## Silica-Coated SWNTs Form Unique Nanostructures

Although carbon nanotubes (CNTs) have many properties, such as high thermal and electrical conductivities and mechanical strength, that are advantageous to nanotechnology applications, their strong affinity for one another limits their compatibility with other materials. Dispersal of CNTs in a nanocomposite therefore presents a serious processing challenge. A.R. Barron's research group at Rice University has previously coated single-walled CNTs (SWNTs) with silica, thereby eliminating the undesirable intermolecular attractive forces. However, this method requires the use of cationic surfactants, which are less common than anionic surfactants, because an acidic medium is used. Furthermore, this acidic method produces hydrofluoric acid (HF), which converts some of the silica coating to fluorosilicates. More recently, Barron and R. Colorado, both from the Department of Chemistry and Center for Nanoscale Science and Technology at Rice, have developed a method of coating SWNTs with silica under basic conditions that are free of HF and can make use of the more common anionic surfactants.

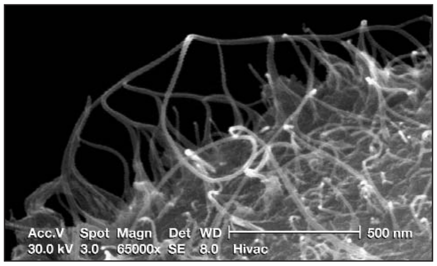


*Figure 1. Scanning electron micrograph showing a complex structure consisting of welded $SiO_2$–single-walled carbon nanotubes. Reprinted with permission from* Chem. Mater. ***16*** *(14) (July 13, 2004) p. 2692. ©2004 American Chemical Society.*

As reported in the July 13 issue of *Chemistry of Materials* (p. 2691), the researchers adapted a previously published method for forming silica spheres and suspended SWNTs with a basic sodium silicate solution. Addition of ethanol induces the formation of silica acid, $Si(OH)_4$, which quickly condenses onto SWNT surfaces to form polysilicic acid, that is, amorphous silica. The suspension consists of individual and bundled SWNTs, so the coated structures consist of individual and bundled SWNTs as well. Colorado and Barron also prepared films that they said formed mats composed of overlapping and interwoven coated tubes and bundles. The researchers said that scanning electron microscopy revealed a variety of unique nanostructures, including loops, curls, interconnects, and bridging structures (see Figure 1). Furthermore, the researchers showed that the coating process effectively fastens short tubes together to form longer structures. Colorado and Barron said that they are now "examining the potential of solution-based methods of producing silica-coated SWNTs and mats for manipulating conducting/semiconducting SWNTs and insulating coatings to assemble useful nanoelectronic devices."

STEVEN TROHALAKI

## Novel Liquid-Crystal Phases Formed with Introduction of Chirality

Smectic liquid-crystalline systems are molecular structures whose constituent molecules are arranged in a series of layers with the molecules' axes perpendicular to the plane of the layers. The introduction of chiral, or "handed," compounds into such a system can lead to a wide variety of helical, polar, and frustrated macrostructures. I. Nishiyama of the Yokoyama Nanostructured Liquid-Crystal Project at JST in Japan, J.W. Goodby of the University of Hull, and their colleagues have recently demonstrated how the introduction of chirality into smectic liquid crystals can lead to novel liquid-crystal phases.

As reported in the August 24 issue of *Chemistry of Materials* (p. 3212), Nishiyama, Goodby, and JST colleagues J. Yamamoto and H. Yokoyama have investigated the molecular assembly of mixtures of the *R* and *S* chiral enantiomorphs (handedness) of bis{4′-(1-methylheptyloxycarbonyl)biphenyl-4-yl}alkanedioates. Five homologues of this chiral molecule can be distinguished: SS*n* (*n* = 2–5) and RR*n* (*n* = 4), each of which demonstrates a different phase-transition behavior.

All forms of this enantiomorphic compound are present as an isotropic liquid at temperatures above ~105°C and as a smectic liquid crystal at sufficiently low temperatures. Beyond that, interesting new phase transformations were observed, depending on the chiral composition of the materials. The even-membered chiral molecules (SS2, SS4, and RR4) were seen to transition into a mesophase, denoted as $M_2$, that exhibited a striped "parquet-like" texture. In addition, SS4 and RR4 formed another mesophase ($M_1$) between the isotropic liquid phase and $M_2$. This $M_1$ phase is characterized by its optical isotropy, regardless of orientation. Peaks observed during differential scanning calorimetry (DSC) experiments verify that $M_1$ and $M_2$ are thermodynamically real phases rather than simply transient or metastable molecular organizations. Furthermore, these phases represent "highly chiral" versions of the conventional antiferroelectric phase observed at intermediate temperatures. The SS4–RR4 phase diagram (Figure 1) summarizes the compositional and temperature features of this enantiomorphic liquid-crystal system.

X-ray diffraction (XRD) analysis of the $M_1$ and $M_2$ phases showed only broad scattering features, indicating a liquidlike short-range order in both. The pattern obtained from $M_1$, the optically isotropic phase, is a ring of scattered intensity, indicating the possible formation of a layered structure. In contrast, discrete diffraction spots are observed for the $M_2$ phase, indicating that the assembled molecules with "parquet-like" texture have some three-dimensional (3D) crystalline order as well. These results were further investigated by measuring the frequency dependence of Young's modulus for the two mesophases. $M_2$ clearly demonstrated elastic behavior, consistent with the previously assigned 3D structure. $M_1$, on the other hand, had no elasticity, ruling out the existence of a layered or 3D structure. Although the nature of the structure remains unclear, the researchers suggested a "sponge" phase of randomly interconnected layer planes as a possibility. The combined results of DSC, XRD, and mechanical testing confirm the existence of new liquid-crystalline phases produced by the introduction of chirality into a smectic system.

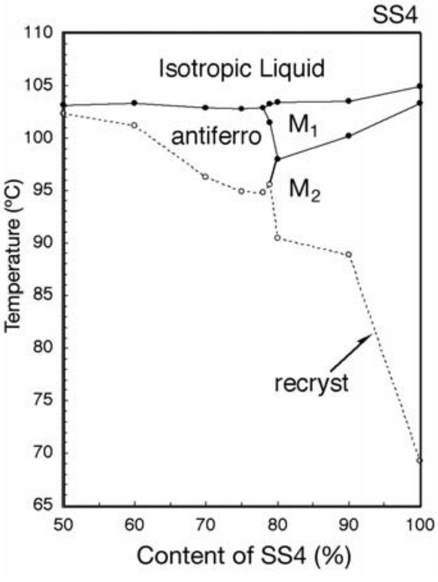


*Figure 1. Phase diagram between chiral molecule SS4 and the racemic mixture (SS4:RR4 = 1:1). Reprinted in part with permission from* Chem. Mater. ***16*** *(17) (August 24, 2004) p. 3213. ©2004 American Chemical Society.*

ANDY FRANCIS

## High-Strength Reticulated Porous Ceramics Fabricated by Two-Step Centrifuge Process

Reticulated porous ceramics (RPCs) are technologically important materials for a wide range of applications, including supports for space mirrors, molten metal fillers, catalyst supports, and heating elements. High-temperature stability and excellent thermal shock resistance are the properties responsible for their use in such diverse applications. RPCs are typically produced by the impregnation of a polyurethane sponge with a ceramic slurry. After slurry removal and drying, the sponge is burned out and the ceramic skeleton (struts surrounding pores) is sintered at high temperature followed by pressing. However, with traditional techniques such as the roll-press process, uniform, flaw-free structures are difficult to produce. X. Pu, X. Liu, F. Qiu, and L. Huang of the Chinese Academy of Sciences in Shanghai have developed a two-step process to increase the strength and further enhance the applications of RPCs.

The researchers used β-silicon nitride powder (mean particle diameter, $d_{50}$ = 3 μm) as the matrix material, with 7 wt% alumina ($d_{50}$ = 0.62 μm), 23 wt% silica sol, 1.5 wt% carboxymethylcellulose, and 0.2 wt% of Nopco 267-A, used as the sintering aid, binder, thickening agent, and antifoaming agent, respectively.

These results are reported in the July 2004 issue of the *Journal of the American Ceramic Society* (p. 1392). In the first coating stage, the polyurethane sponge was immersed in the ceramic slurry, compressed to ensure all pores were filled, and centrifuged to remove excess slurry. After drying the preform, the previous procedure was repeated. According to their results, the two-step process increases the structural integrity of the RPC due to enhanced adhesion between the body and slurry after the first coating. Pu and co-workers compared the weight of the sample between coating procedures and observed a twofold increase after the second coating procedure. To maintain structural integrity during centrifuging, the researchers suggested that the recoating step be done as quickly as possible.

According to Pu, the strut diameter and coating uniformity is strongly influenced by the viscosity of the slurry, especially after the second coating procedure. Optical photographs of the samples, taken after coating with slurries of various viscosities, show the increase in strut diameter and coating uniformity after the second coating. Furthermore, more viscous slurries produced thicker, more uniform struts with fewer flaws. The researchers said that in contrast to conventional processing techniques, this two-step process should also be successful in fabricating RPCs of irregular shape.

JEREMIAH T. ABIADE

## Cracks in Rubber Propagate Faster than the Speed of Sound

Since the classical work by Griffith, Inglis, and Irwin on the physics of cracking, one of the most fundamental questions associated with crack dynamics is the maximum speed that cracks can propagate. Depending on the type of loading (e.g., tensile, shear, or antiplane shear), there is a unique maximum speed cracks can achieve. For tensile-loaded cracks, theory predicts that this limiting speed is the Rayleigh wave speed, the speed of elastic waves on a surface. Recent theoretical work, including atomistic simulations, has challenged this classical view. Now, P.J. Petersan and co-workers from the University of Texas at Austin have shown experimentally that tensile-loaded cracks in rubber can actually propagate faster than the Rayleigh wave speed and even break the sound barrier.

As reported in the July issue of *Physical Review Letters* (105504), Petersan and colleagues identified the intersonic crack speed by the observation of shock fronts near the crack tip by high-speed photography (see Figure 1). The experiments were conducted using highly stretched sheets of rubber. In this nonlinear material, cracks in tension (mode I) exceeded the shear wave speed and traveled in the intersonic range between shear and longitudinal wave speeds. These results have important implications for understanding fundamental crack dynamics, demonstrating that the classical understanding of crack dynamics needs to be revised.

What is the physical explanation for this phenomenon? Through observations made earlier in large-scale molecular dynamics simulations, M.J. Buehler and H. Gao of Max Planck Institute, Stuttgart, and F.F. Abraham of Almaden Research Center in San Jose discovered that hyperelasticity (i.e., the elasticity of materials at large strains), although mostly neglected in existing theories of fracture, is crucial in understanding crack dynamics. In their article published in the November 13, 2003, issue of *Nature* (p. 141), Buehler and colleagues hypothesized that energy flow toward a crack tip occurs in a region whose size is described by a so-called characteristic energy length scale $\chi$. This length scale competes with the size of the hyperelastic region. If the size of the region of energy flow $\chi$ is comparable to the size of the hyperelastic region ($r_H$), energy flow is completely dominated by the local large-strain or hyperelastic properties.

"For instance," Buehler said, "if material stiffens with strain as in the case of rubber used in Petersan's experiments and in the molecular dynamics simulations, energy flow is enhanced because of the stiffer material properties, and cracks can thus break through the sound barrier. The observation of intersonic mode I cracks in rubber seems to be an example for the importance of hyperelastic effects in real materials. "

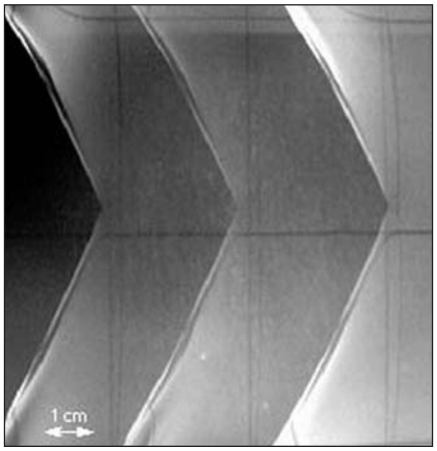


*Figure 1. Multiple-exposure photograph of a crack propagating in a rubber sample ($\lambda_x = 1.2$, $\lambda_y = 2.4$); speed of the crack, ~56 m/s.*

Petersan said, "We agree that the rupture of rubber opens up a new regime in the study of fracture and look forward to understanding the mechanism which explains it."

## Fluorine-Containing Molecules Serve as Structure-Directing Agents in Synthesis of Molecular Sieves

Water-soluble organic molecules have been used as structure-directing agents (SDAs) in the synthesis of zeolites. By filling the cavities in the material, these molecules direct the hydrothermal crystallization of zeolite and zeolite-like materials. Usually, hydrogen atoms attached to the organic molecules are in charge of the chemical interaction with the zeolite inorganic framework. By replacing hydrogen atoms with fluorine atoms as SDAs, J. Pérez-Pariente and colleagues at the Instituto de Catálisis y Petroleoquímica, Spain, significantly changed the surface properties of their zeolites.

As reported in the August 24 issue of *Chemistry of Materials* (p. 3209), the researchers prepared a group of fluorine-containing SDAs such as 1-(fluorobenzyl)-pyrrolidine (F-PB) and difluorinated dibenzyldimethyl-ammonium cations (DBDM) by reacting *o*-, *m*-, or *p*-fluorobenzyl chloride with pyrrolidine, dimethylamine, or benzyldimethylamine. Inorganic gels and SDAs (1:1:1:$x$:40 $R:Al_2O_3:P_2O_5:SiO_2:H_2O$, where R is the SDA and $x$ is 0 for alumino-phosphate, AlPO, and 0.5 for silico-alumino-phosphate, SAPO, gels) were heated at 150ºC for 72 h. Another silica gel (0.54:0.54:1:7.93 $R:HF:SiO_2:H_2O$) with the quaternary monofluorinated DBDM cations was heated at 135ºC for 46 days in a fluoride medium. The control material AlPO-5 (AFI), which is an aluminophosphate with 12MR (12-membered ring) one-dimensional channels, was made from benzylpyrrolidine (BP).

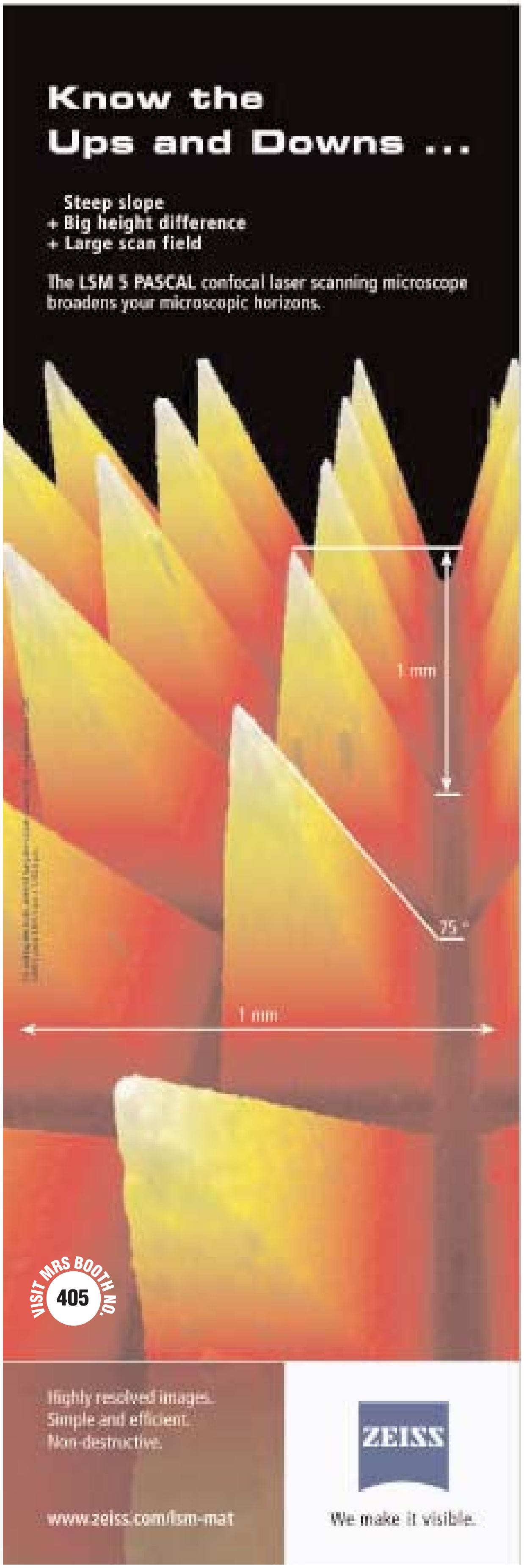
X-ray diffraction patterns of the different materials revealed that the nature and crystallinity of the monofluorinated derivatives used as SDAs depended strongly on the position of the fluorine atom in the aromatic ring. The crystallinity of the materials was found to be higher when fluorine was in the *meta*-fluoro (mF) position rather than in the *para*-fluoro (pF) position, and the stability of the AlPO-5 crystal (framework code type AFI) structure with different SDAs follows the order mF-BP > BP > oF[*ortho*]-BP >> pF-BP. The researchers said that the *meta*-fluoro derivative served as the best template because of the electrostatic interactions between the fluorine atom and the inorganic zeolite pore; the *ortho*- and *para*-fluoro derivatives showed poor crystallinity of the AFI phase in the product due to the structural hindrance. Magic angle spinning nuclear magnetic resonance data showed that the template molecules were intact inside both zeolites (DBDM), which were made in a fluoride medium, and AFI(BP) materials.

LUCY YUE HU

## Flame-Spraying Technique Yields Aluminate Bulk Glasses and Nanoceramics

Alumina, $Al_2O_3$, is the basis of a number of important ceramic systems. It is desirable to form alumina-rich bulk glasses because of their superior mechanical, chemical, and optical properties. However, it is very difficult to form bulk glass from pure alumina liquid, a reluctant glass former, because of the extremely high cooling rates required, typically in the range of $10^7$ K $s^{-1}$. The addition of rare-earth oxides reduces the cooling rates to under $10^3$ K $s^{-1}$, which is still too high to obtain glasses with dimensions of more than a few millimeters. A. Rosenflanz and co-workers at 3M in Minnesota have utilized a flame-spraying technique to generate glass beads that contain 80 mol% alumina (the balance is rare-earth oxide). They then sintered the beads, yielding bulk alumina glass with the appropriate shape. Devitrification of the bulk glass using heat treatment resulted in a nanoceramic with twice the hardness of the original bulk glass.

As Rosenflanz and colleagues reported



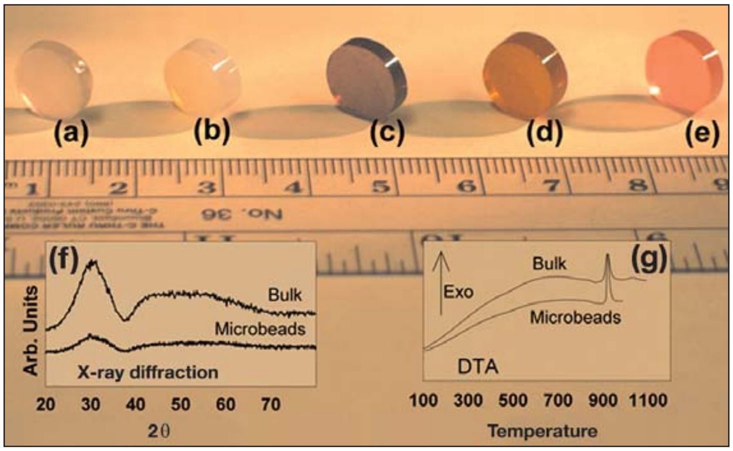


*Figure 1. Bulk rare-earth aluminate glasses with the ALZ composition formed using the method described. No dopants were used for samples (a) and (b), while 5 wt% $Nd_2O_3$, $Eu_2O_3$, and $Er_2O_3$ were used for samples (c), (d), and e), respectively. Image (f) shows x-ray diffraction patterns, while (g) shows differential thermal analysis data for the microbead and bulk forms, revealing their amorphous nature and similar thermal behavior. Reprinted with permission from* Nature ***430*** *(August 12, 2004) p. 762. ©2004 Nature Publishing Group.*

in the August 12 issue of *Nature* (p. 761), binary eutectic compositions of alumina and rare-earth oxide ($Al_2O_3$-$RE_2O_3$, RE = La, Gd, Y) as well as $Al_2O_3$:$RE_2O_3$:$ZrO_2$ (ALZ) ternary compositions were investigated. In their flame-spraying technique, particulate precursors were fed into a high-temperature hydrogen–oxygen flame, producing molten particles that were then quenched in water. Glassy beads of the material with diameters of less than 140 μm were obtained. Beads with diameters in the range of 75–109 μm (selected by sieving) were consolidated into bulk glasses by sintering the beads at a temperature within the kinetic window—between $T_g$ (the glass-transition temperature) and $T_x$ (the crystallization temperature). X-ray diffraction, differential thermal analysis, optical microscopy, and scanning electron microscopy revealed that the bulk glass that formed remained amorphous and transparent (see Figure 1).

The alumina-rich bulk glass was then heated above $T_x$ for a short time to form a nanoscale glass–ceramic as a result of simultaneous crystallization and grain growth. The final microstructure contained ~100 nm crystalline grains, a finer and more homogeneous microstructure than that obtained using traditional methods. The glass–ceramics formed in this way also showed superior chemical, mechanical, and optical properties, as compared with silica-based glasses.

This technique yielded alumina-based glass–ceramic composites with superior fracture toughness, important for potential structural applications. This discovery of glass-forming ability and glass-converted nanoscale ceramics can be extended to other nonconventional bulk oxide systems as well, so long as a sufficiently wide kinetic window $\Delta T_x = T_x - T_g$ is available. The method could pave the path to numerous bulk oxide glasses and nanocrystalline ceramics.

GOPAL RAO

## Composite Polymer–Carbon Nanotubes Function as Optoelectronic Memory Devices

In the past few years, interest in making nanoscale electronic devices from carbon nanotubes has skyrocketed, with the hopes of making devices that are smaller and more versatile. In the September issue of *Nano Letters* (p. 1587), A. Star from Nanomix Inc., G. Grüner from the University of California, Los Angeles, and co-workers report the fabrication and characterization of carbon nanotube optoelectronic devices made by using two different methods, both of which employ light-sensitive polymers and carbon nanotubes on silicon wafers. In one method, Au/Ti contacts were patterned on silicon wafers, and then a composite of polymer and nanotubes was deposited. In the second method, nanotubes were grown by chemical vapor deposition on a silicon wafer, then Au/Ti contacts were patterned, and finally the polymer was deposited. Both methods produced light-sensitive nanotube field-effect transistors (NT-FETs). However, NT-FETs fabricated by the second method also work as optoelectronic memories that can be controlled independently, as shown by the change in spectral response of the device using various polymers with unique light absorption characteristics.

Using the second method, a layer of either PmPV, poly{(m-phenylene-vinylene)-co-[2,5-dioctyloxy-*p*-phenlyene)vinylene]}, or P3OT, poly(3-octylthiolphene-2,5-diyl), was deposited over the contacts/nanotubes by drop-casting a solution of the polymer in $CHCl_3$. The optoelectronic memory device functions in a two-step sequence: The polymer layer absorbs incoming photons and converts them to excitons, after which the hole is transferred to the carbon nanotubes, preventing or delaying its recombination with the electron; these charged nanotubes then serve as electrodes to read and erase stored charge.

This novel research is a marked change from previously reported nanotube-based optical devices because the photons are directly absorbed by the polymer, as opposed to previous works that utilize the band absorption of nanotubes or photodesorption of molecular species. When devices are fabricated with both types of polymer, PmPV and P3OT, on neighboring devices, distinct and independent absorption behavior is observed, as shown in the current-versus-time response to light illumination of the modified NT-FETs (Figure 1). Therefore, depending on the type of light-sensitive polymer used for the coating, the nanodevices can be tuned independently.

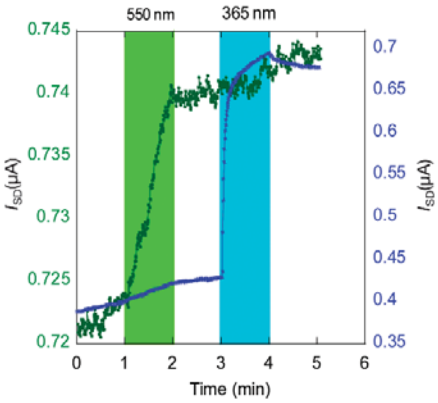


*Figure 1. Optoelectronic response to light of nanotube field-effect transistors coated with PmPV (blue trace) and P3OT (green trace). Shaded regions (blue: UV light, λ = 365 nm; green: visible light, λ = 550 nm) and unshaded regions mark the light-on and -off periods, respectively. Reprinted in part with permission from* Nano Lett. ***4*** *(9) (September 8, 2004) p. 1590. ©2004 American Chemical Society.*

Although the electronic properties of these devices exhibit long-term changes in state as a result of illumination, they can be reset electronically by sweeping the gate voltage. The researchers said that these optical sensors may find application as replacements for charge-coupled devices in high-speed cameras.

ADITI S. RISBUD

## News of MRS Members/Materials Researchers

**Siamak Akhlaghi**, project scientist at Micralyne Inc. (Edmonton, Alberta, Canada), has received the **Silver Abner Brenner Award** from the American Electroplaters and Surface Finishers Society (AESF) for the best paper published in the *Plating and Surface Finishing Journal* during the year 2003. The award-winning article, "Effect of Processing Parameters on the Electroplating of Au-Sn Solders," focuses specifically on a co-electroplating process that has been developed for depositing Au/Sn alloys, from a slightly acidic, chloride-based solution using pulsed currents, onto patterned or blanket metallized ceramic and semiconductor substrates.

**Robert J. Birgeneau**, physicist and currently president of the University of Toronto, has accepted the position of chancellor of the University of California, Berkeley. He expects to begin his tenure in October. Outgoing chancellor Robert M. Berdahl has held the position for seven years and will join the UC–Berkeley faculty.

**Howard E. Katz**, 2004 MRS President, has accepted a position as a professor of materials science and engineering at Johns Hopkins University's Whiting School of Engineering, beginning this fall. Katz has been a Distinguished Member of Technical Staff at Bell Laboratories,

where he began his independent career in 1982.

**Jagdish (Jay) Narayan** (North Carolina State University) has received the **2004 Edward DeMille Campbell Memorial Lecture and Prize** of ASM International. He will deliver the Campbell lecture, "New Frontiers in Thin-Film Growth and Nanomaterials," at the ASM International Meeting in October in Columbus, Ohio.

**Kyoko Nozaki** (University of Tokyo) has received the John Wiley & Sons Inc. and the Society of Polymer Science, Japan (SPSJ), **2004 SPSJ–Wiley Award** for the article "Asymmetric Synthesis of Optically Active Polymers Catalyzed by Metal Complexes."

**Bob R. Powell** (GM Research and Development Center) has received the **GM 2003 John M. Campbell Award** for "fundamental studies of creep deformation in magnesium alloys."

**Takeo Sasaki** (Science University of Tokyo) has received the John Wiley & Sons Inc. and the Society of Polymer Science, Japan (SPSJ), **2004 SPSJ–Wiley Award** for the article "Photorefractive Effect of Liquid-Crystalline Materials."

**Robert L. Snyder** (Georgia Institute of Technology) has received the **2004 J.D. Hanawalt Award** from the International Centre for Diffraction Data (ICDD) in recognition of excellence in the field of x-ray powder diffraction.

**Winnie Wong-Ng** (National Institute of Standards and Technology) has received the **2004 McMurdie Award** from the International Centre for Diffraction Data (ICDD) in recognition of her contributions to the computer-aided evaluation of x-ray powder patterns and editing of the Powder Diffraction File, as well as her work in enhancing the accuracy of powder methods of x-ray crystallography.

**The National Academy of Engineering (NAE)** announced its list of innovative young engineers (ages 30–45) performing cutting-edge engineering research and technical work in a variety of disciplines selected to participate in the 10th annual Frontiers of Engineering symposium held in September, including MRS members:

**Cameron Abrams**, Drexel University

**Valerie Leppert**, University of California, Merced

**John Muth**, North Carolina State University

**Hock Hg**, Bell Laboratories, Lucent Technologies

**Shawn Phillips**, Air Force Research Laboratory Propulsion Directorate

**Sujatha Ramanujan**, Eastman Kodak Co.

**Ainissa Ramirez**, Yale University

**Yang Shao-Horn**, Massachusetts Institute of Technology

## News of MRS Corporate Affiliates/Materials Institutions

The **Center for Biological and Environmental Nanotechnology** at Rice University (Houston, Texas) has received a $100,000 grant from the National Science Foundation to develop an introductory nanotechnology course titled "Nanotechnology: Content and Context," that is being offered jointly by the Departments of Chemistry and Anthropology this fall (*www.ruf.rice.edu/~cben*).

The **Center for Optical Materials Science and Engineering Technologies (COMSET)** at Clemson University was recently named a South Carolina Research Center of Economic Excellence and approved for a $10 million endowed professorship in optical materials (*http://comset.clemson.edu*).

The **Facilities for Materials Characterization** recently opened at Dalhousie University, Halifax, Nova Scotia, Canada, and are managed by the university's Institute for Research in Materials. The organization was developed to enhance the ability of academic, government, and industrial researchers to characterize materials (*www.irm.dal.ca/fmc.html*).

**FEI Company** announced that the **Ernst Ruska Center for Microscopy and Spectroscopy with Electrons** (Jülich, Germany) has selected it as a partner for developing the "next era of analytical microscopy" (*www.feicompany.com; www.er-c.org*).

**Hysitron Inc.** (Eden Prairie, Minn.) and **Lawrence Berkeley National Laboratory** (Livermore, Calif.) have been awarded a Department of Energy (DOE) Small Business Innovation Research (SBIR) grant for developing a quantitative *in situ* transmission electron microscope (TEM) nanoindentation apparatus. The purpose of this product is to quantitatively measure load and displacement with real-time TEM imaging in order to study the mechanical response of materials under stress or strain (*www.hysitron.com; www.llnl.gov*).

The **Oregon Nanoscience and Microtechnologies Institute (ONAMI)** held its grand opening in May 2004. ONAMI conducts research in nanoscience, materials characterization, microfluidics, and microfabrication and applies the research to both short- and long-term commercial opportunities. The institute is a combined effort of universities, high-tech industry, and national laboratories in Oregon. The facilities will be housed at the University of Oregon, Oregon State University, and Portland State University (*www.onami.us*).

**Rapra Technology** (Shrewsbury, U.K.), an independent polymer research and test house, has introduced a service called "polymer contents." There is no charge for this service, and it is custom-created to the needs of individual subscribers. Every month Rapra abstracts 400 journals, conference papers, and other publications. A digest of this information is available at http://www.polymercontents.com (*www.rapra.net*).

The **University of Oregon** (Eugene) has received a grant from the National Science Foundation to purchase a new scanning electron microscope configured for electron-beam lithography. The new system will upgrade and expand the capabilities of CAMCOR (the Center for Advanced Materials Characterization in Oregon), the university's nanoscience and materials science characterization and fabrication facility, which is open to researchers both on- and off-campus (*http://materialscience.uoregon.edu/*). ☐