

mantle and of mantle lying much closer to the surface in a high-temperature, high-pressure apparatus. He then placed these samples together in the same apparatus and heated them for 10 min. After cooling the samples, he separated them and analyzed their mineralogical compositions.

“We generally think of magmas as moving very slowly and geological processes as occurring over hundreds of thousands of years, so it’s really amazing how much happens in just 10 minutes,” Lundstrom said. “In that brief time, considerable migration occurred as sodium diffused through the melt between mineral grains, significantly altering the composition of the material.”

In a positive-feedback loop, the infiltrating sodium causes orthopyroxene to break down into olivine plus the peculiar composition melt. This melt, in turn, causes even more sodium to be pulled in. Lundstrom said that the increase in olivine and the decrease in orthopyroxene within the diffusively infiltrated piece of mantle may explain another perplexing observation: the anomalous ratio of these minerals found in the shallow mantle region beneath mid-ocean ridges.

He said, “We tend to think of volcanic edifices—like the Hawaiian Islands—as resulting from hot spots in the mantle. But these results show that sodium-rich, silica-poor magma can cause the surrounding mantle to melt through a chemical reaction without invoking huge quantities of heat.” Lundstrom also said that the diffusion process could be important to melting the cold lithospheric “plates” that cover the earth.

Model of Interactions Between Coupled Atomic Bose Condensate and Molecular Gas Predicts Formation of Molecular Bose Condensates

Researchers investigating dilute Bose-Einstein condensation (BEC) have proposed a novel, non-Arrhenius chemical kinetics at ultralow temperatures. D.J. Heinzen and R.H. Wynar at the University of Texas—Austin, and P.D. Drummond and K.V. Kheruntsyan at the University of Queensland in Australia have named this phenomenon “superchemistry.” Defined as “the coherent stimulation of chemical reactions via macroscopic occupation of a quantum state by a bosonic chemical species,” superchemistry involves giant collective oscillations between a dilute, trapped Bose-condensed atomic gas and a diatomic molecular Bose gas. Coupling takes place between these two species through coherent Raman transitions, and

leads to the formation of a molecular Bose condensate through stimulated emission of molecular bosons.

Of particular interest in their model is the introduction of the particle number nonconserving potential, similar to parameters used to describe nonlinear optics. In the Arrhenius kinetics model the rates of chemical reaction are independent of the number of particles of product species and tend toward zero at ultralow temperatures. However, as published in the May 1 issue of *Physical Review Letters*, the proposed superchemistry kinetics model shows that chemical conversions inside a Bose condensate are caused by coherent stimulated emission, which is enhanced by the number of molecules already occupying the ground state. The current research considers the specific case of stimulated Raman coupling induced by two laser fields of different frequencies; resonant coupling occurs when Raman detuning goes to zero. A trap potential localizes the interaction volume.

The investigators see potential applications in the area of quantum-controlled chemical synthesis.

TIM PALUCKA

Wavelength-Interchanged Optical Sensor Facilitates Biochemical Analysis

M. Wiki and R.E. Kunz from Centre Suisse d’Electronique et de Microtechnique in Zurich, Switzerland reported in the April 1 issue of *Optics Letters* a novel sensor that allows the simultaneous measurement of several different biochemicals. The miniature (18 cm × 6 cm × 4 cm) integrated-optical sensor relies on wavelength-modulation techniques to interrogate multiple waveguide sensing regions in a single integrated-optical chip for accurate measurements of effective refractive index changes at a high data rate. The sensor can exploit the wide tuning range of vertical-cavity surface-emitting lasers to obtain high-resolution spectral measurements of refractive-indices. The integrated optical chip structure is based upon TiO₂ waveguide structures fabricated over a polycarbonate substrate onto which grating structures are fabricated using a hot embossing process. The experiments with this sensor yielded a resolution (in units of the effective refractive index) $\Delta N_{pp} = 10^{-7}$. The researchers’ method consists of an input grating-coupler scheme. The structure consists of two different grating pads, one used as a reference pad and one of which is obstructed by the transparent biochemical layer to be analyzed. The position of the output resonance peak is a measure of

the effective refractive index of the sensor chip, and hence contains the desired information about the biochemical layer, information that can be extracted by applying a theoretical model of the IO sensor chip. Integrated optics is one well-known technique for label-free detection of (bio)electrical reactions, and has been used for many years. Previously developed integrated-optical sensors include sensors based on uniform grating couplers, chirped grating couplers, surface-plasmon resonance, resonant mirrors, and difference Mach-Zehnder and Young interferometers. But for practical applications, most label-free sensors either do not achieve the desired resolution for multiple channels, or are very bulky and expensive.

CLAUDIU MUNTELE

Blends of Electron- and Ion-Conducting Polymers Yield Fast Electrodes in Supercapacitors

A team of researchers at Linköping University in Sweden described the synthesis of polymer blends that are both electron- and ion-conducting in the May issue of *Electrochemical and Solid-State Letters*. The blends consist of electronically conductive PEDOT-PSS (poly(3,4-ethylenedioxythiophene)-polystyrenesulfonate) and ionically conductive PEO (polyethylene oxide) and give higher energy densities at high power densities compared to pure PEDOT-PSS polymers. The network morphology of the PEDOT-PSS extends these electrodes into the third dimension, making them promising materials for use in supercapacitors, sensors, and electrocatalysts.

“Electronically conducting polymers are of interest for use as electrode materials because their amorphous nature gives them good permeability to electrolytes,” said Olle Inganäs from Linköping’s Applied Physics Division. “However, ionic compatibility is often low, which limits the charge transfer in these systems by the slow ionic exchange.” In recent years, the researchers obtained a patent on a process that involves doping PEDOT with PSS and ionically cross-linking the resulting polymer into highly swollen hydrogels. This yields 3D networks of electronically conducting polymers with more than 90% in an aqueous phase that provides good ionic mobility. “But application of PEDOT-PSS hydrogel electrodes is restricted to aqueous systems, which have comparatively small windows for electrochemical potentials”, said Soumyadeb Ghosh, a postdoc at Linköping University. In order

to force the polymer to swell in organic solvents, he and Inganäs investigated the behavior of PEDOT-PSS blends with PEO, which are known to form conductive PEDOT-PSS networks in a PEO matrix that could provide space for ionic movements.

Films of the polymer blends were cast onto gold-coated silicon wafers from aqueous dispersions and used as active electrodes. Cyclic voltammetry indicated that the PEDOT-PSS/PEO blends show the expected higher ionic mobility. Although the measured current is lower than for swollen hydrogels, the two values become comparable if they are normalized to the mass of PEDOT-PSS that is present in each electrode. This indicates similar efficiencies for both systems. The efficiency of the blend electrode increases with decreasing PEDOT-PSS content (down to about 25%), showing that the high compatibility of the two polymers allows the formation of a network morphology even at low PEDOT-PSS concentrations. Supercapacitor measurements gave high energy densities for the blend electrodes even at power densities five times higher than the drop-off for pure PEDOT-PSS electrodes. "These power densities were calculated using the total weight of the blend", Ghosh said. "This means that we get higher energies with a smaller amount of redox material."

"The increase in ionic mobility in the PEDOT-PSS blend with inclusion of PEO can be ascribed to the intrinsic ionic conductivity of the latter polymer as well as to the swelling of the PEO phase in the acetonitrile solution, creating space for ionic movement," Inganäs said. The researchers reported that the comparative experiments with blended and unblended PEDOT-PSS electrodes in a solid-state cell suggest that "the intrinsic ionic conductivity of PEO does contribute to the enhancement of ionic mobility."

Currently, the group is working "on better crosslinking of the electronically conducting PEDOT-PSS phase and on loading the material with more energy-rich material to increase the energy density, keeping the network morphology and hence the ionic mobility intact," said Ghosh. In the hydrogels, this has been achieved by introduction of polypyrrole, a second conducting polymer.

CORA LIND

Versatile Pattern Transfer Process for Polymers Developed

Researchers from the University of Massachusetts and the University of Groningen, The Netherlands, have

reported a nanoscopic pattern transfer phenomenon. Erik Schaffer, a graduate student at Groningen, and Thomas Thurn-Albrecht, a postdoctoral researcher at Massachusetts, placed a thin film of polystyrene atop an electrode. They placed a second electrode above the film, leaving an air gap between the film and the top electrode. They then heated the polystyrene, liquefying it, and placed a small voltage on the electrodes.

With time, as reported in the February 24 issue of *Nature*, the surface of the film appeared pockmarked. Tom Russell, in polymer science and engineering at Massachusetts, said that the electric field amplified waves on the liquid's surface. The waves were increasingly amplified and eventually were pulled to the top electrode. The phenomenon appears under the microscope as a dark ring on a light background. As time passed, more and more circles appeared. The circles were all the same size, and appeared at a precise distance from one another.

Russell said that the phenomenon occurs because of the interaction of four competing forces. Those forces include the electrical force, which pulls the liquid toward the top electrode; the surface energy of the liquid, which wants the liquid to lie flat; the viscosity of the liquid as crests and valleys form and the liquid moves; and the effects of atmospheric pressure. "It doesn't happen helter-skelter," he said. "It happened at very distinct distances that represents a delicate balance between all of these forces."

Through a process called pattern transfer, the researchers can "imprint" a film with a very specific design. In this process, an electrode is etched with a master pattern. The master electrode has a topography of "hills" and "valleys." When a voltage is applied, the film responds most strongly to the closest portions of the electrode, creating a replica of the master design on the polymer film. The researchers said that their findings have implications in paving the way for still-smaller integrated circuits, magnetic storage in computers, and on-chip sensors—all of this without the use of chemicals.

Additional CeO₂ Buffer Layer Improves Performance of Superconducting Tape

The microstructural development of a superconducting tape (coated conductor) consisting of a layer of YBa₂Cu₃O_y (Y-123) superconducting material (1–3- μ m thick) on an Inconel 625 substrate 100- μ m thick with a layer of yttria-stabilized zirconia (YSZ) 0.8- μ m thick and CeO₂ buffer lay-

ers (~0.03- μ m thick) was studied by researchers at the Los Alamos National Laboratory (LANL). They reported in the May 2000 issue of the *Journal of Materials Research* that an additional buffer layer is useful "for removing the misfit strain from the interface with the superconductor and limiting the extent of interfacial reactions with Y-123."

Since its discovery, Y-123 has been actively investigated for high critical current and high current density applications at liquid nitrogen temperatures. The epitaxially prepared materials studied at LANL exhibit the best critical current and current density in a 1 m Y-123 tape produced to date. These favorable characteristics are believed to result from the use of two buffer layers between the substrate and the superconducting film. The YSZ buffer layer improves performance by preventing the Ni and Cr from the substrate from contaminating the Y-123 layer and providing a biaxially aligned template for its growth. The CeO₂ buffer layer is believed to improve conductor performance by removing the lattice mismatch strain between the YSZ and Y-123 layers. To extend the current technology to the production of conductors longer than 1 m, and possibly improve conductor performance, the microstructural properties of the conductor during processing need to be investigated. This study detected and explained a number of such features.

A Cr₂O₃ layer was detected between the substrate and the YSZ layers by electron diffraction and energy dispersive spectroscopy. The researchers speculate that this layer formed *in situ* during the high temperature deposition of the CeO₂ and Y-123 layers and not during the room temperature deposition of the YSZ. The researchers believe that it is the Cr₂O₃ layer that prevents Ni and Cr from the Inconel from contaminating the Y-123, as neither metal could be detected above the Cr₂O₃. This is an important finding because it proves that the Inconel substrate is compatible with the YSZ layer. This is advantageous because YSZ is the only material known that can be reliably deposited as a biaxially textured film for Y-123 deposition.

No evidence for a reaction between YSZ and CeO₂ was detected; however, there was evidence of misfit dislocation between the layers. According to the researchers, since Y-123 is closely lattice matched to CeO₂, the extra buffer layer apparently moves the misfit strain away from the Y-123 film. The researchers reported, "A volume constraint imposed by the overlying Y-123 film may act as a kinetic barrier and limit the extent of the