conductance to an additional DNA molecule forming a junction. They said, however, that conductance steps do not always have the same values, which reflect microscopic differences in the DNA–electrode contacts. The researchers therefore took more than 500 measurements and constructed a conductance histogram in which they found peaks that occur at multiples of $1.3 \times 10^{-3} G_0$. Conductance histograms of other DNA duplexes also displayed peaks, but at multiples of different values. For $(GC)_n$, the researchers found that the conductance is a linear function of reciprocal DNA duplex length, measured in base pairs. The conductance of the $CGCG(AT)_mCGCG$ duplexes does not decrease nearly as slowly with length as the conductance of the (GC) duplexes and can be fit by a function of the form $\mathbf{A}\exp(-\beta L)$, where $\mathbf{A}$ $(1.3 \times 10^{-3} G_0)$ and β $(0.43 \pm 0.01\ \text{Å})$ are constants and L is the length of the AT segment.

The researchers said that their findings are consistent with previously published models that describe charge transport in DNA as a tunneling-like process for short DNA and a hopping-like process for relatively long DNA duplexes.

Tao said, “The sensitive dependence of the conductance on the DNA sequence suggests the possibility of reading the chemical information of DNA via direct conductance measurement.”

STEVEN TROHALAKI

Diatom Frustules Serve as Scaffolds for 3D Polymeric Structures with Nanoscale Features

Shape-tailored microscale polymeric structures with feature sizes down to the nanoscale are becoming increasingly important for various applications, such as in microelectromechanical systems. Current techniques, such as lithographic-based layer-by-layer fabrication, are not well suited for the production of three-dimensional polymeric structures with complex shapes. In addition, large numbers of polymeric structures with a specific shape need to be created. C. Gaddis and K. Sandhage of the Georgia Institute of Technology have now demonstrated a technique that uses diatoms—single-celled algae—as scaffolds to form free-standing microscale polymeric structures. Diatoms have amorphous silica nanoparticle-based rigid cell walls (frustules). In this study, a thin (submicron) polymeric coating was applied to diatom frustules. The underlying silica frustules were then dissolved, leaving behind the polymer with the shape and features of the diatoms.

Diatom frustules come in a wide range of shapes with nanoscale features. They can be precisely replicated in a massively parallel manner with ease. The frustules used in this study, as reported in the *Journal of Materials Research* (Web release date of accepted preprint, July 1) had hollow cylindrical shapes with diameters of 8–12 µm and mesoscale pores with diameters of several hundred nanometers in rows along the cylinder length. After being cleaned, the diatom frustules were dipped in a coating solution containing a two-part, 5-min-curing epoxy mixture dissolved in acetone. After evaporation of the acetone, the epoxy was allowed to cure. The concentration of the epoxy in the solution was adjusted to obtain a coating that preserved the pores and fine features of the diatom frustules. The coated frustules were then dipped in hydrofluoric acid to dissolve the silica diatom shells, leaving behind the polymer coatings in the shape of the diatoms (see Figure 1). Gaddis and Sandhage found the polymer structures to be very similar in morphology to the starting diatom frustules.

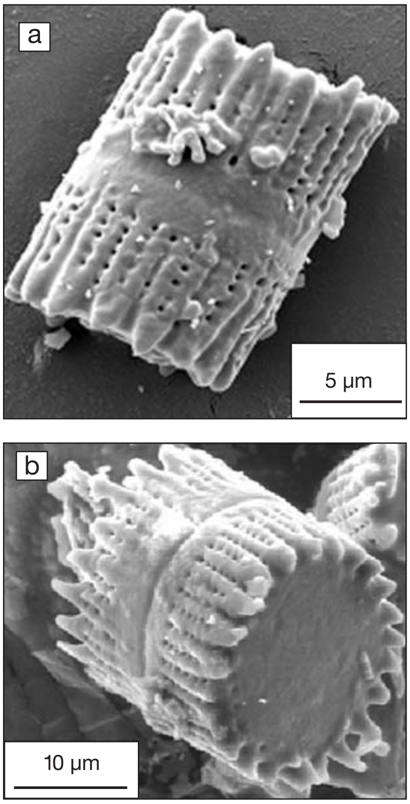


Figure 1. (a) Secondary electron image of a silica-based diatom frustule used as a transient scaffold; (b) secondary electron image of an epoxy structure derived from a diatom frustule scaffold. Reproduced with permission from the Journal of Materials Research.

In addition to diatom species, other self-replicating biomineralized micro- and nanostructures (such as microshells and sponges) can be used to yield various 3D polymeric shapes with desired morphologies. The technique is not limited to naturally available diatoms or biomineralizing organisms. According to the researchers, genetic engineering could be used in the future to produce replicable bioscaffolds with non-natural shapes. The polymeric coatings are not confined to epoxy-based compositions. Other polymer structures can be produced, so long as a dilute coatable solution can be formed and the underlying scaffold can be removed, leaving the polymer structure intact without being affected by the selective dissolution treatment. Upon scaleup, the researchers said, the current process can be used to produce large quantities of inexpensive three-dimensional polymer micro/nanoscale structures for use in various biomedical, chemical, catalytic, photonic, aerospace, and other applications.

GOPAL RAO

C_{60}-Based Organic Diode Performance More than 100× Better than Other Organic Semiconductor Devices

In recent years, organic semiconductor devices (OSDs) have found increasing practical applications in displays, transistors, lasers, memory, and diodes. So far, however, their performance has lagged far behind their inorganic counterparts, particularly with respect to response speed and current density. L.P. Ma, J.Y. Ouyang, and Y. Yang of the University of California, Los Angeles, have achieved a more than 100-fold improvement in response speed and current density, compared with common OSDs, with their C_{60}-based organic diode, formed with one ohmic contact and one rectifying contact. As reported in the June 7 issue of *Applied Physics Letters* (p. 4786), the researchers used a C_{60} electron acceptor layer sandwiched between a Cu cathode and an Al anode; they heat-treated the device for 5 min at 120°C to achieve the huge leap in performance.

The scientists fabricated the organic diodes by first depositing Cu using thermal vacuum deposition onto a smooth glass substrate followed by C_{60} (100 nm thick) and Al, creating a 0.0625 mm^2 device. Only after the heat treatment did the scientists measure injection current densities of 363 A/cm^2 at 2.4 V and 1 MHz current responses. Previous attempts to

Review Articles…

Applied Mechanics Reviews **57** (3) (May 2004) contains A.C.J. Luo, "Nonlinear Dynamics Theory of Stochastic Layers in Hamiltonian Systems," p. 161; J. Yang and Y. Hu, "Mechanics of Electroelastic Bodies under Biasing Fields," p. 173; and V. Singhal, S.V. Garimella, and A. Raman, "Microscale Pumping Technologies for Microchannel Cooling Systems," p. 191.

Geophysics **69** (3) (May–June 2004) contains J. Spetzler and R. Snieder, "The Fresnel Volume and Transmitted Waves," p. 653.

Journal of Materials Research **19** (7) (July 2004) contains G. Witte and C. Woll, "Growth of Aromatic Molecules on Solid Substrates for Applications in Organic Electronics," p. 1889; W.R. Salaneck and M. Fahlman, "Hybrid Interfaces of Conjugate Polymers: Band Edge Alignment Studied by Ultraviolet Photoelectron Spectroscopy," p. 1917; H. Hoppe and N. Serdar Saraciftci, "Organic Solar Cells: An Overview," p. 1924; G. Horowitz, "Organic Thin-Film Transistors: From Theory to Real Devices," p. 1946; W. Clemens, W. Fix, J. Ficker, A. Knobloch, and A. Ullmann, "From Polymer Transistors Toward Printed Electronics," p. 1963; and J.R. Sheats, "Manufacturing and Commercialization Issues in Organic Electronics," p. 1974.

Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures **22** (4) (July 2004) contains R.J. Colton, "Nanoscale Measurements and Manipulation," p. 1609.

Review of Scientific Instruments **75** (7) (July 2004) contains N.V. Lavrik, M.J. Sepaniak, and P.G. Datskos, "Cantilever Transducers as a Platform for Chemical and Biological Sensors," p. 2229.

Semiconductors **38** (6) (June 2004) contains T.L. Makarova, "Magnetic Properties of Carbon Structures," p. 615.

…and Special Issues/Sections

IEE Proceedings G: Circuits, Devices and Systems **151** (3) (June 2004) is a special issue containing selected papers from the 15th International Symposium on Power Devices and Integrated Circuits (ISPSD '03).

IEEE/ASME Transactions on Mechatronics **9** (2) (June 2004) contains a focused section on micro- and nanomanipulation.

IEEE Journal of Selected Topics in Quantum Electronics **10** (2) (March–April 2004) is a special issue on optical communications.

IEEE Journal of Solid-State Circuits **39** (7) (July 2004) is a special issue containing selected papers from the European Solid-State Circuits Conference.

IEEE Transactions on Semiconductor Manufacturing **17** (2) (May 2004) contains a special section including papers from the 2003 International Conference on Microelectronic Test Structures (ICMTS).

Journal of Materials Research **19** (7) (July 2004) is a special focus issue on organic electronics.

Journal of Modern Optics **51** (12) (August 15, 2004) is a special issue containing the proceedings of the Symposium on Quantum Challenges 2.

Journal of Physics and Chemistry of Solids **65** (8–9) (August–September 2004) is a special issue containing papers on "Inhomogeneous and Strongly Correlated Materials" and contains selected papers from the International Conference on the Study of Matter at Extreme Conditions.

Journal of Spacecraft and Rockets **41** (3) (May 1, 2004) contains a special section on "Space Environmental Effects on Materials," including selected papers presented at the 6th International Conference on Protection of Materials and Structures from the Space Environment (ICPMSE-6).

Microelectronics Reliability **44** (7) (July 2004) contains a special section including five papers that were presented at the 2003 GaAs REL (Reliability) Workshop.

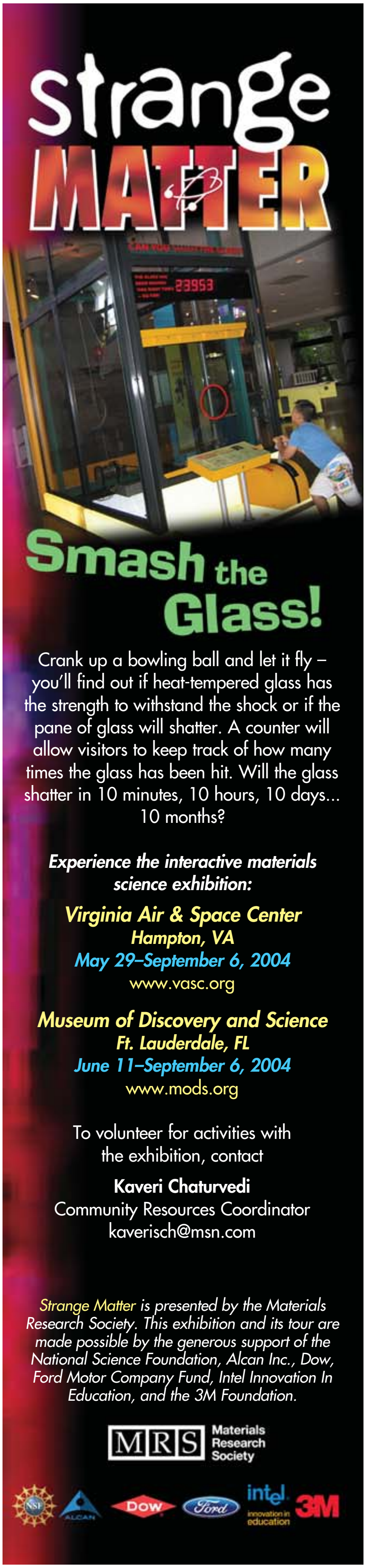
Optical Engineering **43** (7) (July 2004) contains a special section on illumination engineering.

Optical Materials **26** (2) (July 2004) is a special issue containing the proceedings of the Second International Conference on Sol–Gel Materials: Research, Technology, Applications (SGM'03).

Powder Diffraction **19** (2) (June 2004) contains a special section on microanalysis.

Proceedings of the IEEE **92** (7) (July 2004) is a special issue on "Pulsed Power: Technology and Applications."

Solid-State Electronics **48** (9) (September 2004) is a special issue containing papers from the European Workshop on Nonvolatile Memories with Discrete Storage Nodes.



develop organic diodes have resulted in devices with maximum frequency response of no more than 10 kHz and with output current densities of less than 1 A/cm^2 under an applied ac voltage. Since response speed is governed by the capacitance of a device, the researchers predict that reduced device areas will yield a 10-fold or more improvement in response time when scaling the device to micron-scale dimensions.

The scientists attribute the enhanced performance to the heat treatment, prior to which the performance was poor. They believe that the heat treatment causes the Cu to diffuse into the C_{60} layer, forming a stable metallic interface to the C_{60} layer. The device's strong electron acceptor properties lead to a conducting charge-transfer complex similar to the heavily doped interface in silicon technology to form a good ohmic contact. This situation allows for efficient electron injection from the Cu cathode into C_{60}, increasing by about three orders of magnitude after heat treatment. Atomic force microscopy revealed that the C_{60} recrystallized, enhancing carrier mobility. Al, on the other hand, forms covalent bonds to C_{60}, resulting in the observed work-function increase from 4.2 eV to 5.2 eV, which is consistent with the observed *I–V* curve reversal.

Organic diodes, with their response speed in ac mode below 10 kHz, are not stable in air. The C_{60}-based organic diode, however, did not show any noticeable performance decay, even after a 40 h stress test in air without encapsulation at 2.4 ac voltage and 1 MHz frequency, whereas normal organic diodes were found to have a reported lifetime of no more than 17 h even under current conditions that are three orders of magnitude less severe.

Alfred A. Zinn

Protein Hydrogels Engineered to Promote Cell Growth

A research team at The Johns Hopkins University (JHU) has created a class of artificial proteins that self-assemble into a gel that can be tailored to send different biological signals stimulating the growth of selected types of cells. Tissue engineers use hydrogels to provide a framework or scaffold upon which to grow cells. The researchers hope to advance their technique to the point that it can be used to treat medical ailments by growing replacement cartilage, bones, organs, and other tissue in the laboratory or within a human body.

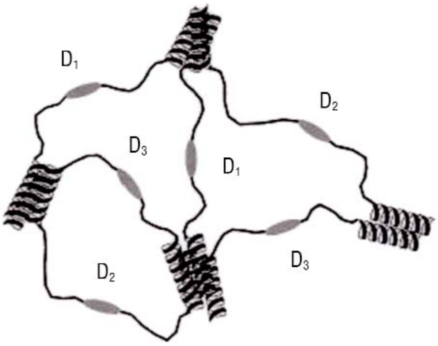


Figure 1. Schematic illustration depicting a hydrogel network with three distinct bioactive domains (D) formed by the self-assembly of modular proteins. Illustration by Will Kirk.

"We're trying to give an important new tool to tissue engineers to help them do their work more quickly and efficiently," said James L. Harden, whose laboratory team, L. Mi and S. Fischer, developed the biomaterial. Harden, an assistant professor in the Department of Chemical and Biomolecular Engineering at JHU, reported on his work at the 227th national meeting of the American Chemical Society in Anaheim, Calif., on March 28.

Harden's hydrogel is made by mixing specifically designed modular proteins in a buffered water solution. Each protein consists of a flexible central coil containing a bioactive peptide sequence and flanked by helical-associating end modules. The helical ends are based on the leucine zipper, a well-known motif in nature.

"We utilized three different types of these leucine zippers," said Harden, "an acidic helix A with glutamic acid residues in both the e and g positions, a basic helix B with lysine residues in both the e and g positions, and a mixed helix C with glutamic acid residues in the e positions and lysine residues in the g positions. The charge patterning of these helices supports the formation of very stable heterotrimer bundles of A+B+C due to favorable electrostatic interactions between the acidic and basic e and g residues on neighboring helices."

These end modules are designed to attract each other and form three-member bundles. This bundling leads to the formation of a regular network structure of proteins with three-member junctions linked together by the flexible coil modules (see Figure 1). In this way, the biomaterial assembles itself spontaneously when the protein elements are added to the solution.

"The helices have a hydrophobic strip of leucines along one face," said Harden. "When these proteins are put in water, they associate by overlapping these hydrophobic strips in order to keep water from coming into contact with the hydrophobic portions."

The assembly process involves three different "sticky" ends. But between any two ends, one or more bioactive sequences can be inserted, drawing from a large collection of known sequences. Once the gel has formed, each central bioactive module is capable of presenting a specific biological signal to the target cells. Certain signals are needed to stimulate the adhesion, proliferation, and differentiation of cells in order to form particular types of tissue.

Harden's goal is to provide a large combinatorial library of these genetically engineered proteins. A tissue engineer could then draw from this collection to create a hydrogel for a particular purpose.

"We want to let the end user mix and match the modules to produce different types of hydrogels for selected cell and tissue engineering projects," Harden said.

News of MRS Members/Materials Researchers

Diran Apelian of Worcester Polytechnic Institute has been named a fellow of the Metal Powder Industries Federation in recognition for his innovative work in metal processing and in building bridges between the industrial and academic communities.

Shefford P. Baker, of the Department of Materials Science and Engineering at Cornell University, was promoted to associate professor with tenure in November 2003.

Alexandre Blais, a postdoctoral fellow at Yale University, has received the 2004 **Howard Alper Postdoctoral Prize** from the Natural Sciences and Engineering Research Council of Canada in recognition of his research findings to improve the practical aspects of quantum-bit (qubit) construction and to offer a new way to maintain quantum coherence, the key to a successful quantum processor. The prize is one of Canada's premier awards for recent doctoral graduates. Blais received his PhD degree from Université de Sherbrooke in Canada.

Damon Canfield, president and CEO of New Product Innovations (NPI), has been named an **Ernst & Young Entrepreneur of the Year** for 2004. The award recognizes Canfield's leadership in transforming NPI from a technical services organization providing product engineering and materials