## Wetting Transition May Enable Fluid Microchips or Microreactors

Researchers at the Max-Planck-Institute of Colloids and Interfaces have discovered wetting phenomena at surfaces which are laterally structured on the micrometer scale. These surfaces contain hydrophilic and hydrophobic domains and, thus, have a position-dependent surface tension. This leads to two-dimensional wettability patterns which act as templates for the three-dimensional morphology of the liquid layers. If the hydrophilic surface domains have the shape of long stripes, the liquid forms channels along those stripes. As the volume of the liquid increases, these channels undergo a shape instability from a homogeneous channel state to another state with a single bulge. This instability differs from the classical Rayleigh-Plateau instability and represents a new type of wetting transition between two different morphologies of constant mean curvature. This latter transition can only occur because the contact angles of the channel do not satisfy the classical Young equation.

In terms of applications, the presence of this transition makes it impossible to construct long homogeneous channels with a contact angle which exceeds 90 degrees. However, the bulge arising from this instability may coalesce with a neighboring channel, leading to a microbridge between two channels. These bridges can be used to construct fluid microchips or microreactors. After a certain pattern of liquid channels and bridges has been created, it may be stabilized by freezing, polymerization or sol-gel reactions.

The researchers' article published in the January 1 issue of *Science* contains a detailed comparison between theory and experiment. This comparison shows that, on the micrometer scale, the liquid channels can be understood in terms of position-dependent surface tensions and are not affected by line tension. However, the latter tension should have an observable effect as soon as the surface domains become sufficiently small, leading to the study of the corresponding morphologies on the nanometer scale.

## 1999 ICDD Crystallography Scholarship Recipients Announced

The International Centre for Diffraction Data (ICDD) Crystallography Scholarship Committee has selected five recipients for the 1999 Scholarship program. They are **Byron DeLaBarre** (McMaster University), "Determining the Phases for a Difficult Protein Structure"; **Shannon Patrick Farrell** (University of Western Ontario), "Sulpher K- and L-Edge XANES of 3d Transition Metal Sulphides and Silicate and Germanate Glasses"; **Cora Lind** (Georgia Institute of Technology), "New Negative Thermal Expansion Materials Related to Cubic $ZrW_2O_8$"; **Oshrit Navon** (Ben-Gurion University of the Negev), "Polymorphism and the Influence of Crystal Forces on Molecular Conformation"; and MRS member **K. Scott Weil** (also a 1998 recipient) (Carnegie Mellon University), "Investigation of the Formation, Structure, and Magnetic Behavior of Compounds in the Nickel-Molybdenum-Nitride System."





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## Europium Sensor Detects Nerve Agents

An extremely sensitive and selective sensor that can detect minute traces of the chemical nerve agents sarin and soman has been tested by researchers at Johns Hopkins University. The sensor is described in the January 15 issue of *Analytical Chemistry*, published by the American Chemical Society, with a website publication of December 10. The sensor, which combines molecular imprinting with optical luminescence, is able to detect sarin and soman in water at levels as low as 600 parts per quadrillion. "It's a million times more sensitive than other reported solution sensitivities," said George Murray, a senior research chemist with Johns Hopkins' Advanced Physics Laboratory. "Just a thousand molecules probably is all it would take for us to detect it," he said.

"Molecular imprinting is analogous to making a plaster impression of the particular molecule you want to find," said Murray. "The cast is made of a stiff plastic so that when the molecule is removed, the shape of the molecule in the cast is preserved," he said. Because the structure of each molecule is unique, the probe only recognizes the specific molecule for which the researcher is probing.

The actual probe developed by Murray and his colleagues for detecting nerve agents in water is a tapered optical fiber, which is treated with the metallic element europium. The fiber is hooked to a spectrometer and a light source. Light is directed to the end of the fiber in the solution being examined and the light that returns from the tip is analyzed by the spectrometer.

## Molecular Dynamic Simulations Allow Estimates of Flexible Membrane Bending Rigidity

Along with biologists, physicists and chemists have studied the unusual properties of flexible cell membranes which are very anisotropic: They consist of bilayers of molecules and thus are very thin with a thickness of only 4–5 nm; their lateral extension, however, is much larger and can be 10s of micrometers. Therefore, flexible membranes are able to bridge the gap between the nano- and the microworld. Scientists' understanding of these structures has been based on two theoretical approaches. On the one hand, the behavior of membranes on the micrometer scale is well understood in terms of smooth surfaces as described by differential geometry. In this way, the many different shapes and topologies as observed in the optical microscope can be explained. On the other hand, the understanding of membranes on the nanometer scale comes from computer simulations in which discrete molecular models with atomic resolution can be studied. However, these two approaches have remained distinct and unrelated. In the January 4 issue of *Physical Review Letters*, researchers at the Max-Planck-Institute of Colloids and Interfaces have published an explicit connection between these two different levels corresponding to the nano- and the microworld, respectively. Using molecular dynamics simulations of large membrane segments, they studied both the self-assembly process and the physical properties of such bilayer membranes. On molecular scales, these membranes are observed to be mobile and to have rough surfaces arising from molecular protrusions, that is, from the relative displacements of individual molecules. On length scales, which are only somewhat larger than the membrane thickness, however, the membranes are found to undergo





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smooth bending undulations.

Using these computer simulations, the researchers estimated the bending rigidity, the most important elastic constant which enters the description on the micrometer scale. This elastic constant was extracted from a detailed analysis of thermally excited membrane fluctuations. The researchers found that the numerical value of the bending rigidity as determined from the fluctuation spectrum turns out to be consistent with a relatively simple model in which each monolayer of the bilayer is treated as a thin structureless film with vanishing two-dimensional shear modulus.

## X-Ray Diffraction of Iron at Ultrahigh Pressures Linked to Elastic Properties of Earth Innercore

Scientists at the Carnegie Institution of Washington have published in the December 24 issue of *Nature* results of a high-pressure study of iron as it exists at the Earth's interior. By using x-ray diffraction techniques with diamond anvil cells, Ho-Kwang Mao, Russell Hemley, and colleagues at the Geophysical Laboratory have determined the elastic properties of iron under ultrahigh pressure. Their work suggests that the inner core propagates sound in the same manner as highly compressed iron near its melting temperature.

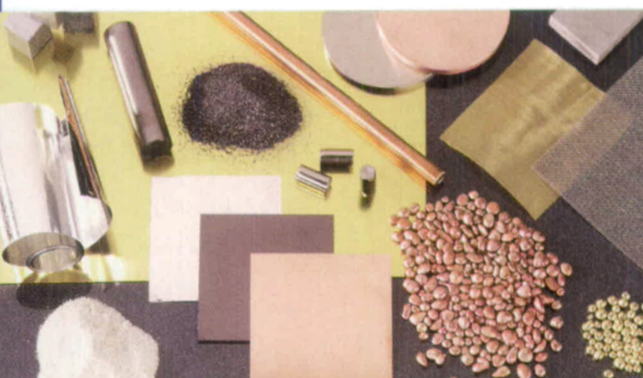
The Earth's core is found between 2890 and 6370 km depth, which corresponds to pressures between 1.3 and 3.6 million times atmospheric pressures. The outer region is liquid, while the inner core is solid. The inner core is where scientists have observed some peculiar phenomena. Seismologists have found that sound waves traveling through the inner core in an east-west direction are slower than those traveling in a north-south direction. Scientists have speculated as to what the texture of the core could be like to produce this difference in seismic waves.

Previously, scientists could not measure experimentally the elasticity of iron and other materials at the extreme pressures that exist deep within the Earth. Recently, however, the Carnegie group developed an x-ray diffraction method that allows the determination of elasticity of iron from which the sound velocity can be determined. The researchers found that the elasticity of hexagonal-close-packed iron, which appears to be the form of iron under these extreme pressures, can account for the slow seismic wave velocity and the anisotropy observed at the inner core. They also suggest that the speed of the seismic waves points to an inner core that is close to melting. The scientists said that an alternative scenario is possible: that the presence of additional components with low shear-wave velocities and densities similar to iron could also be present in the inner core.

## Powered Zinc Oxide Layer Produces Laser Action

A team of materials scientists, physicists, and electrical engineers from Northwestern University have shown that powdery layers of zinc oxide and









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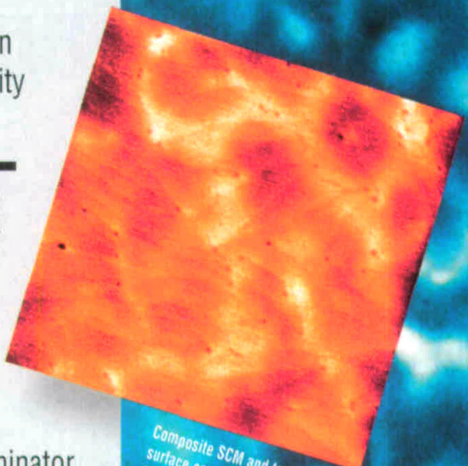

Composite SCM and topography of GaN surface correlating dislocation pits and free carrier concentration, 2.5μm

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AFM phase image of liquid crystalline dendrimer showing birefringent "fan"-like domains*

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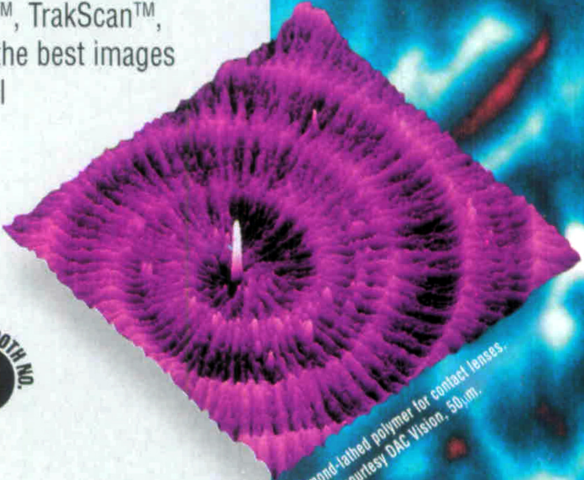

Diamond-lathed polymer for contact lenses. Sample courtesy OAC Vision, 50μm.

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*Sample courtesy A.P. Shilov, Moscow State University, 25μm

Background: MFM image of a $Fe_{80}B_{16}Si_4$ ribbon revealing stress-induced magnetic structure that can lead to power losses in electrical transformers, 30μm scan courtesy M.E. Hawley, Los Alamos National Lab gallium nitride can produce blue laser light when it is pumped with light from another laser. The observation, reported in the December 21 issue of *Applied Physics Letters*, changes scientists' understanding of solid-state lasers and suggests that these devices can be made much more simply than they have been.

A laser typically amplifies light inside a cavity formed by mirrors. Semiconductor lasers, in which the light is reflected back and forth between the end facets of a crystal, have been made only by complicated techniques to grow near-perfect crystal films on underlying template surfaces that precisely align the atoms of the crystal.

The expense of fabrication and the narrow choice of suitable substrate materials has limited the range of applications for these tiny lasers, said Robert P.H. Chang, director of the Materials Research Center at Northwestern, who led the study. He said, "We wanted to know if lasing could occur without mirrors and whether it is possible to make solid-state lasers with powder films."

Chang, a professor of materials science and engineering in Northwestern's Robert R. McCormick School of Engineering and Applied Science, with graduate student Hock Ong and visiting scholar Ji Dai, grew thin films of zinc oxide on ordinary glass wafers. Zinc oxide is a semiconductor with a blue luminescence and a high optical gain to amplify light. The powdered zinc oxide layer has a highly disordered structure. The researchers were able to show that this disorder paradoxically enhances the lasing effect. Traditional semiconductor lasers, with well-defined cavities, have perfectly ordered structures to minimize light scattering. In those devices, normal light scattering reduces laser output.

Hui Cao, an assistant professor of physics and astronomy, and visiting scholar Yi-Guang Zhao evaluated the laser properties of the zinc oxide films. Cao said, "Scientists have been trying to eliminate scattering, which you always think of as bad for a laser. But we went to the other extreme. In a totally disordered medium, scattering is very strong, and it actually helps lasing because it forms closed-loop paths for the light and creates feedback. It makes its own laser cavities."

When they pumped the zinc oxide layer with a conventional laser at low power, Cao and Zhao found that the material gave off light with a broad band of wavelengths. But as the pump power was increased, the bands sharpened, and above a certain threshold, very sharp frequency bands appeared. The narrow frequency range of those bands and their strong polarization confirmed that the light was a laser emission.

The researchers observed the cavities forming and lasing in the zinc oxide powder film using a camera at high magnification. Cao said that the random orientation of the self-formed laser cavities in the film is also an advantage because it makes the laser output omnidirectional. She said, "Traditional lasers are highly directional, while LEDs [light-emitting diodes] shine in all directions. But if a zinc oxide laser device ultimately works, it could replace LEDs in luminescent display devices because the light would go in all directions but with much greater efficiency. A laser at the same power consumption could be 1,000 times brighter than a LED."





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## President Clinton Names 1998 Recipients of the National Medal of Science

President Clinton announced the 1998 recipients of the United States' highest science honor, the National Medal of Science. The recipients include Materials Research Society (MRS) member **John W. Cahn**, Fellow at the National Institute of Standards and Technology, for his profound influence on the course of materials and mathematics research, and his enormous contributions to three generations of materials scientists, solid-state physicists, and mathematicians; **Cathleen S. Morawetz**, Professor Emerita at the Courant Institute of Mathematical Sciences of New York University, for pioneering advances in partial differential equations and wave propagation resulting in application to aerodynamics, acoustics, and optics; **Eli Ruckenstein**, Professor of Chemical Engineering, State University of New York in Buffalo, for his world class pioneering theories and experimental achievements in colloidal and surface phenomena, catalysts, and advanced materials; and MRS member **George M. Whitesides**, Professor of Chemistry at Harvard University, for his innovative and far-ranging research in chemistry, biology, biochemistry, and materials science that has brought breakthroughs to transition metal chemistry, heterogeneous reactions, organic surface chemistry, and enzyme-mediated synthesis.

## Creation of Dimethacrylates Through Photopolymerization Leads to Longer-Lasting Dental Paste

Virginia Tech graduate student Nazan Gunduz and her fellow researchers in chemistry have developed dental materials through a process called photopolymerization. This process uses light as an activator to turn a liquid coating into a plastic to create, for example, insulating layers in electronic components or protective coatings on metal cans. It is also used to harden dental filling material. Gunduz used PhotoDSC technology (a combination of light activation and differential scanning calorimetry) to measure the attributes of materials developed by her research group.

Allan Shultz, an adjunct professor at Virginia Tech who was scheduled to deliver a talk at the American Chemical Society Biennial Polymer Symposium held November 22–25, 1998 in Williamsburg, VA, said, "Chemists in our group at Virginia Tech have synthesized four new monomers, or dimethacrylates, that have low viscosities. It will be possible to form a dental paste using only one of these new dimethacrylates rather than the mixture presently used. Also, due to the structures of the new dimethacrylates, the resulting tooth fillings will not absorb as much water as present fillings. Their good mechanical properties will therefore not be decreased as much as those of present fillings and the fillings should last longer."

Shultz said that Gunduz's group has studied the photopolymerization kinetics of the four new dimethacrylate monomers and of the viscous monomer used in present dental resins. "A close approximation to present dental practice was followed by using a camphor quinone/amine photoinitiator system and blue light activation. The instrumentation employed was a commercial double beam light accessory (Perkin-Elmer DPA 7) attached to a DSC apparatus (Perkin-Elmer DSC 7)," Shultz said. The blue light illuminated both a reaction cell and a reference cell; the differential power input required to maintain the same temperature in the two cells is equal to the heat generation rate of the reacting material. The heat generation rate is proportional to the reaction rate. The researchers could therefore calculate the reaction rate at any chosen time and the total amount of reaction that occurred in a given time period. The researchers said that variation of photoiniator amount, light intensity, and temperature produced a great amount of data of both scientific and practical value. Analyses of the rates of monomer conversion and the ultimate conversion of the monomers to hardened network products allowed the researchers to compare the kinetics, efficiencies, and activation energies of the different monomers.

Currently, dentists use a thick paste mixture of two monomer liquids plus an inorganic filler such as fine sand or silica to produce white fillings for repairing front teeth. They use one monomer which is a thick, viscous liquid and the other a thin liquid. The thin liquid monomer gives the paste the needed consistency for the dentist to handle. The mixture also contains a photoinitiator that, upon exposure to blue light, causes the monomers to join into a hard polymer network. The monomers used by the Virginia Tech research group were found to be superior to those currently used by dentists.

## DOE Funds 25 Energy-Saving Projects

Under its Inventions and Innovation Program, the U.S. Department of Energy has awarded $1.6 million in grants to 25 organizations to help bring their energy-saving inventions to the marketplace. Dan Reicher, Assistant Secretary for Energy Efficiency and Renewable Energy, said, "Their inventions will help use energy more efficiently and cut greenhouse gases and other emissions."

The award recipients include Fuel Cell Technologies, Inc., New Milford, CT, "Industrial Fuel Cell Micro-Generator" ($39,984); Trilliam Thermo Technologies, Inc., Pacific City, OR, "High-Temperature Refractory Ceramic," ($40,000); W. Brandt Goldsworthy & Associates, Inc., Torrance, CA, "Development of a Composite Reinforced Aluminum Conductor," ($55,000); Energy Research Company, Staten Island, NY, "*In Situ*, Real-Time Measurement of Melt Constituents in the Aluminum, Glass, and Steel Industries," ($100,000); and Forsyth Electro-Optics, Inc., Philadelphia, PA, "Fault Warning Device Using Fiber-Optic Partial Discharge Sensor for Prevention of Destructive Arc Faults in Metal-Clad Electrical Switchgear and Bus," ($100,000). □

ABSTRACT DEADLINE FOR MATERIALS RESEARCH SOCIETY 1999 FALL MEETING

**June 7** for abstracts submitted via e-mail, fax, or mail

**June 21** for abstracts submitted via the MRS Website



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