

## Hydrogels May Allow Designer-Controlled Release of Medicines or New Materials for Tissue Engineering

C.C. Chu, professor of fiber science in the textiles and apparel department in Cornell University's College of Human Ecology and the University's Biomedical Engineering Program, and his students have developed a polysaccharide (e.g., dextran)-maleic acid-based hydrogel and polysaccharide (e.g., dextran)-synthetic biodegradable polymer (e.g., polylactide)-based biodegradable hydrogels with a wide range of controlled swelling behavior. In one of the hydrogel inventions, Chu combined dextran and maleic acid to develop one type of hydrogel that can increase its swelling without lessening its structural stability and mechanical strength. In addition, the dextran-maleic acid-based hydrogel has reactive sites for additional chemical modification, if desirable, for example, the attachment of bioactive compounds. These properties allow the controlled release of medications with large or small molecular weights, such as peptides and proteins that are normally difficult to deliver through diffusion from nonbiodegradable carriers. The other class of hydrogels has both polysaccharide and synthetic biodegradable components. Chu said, "We have found that the release profile of medications is not only controlled by molecular weight but also by manipulating the composition ratio of these two hydrogel components. Thus, we can develop a release profile to suit any medication or rate of release we want."

As reported in their article in the *Journal of Biomedical Materials Research* published at the end of 1999 (46:160), Chu and his research team synthesized a class of hydrogels, dextran-maleic acid (Dex-MA) by the reaction of dextran with maleic anhydride in the presence of the catalyst triethylamine. They found that the optimum reaction condition was achieved with a 2:1 molar ratio of maleic anhydride to the hydroxyl group of dextran, with 0.5 mol % triethylamine catalyst to maleic anhydride, synthesized at 60 C for 10–20 h. The researchers found that an increase in the hydrogels' swelling ratio was associated with an increase in the degree of substitution (DS) by MA, irrespective of the pH of the medium, which is contrary to hydrogels prepared by crosslinking conventional vinyl groups such as acrylic acid. Hydrogels that use acrylic acid for crosslinking usually show a reduction of swelling ratio with an increase in DS.

Chu said, "These new biomaterials not only contain enormous amounts of water,

which make them more biocompatible with the human body, but also have greater mechanical strengths, integrity, and stability than other hydrogels."

In another article to be published in an early 2000 issue of the *Journal of Polymer Sciences, Polymer Chemistry*, Chu and his team report on the synthesis and characterization of biodegradable hydrogels consisting of relatively hydrophobic synthetic biodegradable polyesters (e.g., poly(D,L) lactic acid (PDLLA)) and hydrophilic polysaccharide (e.g., dextran) segments with a polymer network structure. Chu said that these hydrogels can serve as a three-dimensional porous network with a large surface area on which to anchor cells and tissues like skin, cartilage, compounds for healing wounds, and for repairing blood vessels and introducing viruses in gene therapy. The porous 3-D network hydrogel not only provides much more surface area than currently used nonwoven fiber-based substrates but also has a wide range of controllable pore sizes. In addition, the hydrogel has sites onto which bioactive substances, such as materials for tissue engineering, can be attached. It is engineered by forcing together a natural and a synthetic compound to form an homogeneous gel that does not separate and has both hydrophilic and hydrophobic properties. By changing the composition of the hydrophilic to hydrophobic components, the bicomponent biodegradable hydrogels can accommodate bioactive agents of any degree of hydrophilicity to hydrophobicity. The hydrogels' hydrophilicity and hydrophobicity are the chief means by which they control drug release.

## Insight into Pollen Adhesion Reactions May Yield New Forms of Superglue

In experiments to measure the binding force between pollen grains and stigma cells in *Arabidopsis*, a team of plant biologists and physicists at the University of Chicago has discovered the nature of the adhesion reaction at the chemical level. The strength and specificity of pollen binding could form the basis of a family of superglues with wide ranging applications in medicine and technology. David Grier, associate professor of physics in the James Franck Institute at the University of Chicago, said, "You could conceivably design adhesion systems where you want two things to stick to each other but not to themselves. And because pollen-stigma binding is so species specific, you could make as many different such glues as there are plants."

When a pollen grain of the right species lands on the pistil and comes into contact with a female stigma cell, a tight binding between the outer surface of the pollen grain—the exine—and the stigma cell occurs. After binding, the stigma cell causes the pollen grain to absorb water, enabling it to send a pollen tube down through the female tissue to the flower's ovary. Sperm carried inside the pollen grain makes its way down the tube and fertilizes eggs within the ovary forming a zygote. Scientists have known very little about how the right pollen adheres to the right stigma while pollen from other species falls off. The interaction between pollen and stigma in *Arabidopsis* is also interesting to scientists because it happens under dry conditions—unusual circumstances for cell-cell adhesion, which usually requires water.

To test the force of adhesion between pollen and stigma cells, postdoctorate Greg Zinkl and assistant professor of molecular genetics and cell biology Daphne Preuss worked with Grier and undergraduate student Ben Zwiebel to measure the strength of the pollen-stigma bond. Grier attached a single pollen grain to the end of a flame-drawn glass fiber. He then brought it into contact with a stigma cell and waited a few seconds to let the two bind. Next, Grier withdrew the stigma (which was attached to a moveable stage) thereby causing the glass fiber to bend. When contact between the pollen grain and stigma cell was broken, the glass fiber snapped back to a horizontal position and the stage was stopped immediately. Grier was able to calculate the binding force of the pollen grain and the stigma cell using the angle to which the glass fiber bent, and the distance the stage needed to be retracted for contact between the pollen grain and stigma cell to be broken.

As reported in the November 9, 1999 issue of *Development*, the researchers found that the adhesion between pollen and stigma of the same species was unexpectedly strong, perhaps helping pollen borne by high winds to tightly bind to flowers of their species. The binding force averaged  $5.0 (\pm 2.6) \times 10^{-7}$  N as compared to  $1.5 (\pm 0.8) \times 10^{-7}$  N for adhesion force of *Poa pratensis* pollen to *Arabidopsis* stigmas.

Zinkl and Preuss also showed that adhesion between pollen and stigma does not rely on proteins embedded in the exine, but instead on the exine itself, which is made up of a stable polymer made up of fatty acids and phenolics as well as a lipid and protein-rich matrix. Using pollen grains lacking exine proteins due to a genetic mutation, Preuss

showed that these grains retained the ability to bind to same-species stigmas.

Preuss said, "This indicates that the binding factors for the pollen grain reside within the exine itself, perhaps even the cell wall of the pollen grain, which was once thought to be inactive in the binding process."

### High-Velocity Thermal Spray Produces Shock Synthesis of Novel Phases of Si, Ge, and Diamond

Shock synthesis of high-pressure phases of Si, Ge, and diamond was accomplished using thermal spray by scientists at the Center for Thermal Spray Research (NSF-MRSEC) in collaboration with the Center for High Pressure Research at the State University of New York at Stony Brook.

They report, in the September 1999 and January 2000 issues of the *Journal of Materials Research*, that thermal spray can be treated as a "dynamic-pressure anvil" allowing synthesis of high-pressure metastable forms of nanocrystalline Si and diamond, where shock pressures of 0–30 GPa are achieved. The researchers said that there is exciting scientific and applied interest in forming deposits of novel phases, such as nanodiamond and nanosilicon, by continuously generating high-velocity particles and impacting these on a substrate. Powders are injected into a high energy flame, where they melt and accelerate, impacting on a substrate, and creating a shock wave which propagates through the substrate and prior deposited layers, yielding phase transitions to high pressure forms.

During thermal spraying, cubic Si (Si-I) transforms to Si-II, with a  $\beta$ -Sn type structure. A number of metastable phases were observed during subsequent spontaneous depressurization. The metastable, high pressure form of Si transforms to nanocrystalline (2–5 nm) Si-IX, Si-IV (hexagonal diamond-Si), R-8 and BC-8 phases. In the case of Ge, a metastable phase, ST-12, was observed. The ST-12 is a decompression product of Ge-II, with a  $\beta$ -Sn type of structure. The transformation pressure of Ge-II is slightly lower than that of Si-II.

Nanocrystalline diamonds were deposited (>20  $\mu$ m on steel substrate) by thermal spray of Ni-clad graphite powder. The high-velocity impact generates a shock wave which propagates through the particle and the underlying deposits. TEM and Raman spectroscopy reveal that this deposit contains cubic diamond nanocrystals (5–10 nm) in the graphite matrix. It was also observed that a portion of the deposit contains "closed-curved graphite"

which is a tubular form of graphite.

The broader implications of this work include the production of other pressure phases whose bulk synthesis is precluded by economic considerations. The low cost of thermal spray will greatly enhance our capacity to test and utilize high pressure phases, which remain largely a curiosity because of their cost of production. Additionally, preliminary results indicate that these shock-pressure induced structures may have interesting electrical (e.g.,

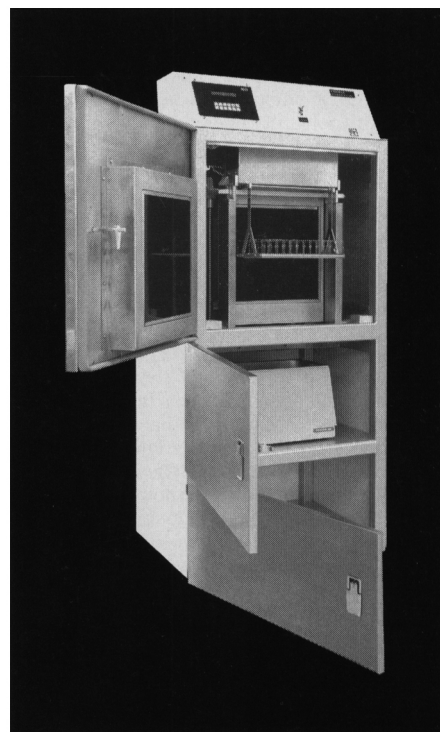
Si and Ge) and mechanical (e.g., diamond-based hardness on functional surfaces) properties.

### NREL Researchers Explain Anomalous Photoluminescence of Ordered GaInP<sub>2</sub> and Pressure-Dependence of Transitions in Alloys of GaAs<sub>1-x</sub>N<sub>x</sub>

In recent work on their study of electronic theory of metal and semiconductor

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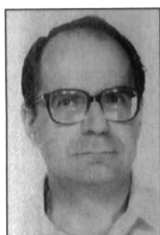
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**Fabrizio Galluzzi**, full professor of electronic materials and technologies at the University of Roma Tre, Italy, died June 13 in Ascoli Piceno, Italy.

He was born in Rome in 1945 and received the "Laurea" degree in solid-state physics in 1969 at the University of Rome. From 1970 to 1977 he worked as a research associate at the Snam Progetti Laboratories in Monterotondo, Rome. From 1978 to 1984 he worked at the ENI Association for Scientific Research as Energy Materials Group Leader. From 1985 to 1992 he was at ENI Corporate Research Company as the Solid-State Physics Department Head and then Materials Science Department Head.

In 1992 he became an associate professor at the Engineering Faculty of the University of Rome Tre, and then full professor in 1993. After one year at the University of Messina, he returned to the University of Rome Tre as full professor.

His scientific interests were widely spread, concerning fundamental research (quantum mechanics, solid-state physics, chaos and catastrophe theories, thermodynamics), as well as applied research (optoelectronic devices based on crystalline and amorphous semiconductors). His was a well-rounded personality with personal interests in different fields, including politics of science, art, history, and poetry.

At the beginning of his research activity he studied electronic transitions of the metastable M center in alkali halides. Soon after, he investigated Raman excitation profiles of polyatomic molecules and the site selective excitation of complex systems. A noticeable result achieved in this field, in collaboration with the Los Alamos Center of Non Linear Studies, was the identification of a new Raman band in acetanilide molecular crystals and its theoretical interpretation in terms of self-trapped solitons. His scientific work on Raman spectroscopy also included the vibrational properties of amidic-type organic crystals and of amorphous and microcrystalline materials.

He also studied vibronic transitions in the uranile ion, in particular absorption and emission fine structure, emission lifetimes, and isotopic shift.

In 1978 he began work on solid state devices based on crystalline semiconductors. In collaboration with the Politecnico di Lausanne, he investigated semiconductor-electrolyte photovoltaic junctions, analyzing recombination processes at the solid-liquid interface and realizing operative prototypes of photoelectrochemical cells. Between 1983 and 1985 he studied organic semiconductor (polyacetylene)-electrolyte junctions, developing a geminate recombination model for photogenerated carriers.

In the same period he was also involved in the definition of solar-grade silicon, identifying the material requirements for low-cost solar energy conversion. During this activity he gave an original contribution to the development of new characterization techniques for the spatially resolved investigation of diffusion length and recombination velocity at grain boundaries.

He designed a new photovoltaic heterojunction between *p*-type silicon and indium-doped cadmium sulphide, realizing devices with conversion efficiency greater than 10% by proper control of the deposition process. He also developed an optical method of spectral shifting for the widening of the heterostructure spectral response. In collaboration with the University of Pavia he worked on electroluminescent devices based on II-VI semiconductors realizing a new light-emitting device with a metal/ZnS:Mn/insulator/TCO structure.

From 1984 to 1992 Prof. Galluzzi's main research activity was focused on amorphous semiconductors and related devices. In particular he investigated the effect of structural and compositional changes on the optoelectronic properties of amorphous silicon, developing deposition systems able to optimize the material quality. In particular, he was involved in the realization of photovoltaic devices, either homo- and heterojunction, as well as tandem cells based on amorphous silicon and its alloys. In this context he adopted an innovative plasma deposition system configuration with separated multiple chambers able to avoid cross-contamination among different gas feedstock used for different layers. By using double or triple junction structures he improved cell stability under sunlight exposure, achieving device characteristics among the best in Europe. Such performances were then extended to photovoltaic integrated modules up to areas of 1000 cm<sup>2</sup>.

Among the research activities on amorphous semiconductors, he was also involved in the development of large area electronic applications, realizing active matrices of thin film transistors for liquid crystal display addressing, and arrays of photoresistances for the implementation of configurable neural networks.

During the academic years (1993–1999) his research activities were focused on the possibility of integrating new optoelectronic functionalities in silicon technology. After an initial investigation of amorphous silicon-carbide based thin-film photodiodes with voltage-controlled spectral sensitivity, he coordinated research activities concerning silicon-germanium and germanium-based infrared detectors, in collaboration with the University of Seattle and Daimler Benz of Ulm, and light-emitting *p*-*i*-*n* structures based on amorphous silicon-oxide, in collaboration with the Walter Schottky Institut of Munich. However his main research activity during the professorship was dedicated to polycrystalline diamond, investigating fundamental properties, such as photoluminescence and Raman scattering, as well as analyzing the application of CVD diamond for solar-blind UV detectors.

Professor Fabrizio Galluzzi was an IEEE, MRS, and SPIE member, authored more than 100 papers, and held several international patents. During all this activity he remained the most amiable of people, always willing to help students and colleagues in solving both scientific and organization problems.

His scientific contributions and extraordinary human qualities will be sorely missed.

SALVATORI STEFANO

alloys, researchers in the Solid State Theory Group at the National Renewable Energy Laboratory (NREL) explain the origin of luminescence properties of ordered GaInP<sub>2</sub>—published in the September 6, 1999 issue of *Physical Review Letters*—and the origin of anomalous phenomena exhibited by GaAs<sub>1-x</sub>N<sub>x</sub> alloys—published in the Rapid Communications section of the October 15, 1999 issue of *Physical Review B*.

While exploring the electronic consequences of genetic sequence errors in superlattices, the research team uncovered electron-hole charge separation in CuPt-ordered GaInP<sub>2</sub>. Alex Zunger, Institute Research Fellow at NREL, said that within the sequence mutated In-In layer embedded in the Ga-In-Ga-In... (CuPt) structure, holes localized on the mutated segment while electrons reside on the unmutated segment. More specifically, the sequence mutation creates a spatially indirect, low-energy transition ( $E_{LE}$ )—from  $e1$  to  $h1$ —in addition to the spatially direct, excitonic transition ( $E_X$ )—from  $e1$  to  $h2$ . The researchers said that these results explain the type-II behavior (of spatially indirect band-to-band transition) exhibited from the below-bandgap luminescence emission for CuPt-ordered GaInP<sub>2</sub> samples. When the researchers reduced the mutated segment from 2D quantum well to 0D quantum disk, the same hole localization persisted.

The researchers said that their calculated energies "provide strong evidence that the experimentally seen peculiar luminescence properties of ordered GaInP<sub>2</sub> are a consequence of quantum-disk-like microstructures formed due to the sequence mutations in [111]-superlattices."

In a study conducted by the same group, T. Mattila, S-H. Wei, and Zunger account for unusual behavior demonstrated in the two lowest interband transitions of nitrogen-poor GaAs<sub>1-x</sub>N<sub>x</sub> alloys in which the lowest-energy transition  $E_c$  quickly shifts to the red as the nitrogen concentration is increased, and as pressure is applied it slowly shifts to the blue. Ordinarily, as pressure is increased in alloys, the energy of  $E_c$  tends to saturate. In regards to the higher energy transition  $E_v$ , increased nitrogen concentration causes it to shift to the blue, and as pressure is applied, the intensity of the transition increases and its energy shifts to the blue at a rate similar to the lowest-energy transition. Zunger said that the nitrogen impurity perturbs the lattice to such an extent that the band edge states of GaAs ( $\Gamma_{1c}$ ,  $L_{1c}$ ,  $X_{1c}$ ) become mixed. The interaction leads to the alloy behavior as a function of pressure, composition, and so on.

The researchers calculated pressure

coefficients for the GaAs  $\Gamma_{1c}$ ,  $L_{1c}$ ,  $X_{1c}$  states by using the empirical pseudo-potential method (EPM) compared with the experimental values and with the values obtained using the first-principles linear augmented plane-wave method within the local density approximation (LDA).

### Atoms of Supercooled Metallic Liquids Chiefly Move in Lockstep

Atomic-scale measurements have revealed that, while atoms in a supercooled metallic liquid are transported by single-atom hopping, they chiefly move together in clustered lockstep. As reported in the November 11 issue of *Nature*, the study involved examining slow beryllium atomic motion on both microscopic scales using nuclear magnetic resonance (NMR) and macroscopic scales using diffusion measurements in zirconium-based bulk metallic glasses. X-P. Tang, assistant research professor in physics, and Yue Wu, associate professor of physics and astronomy, both at the University of North Carolina—Chapel Hill, employed an NMR technique they developed to determine how local environments of beryllium atoms change when motion occurs and the rate of such changes. They concluded that below 620 K, diffusion is mainly by single-atom hopping while above 620 K, diffusion occurs by both single-atom hopping and collective motion.

Wu said, "Atoms in a chilled metallic liquid manage to move more efficiently as a group than individual hopping, although the latter survives better at lower temperatures below the region of glass transition. This could be significant for understanding the nature of glass transition, which occurs when liquid cools rapidly and changes from a molten form to an amorphous solid without crystallization."

A. Lindsay Greer of Cambridge University observes that "one view of the glass transition is that the same transport processes might operate above and below  $T_g$  [in this case, ~620 K], with only the 'freezing out' of structural changes giving different temperature dependence below  $T_g$ . This view is defeated by Tang and colleagues' data, which show a clear change in diffusion mechanism at  $T_g$ ."

### Suresh Appointed Head of the Department of Materials Science and Engineering at MIT

Subra Suresh, R.P. Simmons Professor of Metallurgy at the Massachusetts Institute of Technology, has been appointed head of the Department of Materials Science and Engineering at MIT. In addition

to his research and teaching, he is currently chair of the Advanced Materials Program of the Singapore-MIT Alliance, a major collaboration in distance education and research among MIT and two Singaporean universities.

Suresh received his Bachelor of Technology degree from Indian Institute of Technology, Madras, in 1977, an MS degree from Iowa State University in 1979, and a ScD degree from MIT in 1981. Between 1981 and 1983, he was an assistant research engineer in the Department of Materials Science and Mineral Engineering at University of California—Berkeley, and the Lawrence Berkeley Laboratory. He joined the faculty at Brown University in 1983 where he became professor of engineering in 1989. He joined MIT in 1993 as the R.P. Simmons Professor.

He is internationally recognized for his major contributions to the broad fields of mechanical properties of materials, fracture and fatigue, the multidisciplinary area of graded materials, and coupled properties of small-volume structures. His current research activities include mechanical properties of structural materials, thin-film and miniature structures,

fully coupled mechanical-nonmechanical properties of piezoelectric and magnetostrictive materials, fracture and fatigue, and instrumented micro- and nano-indentation of homogeneous and graded materials and films.

Suresh is the author or coauthor of 175 research articles in international journals and conference proceedings, and is the coeditor of five books. He holds nine U.S. and international patent applications, several of which have been licensed for commercial development. He has authored a book entitled *Fatigue of Materials*, and is co-author of *Fundamentals of Functionally Graded Materials*.

Among the numerous awards and honors received by Suresh are the TFR Swedish National Chair in Engineering (1997–1998), the Distinguished Alumnus Award (1997) from the Indian Institute of Technology, Madras, Honorary Membership of the Materials Research Society of India (1996), and the Presidential Young Investigator Award (1985–1990).

Suresh was elected a Fellow of The Minerals, Materials and Metals Society in 1999, American Society of Mechanical Engineers (1996), the American Ceramic

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Circle No. 7 on Inside Back Cover

## ATP Awards 37 R&amp;D Projects in 1999

The Advanced Technology Program (ATP) of the National Institute of Standards and Technology (NIST) announced awards in October for 37 research and development (R&D) projects. ATP provides cost-shared funding to industry for high-risk R&D projects with the potential to spark important, broad-based economic benefits. Among the grants are the following given for materials-related projects.

**Advanced Rechargeable Lithium Polymer Sulfur Batteries**, PolyPlus Battery Company, Berkeley, CA to develop and test rechargeable, long-life lithium-sulfur batteries offering increased energy density, reduced size and manufacturing cost, and enhanced safety, thereby boosting power sources for mobile technologies such as laptop computers and cell phones.

**A Strategy for Reclaiming U.S. Leadership in High Value Polymers (Polyolefins)**, Catalytic Advanced Technologies, Inc., Mountain View, CA to develop rapid synthesis, computational, and screening technologies that can identify catalyst structures for making new, high-performance polymers, which would offer substantial economic, safety, and environmental benefits in automotive, medical, and other applications.

**Photovoltaic Micro-Concentrator Systems**, SunPower Corporation, Sunnyvale, CA, to develop technology for an innovative photovoltaic cell combining new silicon photocell technology with a novel light concentrator to enable low-cost, high-performance flat-panel photovoltaic units for solar power applications.

**Mid-IR Cavity Ring-down Spectroscopy**, Informed Diagnostics, Inc., Sunnyvale, CA to develop electro-optical technology for a portable device based on cavity ring-down spectroscopy (CRDS), enabling highly sensitive "sniffers" for detecting explosives or drugs in security applications and for a variety of diagnostic applications in medicine.

**Ultra-Compact Packaging Technology for Telemedicine**, Telecommunications and Next Generation I/O (NGIO), Picolight Incorporated, Boulder, CO to develop advanced packaging technologies and prototype cost-effective miniature fiber-optic datacom transceivers for use in desktop and laptop computers and other consumer products.

**Integrated MEMS Reactor Gas Monitor Using Novel Thin Film Chemistry for the Closed Loop Process Control and Optimization of Plasma Etch and Clean Reactions in the Manufacturing of Microelectronics**, ATMI, Inc., Danbury, CT to develop novel in-process gas sensors for the etching stage of semiconductor wafer manufacture, enabling more efficient, lower emission processing in the next generation of semiconductor fab lines.

**Ceramic Matrix Composites for Advanced Engine Components**, Siemens Westinghouse Power Corporation, Orlando, FL to develop and demonstrate hybrid ceramic matrix composite materials for use in making advanced gas turbines, with the aim of increasing the power output and reducing engine fuel costs, emissions, and associated clean-up costs.

**Bioengineering of a Liver Assist Device**, Organogenesis, Inc., Canton, MA to develop a practical liver assist device (LAD) that can take over some or all of the functions of the human liver, enabling patients with acute liver failure to stabilize and survive until donor livers are available, or to regenerate their own livers over time.

**MEMS-Based Infrared Micro-Sensors**, Ion Optics, Inc., Waltham, MA to develop an integrated, mid-infrared gas absorption "sensor-on-a-chip" to enable compact, low-cost instruments for detecting specific atmospheric contaminants such as carbon monoxide or natural gas.

**Colloidal Gold as a Targeted Drug/Gene Delivery System**, CytImmune Sciences Inc., College Park, MD to develop novel cancer therapeutics, with biologics and gene therapies on colloidal gold to effectively deliver these therapeutic agents to targeted cells, greatly improving the efficacy of the agents while reducing toxic side effects.

**A Functionally Specific Three-Dimensional Polymer Implant for Articular Cartilage Repair and Regeneration**, THM Biomedical, Inc., Duluth, MN to design, fabricate, and demonstrate a bioresorbable implant that stimulates the repair and regeneration of articular cartilage, including the cartilage layer that attaches to the bone, potentially providing a simple, rejection-free

device that will greatly reduce the need for hip and knee replacements.

**Tissue Engineered Heart Valve Prostheses**, St. Jude Medical, Inc., St. Paul, MN to develop a tissue-engineered heart valve prosthesis that, once implanted, will attract and integrate the patient's own cells in critical areas of the valve, making a more reliable, longer-lasting replacement valve, particularly for children whose bodies outgrow conventional prosthetic valves.

**Development of Lead-Free Solder Electroplating Technologies**, Lucent Technologies, Inc., Murray Hill, NJ to develop commercially viable electrochemical processes to enable the use of tin-silver and tin-bismuth solders as drop-in replacements for lead-based solders for the U.S. electronics industry.

**Combinatorial Methodology for Coatings Development**, General Electric Corporate Research and Development, Niskayuna, NY to develop combinatorial methods to achieve several orders of magnitude increase in the rate of screening of new coatings for the automotive and information display industries, accelerating the introduction of new products while also improving their quality.

**Bulk GaN and Homoepitaxial Device Manufacturing**, General Electric Company Corporate Research and Development, Niskayuna, NY to develop a commercially viable process for producing gallium nitride crystals, an important material for high-performance optoelectronics and electronics, in bulk at low cost.

**Motors and Generators for the 21st Century**, IAP Research, Inc., Dayton, OH to develop novel manufacturing processes based on powder compaction technology to produce electric motors with double the power and torque density of existing motors at half the production cost.

**High Performance Rechargeable Alkaline Battery**, Rechargeable Battery Corporation, College Station, TX to develop the technology for secondary zinc alkaline manganese-dioxide battery cells, a new type of high-performance, low-cost rechargeable alkaline battery with significant safety and environmental benefits that could be used in large consumer applications, including electric vehicles.

Society (1995), and the American Society for Materials International (1994). He recently served as the chair of the Executive Committee, Materials Division, ASME. He is the coordinating editor and a principal editor of the international journals *Acta/Scripta Materialia*, and a series editor for the Cambridge University Press Solid State Science Series. During 1999–2000, he holds the appointment of Clark Millikan Visiting Professor at the California Institute of Technology.

**Neal Lane Honored for Prominent Contributions to Scientific Research and Policy**

Neal Lane has received the American Chemical Society’s (ACS) Public Service Award in September for his continued leadership and support in the advancement of science education and science policy. The award is given annually to recognize an outstanding individual who has worked to promote the expansion of scientific knowledge for the benefit of society.

Ed Wasserman, president of ACS, said, “Neal Lane not only supports federal investment in science, but also has a personal history as a federally funded scientist. He has fought for research funding and has performed extensive research of his own. He not only campaigns on behalf of science education, but also has been recognized as a superior educator.”

ACS acknowledges him as a champion of federal support for both disciplinary and cross-disciplinary research. During congressional testimony this year on federal funding for research and development, Lane continued to advocate strong federal funding for research and development. During his tenure as director of the National Science Foundation, Lane secured strong funding from Congress for both basic research and science education. He accomplished this by educating lawmakers on the importance and practical benefit of federal investment in science and training, and by working closely with scientific and professional societies.

Lane received his BS, MS, and PhD degrees in physics from the University of Oklahoma.

**Novel PBG Composite Glass Materials Enables Miniaturization of Opto-Electronic Devices**

Researchers at the Naval Research Laboratory (NRL) have fabricated photonic bandgap (PBG) nanochannel glass materials for use in the development of a class of extremely compact and efficient opto-electronic devices.

To fabricate this material, the researchers inserted an etchable glass rod into a glass tube and drew it at high temperatures to yield filaments having a reduced overall diameter. They stacked and re-drew the filaments, further reducing their diameter. Afterwards, sections of the nanochannel glass were wafered and polished. Etching the wafers results in a glass matrix containing a regular array of submicron-diameter holes. The researchers also performed additional processing, such as filling the holes with another dielectric or semiconductor material.

According to Armand Rosenberg of the Optical Sciences Division of NRL, the PBG nanochannel glass material resulting from this process is a fundamental building block of the optical analog of electronic integrated circuitry.

Rosenberg said, “Structures that exhibit photonic bandgap optical effects are composed of alternating layers or rows of dissimilar materials. The thickness of the alternating layers is on the order of the wavelength of light. By manipulating the structures of these materials, it becomes possible to engineer materials with customized optical properties, suitable for a variety of applications. A major application area is controlling the propagation of light in opto-electronic devices, similar to how the flow of electrons is controlled in semiconductor devices. The size of present optical

and opto-electronic devices could be greatly reduced and their efficiency increased if the propagation of light could be better controlled and optical losses due to scattering are eliminated. The PBG materials we have developed will enable the miniaturization of such optical and opto-electronic devices. In addition, new devices will be possible based on the unusual combinations of optical and electrical properties of these novel PBG materials, which are not found in nature.”

The research team, including Elizabeth Bolden and Brian Justus, reports that its present goal is to optimize the properties of the two-dimensional PBG crystals currently fabricated at the laboratory. The research team has already demonstrated PBG nanochannel glass materials with photonic bandgaps varying from infrared to ultraviolet wavelengths. According to Justus, “The specific optical properties of these PBG materials are highly dependent on their physical characteristics, such as the symmetry, structure, and composition of the layered materials. Slight modification of these characteristics can significantly enhance the observed photonic bandgap effects.”

**Kunio Takayanagi Named 1999 Surface Structure Prize Laureate**

Kunio Takayanagi received the 1999 Surface Structure Prize for “his quantitative

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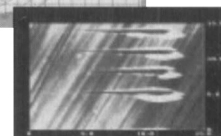
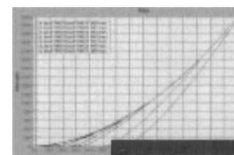
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- Root cause identification
- Product design improvement suggestion



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determination of the atomic geometry of Si(111)-(7 × 7). This is the singularly most important structure determination in all of surface science. It brought together fragmentary results from a host of other techniques into a single coherent structure that has withstood the test of time and revealed the amazing complexity of new two-dimensional compounds formed at semiconductor surfaces. It resolved an intense controversy about the structure that had continued for nearly three decades. It was a 'tour de force' of experimental sample preparation. It led to significant new insights into the energetics of semiconductor surface reconstructions, especially as contrasted with the Ge(111)-(2 × 8) structure. This surface structure determination is, overall, an amazing accomplishment of truly historic proportions."

Takayanagi received his PhD degree in 1976 from the Tokyo Institute of Technology. He held a Humboldt Fellowship at the Fritz-Haber Institute in Berlin during 1977–1979. His research and teaching has otherwise been based at the Tokyo Institute of Technology where, since 1989, he has been a professor of physics and materials science. He is the director of the "Particle Surface" Project being funded by ERATO (Exploratory Research for Advanced Technology) and the Japan Science & Technology Corporation. He has received many awards, including the Nishina Prize from the Physical Society of Japan.

### Dimethyl Ether Used as Fuel Burns Cleaner than Propane or Butane

Researchers at The Pennsylvania State University suggest that dimethyl ether (DME), which is normally produced by dehydration of methanol but can be produced from natural gas and from coal-derived syngas, may have broad use as an alternative clean fuel. In a study of the emissions produced when burning DME as a substitute for n-butane or propane published in *Energy & Fuels* (13: 650), researchers found that DME had lower carbon monoxide emissions and the same or lower nitric oxide emissions than either of these commercially available fuels.

"In China and India, propane and butane are used in great quantities for utility purposes such as cooking," said Andre L. Boehman, director of the Penn State Combustion Laboratory and assistant professor of fuel science. "Switching to a fuel that generally has lower emissions and is coal-derived could make cleaner fuel available from local resources."

The researchers found that in a series of tests, carbon monoxide emissions were

lower when burning DME than for either butane or propane. They also found that in most cases nitric-oxide emissions were lower, but that even in the worst case, nitric-oxide emissions were no higher than when burning butane and propane.

Boehman said, "We concluded that in terms of its comparative carbon monoxide and nitric-oxide emissions, DME is a viable alternative utility fuel."

With a favorable emission profile, Boehman is now investigating DME as a replacement fuel in diesel engines. According to Boehman, DME would make a poor replacement for gasoline because its octane rating is very low. However, diesel fuels are catalogued by cetane rating, a measure of a fuel's ease of spontaneous combustion once the proper temperature and pressure are reached. Methanol, an alternative fuel being investigated for automotive spark-ignited internal combustion engines, would make a poor diesel fuel as it has a high octane rating, but only a 5-cetane rating. Diesel fuel has a cetane of 45 and dimethyl ether has a cetane of 55.

### Chromium Chloride Serves as Catalyst to Convert Nitroarenes into Anilines

Chemists from the University of Rochester have demonstrated how chromium chloride makes it possible to use combinatorial chemistry in the manufacture of anilines. Traditionally scientists produce anilines by starting with powdery compounds known as nitroarenes, which are dissolved in a solvent. Then chemists use palladium as a catalyst to convert the nitroarenes to anilines, which chemists separate out and purify in a time-consuming process.

As reported in a recent issue of *Angewandte Chemie* (38:2777), postdoctoral researcher Anitha Hari and assistant professor of chemistry Benjamin Miller describe the use of chromium chloride as a catalyst. According to their report, when raw nitroarenes are fixed on polymer beads that are then immersed in a solvent, the material clings to the beads. Also in the solvent is a strip of manganese. Chromium chloride acts as a catalyst, going back and forth between the strand of polymer beads and the strip of manganese and converting nitroarenes to anilines. The nitroarenes are converted to anilines directly on the polymer beads, and the chromium is continually regenerated by the manganese.

By slightly altering the properties of the polymer beads, Miller can produce a large variety of anilines in one experiment. The

system acts as a tiny factory producing different chemical compounds. The anilines are very easy to separate out as chemists can pull out the polymer beads and wash off the anilines. Because the chromium, which is very expensive and toxic in high amounts, is recycled by the manganese, little residue is left on the anilines. Anilines are used in the manufacture of drugs, dyes, plastics, and film.

### Ancient Iron-Rich Rocks Point to Early Occurrence of Land-Based Life

Iron-rich rock formations dating to 2.3 billion years ago suggest that the Earth's land masses were covered with living organisms at least a billion years earlier than previously thought, according to Hiroshi Ohmoto, professor of geosciences and director of the Astrobiology Research Center at The Pennsylvania State University.

Ohmoto, in collaboration with Nick Beukes of Rand Afrikaans University, Johannesburg, South Africa, investigated laterites, iron-rich deposits that form when organic acids leach iron from upper layers of rock and then deposit them as oxides in layers below. The normal makeup of a laterite is three bands—an iron-deficient layer covered by an iron-rich layer that is covered by an iron-deficient layer. Modern laterites form in the tropics where large amounts of organic material rapidly decay.

"In order for laterites to form, there must be organic material and atmospheric oxygen," Ohmoto told attendees at the annual meeting of the Geological Society of America on October 26, 1999 in Denver. "Since we have now traced these laterites to 2.3 billion years ago, there must have been atmospheric oxygen and terrestrial life at that time." Ohmoto originally looked at formations in Waterval Onder, South Africa, an area near Pretoria. However, in this area, the iron-rich layer and upper iron-poor layer have eroded. So the researchers looked at core samples drilled by miners who typically drill through these layers looking for gold and uranium ores buried much farther down.

"We looked at two cores in South Africa and one in Botswana that showed the complete series of rocks," said Ohmoto. "It appears that this laterite formation covers a rather large area."

There are several places farther west where the formation is exposed, but these locations had previously been dated as much younger rock. The researchers have now identified these laterite formations as part of the same, much older formation,

because it sits directly on the Hekpoort basalt, an extensive basalt formation that was extruded 2.3 to 2.4 billion years ago.

Ohmoto said, "Because we can trace the basalt all the way across, even to a

depth of 2,600 feet, we know that the laterite deposits directly above are only slightly younger than the basalts." Geologists currently are involved in a debate as to when significant amounts of

oxygen appeared in the Earth's atmosphere. These laterites suggest that oxygen was plentiful 2.3 billion years ago, both for the generation of land-based biota and to convert iron to iron oxides. □

## WASHINGTON NEWS

### Officials Largely Support NRC Report on Materials Facilities Management

Although operating the nation's major materials research facilities will present some tough challenges in the coming years, the responsible federal agencies seem to be approaching the future with a cooperative spirit. Their differences appear to be manageable—but not necessarily minor. That is the rough consensus of several top officials involved in materials research issues, following release of the recent report by the National Research Council's Committee on Developing a Federal Materials Facilities Strategy.

The report, "Cooperative Stewardship" (see *MRS Bulletin*, December 1999), calls for expanded management responsibilities for the three agencies responsible for the facilities: Department of Energy (DOE), the National Science Foundation (NSF), and the National Institute of Standards and Technology (NIST). It also recommends more formal coordination with other agencies representing facilities users—especially the National Institutes of Health (NIH), which represents biomaterials researchers, the fastest-growing segment of users at the major facilities. The report calls for a permanent interagency working group to handle materials research-related issues.

Despite the growth in bio research, there is no support for giving NIH any direct operational responsibilities, even though that agency—with a research budget that dwarfs current operational funding for all 12 of the nation's major materials facilities—is capable financially of handling the task.

"As I perceive the arrangement, DOE, NIST, and NSF will remain undiluted in their basic stewardship, but NIH will have a significant say over funding levels and operations," according to Arthur Bienenstock, associate director for science at the White House Office of Science and Technology Policy. NIH is expected to have plenty of opportunity to develop beam lines, complementary detectors,

protein handlers, and necessary instrumentation.

NIH envisions a slightly different approach. Marvin Cassman, director of the National Institute of General Medical Sciences (NIGMS), said it may be time to rethink how the facilities are funded. "Somebody needs to make the case that these [facilities] can't be considered offshoots of [scientific] disciplines," Cassman said. "These are not just materials science resources. They are national scientific resources."

This position was also suggested in the NRC report, which recommends dropping the traditional term "materials facilities," in favor of "multidisciplinary user facilities," or just "user facilities."

Although NIH has contributed more than \$30-million to several synchrotron facilities over the past few years, which has earned NIH—and Cassman—praise from the materials research community, Cassman believes that the ad hoc approach is inadequate and should only be considered a temporary strategy. Instead, "NIH should actively support an increased appropriation to DOE and NSF for the purpose of operating the synchrotrons," he said. "My concern is that funds for parts of the ring, such as the undulators, and essential infrastructure, such as the laboratory office modules, are no longer available through DOE. And they should be, as should the resources for upgrades at Brookhaven and Stanford, for example."

The most serious materials research-related problem may be the quality of the instruments at some of the neutron facilities, something the NRC report described as "gross inadequacies." John Rush, director of Neutron-Condensed Matter Science at NIST, acknowledged that there are problems. For example, although most synchrotrons support as many as 75 experimental stations, U.S. neutron sites typically have only 10 or 15.

One reason, according to Rush, is perennial underfunding for modernized instrumentation, which has caused several U.S. facilities to lag behind some mod-

ern technologies available in Europe. Another reason is fewer partnerships with users such as those enjoyed at the synchrotron facilities. This has been harmful, Rush said, because it is difficult to staff a large facility adequately without partnering. Rush said the situation should improve in the next few years, however, because DOE recently invested substantially in the Oak Ridge and Los Alamos neutron sites.

Another potentially serious funding-related issue mentioned in the NRC report is the renewed possibility of user fees. The idea currently has the support of some White House Office of Management and Budget officials, some finance officials within DOE, and within the congressional appropriations committees. Fees are viewed as a way to raise more operating funds without increasing federal spending. Finance officials reportedly are worried about handling rising costs at the major facilities, as well as the new expense of building and running the spallation neutron source.

The problem, as materials science officials are quick to point out, is that most of the money to pay the fees would have to come from federal funds. According to Bill Oosterhuis, the Condensed Matter Physics & Materials Chemistry Team Leader at DOE's Materials Sciences Division, 80% of the user fee would come from federal money. "So if we charged user fees, we would be taking money from one [federal] agency and giving to another, while tacking on the overhead to manage the transactions, with no value added."

Criticism of user fees was almost universal among materials research officials. "We've gone through this many times over the past three decades," according to one of the NRC report's authors, who recalled that, in the beginning, user fees were charged, but they proved so unworkable within the annual budgeting process that they were abandoned in the late 1970s. Every few years, the official said, new budget people arrive, notice that researchers are not paying for time at