

edge. The presence of such states results in a trapped electron potential of -0.39 V, which exceeds the reduction potential of the O_2/O_2^- at pH 7 (-0.16 V), and enables the formation of OH radicals by visible-light irradiation.

The researchers, therefore, analyzed the photocatalytic activity of new materials by observing the degradation of typical pollutants in water and air by artificial and natural light. They observed complete photomineralization of the ubiquitous water pollutant 4-chlorophenol in the presence of the catalyst after 180 min of irradiation with visible light ($\lambda = 455$ nm). The researchers also confirmed high photocatalytic activity of the substances by photodegradation of 4-chlorophenol and the azo dye remazol red by illumination experiments in diffused indoor daylight. Furthermore, they found that the catalyst supported on filter paper catalyzes the oxidation of gaseous acetaldehyde, benzene, and carbon monoxide.

ANDREI A. ELISEEV

Micromirrors Fabricated by the Micro-Origami Technique Characterized by Optical Actuation

The development of semiconductors goes hand in hand with research into microelectromechanical systems (MEMS) devices because the latter, in a lot of cases, are built on semiconductors and consequently the progress of semiconductor research depends on the study of micro technologies. J.M. Zanardi Ocampo from ATR Laboratories in Kyoto, T. Ohnishi from Konan University in Kobe, R. Izumoto from Osaka City University in Osaka, and their colleagues addressed the formation of reliable hinges for movable parts of MEMS equipment, by means of micromirrors, and the actuation of the resulting micromirrors. As reported in the November 3, 2003, issue of *Applied Physics Letters*, the researchers have fabricated standing micromirrors by the micro-origami technique they developed in which the hinges bend as the result of strain in a pair of lattice-mismatched epi-

taxial layers. They then characterized the micromirrors by way of optical actuation.

To form the mirrors, the researchers used GaAs(100) as a substrate, $Al_{0.5}Ga_{0.5}As/AlAs$ (40 nm) as a sacrificial layer, and $In_{0.22}Ga_{0.78}As$ (56 nm) as a strain layer, followed by a GaAs (88 nm) spacer layer. On top of that, they grew the mirror plate. They then processed the samples by photolithography and wet etching. Etching was selectively applied first to the component layer, then to all layers down to the etching stop layer and finally to the sacrificial layer. Powered by the strain relaxation of the InGaAs layer, the mirror stands by itself.

An Ar laser beam was focused on the surface to perform actuation of the mirrors. A HeNe laser probe beam was also focused on the mirror's surface and reflected onto a target placed several hundreds of millimeters away from the sample. This image was processed to analyze the mechanical response of the mirror during actuation. When the mirror was irradiated with the Ar laser, the HeNe probe light indicated a deflection in its inclination, which was positive. After the Ar laser optical excitation was interrupted, the mirror returned to its original angle. Thus, the frequency response of these mirrors was studied by applying a modulated optical excitation.

In order to explain this optical actuation, the researchers considered several phenomena. Light radiation pressure would not account for an increase in the mirror's inclination angle, as was found here, but rather a decrease. Actuation by heating and expansion of the surrounding air cannot be the reason because the mirrors move in vacuum as well. Stress by carrier generation remains a possible cause but short surface recombination times in GaAs and thinning of the epitaxial films can impede the actuation. As the researchers report, the most reasonable explanation could be uneven thermal expansion within the materials and thus deformation of the structures.

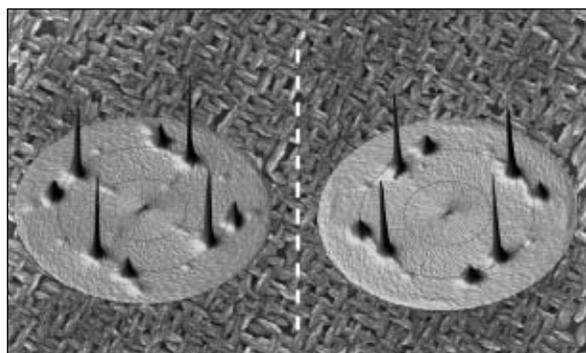
EKATERINA A. LITVINOVA

Chiral Surface Produced through Electrodeposition

J.A. Switzer and colleagues at the University of Missouri—Rolla have developed a process for separating or detecting chiral molecules using electrodeposited chiral surfaces, in contrast to the current process that requires a homogeneous catalyst or an enzyme solution. The electrodeposited chiral surface can then be used as this type of catalyst.

As reported in the October 2, 2003 issue of *Nature*, the researchers immersed a thin layer of gold in a liquid containing copper and the enantiospecific chemical tartrate while applying an electric current to the system. The electricity caused copper oxide to bond to the achiral Au(001) surface. The chirality of the film was determined by the chirality of the tartrate ion in solution. The researchers used x-ray diffraction to determine the orientation of the entire film, and x-ray pole figure analysis to determine the film's absolute configuration (see figure). Initial tests revealed that the material differentiates the enantiomeric forms of the chiral tartrate without breaking down or being permanently altered.

Switzer said, "We've made a material where the entire product is chiral, not just the



X-ray pole figures of ~ 300 nm CuO films electrodeposited onto a Au(001) surface. The background is a scanning electron microscope image of one of the CuO films. The pole figures—which represent data, not images of molecules—were created by use of an x-ray diffractometer.

surface. In earlier experiments, you would modify a surface with a chiral modifying agent, and if the agent washes off, the surface is no longer effective. In our research, the film itself is chiral, so the effectiveness remains even after many chemical reactions."

Switzer said that the production of chiral surfaces is significant for the synthesis and detection of chiral molecules such as pharmaceuticals.

Photosensitive Membrane Fabricated by Molecular Imprinting

Molecular imprinting technology is an emerging method for the preparation of synthetic materials that use molecular recognition for selective separation and chemical identification. To prepare molecularly imprinted polymers (MIPs), a functional monomer and a cross-linker are polymerized in the presence of a template molecule. The template is then extracted, leaving cavities that are complementary in both shape and chemical functionality

to those of the template. The MIPs become capable of selectively absorbing the template species. Because of the stability, pre-designed selectivity, and easy preparation of MIPs, they have been used for affinity chromatographic stationary phases, artificial antibodies, synthesis mediators, sensor components, and adsorbents for solid-phase extraction. The common forms of MIPs are bulk materials and membranes. N. Minoura of the National Institute of Advanced Industrial Science and Technology in Japan, K. Idei of Japan Science and Technology Corporation, A. Rachkov of Nihon University, and colleagues have prepared and characterized molecularly imprinted polymer membranes with a photoregulated ability to interact reversibly with a pre-determined compound.

The researchers report their work in the December 16, 2003 issue of *Chemistry of Materials*. In their synthesis, *p*-phenylazoacrylanilide (PhAAAn), a derivative of azobenzene with photoresponsive properties, was selected as the functional monomer. After it was polymerized, the polymer's chemical properties changed reversibly by isomerization of this photoresponsive chromophore. Dansylamide (DA) was chosen as the template in the MIP synthesis because DA has the ability to decrease the rate of photoisomerization in solutions of PhAAAn. To improve the membrane's flexibility, the cross-linker consisted of a mixture of ethylene glycol dimethacrylate (EGDMA) and tetraethylene glycol diacrylate (TEGDA). After DA, PhAAAn, EGDMA, and TEGDA were dissolved in acetonitrile, the free-radical polymerization was initiated by 2,2-azobis (4-methoxy-2,4-dimethylvaleronitrile) between two glass plates at 35°C. The formed MIP membrane was about 80 μm thick. Another control membrane was prepared using the same procedure without adding the template DA.

The capacity and selectivity of the membranes were tested by incubating the membranes in the DA acetonitrile solutions at a concentration of 10 μM. The MIP membrane absorbed more DA than the control membrane, and its capacity is about 1.2 nmol of DA/cm², or 0.15 nmol/mm³. The affinity of the binding sites can be controlled by illuminating the samples with the light of different wavelengths. Upon illumination with UV light, the absorbed DA from the MIP membrane

was released. Following a second illumination with visible light, the concentration of DA in solution and in the MIP membrane returned to levels close to those seen before the application of UV radiation. The control membrane did not show this property. Because the MIP membrane was tailored by imprinting DA, it also showed the selectivity and recognition to DA rather than to other molecules.

Such MIP membranes showed a higher absorption level of DA than other reported levels of photoinduced effects in azobenzene-containing materials. The researchers said that molecular imprinting technology can be used to design photonic devices such as photoswitches and photosensors.

YUE HU

Tandem OLEDs Deliver High Luminous Efficiency

Organic light-emitting diodes (OLEDs) are being developed for their application in displays, and therefore a high brightness is required. Extreme brightness (>10⁵ cd/m²) using current densities as large as 1 A/cm² has been reported for OLEDs. However, at these high current densities, failure of the device due to coulombic degradation and excessive heating is a major problem. Therefore, research has focused on a way to obtain an OLED-based device with high brightness and high efficiency at low current densities. At the Display Technologies Laboratory of the Eastman Kodak Company in Rochester, N.Y., L.S. Liao, K.P. Klubeck, and C.W. Tang have designed a tandem OLED that can give luminous efficiencies as large as 136 cd/A for current densities of 1.0 mA/cm².

In order to build a tandem OLED structure, multiple active regions are stacked vertically in a device in series. The main issue when designing such a structure is the choice of the intermediate electrode

material between the units, which is the region that should not only provide connection, but also hole and electron injection, separately, into the adjacent electroluminescent (EL) units. In the past, researchers have used transparent inorganic layers such as indium tin oxide, Mg:Ag/indium zinc oxide, or V₂O₅ as intermediate electrodes to connect the OLEDs. As an alternative, Liao and colleagues have fabricated a tandem OLED structure using an organic connecting unit to replace the inorganic intermediate electrode. According to their article scheduled for publication in the January 5 issue of *Applied Physics Letters*, key advantages to using the organic connecting unit include increased transparency compared with inorganic materials, excellent electrical properties, ease of fabrication by thermal evaporation, and full compatibility with OLED production processes.

The connecting units in the tandem OLEDs consist of a bilayer of doped organic thin films in contact with each other to form a doped organic *p-n* junction at their contact interface. The *n*-type doped layer is tris(8-hydroxyquinoline) aluminum or 1,3,5-tris(*N*-phenylbenzimidazol-2-yl)benzene doped with Li, and the *p*-type doped layer is 4,4'-bis-(1-naphthyl-*N*-phenylamino)-biphenyl doped with FeCl₃. The research team found that the emission of one EL unit is practically independent of the emission of the other EL units in the tandem structure, and thus the units behave as if they are individual devices simply connected in a series. As an example, the researchers show the electroluminescence spectra of a tandem OLED having green and red emission. They also show the EL characteristics of fluorescent and phosphorescent devices with one, two, or three EL units. The researchers show that the luminance of a tandem OLED structure with *N* EL units is *N* times that of a non-tandem unit when operated under the same current density. As the lifetime of an OLED is basically in inverse proportion to its operating current, the researchers said that an important advantage of the tandem structure is that the operational lifetime of the OLED device can be substantially improved. The researchers also said that this tandem OLED structure is also suitable for some special lighting applications.

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