Tobin Marks of Northwestern University presented the Von Hippel Award talk on molecule-based organic and hybrid organic/inorganic electronics. Chemists are exceptionally skilled at designing and constructing individual molecules with the goal of imbuing them with rationally tailored chemical, electronic, optical, and magnetic properties, said Marks. However, the task of rationally assembling such special molecules into organized, supramolecular structures with precise, nanometer-level organizational control, in order to effect specific functions, presents a daunting challenge. Soft or hard matter suitable for unconventional types of electronic circuitry represents a case in point, and in principal offers new capabilities not readily achievable with silicon electronics. By "unconventional" is meant circuitry that can span large areas; can be mechanically flexible and/or optically transparent; can be created by large-scale, high-throughput fabrication techniques; and has molecular-level properties tunability. Through the process of preparing, characterizing, and fabricating prototype devices with such materials, many new things can be learned about the electronic and electrical properties of materials, and the interfaces between them. Marks briefly overviewed recent progress in two interconnected efforts: organic semiconductors for π-electron complementary circuits, and high-κ soft matter gate dielectrics for organic and inorganic electronics.



Tobin Marks, Von Hippel Award recipient

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D.M. DeLongchamp (Natl. Inst. of Standards and Technology) showed how application of a range of advanced structural and spectroscopic tools to OPVs could provide a much deeper level of understanding of the factors that control device efficiency. And M. McGehee (Stanford) reported that the efficiency of DSCs could be improved by adding dyes to the solution to harvest additional light energy that is then transferred to the adsorbed sensitizer dye by the Förster mechanism.

Organic electronic materials and devices have received significant interest in recent years, and are now emerging as an important application for displays, solid-state lighting, and solar energy generation. In Symposium S on Organic Materials and Devices for Sustainable Energy Systems, one important theme centered on more efficient, longer lived organic solar cells. G. Li (Solarmer Energy) reported a world-record efficiency of 7.9% using new polymers and processing technologies developed in collaboration with academic partners. C. Lungenschmied (Konarka Technologies) showed that oxygen exposure causes a doping of the active layer when exposed to light, compromising the internal electric field of the device and hurting performance. They also showed that the effect is partially reversible through an annealing step to drive oxygen out of the active layers. M. Pfeiffer (Heliatek) presented the latest results on accelerated lifetime tests of a 6.1% efficient tandem cell, observing almost no degradation after 2000 hours.

From a fundamental perspective, J.-L. Bredas (Georgia Inst. of Technology) described his group's latest research on modeling of charge separation, the process responsible for photocurrent generation in organic solar cells. They found that the geometrical alignment of the pentacene and fullerene molecules significantly modulates the efficiency of the charge transfer process, by up to a factor of two. They postulate that this could explain why the bulk heterojunction, which contains all interface configurations, is less efficient in the pentacene/fullerene system compared with a planar interface.

On the use of white organic light-emitting devices (OLEDs) as a solid-state lighting source, S. Xia (Universal Display Corp.) reported devices with efficiencies of 80 lm/W (at 1000 nits) and lifetimes exceeding 30,000 hours. S. Reineke (Technische Univ. Dresden, Germany) described work on achieving white OLEDs with over 100 lm/W efficiency using a combination of improved device structure and outcoupling enhancement mechanisms.

Information Processing and Sensing

ZnO is a direct, wide bandgap piezoelectric material with "many great potential applications…. [It] is one of the core areas of physics today," began Sheng Xu of Georgia Institute of Technology in Symposium H on ZnO and Related Materials. In particular, ZnO nanowires have attracted much attention by enhancing these desirable properties through one-dimensional quantum confinement. While vertical growth is heavily studied in all nanowire materials systems, horizontal growth has as many potential applications and yet has seen significantly less attention. Xu utilized an *a*-plane ZnO substrate with two-fold symmetry to encourage horizontal *c*-axis ZnO nanowire growth. The substrate was patterned by electron beam lithography prior to wet chemical processing, allowing for nanowire formation by lateral overgrowth from openings in the pattern. Scanning electron microscope (SEM)

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images verify controlled uniformity, spacing, and dimensions of the nanowires. Two- and five-fold superstructures were fabricated by writing pattern openings of various dimensions to achieve aspect ratios of up to 10,000. This technology has direct application in alternating current nanogenerators, where horizontal ZnO nanowire arrays in serial connection may enhance output voltage.

One-dimensional nanostructures can guide both electrons and photons due to confinement in two dimensions. To obtain high angular resolution of this waveguiding phenomenon, M. Gao (Peking Univ.) combined an *in situ* SEM nanoprobe with far-field micro-photoluminescence (PL) as well as an optical fiber probe with a nanomanipulator. These two techniques have allowed Gao to investigate anisotropic optical properties, confinement efficiencies, and angular distribution of the waveguiding phenomena, all at the nanoscale. ZnO nanowire catalyst arrays were patterned by nanosphere lithography and nanowires grown by chemical vapor deposition (CVD). Angular-resolved PL imaging and spectroscopy of individual nanowires show changes in near band edge intensity at various angles relative to the nanowire growth axis. Confocal micro-PL reveals blueshifting cavity modes with increasing diameters, consistent with an exciton-polariton model. Gao's results emphasize the role of exciton-polaritons and the longitudinal phonon in optical confinement within ZnO nanorods.

In Symposium F on Multiferroic and Ferroelectric Materials, the unique properties of $BiFeO_3$ were on stage. Multiferroic $BiFeO_3$ grown under large compressive strain displays a new phase with a huge axial ratio. R. Ramesh's groups from UC–Berkeley and N. Spaldin's group from UC–Santa Barbara have presented evidence and theoretical support, respectively, for the coexistence of this supertetragonal phase with the well-known pseudo-rhombohedral phase. They further showed that the boundary between the two may be reminiscent of the morphotropic phase boundaries in highly piezoelectric materials. J. Iñiguez (Institut de Ciència de Materials de Barcelona) presented a first-principles prediction of a giant magnetoelectric coupling at the boundary between these two $BiFeO_3$ phases.

Solid-state sensors were the focus of a morning session in Symposium I on III-Nitride Materials for Sensing, Energy Conversion, and Controlled Light-Matter Interactions. S. Pearton (Univ. Florida) described the use of functionalized AlGaN/GaN high-electron-mobility transistor structures to detect, with high sensitivity, targets ranging from hydrogen gas to markers for prostate cancer. Pressure sensing with a similar structure functionalized with a piezoelectric polymer was discussed by F. Ren (Univ. Florida). An alternative nitride-based method for pH sensing with very high sensitivity using a thin InN channel on insulating AlN was presented by J.A. Yeh of the National Tsing Hua University, Taiwan. In the Symposium's session on energy conversion, W. Walukiewicz (Lawrence Berkeley National Laboratory) discussed nitride-based approaches to PV and photoelec-

Graphene Unleashes Cornucopia of New Science

Plenary speaker Andre Geim of the University of Manchester, UK, discussed graphene, a material that has seen an explosion in research activities and interest. Geim started with a historical account of earlier efforts to form two-dimensional atomic planes. In 2004, Geim was able to extract individual atomic layers from graphite. These carbon planes—graphene—could be placed on any substrate and reach sub-mm sizes. Since then, several groups have been able to produce wafer-scale graphene sheets; the most recent work reports 30 in. wafers. Geim said that graphene represents a new class of materials—isolated one-atom-thick crystals. A large number of superlatives can be applied to graphene. These include the thinnest imaginable material, the strongest material ever measured, the stiffest known material, the most stretchable crystal, record thermal conductivity, highest current density at room temperature, highest intrinsic mobility, and most impermeable material.

Andre Geim (University of Manchester, UK) gives the plenary address on graphene.

One of the interesting aspects of graphene is that it allows for rich new physics, said Geim, with access to relativistic-like physics in a condensed-matter experiment. Some examples of this aspect include Klein tunneling, conductivity "without" charge carriers, relativistic fall on superheavy nuclei, and visualization of the fine structure constant. There are also possibilities in terms of creating new graphene-based materials, graphane for instance that includes one hydrogen atom bonded to each carbon atom. Geim said that graphene has unleashed a cornucopia of new science, not just electronic properties but also new optical, mechanical, and chemical properties. Some possible applications, he said, include ultrahigh frequency graphene transistors and transparent conductive coatings.

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trochemical energy conversion and announced a novel GaN/Si tandem solar cell with a large open circuit voltage. K. Fujii (Tohoku Univ.) reported that the N-polar face of *p*-GaN was much more effective for solar water splitting than the Ga-polar face. I. Pryce (California Inst. of Technology) and A. Nurmikko (Brown) described nanostructuring approaches to improve light absorption and emission, respectively, in InGaN/GaN quantum well structures.

In Symposium J on Diamond Electronics and Bioelectronics, S. Deleonibus (CEA, LETI, France) highlighted the opportunities for carbon-based electronics in the Nanoelectronics Roadmap. Diamond can be deployed as a heat dissipator in heterogeneous three-dimensional co-integration with silicon. The silicon-on-diamond (SOD) stack can replace silicon-on-insulator (SOI). The SOD metal oxide semiconductor field-effect transistor structure has been fabricated on a 60-nm channel on a 100-mm wafer. Excellent thermal dissipation of SOD addresses the power dissipation issues in the miniaturization process when the thinning of the silicon channel inevitably results in an increase of thermal resistance.

The use of diamond in quantum technology received great interest, with several talks focusing on the characterization and generation of single spins in diamond. D.D. Awschalom of the Center for Spintronics and Quantum Computation at UC–Santa Barbara talked about the high-speed coherent control of single spins in diamond. The ability to electrically manipulate, at gigahertz rates, the quantum states of electrons trapped on individual defects in diamond crystals can potentially develop quantum computers that could use electron spins to perform computations at unprecedented speed. Using electromagnetic waveguides on diamond-based chips, the researchers were able to generate magnetic fields large enough to change the quantum state of an atomic-scale defect in less than one billionth of a second.

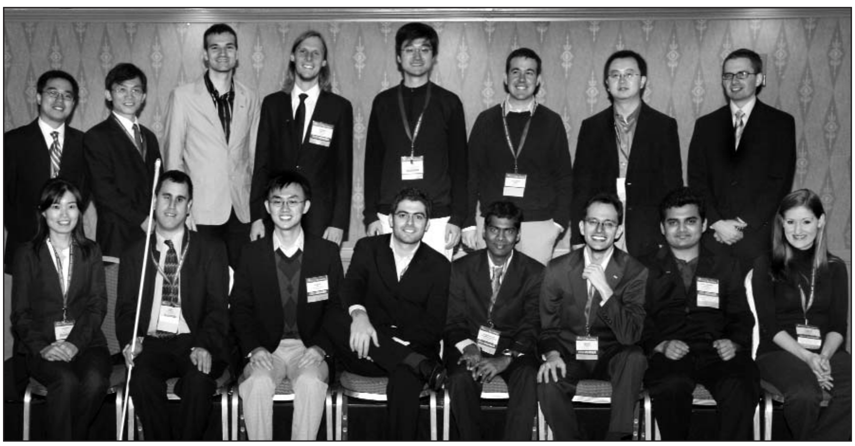
Also in Symposium J, K.P. Loh (Natl. Univ. of Singapore), as well as M. Nesladek (Hasselt Univ.), demonstrated that boron-doped nanocrystalline diamond (NCD) grown on glass exhibited promising performance compared to indium tin oxide (ITO) and fluorine-doped tin oxide (FTO) when utilized as organic PV anodes. Despite the fact that the transparency and electrical conductivity of NCD had not been optimized and was poorer than that of ITO and FTO, the photocurrent conversion efficiency obtained on NCD was much higher than that of ITO and FTO by 40–50%. This was attributed to the better energetic offset of organic dyes on diamond in terms of lower hole injection barrier and larger open circuit potential compared to ITO and FTO. The organic-NCD interface also exhibited greater photostability in the electrolyte compared to ITO.

Nanoscale-sized diamonds are emerging as important nanomaterials for bio- and medical applications due to their excellent physical, chemical properties, biocompatibility, and the ability to immobilize biologically active molecules on nanodiamond surfaces. The major objective of C.-L. Cheng's work at the National Dong Hwa University, Taiwan, was the development of a smart nano-bio-probe

Graduate Students Receive Gold and Silver Awards

Graduate Student Awards were announced during an evening ceremony on December 2 at the 2009 Materials Research Society Fall Meeting in Boston.

Gold Graduate Student Awards were awarded to (left to right): **Dae-Hyeong Kim** (University of Illinois, Urbana Champaign), **Cole A. DeForest** (University of Colorado), **Prashant Nagpal** (University of Minnesota), **Mary M. Caruso** (University of Illinois, Urbana-Champaign), and **Tzahi Cohen-Karni** (Harvard University).



Silver Graduate Student Awards were awarded to (front row, left to right): **Xiaoying Liu** (Harvard University), **Cary A. Supalo** (Pennsylvania State University), **Sheng Xu** (Georgia Institute of Technology), **Charbel Madi** (Harvard University), **Kadhiravan Shanmuganathan** (Case Western Reserve University), **Daniel Heller** (Massachusetts Institute of Technology), **Vivekananda P. Adiga** (University of Pennsylvania), and **Carlee E. Ashley** (University of New Mexico); and (back row, left to right): **Yue Bing Zheng** (Pennsylvania State University), **Linyou Cao** (Stanford University), **Pierre-Luc T. Boudreault** (Université Laval), **Dennis Meier** (Universität Bonn), **Xin Li** (Pennsylvania State University), **Alfonso Reina** (Massachusetts Institute of Technology), **Yang Liu** (Purdue University), and **Michael D. Kelzenberg** (California Institute of Technology).

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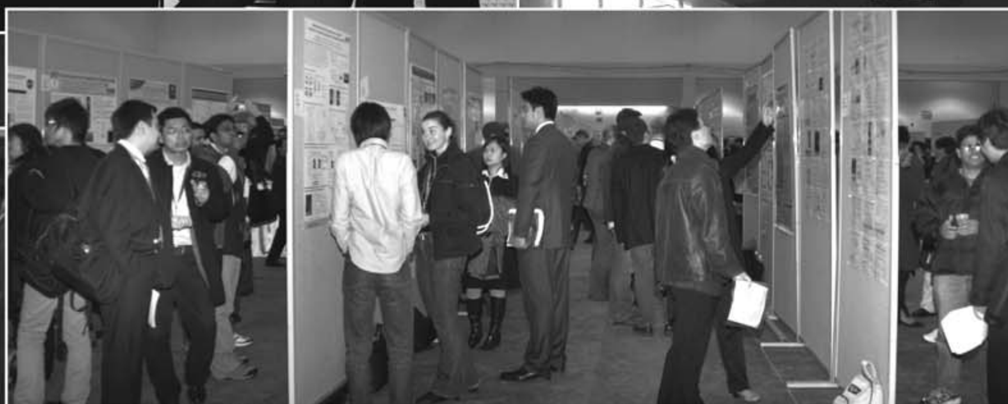



using nanodiamond. The spectroscopic properties of nanodiamond, such as its unique Raman signal and natural fluorescence, were used as bio-markers to probe the interactions of bio-molecules with cells at the single cellular level. Cheng described several examples of the interactions of nanodiamonds with cells, including the use of nanodiamond to carry anti-cancer drugs to cancer cells by conjugating the drug, paclitaxel, to the nanodiamond surface to interact with lung cancer cells. The results demonstrated the functionality of paclitaxel was still preserved after the delivery of the nanodiamonds. Cheng also described the use of nanodiamonds for Raman mapping in biological systems taking advantage of the unique Raman peak for diamond. For example, by labeling cancer cells with nanodiamond and then using laser irradiation to destroy the nanodiamond, nanoscale surgery was demonstrated to eliminate cancer cells.

Materials Across the Scales

The performance of current high-powered devices are limited by phonons and phonon interactions with electrons; hence, the fundamentals of these interactions must be understood "to get GaN devices to work better," began Brian K. Ridley, University of Essex, UK, in Symposium CC on Phonon Engineering for Enhanced Materials Solutions. The lifetime of a longitudinal optical phonon, prior to decay into transverse optical and either transverse acoustic or longitudinal acoustic modes, depends on many variables. Ridley employed coupled mode theory to explain the experimentally observed dependence of LO phonon lifetimes in GaN on electron density and phonon wave vector. From these comparisons, Ridley concluded that the ultrashort phonon lifetimes observed in high field-effect transistor channels may be associated with the migration of coupled modes with enhanced group velocity. The overall symposium covered key aspects for phonon manipulation, including generation and detection of coherent phonons, phonon dispersion relations, phonon scattering, and phonon transport.

Symposium NN, on Advanced Microscopy and Spectroscopy Techniques for Imaging Materials with High Spatial Resolution, showcased the latest developments for determining the local structure, composition, and bonding of complex materials at the atomic scale using electron microscopy and atom probe techniques. Y. Zhu and collaborators at Brookhaven National Laboratory have developed an imaging system on the Hitachi HD-2700C electron microscope that has enabled them to simultaneously image individual atoms on the surface and in the bulk by using the secondary electrons that emerge from the surface as well as the transmitted electrons that travel through the bulk. This novel electron optical design has achieved an unprecedented spatial resolution in surface imaging, more than a four-fold improvement compared with any existing scanning electron microscope. Observations of individual uranium atoms at the top and bottom of a 2-nm carbon film and the surface atomic arrangement of a $YBa_2Cu_3O_7$ superconductor sample were presented. This work opens the door to a wide range of applications, including

Symposium X Covers Regenerative Medicine, Taiwan's Changing Economy, and Solar PV

Since the first organ transplant in 1954 in Boston, patients and physicians have continued to face two seemingly insurmountable issues: organ rejection and the lack of sufficient donor organs to meet demand. Anthony Atala of Wake Forest University and his colleagues are working to solve these problems by engineering replacement organs and tissues in the laboratory and developing cell therapies to restore organ function. His team learned to target the bladder progenitor cells in tissues that are pre-programmed to regenerate. That discovery led to the successful implantation of laboratory-engineered bladders into patients and the development of therapies using cartilage and muscle cells. Atala and his team are currently exploring new ways to engineer organs, such as using inkjet technology to print them in layers. Atala's team also discovered a new type of stem cell in amniotic fluid and placenta that has the potential for a variety of treatments, from diabetes to liver and kidney disease. The cells are neither embryonic nor adult stem cells, but have the properties of both. This system avoids the tumor potential and rejection concerns surrounding the use of other stem cells. These stem cells can be rapidly expanded to large quantities sufficient for clinical translation, thus avoiding the limitations of adult stem cells. The stem cells could be stored at the time of birth for future "self" use, or could be banked in large quantities, thus avoiding rejection.

Taiwan, a country that used to harvest rice by hand and mainly exported pineapple products in the 1960s can now produce thousands of computers in a single hour. This was made possible, said Maw-Kuen Wu, former Minister of the National Science Council, due to a strong system of government policies. Now serving as director of the Institute of Physics at Academia Sinica in Taiwan and director general of the National Nanoscience and Nanotechnology Program of Taiwan, Wu expounded upon the strategies that resulted in the "Taiwan Miracle." He said that a National Science Council, consisting entirely of scientists serving in minister level positions of the government, was formed to direct research spending according to a National Science and Technology Development Plan. Every four years, this council meets to evaluate current technological fields and re-examine the country's plan for the future. The government supports the development of research and industry by providing appropriate infrastructure, recruiting scientists from abroad, offering tax incentives to encourage industrial research, and by spending a significant percentage of the gross domestic product funding national research and design. Furthermore, between 1980 and 2000, a large number of universities were established in Taiwan to increase the number of college-educated citizens. Professors and scientists are sent to high schools to give talks, to enlighten the younger generation and to spark their interest in emerging science and technology. Recently, technologies developed in Taiwan include high spatial and temporal resolution imaging techniques that can be used to non-invasively image internal biological structures, energy-saving windows that disperse natural light throughout a room, and transparent carbon nanotube displays.

With over a billion dollars of venture capital that has gone into photovoltaics in 2008, this technology is no longer an outlier, said Lawrence L. Kazmerski of the National Renewable Energy Laboratory. Various current PV technologies with a focus on thin films include copper indium gallium diselenide (CIGS), CdTe, organic solar cells, and dye-sensitized solar cells. In providing an overview of the history of solar PV development, Kazmerski's main messages are that the time from laboratory to manufacturing needs to be drastically reduced, investments in policy and research and development (R&D) require equal priorities, the workforce needs to be significantly increased, and a balanced R&D portfolio is required in terms of the different photovoltaic technologies.

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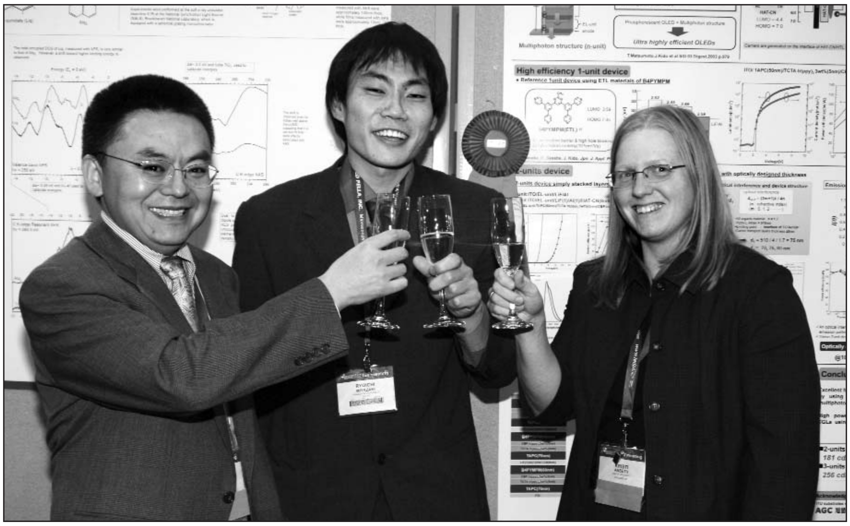
imaging dopant atoms in electronic devices, and studying the active sites and role of individual atoms and their bonding state during catalytic chemical reactions.

Also in Symposium NN, E.A. Marquis (Univ. of Oxford) presented results on employing atom-probe tomography to study the temporal evolution, on atomic scale, of model alloys with increasing degrees of complexity, which sheds light on the pertinent diffusion mechanisms. The simplest example was for an Al-Sc-Mg alloy, where, by measuring the mean precipitate radius and the chemical compositions of the precipitate and matrix phases, she found that the assumptions of the classical Lifschitz-Slyozov-Wagner (LSW) coarsening model yield the diffusion coefficient of Sc in Al. For the more complex Al-Ag system, by focusing on the early times of precipitation, it is possible to obtain a better understanding of the formation of Guinier-Preston zones. The early times are governed by Ag-V interactions and the coarsening stage obeys LSW kinetics. The more complex W-Re and Fe-Cr bcc alloys are Marquis's current research topics. Their temporal evolution is important for understanding the behavior of nuclear alloys under particle irradiation conditions.

Previously, high-quality results from frequency-modulated atomic force microscopy were limited to samples measured in a vacuum. In his work on FM-AFM in a liquid environment, T. Fukuma (Kanazawa Univ., Japan) has been able to achieve a resolution of 2–3 Å for structures in liquid. As reported in Symposium OO on Dynamic Scanning Probes, Fukuma achieved this through the use of stiff cantilevers, a smaller oscillation amplitude, and a low-noise cantilever deflection sensor. With this increased resolution, he has further improved the technique of FM-AFM through use of a three-dimensional scanning technique. Expanding on traditional two-dimensional scanning techniques, which use a sinusoidal wave to guide the tip, Fukuma added a Z modulation of the tip, thus gathering three-dimensional information. Using this method he imaged the interaction surface of mica and water and found that the structure relaxes at the surface, which agrees with the result of experimental x-ray diffraction work. Furthermore, because information is gathered in three dimensions, Fukuma can look at individual cross sections throughout the structure. In doing so, he was able to image both a hydration layer above the sample and absorbed water in structural cavities on the mica surface.

As researchers focus more and more on smaller technological devices, they are finding new ways to study the micromechanics of fracture and fatigue that cause these devices to fail. W. Soboyejo (Princeton) has studied crack growth in microelectromechanical systems (MEMS) and delamination in OLEDS, which he discussed in Symposium FF on Mechanical Behavior of Nanomaterials. To examine MEMS crack growth, Soboyejo machined notched beams into the material, allowing

Poster Prizes Awarded at 2009 MRS Fall Meeting



The 2009 Fall Meeting Chairs awarded prizes for the following best poster presentations: **(C6.50) Large-Area Rail-Guided Self-Assembly of Heterogeneous Microstructures on Flexible Substrate Using a Cross-rail Structure,** J. Kim, Y. Song, and S. Kwon (Seoul National University, Korea); **(D4.39) Core-Shell Microcapsules for Self-Healing Electronic Materials Systems,** S.A. Odom, B.R. Long, M.M. Caruso, J.A. Ritchey, A. Prokup, S.R. White, N.R. Sottos, A.A. Gerwith, and J.S. Moore (University of Illinois at Urbana-Champaign); **(E7.13) Room Temperature Ferromagnetism in GaMnN Dilute Magnetic Semiconductor Devices,** N. Nepal, M.O. Luen, J.M. Zavada, S.M. Bedair, P. Frajtag, and N. El-Masry, (North Carolina State University); **(F3.30) Synthesis and Size-Dependent Ferroelectric Ordering of Colloidal GeTe Nanoparticles,** M.J. Polking and R. Ramesh (University of California, Berkeley), H. Zheng and P. Alivisatos (UC, Berkeley; Lawrence Berkeley National Laboratory), J.J. Urban, D.J. Milliron, C.F. Kisielowski, and J.W. Ager (LBNL), M.A. Caldwell (Stanford University), and S. Raoux (IBM Almaden Research Center); **(K18.31) Thermal and Structural Characterizations of Individual Carbon Nanotubes,** M.T. Pettes and L. Shi (University of Texas at Austin); **(M11.64) Size-Dependent Persistent Photoconductivity and Surface Band Bending in M-Axial GaN Nanowires,** Hsin-Yi Chen and K.-H. Chen (National Taiwan University; Academia Sinica, Taipei, Taiwan), R.-S. Chen (Academia Sinica), and F.-C. Chang, L.-C. Chen, and Y.-J. Yang (National Taiwan University); **(S3.13) Ultra High Efficient Green Phosphorescent OLED Having Multiphoton Structure,** R. Miyazaki, T. Chiba, Y.-J. Pu, K.-I. Nakayama, and J. Kido (Yamagata University, Japan); **(S8.33) Exciton Formation in Metal-Organic Mixed Layers,** A. Yadav, Y. Jin, M. Shtein, and P. Pipe (University of Michigan); **(S11.11) Stability of Electrical Properties of Silicon (100) Surfaces Passivated with 9,10-Phenanthrenequinone,** S. Avasthi, Y. Qi, G. Vertelov, A. Kahn, J. Schwartz, and J.C. Sturm (Princeton University); **(FF5.19) Nano-Indentation Study of Three-Dimensional Periodic Nanoframes,** J.-H. Lee, S. Kooi, and E.L. Thomas (Massachusetts Institute of Technology); **(KK11.63) Hydrogel-Actuated High Aspect Ratio Polymer Nanostructures for Reversible Pattern Generation,** L. Zarzar, P. Kim, X. Zhao, and J. Aizenberg (Harvard University); **(RR3.12) De Novo Regeneration of the Hierarchical Extracellular Matrix with Protein nanoFabrics,** A.W. Feinberg and K.K. Parker (Harvard University); **(SS5.36) AFM Force Spectroscopy on TAT Membrane Penetration,** E.A. Hager-Barnard, B.D. Almquist, and N.A. Melosh (Stanford University).

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him to test at a single grain level. Small fatigue crack growth is initiated in the beams after repeated cycling, and cracks opened from the notch into alternating slip bands in the crystal. Soboyejo has developed several fracture models based on these results. He has also looked at the failure of OLEDs used for displays, observing that failure occurs when the adhesion between the layers of the OLED breaks down. Using atomic force microscopy with coated tips and surfaces to study the adhesion, Soboyejo found that delamination was caused by blisters at the interface of the layers, nucleated from dust on the interface and creating an imperfect initial contact. As the OLED is heated through use, these imperfections nucleate into telephone cord blisters, which grow to the blisters that interfere with operation.

Nanoscience and Technology

The drive for increased energy efficiency is moving lighting away from incandescent lighting toward fluorescents and LEDs. However, fluorescents include mercury while LEDs are hindered by poor light color quality. S. Coe-Sullivan, co-founder of QD Vision Inc., an off-shoot from lab-work done at the Massachusetts Institute of Technology, explained why quantum dots (QDs) could solve these problems, in Symposium N on Colloidal Nanoparticles for Electronic Applications. QD Vision's Quantum Light™ optics is a commercially available product that takes advantage of QDs for lighting. In an example, a thin film of quantum dot ink was coated on the diffusive cover plate of an LED lamp. The QDs absorb blue light from the LEDs and convert it to red light. Together, this LED-QD (QLED) combination yields a pleasing incandescent light quality much more efficiently than conventional phosphor-based solutions. While QLEDs are currently powered by a laser source, future work is focused on electrical pumping. QLEDs, Coe-Sullivan said, appear to be very promising for printable electroluminescent devices.

Feature sizes in electronic devices are rapidly approaching the molecular level. Low cost, high throughput, and nonlithographic patterning techniques are therefore required to fabricate nanowires (NWs) and other nano-architectures. In Symposium L, on Large-Area Electronics from Carbon Nanotubes, Graphene, and Related Non-carbon Nanostructures, A. Colli (Nokia Research Centre, Cambridge, UK) described nanowire-lithography (NWL) that uses free-standing NWs, grown and assembled by chemical methods, as etch masks to transfer their one-dimensional morphology to an underlying thin film.

MRS Medalist Gerbrand Ceder Offers "Virtual Playground" to Advance Development of Li Batteries

MRS Medalist Gerbrand Ceder of the Massachusetts Institute of Technology.

With the average time from the discovery of a new material to its commercialization being 18 years, time is of the essence for materials innovations aimed at solving the world's current energy problem. During his award talk, MRS Medalist Gerbrand Ceder of the Massachusetts Institute of Technology urged a packed audience to increase the role of first principles computational design—which relies on quantum mechanics to determine material properties—in an effort to accelerate this innovation process. The key issue, he said, is no longer accuracy but rather translating desirable engineering properties (such as high voltage, high capacity, and safety in the case of Li ion batteries) into computable quantities (such as Li chemical potential, thermodynamic phase stability upon Li removal, and material stability against reduction). For example, he said, phase diagrams computed from first-principles led to the design of a cathode material coated with a glassy second phase with high Li^+ conductivity. The resulting cathode could be charged and discharged within minutes. Ceder's ultimate goal is to create a Materials Genome, or a library of the computed properties of all reported inorganic compounds (estimated to number between 10^4 and 10^5), using high-throughput computing. His group has already automated first-principles computations and has performed tens of thousands of calculations in an attempt to find new, promising cathode materials.

Mirkin Presents Kavli Lecture on Polyvalent Gold Nanoparticle Conjugates

Chad Mirkin (right) receives the Fred Kavli Distinguished Lectureship in Nanoscience from MRS President Shefford Baker.

Chad Mirkin of Northwestern University, recipient of the Fred Kavli Distinguished Lectureship in Nanoscience, gave a presentation on polyvalent gold nanoparticle conjugates, describing their synthesis, applications in biodiagnostics, and intracellular gene regulation. DNA can be attached to gold nanoparticles to create polyvalent gold nanoparticle-DNA conjugates that can be hybridized, as discovered by Mirkin over a decade ago. Thus, one can synthetically dial in a set of tailorable and highly predictable recognition properties and then use hybridization with linker strands or particles to build designer materials. More recently, it was found that by using self-complementary (single component) and non-self-complementary (binary component) DNA linkers, fcc and bcc unit cells respectively could be formed. Moreover, the unit cells can be programmed by varying the DNA linker length, yielding over 30 types of crystal lattices with tailored and programmable lattice parameters. Mirkin described the properties of these oligonucleotide-nanoparticle conjugates as used for medical diagnostic and gene regulation applications, thus moving nanoscience out of the laboratory and into practical applications that positively affect the quality of life.

The Kavli Foundation supports scientific research, honors scientific achievement, and promotes public understanding of scientists and their work. Its particular focuses are astrophysics, nanoscience, and neuroscience.

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Multidisciplinary Workshop on Solar Technologies Precedes Fall Meeting

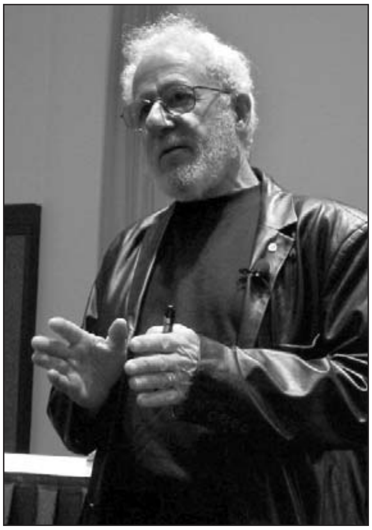
What do you get when you mix materials researchers, chemists, and mathematicians in search of the next renewable energy technology? A multidisciplinary workshop on third-generation solar technologies, and a mountain of challenges.

Such a workshop was held on Sunday at the start of the 2009 MRS Fall Meeting, open to all attendees and drawing a strong crowd. To set the tone for this multidisciplinary approach, Z. Kafafi, director of the Division of Materials Research (DMR) at the National Science Foundation, introduced NSF's relatively new SOLAR initiative supporting groups of three or more co-principal investigators with one person each in chemistry, materials, and mathematical sciences. The purpose is to take transformative approaches toward achieving highly efficient harvesting, conversion, and storage of solar energy.

A. Heeger (Univ. of California, Santa Barbara) led the workshop with an overview on plastic solar cells, focusing on self-assembly of bulk heterojunction nanomaterials by spontaneous phase separation. To satisfy the basic needs of photon absorption, photo-induced charge separation, and charge collection at electrodes, he described a system of a semiconducting polymer (a donor) and fullerene (an acceptor) to make a bulk heterojunction material. The polymer absorbs the photons and undergoes ultrafast electron transfer to the fullerene with electrons migrating on the fullerene network and holes on the polymer network to the electrodes where they are collected. The length scale for diffusion of excitons (e–h pairs) is on the order of 10–20 nm, which can be achieved through fabrication of a bicontinuous interpenetrating network, "creating charge-separating junctions everywhere," Heeger said. When exposed to light, the donor-acceptor interface of the interpenetrating phases forms essentially a parallel plate nano-capacitor with positive charges on the polymer phase and negative on the fullerene phase. The voltage across this capacitor equals the open circuit voltage. Heeger explored a range of challenges from breaking the symmetry to separate the charge, the connection of microscopic to macroscopic open circuit voltages, achieving a smaller energy gap for better light harvesting, and the mathematical interpretation of imaging interfaces.

Heeger's presentation and the ones following it in the morning session set up a range of challenges from materials and chemistry communities for the mathematicians, who spoke in the afternoon. Rounding out the day was a panel discussion interweaving input from the varied communities. Despite significant progress in each of the disciplines represented, the complexity of real systems leaves a wide gap between what can be understood experimentally and what can be modeled. An ongoing focus was on getting the morphology right and the effect of additives, noting how small changes can lead to significant and unexpected results. This further increases the challenge of predictive modeling, but also the need for it.

G. Bazan (UCSB) considered the challenge of going from molecules to materials, with the added factors, for example, of aggregation, collective behavior, and controlling weak forces. Controlling conjugated polymer molecular weight and developing processing protocols were also discussed. D. DeLongchamp (Natl. Inst. of Standards and Technology) focused on using a range of techniques such as electron microscopy, diffraction, and depth profiling to more accurately understand the morphology, giving examples that show how the surface is often not representative of the phase and composition distribution deeper in a material, particularly at interfaces, and how composition and morphology translate into differences in performance—or not. Further down the road of device engineering, A.K.-Y. Jen (Univ. of Washington) examined new design concepts and architectures, presenting an "inverted" structure, which changes the architecture to increase stability and reduce degradation of organic photovoltaics.



A. Heeger (UCSB) gives overview on plastic solar cells.

From the mathematical side, R. Krasny (Univ. of Michigan) honed in on charge transport, using point vortex methods to gain insight into diffusion of charge. S. Mitran (Univ. of North Carolina) presented the need for optimization with a goal of predicting the performance of different geometries, and the need for modeling in three dimensions plus time. Rather than examining incremental changes in geometry, his concept is to use modeling to go in orthogonal directions and broaden the field of possibilities. A concept from the University of California, Merced, modeled nanorods embedded in a photovoltaic to reduce scattering and better capture light by sending it the direction needed. The model used experimental data to inform and optimize design parameters. I. Gamba (Univ. of Texas, Austin) focused on mesoscale modeling using statistical kinetics to look at transport in tuned electrocatalytic nanostructures for solar generation of hydrogen fuel, using an idealized structure.

The workshop culminated in a panel discussion with J.K. McCusker (Michigan State Univ.), D. Moses (UCSB), E.T. Samulski (Univ. of North Carolina) and D. Olson (Natl. Renewable Energy Lab.). While models are still rudimentary compared to the complexity of the solar technologies discussed in this workshop, there are opportunities for collaborations. McCusker said that modeling can have an important role to direct molecular design. Samulski added that it can help correlate molecular structure with measurements. Olson said an additional way that modeling can help is in modeling transport to direct synthesis choices. A further comment was the importance of having mathematicians included in an integral way in research design from the start, rather than just handing off pieces of a project for a mathematician to calculate.

Apparent from the workshop—organized byThuc-Quyen Nguyen of the University of California, Santa Barbara and Michael Brenner of Harvard University—phase separation, charge transport, charge collection, and recombination continue to be important areas for joint solar work incorporating the complementary approaches of materials science, chemistry, and mathematics. The workshop was sponsored by the Division of Mathematical Sciences in the National Science Foundation.

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The final result is a heterostructure with two NWs of equivalent dimensions perfectly lying on top of each other.

In this work, fully or partially oxidized silicon NWs (Si NWs) were used to implement the NWL concept on silicon and graphene. Si NWs in bulk quantities were grown by chemical methods, and dispersed on thin (<100 nm) SOI wafers and on graphene flakes produced on SiO_2 by mechanical exfoliation. The NW morphology was carved into the SOI by selective

Government Seminars Cover Funding for Materials in DARPA, DOE, DHS, NSF, TIP, and NIH

Brian Holloway, a program manager in the Defense Sciences Office (DSO) of the Defense Advanced Research Projects Agency (DARPA), said, "The best way to connect with DARPA is to present revolutionary ideas before they come into vogue within the scientific community. If you read about a new idea, DARPA has probably already considered it. If you see an initiative or problem being worked on [in DARPA], it's almost too late unless you have an extremely novel idea." DARPA seeks high-risk, high-reward proposals to solve problems presented in the agency's call for proposals. The timeline to achieve results is *rapid.* Holloway said that 12–18 months into the funded project, publications will already be seen. He said that future investments in the DSO materials program will continue to explore the frontiers of materials science, which include new science-based tools for the development of new materials, novel materials for energy and water harvesting, new mechanical designs that exploit or challenge new materials and materials systems, and innovative electromagnetic materials that will revolutionize the field of electronics. This aggressive vision to pursue the development of radically new materials and materials systems is producing the critical technologies that will allow for the next generation of high-performance military platforms, he said.

On the other end of the spectrum is the Department of Energy (DOE), which funds curiosity-driven and energy oriented use-inspired research. Linda Horton, director of the Materials Sciences and Engineering Division of the Office of Basic Energy Sciences (BES) in DOE said that BES is interested in fundamental studies with a goal of achieving a paradigm shift for deterministic design and discovery of new materials. Among the highlights of the budget appropriation and funding levels for 2010 are three DOE Energy Innovation Hubs. She also said that an Early Career Research program and a graduate fellowship program were initiated with funding for the first year's awards from the U.S. recovery act known as ARRA.

While DARPA funds projects to assist military personnel, the Department of Homeland Security within the Department of Defense focuses on projects protecting civilians. Eric Houser, project manager from DHS, described the many materials projects and funding opportunities in the Explosives Division, specifically in the Explosive Trace Detection Project. Houser advised materials researchers to team up with an industry partner who will provide the platform for testing, then contact a program manager in DHS to start the proposal process.

U.S. Government Agencies Web Site

Basic Energy Sciences (DOE): www.sc.doe.gov/bes

Division of Materials Research (NSF): www.nsf.gov

DARPA (DoD): www.darpa.mil

DHS (DoD): www.dhs.gov

National Institutes of Health: www.nih.gov/science/ nanotechnologygrants.nih.gov

TIP (NIST): www.nist.gov/tip

Opportunities for materials research funding at the National Science Foundation keep growing and evolving in an attempt to diversify and broaden participation. Zakya Kafafi, director of the NSF Division of Materials Research within the Directorate for Mathematical and Physical Sciences, said that $308.97 million has been requested for her division for FY2010. She discussed the new SOLAR initiative jointly with the Chemistry and Mathematical Sciences Divisions with a budget for $10 million in FY2010 with the expectation of tripling the initial investment in FY2011. She also announced that the Materials Research Science and Education Centers will undergo some restructuring and will include two types of centers: (1) stand-alone interdisciplinary research teams or groups (IRGs), and (2) two or more IRGs with a strong international component. The purpose of restructuring the centers program is to broaden participation and promote creativity and innovation while encouraging international collaborations. Also, the Partnerships for Research and Education in Materials (PREM) program has recently expanded to institutions primarily serving women and people with disabilities. Already in FY2009, the funding for six new programs was made possible from ARRA.

Funding opportunities in materials research are also available through the Technology Innovation Program (TIP) which is part of the National Institute of Standards and Technology. TIP was designed to support, promote, and accelerate innovation through high-risk, high-reward research in areas of critical national need. Tom Wiggins, director of the Selection Management Office for TIP, anticipates that funding in 2010 might continue for projects in civil infrastructure and manufacturing. However, no decisions as to funding have been made for FY 2010 and other areas of interest such as personalized medicine, energy, sustainability, water, and complex networks are under development. It is possible that any of these seven areas of interest could be funded. TIP continues to accept white papers to assist the program to develop ideas for future calls.

Ravi Basavappa of the National Institutes of Health (NIH) presented an overview of support for materials research within the NIH with a focus on nanotechnology. He said that many fundamental biological processes occur at the nanoscale, and to probe and manipulate biological systems at their fundamental length scale, nanoscale approaches are important. In 2008, NIH funded nanotechnology to the tune of $311 million. NIH has in fact established a nanotechnology task force, he said. The current NIH nanotechnology research portfolio includes three large programs of excellence in nanotechnology (PENs) and the National Cancer Institute (NCI) Alliance for Nanotechnology in Cancer. Basavappa said that the majority of NIH's nanotechnology investment occurs at the individual laboratory scale. In terms of funding opportunities, there are currently two broad nanotechnology-related funding programs. NIH is also very interested in environment, health, and safety issues related to nanotechnology.

More information on materials funding can be accessed at the Web sites of the various departments and agencies.

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Paul Drzaic Receives MRS Woody Award

MRS president Shefford Baker (Univ. Minnesota) named Paul Drzaic (Drzaic Consulting Group) as the recipient of the 2009 Woody Award. The award is given in recognition of outstanding service and dedication on behalf of the Materials Research Society as exemplified by Woody White (MRS President, 1984). Drzaic has held a number of volunteer leadership positions, including currently chairing the *MRS Bulletin* editorial board.

Paul Drzaic (left) accepts Woody Award from MRS President Shefford Baker.

Expanding Access to Materials Education

A Tribute to Marni Goldman

Symposium PP on Materials Education was dedicated to the memory of Marni Goldman (1969–2007), who served as the education director of the Center on Polymer Interfaces and Macromolecular Assemblies (CPIMA) at Stanford University. In a tribute to Goldman, Curt Frank, director of CPIMA, said Marni showed what could be done if there was no limit. There *were* limits, he said, but she ignored them in her quest to expand access to the research laboratory for women, students with disabilities, and those with little prior research experience.

Goldman was born with a severe form of muscular dystrophy. Through her own determination and with the support of her family, she opened doors for herself in the field of materials research, then opened those doors wider for others. During the first day of the symposium, many materials educators who have worked with Goldman came to tell their stories and present their projects. Goldman's parents, Michael and Marilyn (Micki) Goldman were among the attendees.

Among the first strides Goldman made was getting access to the University of Pennsylvania, as told by Peter Davies. In those days, he said, there was no wheelchair access, so the university asked what Goldman needed, and the campus became accessible. When Goldman went to UC–Berkeley for her PhD studies, she told Lisa Pruitt that she wanted to do research in the laboratory. Pruitt said she recruited undergraduate students to conduct the laboratory research under Goldman's direction. Since then, the laboratory always includes the contributions of undergraduate students.

Annemarie Ross interned with Goldman at CPIMA. Ross is now on the faculty at the Rochester Institute of Technology/National Technical Institute for the Deaf where, she said, "I have an opportunity to emulate her [Goldman's] magic and become a role model for our future disabled scientists." At RIT/NTID, deaf and hard of hearing students engage in a cooperative workshop experience with industry. The programs at RIT are developed through the industry perspective. Along with the course challenges students have from the associate degree program to the PhD program, and among the usual inhibitions they have going into the work world, Ross said her students have to also overcome communication barriers. Ross said that through the cooperative workshop where students partner with industry, they get the practice they need in navigating communication in the work place while they have the support of their faculty. By the time they enter the workforce, they are already experienced.

Other talks in this session included broader topics of addressing diversity in Science, Technology, Engineering, and Mathematics education to specific examples of tools developed to enable students with disabilities to conduct research. Plans are underway to publish the first proceedings to appear in print from an MRS materials education symposium.

deep-reactive-ion-etching (DRIE), whereas on graphene, a conformal nanoribbon (GNR) was etched by using an oxygen plasma. Colli showed field-effect devices made of a single Si NW or GNR fabricated by NWL. The resulting conformal network etched into the underlying wafer is monolithic, with single-crystalline bulk junctions, and thus does not result in any degradation of conductivity compared to a single NW directly bridging the electrodes. This opens new possibilities for large-area electronics based on nanostructured thin films, irrespective of the material of choice. Colli concluded by extending the potential of the NWL concept into the third dimension. An array of vertically stacked NWs was formed from a single NW mask, revealing a promising line of development for future three-dimensional nano-electronics.

It was evident in Symposium K on Nanotubes and Related Nanostructures that the study of nanotubes and graphene has progressed toward real-time monitoring and atomic-scale detection. In addition, boron nitride (BN) nanostructures have gained increasing attention. Y. Bando and colleagues at the National Institute for Materials Science, Japan, reviewed the properties of polymer composites of BN nanotubes (BNNTs), A. Loiseau and colleagues at the Office National d'Etudes et Recherches Aérospatiales (ONERA) reviewed the study of the optical bandgap of BNNTs, and Y.K. Yap and colleagues at Michigan Technological University reported a series of first discovery on BN nanostructures, including patterned growth of BNNTs by a catalytic CVD approach, a summary of the superhydrophobic properties of vertically aligned BNNTs, and new BN nanostructures such as BN nanoribbons (BNNRs) and heterojunctions of CNTs and BNNTs.

"III–V nanowires suffer from a mixture of crystal structures," said Kimberly Dick, Lund University, citing specific examples in InAs and GaP nanowires. An uncontrollable mixture of crystal structures can result in a high density of stacking defects, leading to uncontrollable device performance, she said in Symposium M on Multifunction at the Nanoscale through Nanowires. Many III–V nanowires have zinc blende (ZB) or wurtzite (WZ) phases, but a mix of these crystal structures along the growth axis of a single nanowire can drastically affect optical properties, cause electron scattering, and/or suppress thermal conductivity in "sawtooth" (twin plane superlattice, TPS) nanowires. "You can imagine, however, if we could [vary the crystal structure] in a controlled way, then we could control the properties," Dick said, and presented many examples

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of such control over crystal structure. Dick showed experimental results of pure WZ structures in small-diameter InAs nanowires, and demonstrated how increasing nanowire diameter can cause increased stacking fault density, eventually forcing a transition to pure ZB structure at larger diameters.

Health and Biological Materials

How does one "deliver the undeliverable?" asked Vladimir P. Torchilin (Northeastern Univ.) in Symposium YY on Compatibility of Nanomaterials. Carriers of drugs into the body serve to protect the body from the drug, protect the drug from the body, and to control the distribution and clearance of the drug. Such control can be a particular challenge, Torchilin said, because delivery is typically through damaged tissue with reduced or a different function. The delivery system needs to use approved components, and the process needs to be simple and scalable, reproducible, and cheap. Drugs, which are poorly soluble, have very low stability in the body, demonstrate fast elimination and/or poor accumulation in the required zone, and are very difficult to convert into acceptable dosage forms, he said. Most delivery systems use liposomes, discovered in 1963, and micelles, discovered in the late 1980s. There are about 40 such drugs on the market and 200 in clinical trials. Solubility is the key, with more than half of potential drugs being abandoned because of lack of solubility, he said. Micelles are of particular interest because they can make insoluble drugs soluble. Micelles prepared from poly(ethylene glycol)-diacyllipids conjugates, such as polyethylene glycol-phosphatidylethanolamine, are of particular interest because they are FDA-approved and versatile. Another approach is the layer-by-layer (LbL) technology, using a coating with alternating layers of nanoparticles of poorly soluble drugs with layers of oppositely charged biocompatible soluble polymers to make stable nanocolloids of many poorly soluble drugs. Such systems can have drug capacities of up to 95%, rather than more typical systems in which only about 10% of the system is the active drug. Torchilin also discussed overcoming issues of stability, shown through the example of polymeric micelles containing a hydrophobized derivative of siRNA. Furthermore, fast clearance can be overcome using block copolymer micelles containing radio-opaque molecules such as heavily iodinated micelles, so that imaging can be done before the drug clears.

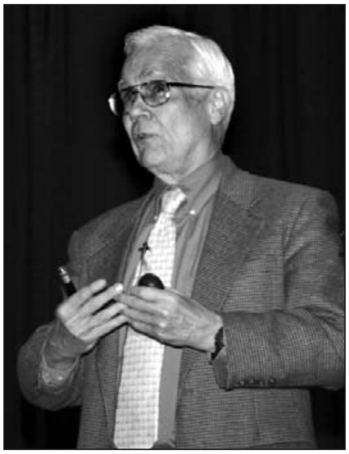
Functional biomaterials are being developed that exhibit unique interactions with cells and tissues. For example, in Symposium VV on Micro- and Nanoscale Processing of Biomaterials, J. Aizenberg (Harvard) described fabrication of nanopillar arrays that serve as actuatable, cell-biomaterial interfaces. Conventional silicon fabrication methods were used to prepare the nanopillar structures; these structures were shown to induce neuron-like morphologies in undifferentiated cells. Undifferentiated cells were manipulated by altering the length and distribution of the nanopillar structures. It is anticipated that tunable nanobiomaterials could serve as bioinductive surfaces, which could be used to direct cell activity in a number of biomedical applications.

R.O. Ritchie (UC–Berkeley) discussed a freeze-casting process used to prepare structures that mimic hierarchical composites found in nature. Ice-templated structures containing alumina and poly(methyl methacrylate) were prepared by manipulation of nanoscale and macroscale features. In these unusual materials, the ceramic phase imparts strength whereas the polymer phase is non-load bearing and serves as a "lubricant" to alleviate locally high stresses. The toughness of these lightweight alumina-based hybrid materials exceeded three hundred times (in energy terms) that of their constituents, with specific strength and toughness properties comparable with metallic aluminum alloys.

In Symposium XX, D. Luo (Cornell Univ.) described their work on developing DNA branching, polymerization and a whole range of other very complex structures built on the design of specific partially matched oligonucleotide sequences. For instance, he detailed the preparation of substrates made of hybrid DNA polymers as sensors and as hydrogels that mimic bacteria environment for the expression and growth of proteins. G. Strouse (Florida State Univ.) described a new synthetic rationale to prepare a wide range of luminescent quantum dots (QDs) made of II–VI and III–V compounds using microwave irradiation. This idea constitutes major progress in the synthesis of colloidal and luminescent QDs. It also offers tremendous flexibility. It is expected that other groups will be able to further use and develop this method and expand it to make other materials.

For further details on the research results reported at the 2009 MRS Fall Meeting, see the symposium summaries posted on the *MRS Bulletin* Web site at www.mrs.org/BulletinF09. Proceedings as well as additional meeting highlights are available at Web site www.mrs. org/F09.

Edward J. Kramer Presents Turnbull Lecture



Edward J. Kramer, Turnbull Lecturer

Edward J. Kramer of the University of California, Santa Barbara, recipient of the David Turnbull Lectureship, actually interacted with David Turnbull in the 1970s. In an interesting format, Kramer interspersed his talk with quotes from Turnbull extracted from his autobiography (the complete autobiography of Turnbull is posted on the MRS Web site at www.mrs.org/David_Turnbull). In recognition of Turnbull's contributions to the modern understanding of phase transitions in materials, Kramer concentrated on phase transitions in a material system not considered by Turnbull: thin diblock copolymer films. A diblock copolymer consists of a block of polymer A joined covalently to a block of polymer B, and even though neither block will crystallize, the AB diblock copolymer in the melt can order into nearly monosized domains of nearly pure A and nearly pure B due to the unfavorable enthalpy of mixing between A and B units constrained by the requirement that the blocks remain covalently bound. The A and B chains are nearly random coils but stretch modestly away from the interface between domains where the joint between the blocks is localized. Films of such diblock copolymers are attracting increasing interest as researchers attempt to extend lithography for microelectronics and magnetic storage media to smaller and smaller dimensions.

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