## Conclusions

Monuments and markers are useful and necessary parts of a high-level waste management strategy. Information should be included that will allow future generations to know what is buried in the repository and how to retrieve the material most effectively and with least danger to themselves and their environment. The changing nature of the waste materials with time should be clearly shown at the ground surface through pictorial means so that future decisions can be made with minimal effort concerning risks and benefits associated with the wastes.

*Virginia M. Oversby received a BA degree in chemistry from Wellesley College and an MA and PhD degree in geology with specialty in geochemistry from Columbia University. She worked in the field of isotope geochemistry for many years and then turned to radioactive waste management. She participated in Australia in the development of the ceramic waste form, SYNROC, and then returned to the United States where she worked for 15 years at Lawrence Livermore National Laboratory. Oversby currently lives in Sweden where she works as a consultant to the Swedish Nuclear Fuel and Waste Management Company, SKB.*

# RESEARCH/RESEARCHERS

## Lipid Thin-Film Sensor Provides Instant Test for Toxic *E. Coli* Organism

Researchers have developed a sensor that instantly detects the presence of toxic *E. coli* bacteria. Raymond Stevens, a chemist at the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab.), said that the sensors his team have developed are capable of providing an on-the-spot litmus test for *E. coli* strain 0157:H7.

Stevens said, "These sensors have been designed so that the presence of this strain of *E. coli* causes a color change, from blue to red. The greater the color change in the sensor, the higher the concentration of 0157:H7. The color change is instantaneous."

The working part of the sensor consists of a single type of molecule fabricated into a thin film. This molecule has a two-part composite structure. The surface of the molecule binds the bacteria. The backbone underlying this surface is the color-changing signaling system. The backbone of the sensor molecule is composed of a long diacetylene lipid, a molecule similar to the phospholipids that are the building blocks for cell membranes. Exposure to uv light links the molecules together by activating a triple bond within the diacetylene lipids, creating a blue-tinted polydiacetylene (PDA) film. PDA films are sensitive to changes on their surface as manifested by the wavelength of light they transmit. When *E. coli* 0157:H7 toxins bind to their synthetic membrane surface, the backbone chain of PDA reorganizes. The sensor that was blue turns red.

The Biomolecular Materials Program focuses on adapting nature's biological systems to problems outside the living organism. In this case, Stevens said, "We have made synthetic surfaces that mimic the unique cellular binding sites for the toxins produced by *E. coli* 0157:H7 interactions. When these toxins are produced, they hunt around for places to bind. When they find the right receptor site, they attempt to bind. This activity in humans causes disease. In the sensor, it is what triggers the color change."

Stevens, who also is an assistant professor of chemistry at the University of California at Berkeley, developed the sensors in concert with Berkeley postdoc Quan Cheng. The device is a modification of one originally described in *Science* by scientist Mark Bednarski and materials scientist Deborah Charych. All are current or former members of Berkeley Lab.'s Biomolecular Materials Program in its Center for Advanced Materials.

## XAFS Determines Chemical Properties of Tc in Radioactive Waste

Using x-ray absorption fine structure (XAFS) spectroscopy, scientists at Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab.) have developed methods to examine the *in situ* chemical properties of technetium, a component of radioactive waste. The radioactive isotope Tc-99 is abundant in nuclear waste and has a long half-life of about 200,000 years. This XAFS method holds promise for detecting a variety of other chemical species in radioactive wastes, and can be used for evaluating the safest way to isolate these radioactive elements from the environment.

When storing technetium in cement, Tc takes on a form that is water-soluble. Deputy Division Director Norman Edelstein of the Chemical Sciences Division said, "Technetium's most common oxidation state is the pertechnetate ion ($TcO_4^{-1}$), which is a very soluble material. So if the method of mixing cement with radioactive waste containing pertechnetate is to be successful, it's necessary to reduce the technetium to a less soluble material, such as $TcO_2$."

Scientists from Savannah River Technology Center and Washington State University had developed a cement formulation for immobilizing waste that includes blast furnace slag and fly ash mixtures. According to Jerome Bucher of the Chemical Sciences Division at Berkeley Lab., a technique was needed to examine Tc in the cement-blast furnace slag mix. "X-ray absorption spectroscopy is ideal for this problem. We were able to look at many of their formulations and determine that the technetium was not completely reduced from the pertechnetate form by the blast furnace slag materials," Bucher said. With XAFS spectroscopy, the oxidation state of the technetium in the cement can be obtained without chemically separating it from the cement, while structural information can simultaneously be gathered on nearby atoms. The oxidation state, combined with information about nearby atoms, indicates whether the technetium is in a mobile, water-soluble form, or in a more insoluble form.

To obtain data using XAFS, researchers irradiate a sample contained in a cell millimeters thick and about 2 cm long with x-rays. This ejects an inner shell electron of the ion, and other electrons fall back to the inner shell emitting radiation that is characteristic of the particular element

## SBIR Update

**Essential Research, Inc.** (Cleveland, Ohio) has been awarded a Small Business Innovation Research grant from the National Aeronautics Space Administration (NASA). The grant will fund research and development of a high-efficiency, radiation-resistant solar cell (InP and Ge substrates) to provide power for satellites. The Phase II award provides $600,000 of funding for the 24-month effort.

that the ion is based upon. The characteristic radiation emitted from the ion is measured as a function of x-ray energy to determine the oxidation state of and chemical species containing the ion. Because inner shell electrons are bound so tightly to their nuclei, extremely high-energy radiation is necessary to push them into a higher shell—thus the need for x-rays.

The researchers prepared a series of cement mixtures, each containing technetium waste simulant and a different component of blast furnace slag, and then measured the oxidation state of the Tc in each sample. They found that FeS and $Na_2S$ were equally effective chemical additives for reducing the pertechnetate ion into more stable forms.

## High-Output Accelerator Predicts Nuclear Blast Physics

For periods of tens of nanoseconds, the Particle Beam Fusion Accelerator, Z-Pinch (PBFA-Z) at Sandia National Laboratories produced 1.8 MJ of energy, providing data for computer simulations used to predict the physics within, and effects of, a nuclear blast. Since underground nuclear explosions have been halted, scientists intend to rely on this type of laboratory data instead. Keith Matzen, department manager of Target and Analysis Theory, presented the results on November 11, 1996 at the annual meeting of the American Physical Society Division of Plasma Physics.

The large output of power and energy is accomplished by converting the accelerator's electrical output into plasma called a z-pinch, which efficiently produces x-rays. The z-pinch creates a magnetic field that, as it contracts around ionized gas, pinches it vertically along (in mathematical terms) the z-axis.

PBFA-Z creates tremendous heat by very quickly stopping the plasma's rapid motion within the field's confines. The lines release the current—17 MA—over a time interval of nanoseconds and into a very small target, thereby magnifying the power exerted in that time. The burst of electricity passes vertically through a cylindrical container 4 cm in diameter and 2 cm long. Inside the can, whose inner surface is gold plated, is a network of 120 fine tungsten wires in a cylindrical array. The entire assembly is in vacuum.

The electric current passes downward through the can wall and runs back through the tungsten wires inside the can, immediately vaporizing the wires and generating an ionized tungsten plasma, and simultaneously creating an enormous magnetic field. Driven by the magnetic field located between the lining of the can and the periphery of the wires, the wire plasmas are pushed rapidly inward by the field's intense pressure. This compresses the tungsten plasma, increasing its density and temperature.

By compressing the plasma suddenly, the contracting magnetic field rams tungsten atoms from one side of the can into tungsten atoms driven in by the contraction of the far side. These collisions bring the ionized atoms to a sudden halt and generate heat, which is released in the form of x-rays.

## Ultralow Power Consumption Achieved for Quantum-Based Memory Cell

Researchers at Texas Instruments have demonstrated a high-density, ultralow-power memory cell based on a quantum device technology. Known as tunneling-based static random-access memories (TSRAMs), the cells achieved 50 nW of standby power per cell, with less than 10 nW expected after scaling. This is more than 200 times lower than previously recorded SRAMs in similar materials. The process was demonstrated using InP, but the researchers say it is applicable to GaAs because of the similarities of the semiconducting materials. Previously, "fast digital processors in GaAs could not get the large amounts of fast memory 'on chip' required to build single-chip GaAs processor solutions," said Paul van der Wagt, one of the researchers whose work was presented at the 1996 IEEE International Electron Devices Meeting in December.

The quantum process technology integrates resonant-tunneling diodes (RTDs) and heterostructure field-effect transistors (HFETs) on one substrate, which allows logic circuits to be implemented using as few as one-tenth the number of components previously needed.

For the TSRAM cell design, the current density of the RTDs has been reduced to 1 A/cm$^2$. When used in pairs, these RTDs define two stable voltage levels that provide the high or low values of a memory bit. With an additional two integrated RTDs, the researchers obtained a multi-valued memory cell (100 mW) that attains three logic states within the same cell area.

On an InP substrate, the researchers used an InAlAs buffer, InGaAs channel, and an InAlAs barrier with an $n^+$ cap. The RTDs were connected to the gate of an HFET. According to the researchers, "Either the write-HFET or read-HFET steers the storage node [SN] voltage either low or high, depending on which of these currents is larger. The RTD latch can maintain two stable SN voltage levels as long as the RTD peak current is larger than the HFET leakage currents plus an RTD valley current." This technology elicits a cutoff frequency $f_T$ and maximum frequency of oscillation $f_{max}$ of over 100 GHz for 0.25 μm gate length.

The researchers are also investigating quantum-based TSRAMs to enhance Si dynamic random access memory (DRAM) cells. In the storage function, an RTD latch has two stable voltage points: so long as the RTD's peak current is larger than the total leakage current of the SN plus the RTD valley current, the RTD will hold the SN close to one of these two points.

## Disordered Liquid Mercury Surface Dominates Order-Promoting Interactions of Alkanethiol Chains

While alkanethiols tend to order themselves, when placed on a surface of liquid mercury, the organic film becomes disordered like the subphase, indicating that the interactions between the end group on the chains and the subphase overcome the order-producing interactions between the chains. Researchers used grazing-incidence x-ray diffraction (GIXD) to study $CH_3(CH_2)_{n-1}SH$ (represented by $C_n$ with $n$ = 8, 12, 16, 18, 22, and 30) on liquid mercury surfaces. According to the researchers' article published in the November 21, 1996 issue of *Nature*, alkanethiol monolayers were deposited through three methods—chemical vapor deposition, self-assembly from an ethanol bath, and spreading from a dilute chloroform solution. X-ray analysis with wavelengths between 0.65 Å and 1.2 Å carried out at the National Synchrotron Light Source at Brookhaven National Laboratory revealed no significant changes in the structure of the liquid mercury surface and no in-plane, long-range order of the alkane chains. The researchers also found that oscillations scaled with the length of the $C_n$ molecule, indicating a similar monolayer structure for all lengths. The researchers studied wavevectors from 1.5 to 1.7 Å$^{-1}$ where, they said, "structurally similar SAMs [self-assembled monolayers] and Langmuir monolayers show the lowest order in-plane peaks." They concluded that the covalent Hg-S bond of the disordered subphase imposed its structure on the adsorbate film.

The ability to control the structure of organic thin films is important in areas from nanoscale electronics to corrosion resistance.

## Quasi-Liquid Character of Ice Surface Supports Theories of Slipperiness and the Ozone Hole

Detailed molecular-scale pictures of the surface of crystalline ice reveal that at 90 K, water molecules on the surface of ice continue to vibrate, giving the surface a "quasi-liquid" character that could account for catalytic chemistry as well as slipperiness. The high degree of vibrational motion exhibited by water molecules in the surface layers of ice is attributed to the absence of other water molecules above them, together with the weakness of the bonds between water molecules. This not only gives rise to a liquid-like vibrational motion, it also frees the water molecules to interact with other molecules to which they are exposed, such as those in the atmosphere.

Temperatures in the polar stratospheric clouds are around 200 K, leading Michel Van Hove, a chemist at Ernest Orlando Lawrence Berkeley National Laboratory, and his colleagues to believe enough vibrating layers of water molecules exist to create a thin film of quasi-liquid water on the ice crystallites in the clouds.

"This watery film could be the catalyst that provides a crucial link in a long chain of chemical reactions which leads to the creation of the ozone hole," Van Hove said.

At temperatures around 230 K and above, Van Hove and his colleagues believe that the surface film of ice becomes a true liquid which would account for its uniquely low coefficient of friction.

The researchers created a thin film of ice, about 10 Å thick, by condensing water vapor on a cold platinum surface in an ultrahigh vacuum. They then studied the surface ice using tensor-low-energy electron diffraction (tensor-LEED), providing a timely and practical means of determining the position of atoms on a given surface. Once models of the surface structure of ice were obtained, the results were analyzed, using total-energy calculations and molecular dynamic simulations.

"What we see is that the outermost molecular film of ice solidifies only up to a point," said Van Hove. "Large vibrational amplitudes continue to exist down to at least 90 K."



## Chou and Rice Receive ASME Int'l Awards

At The American Society of Mechanical Engineers' (ASME) International Mechanical Engineering Congress and Exposition, November 17–22, 1996 in Atlanta, Georgia, Tsu-Wei Chou, Nowinski Professor of Mechanical Engineering at the University of Delaware, and James R. Rice, Gordon McKay Professor of Engineering Sciences and Geophysics at Harvard University, received the Charles Russ Richards Memorial Award and the Nadai Award, respectively.

The Richards Award is presented to an engineering graduate who has demonstrated outstanding achievement in mechanical engineering 20 years or more following graduation. Chou's research interests and contributions have been in the application of analytical techniques to the study of a broad range of material problems, including applying the concept of physical defects to understanding the deformation behavior of metallic, biological, and geological systems. His interests have also included analytical modeling of the microstructure-performance relationship of polymeric fiber composites, as well as processing science and damage mechanics studies of metal- and ceramic-based composites.

Rice received the Nadai Award for "his major contributions to the fundamental understanding of plastic flow and fracture processes in engineering and geophysical materials and for the invention of the J-Integral, which forms the basis for the practical application of nonlinear fracture mechanics to the development of standards of safety of structures."

Rice's contributions have included fracture and plasticity theory in mechanical engineering and materials science, computational mechanics methodology, and earthquake source physics and crustal deformation modeling. His materials research has addressed the elastic-plastic continuum mechanics of crack growth, micromechanisms of cavitation in ductile and creep rupture, constitutive equations in crystal plasticity, atomistic and dislocation aspects of brittle versus ductile response of crystals, as well as interfacial fracture mechanics, thermodynamics of adsorption and embrittlement of interfaces by solute segregation and the dynamics of cracking through heterogeneous solids. □

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