crystal growth. This assertion is supported by short ion-dipole distances in the product crystal, as well as the observation that the degree of polar order in the crystal varied directly with the magnitude of the dipole moment of the guest.

The scientists said that the polar order of the bulk crystal cannot be the result of guest-to-guest interactions because of the large separation between the guests brought about by the host structure. The guest dipoles are further separated by the tilting of the BPDS pillars and guest dipoles relative to the crystallographic *c*-axis of the crystal. This tilting is the result of the distortion of guanidinium sheets during crystal growth to accommodate the guest molecules. The value of the tilt angle is the same for all pillars and guests in a single layer of the crystal, but is reversed in adjacent layers, which serves to further separate the guest dipoles. In addition to the physical separation of the guests, the charged guanidinium sheets also act as a dielectric screen for dipole-dipole interactions between guests in adjacent layers. Additional evidence for the absence of guest dipole-dipole interactions comes from molecular modeling, which shows that guest dipole-dipole interactions favor a different guest-dipole configuration than the one observed in the product crystal.

GREGORY KHITROV

Electrodeposition Found as a Versatile Tool in the Preparation of Magnetic Nanostructures

In an effort to investigate the suitability of electrodeposition for the controlled preparation of high-quality structures on an atomic scale, Yukimi Jyoko of Fukui National College of Technology in Japan and Walther Schwarzacher of the University of Bristol studied the growth of magnetic Co/Pt and CoNi/Pt nanostructures, as reported in the August issue of *Electrochemical and Solid-State Letters*. The obtained multilayered nanostructures exhibit perpendicular magnetic anisotropy and a large magnetic coercivity. The codeposition of Ni, as well as the deposition overpotential, has a significant influence on the film properties.

Magnetic multilayered nanostructures have received considerable attention since the discovery of perpendicular magnetic anisotropy, the magneto-optical Kerr effect, and giant magnetoresistance in metallic multilayers. New magnetic nanostructures have potential for application in high-density magneto-optical recording media or magnetoresistive sensor devices. "Most magnetic nanostructures have been fabricated by sputtering or molecular-beam epitaxy," said Schwarzacher, lecturer of physics. "Electrodeposition, however, may be more promising for all practical purposes, given the efficiency and simplicity of the required equipment."

Recently, he and Jyoko's group at Fukui proved that there is compositional modulation across successive layers in a Co/Pt nanometer-multilayered structure grown on a Pt(111) substrate by electrodeposition under potential control. The present work investigates the role that codeposition of Ni plays on the films' properties.

The researchers grew multilayered Co/Pt and CoNi/Pt thin films on Pt(111) and Cu(111) single-crystal substrates by alternating deposition from a $CoSO_4$- and $NiSO_4$-containing electrolyte and a H_2PtCl_6 electrolyte under potential control. For comparison, alloy films were also prepared by electrodeposition under potential control from a single electrolyte of all three precursors. The CoNi/Pt films crystallized in a fcc structure, while the Co/Pt films or alloy films showed a mixture of fcc Co, hcp Co, and Co stacking faults. X-ray diffraction superlattice profiles confirmed that the CoNi/Pt films exhibit well-defined interfaces between successive layers with compositional modulation on the nanometer-length scale, while the Co/Pt films do not contain pure Pt layers, but a compositionally modulated multilayer structure with graded transitions between a PtCo alloy and Co. "The microstructure and magnetic properties of electrodeposited Co/Pt multilayers depend strongly on the deposition overpotential and the growth mechanism," said Jyoko. The fcc Co/Pt films showed perpendicular magnetic anisotropy and large magnetic coercivity values. With decreasing thickness of the Co layers, remanent perpendicular magnetization was observed. The CoNi/Pt films exhibited even larger coercivities, up to 1.5 kOe. "This suggests the presence of a nonferromagnetic or weakly ferromagnetic Pt-rich phase localized at grain boundaries or segregated grains in the CoNi/Pt nanostructure, which would pin domain-wall motion and also inhibit exchange interactions among grains," according to the researchers' report. This could occur by means of a place exchange between passive hydroxide adsorbates, $Ni(OH)_{2ad}$ and $Pt(OH)_{2ad}$, in the adsorbed intermediate.

The researchers believe that electrodeposition is a promising path for the preparation of magnetic multilayered nanostructures. As the properties of the films depend strongly on the multilayer growth mechanism, the researchers concluded that further studies on the growth kinetics and mechanism are necessary to achieve improved structural and magnetic qualities in the electrodeposited nanostructures.

CORA LIND

SBIR Update

Ion Optics (Waltham, Massachusetts) has been awarded a Phase II Small Business Innovation Research (SBIR) contract from the National Science Foundation to develop a lab-quality water-vapor sensor, built on a single integrated circuit using microelectromechanical systems (MEMS) technology.

Cobalt Impurities Cause Nonlinear Current-Voltage Behavior in Niobium-Doped $SrTiO_3$ Bicrystals

Studies of the interfacial phenomena occurring at grain boundaries in polycrystalline electroceramic components have attributed nonlinearity in current–voltage (*I–V*) behavior to two sources: the degree of coherency of the grain boundary and the formation of additional interface states (such as double Schottky barriers). In the June issue of the *Journal of the American Ceramic Society*, researchers Takahisa Yamamoto, Katsuro Hayashi, Yuichi Ikuhara, and Taketo Sakuma of the University of Tokyo reported the formation of potential barriers in highly coherent bicrystals due only to impurities at the boundary, thus supporting the additional-interface-states theory.

Four niobium-doped $SrTiO_3$ single crystals of dimensions 10 mm × 10 mm × 3 mm were polished to a mirror state along the chosen {001} contact planes (corresponding to the 10 mm × 10 mm faces). Metallic cobalt was evaporated onto the contact plane of one of the crystals to provide a controlled concentration of impurities in one sample (the "cobalt-evaporated" sample); the other contact surfaces remained clean. Bicrystals were then fabricated by carefully aligning and hot-pressing pairs of the single crystals at 1400°C for 10 h under 0.4 MPa pressure in air. After cooling, 1-mm-thick plates were machined from the samples perpendicular to the grain boundaries for current–voltage testing, high-resolution transmission electron microscopy (HRTEM), and energy-dispersive spectroscopy (EDS).

Selected-area diffraction patterns produced by HRTEM show highly coherent boundaries in both samples, with no secondary amorphous phases present in the cobalt-evaporated sample. EDS analysis of the cobalt-evaporated sample clearly demonstrates that the cobalt is dissolved and distributed in the grain boundary, allowing the observed coherency to

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occur. *I–V* measurements show a linear relationship across the grain boundary in the nonevaporated bicrystal, while the cobalt-evaporated sample displays distinctly nonlinear *I–V* characteristics. Since the grain boundaries were shown to be highly coherent, only the presence of cobalt can account for the potential barrier that developed. The researchers attributed this phenomena to the formation of additional interface states at a lower level in a bandgap generated by the solution of cobalt ions at the grain boundary.

TIM PALUCKA

Adding HCl during Chemical Vapor Deposition Produces Controlled Growth of 6H-SiC on On-Axis 6H-SiC(0001) Substrates

Researchers from the Department of Chemical Engineering at Kansas State University and the Department of Mechanical Engineering at Wichita State University have found a reliable epitaxial-growth method for 6H-SiC on 6H-SiC substrates. As reported in the August issue of *Electrochemical and Solid-State Letters*, they achieved this process by adding HCl as a reaction gas during the growth procedure.

Traditionally, chemical vapor deposition (CVD) processes are used to grow various polytypes of SiC. Two methods for the growth of 6H-SiC(0001) polytype are available. The first is on-axis homoepitaxial growth of 6H-Si between 1700°C and 1800°C, and the second is off-axis homoepitaxial, step-controlled growth of 6H-SiC between 1400°C and 1500°C. Both methods are sound, except that slight variations may result in the formation of 3C-SiC. These defects are caused by substrate imperfections, which in turn induce triangular stacking faults.

The researchers suggest a method that can grow reliable 6H-Si films without the 3C-SiC defect. The substrates used were on-axis Si-face *n*-type 6H-SiC(0001), ultrasonically degreased, etched, and rinsed. The gases used for deposition were SiH_4, C_2H_4 (as source), and HCl. The ratio of HCl/Si was kept at 50. The 6H-SiC film was grown on-axis at a reaction temperature of 1475°C.

The researchers said that the benefits of HCl addition are twofold: Not only does HCl act as a pregrowth etch that provides stepped surfaces, it also continuously etches away 3C-SiC nucleation sites so that defects cannot develop. The conclusion from this work is that 6H-SiC films may be deposited reliably (i.e., defect-free) on on-axis substrates at a lower temperature—1475°C, as compared with 1700–1800°C for conventional deposition.

JUNE LAU

Gecko Foot Hair Research Feeds Adhesive Development

In a study on the adhesive nature of the microscopic hairs between the toes of Tokay geckos (native to Southeast Asia) that enable the reptiles to cling to surfaces, biologists at the University of California—Berkeley and Lewis and Clark College have determined that van der Waals forces may account for the adhesion, though they have not ruled out the possibility of water adsorption or other types of water interaction. Robert J. Full, head of the Poly-PEDAL (Performance, Energetics, Dynamics, Animal Locomotion) Laboratory at UC—Berkeley; Kellar Autumn, assistant professor of biology at Lewis and Clark and a former postdoctoral student in Full's laboratory; and their colleagues have measured the forces that these hairs, called setae, exert on a surface in order to prepare a synthetic adhesive that is both dry and self-cleaning.

The key seems to be the hundreds to thousands of tiny pads at the tip of each hair. These pads, called spatulae, measure only about 10^{-5} in. across. Yet, they come so close to the surface that weak interactions between molecules in the pad and molecules in the surface become significant.

In order to measure the forces involved when one hair sticks to a surface, engineer Thomas Kenny of Stanford University micromachined a device to measure the forces involved in attaching the hair to a surface. The dual-axis piezoresistive cantilever was fabricated on a single-crystalline silicon wafer. As they reported in the June 8 issue of *Nature*, with the microelectromechanical system (MEMS) tool, the researchers showed how the gecko engages the surface by pushing in and pulling slightly downward, achieving 600 times greater sticking power than friction alone could achieve.

Engineer Ron Fearing of UC—Berkeley employed a 4.7-mm aluminum bonding wire with a 25-μm nominal diameter to measure the forces when detaching. Using Fearing's device, the research team showed that pulling away is not enough to disengage. The strength of attachment is so strong that a single gecko hair could bend the aluminum wire. If the hair is levered upward at a 30° angle, however, the spatulae at the end of the hair easily detach.

They estimated the van der Waals force for a spatula to be ~0.4 μN. As the number of spatulae per seta varied from 100 to 1000, the researchers estimated the setal force to be in a range from 40 μN to 400 μN.

Though the setae work extremely well in adhering to a smooth surface such as glass, Autumn said that in the natural world, waxy coatings on leaves may hinder adhesion by resisting the intermolecular interactions. Therefore, while geckos may not need more than 10% of their setae to stick to glass, they may need to use more of them to walk on vegetation.

The researchers have ruled out the most common methods used by animals to stick to a surface. Full, Autumn, and their colleagues calculated that suction is much less effective than the measured sticking force of a gecko's foot. Geckos can also cling to a wall in a vacuum. The researchers found no evidence that geckos use a glue: The foot has no glue glands, and no glue residue is left on the surface. The hairs do not interlock with the surface, as with Velcro, and friction is unlikely because friction cannot explain the animals' ability to walk on the ceiling. Electrostatic attraction was ruled out by other researchers.

Autumn and Full report, too, that the gecko hairs are self-cleaning, unlike any other known adhesive.

"We clogged their hairs with microspheres, and five steps later they were clean," Full said. "We don't know why, but it's amazing."

Full and Autumn said that their next goal is to find a way to study individual spatulae and measure their attractive force. Eventually, the researchers want to develop an artificial dry adhesive. Since the hairs and spatulae work so well, Fearing and Kenny have launched an effort to make artificial hairs that use the same sticking technique and could make a strong-yet-dry adhesive.

Self-Assembling Peptides Arise as Possible Biomaterial for Generating Nerve Cells

Researchers Todd C. Holmes, assistant professor of biology at New York University, and Shuguang Zhang, research scientist at the Massachusetts Institute of Technology, have made a self-assembling, peptide-based scaffold that supports living nerve cells. They said that this is the first peptide-based biomaterial of its kind that can be designed at the molecular level.

As reported in the June 6 issue of *The Proceedings of the National Academy of Sciences* (PNAS), peptides of arginine-alanine-aspartate (RAD) 16 scaffolds self-assemble into thin, wavy films containing a network of individual, interwoven fibers ~10–20 nm in diameter. The researchers have grown neurons on these scaffolds, in which the fibers communicate with each other and establish functional synapses.

Holmes said, "The nervous system actually produces factors that prevent regrowth and repair. That's what makes this newly discovered biomaterial so

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