

As reported in the October 21 issue of *Physical Review Letters*, the researchers in cooperation with I. Sharkov from St. Petersburg State University, Russia, and B. Farago from Institut Laue-Langevin, France, realized the inside-detector concept for neutron holography imaging of lead nuclei in a Pb(Cd) single crystal. The researchers used a spherical-shaped single crystal of $\text{Pb}_{0.9974}\text{Cd}_{0.0026}$ for this experiment. It is known that the Cd absorption cross section for thermal neutrons is more than four orders of magnitude larger than for Pb, thus Cd atoms could act as highly efficient detectors. Due to the low concentration of Cd, these atoms are randomly distributed on regular lattice sites and any one Cd atom is surrounded by Pb atoms. The lead nuclei play the role of the object while the cadmium nuclei serve as pointlike detectors inside the sample by emitting gamma rays that are detected outside the crystal.

The researchers registered the gamma-ray image and reconstructed the atomic structure by use of a computer conversion of a hologram to a three-dimensional picture. Furthermore, the researchers restored the object without making use of any *a priori* knowledge about the orientation of the sample.

The researchers said that their results demonstrate the feasibility of atomic-resolution neutron holography as it was originally proposed, so the practical applications appear highly promising. They said that the special properties of the nuclear scattering process of neutrons, including its isotopic sensitivity and its dependence on the magnetic moment, will substantially enlarge the field of investigation opened by this technique.

ANDREI A. ELISEEV

Coherent X-Ray Technique Reveals Interface Structure with Sub-Angstrom Resolution

Several nondestructive methods are available to study the structure of epitaxial films and interfaces, but interpretation of the results depends on the mathematical model applied, which sometimes produces incorrect conclusions. As reported in the October issue of *Nature Materials*, a group of researchers have developed an x-ray method, called coherent Bragg rod analysis (COBRA), for the direct determination of epitaxial structures. Analyzing the coherent Bragg rods, Yizhak Yacoby and Mukhles Sowwan of Hebrew University, Israel, and their co-workers at the University of Washington, Seattle; Argonne National Laboratory, Illinois; Brookhaven National Laboratory, New York; and the University of Michigan, Ann Arbor, were

able to map with atomic precision the structure of the interfacial region of a Gd_2O_3 film (2.7 nm thick) grown epitaxially on a (100)GaAs substrate.

A synchrotron beam line at the Advanced Photon Source was used for observing the diffraction pattern and the sharp Bragg peaks were detected together with the scattered intensity between peaks. COBRA, the technique used in this work, consists of analysis of intensity along the line between any two peaks in reciprocal space. The scattered intensity characterizes the two-dimensional periodic regions such as the substrate truncation, the interface, and the Gd_2O_3 film itself. The researchers measured 13 symmetrically nonequivalent Bragg rods and calculated the others using symmetry. With COBRA, the researchers were able to obtain the position of maximum electron density corresponding to the Gd in the unit cell of each layer of the film with a precision of 0.2 Å. The researchers found that for the Gd_2O_3 layers nearest the interface the position of the Gd atoms favored the stacking order of the GaAs substrate, whereas for layers further from the interface the stacking order relaxed to the value of bulk Gd_2O_3 .

MAXIM NIKIFOROV

Superconductivity Attained in Compressed Lithium

Under close scrutiny in superconductivity are methods of raising the transition temperature to the superconducting state. It is believed, based on BCS theory, that highly compressed materials with low atomic numbers can yield transition temperatures near room temperature. Katsuya Shimizu's group from Osaka University and Takehiko Yagi from the University of Tokyo have demonstrated the ability to attain superconductivity under high pressure in lithium at temperatures of 20 K. This is the highest transition temperature for any element and supports the hypothesis that low atomic number elements have high transition temperatures.

As reported in the October 10 issue of *Nature*, high-purity (99.999%) lithium samples were exposed to pressures ranging from 3.5 GPa to 48 GPa. All treatments were done in ambient argon atmosphere with no water or oxygen present. Pressures greater than 10 GPa were applied at temperatures less than 50 K to control the effect of chemical reaction between lithium and the diamond anvil. Resistivity of the sample was monitored during the experiments. From the experimental results it has been demonstrated that a drop in the resistance occurs in samples compressed to more than 35 GPa. The

transition temperature was determined to be 13 K at pressures of 35 GPa and 20 K at pressures of 48 GPa. At lesser compressions the sample exhibited normal metallic behavior. After releasing the pressure, the sample exhibited its normal reflection of light, an indication of little or no chemical change during the process. Based on this, the researchers concluded that the change in resistance was due to the onset of superconductivity in lithium.

Lithium is the first pure element to exhibit elevated superconducting properties as demonstrated by Shimizu, Yagi, and colleagues. Based on theoretical calculations, superconducting phase-transition temperatures of 80 K should be attained by further increasing the sample compression up to values of 165 GPa in the c16 phase, that is, a cubic unit cell with 16 atoms. According to the researchers, "High-pressure investigation of Li ... should help in the understanding both of fundamental properties of metals and of possible room-temperature superconductivity in metallic hydrogen."

CALIN MICLAUS

Synchrotron Source X-Ray Diffraction Used to Study Phase Transformations in Steel

Phase transformation kinetics are important during processing of polycrystalline metals, steels for example, and ceramics. The kinetics are governed by grain nucleation and growth which ultimately also dictate the mechanical properties of the material, depending on the final average grain size. Though there are a number of proposed phase transformation models, the kinetics are still not well understood. Most of these models are based on the classical nucleation theory (CNT) and the law of parabolic grain growth derived by Zener. Now, a multinational European research group led by S.E. Offerman of Delft University, The Netherlands, has used a synchrotron source to obtain x-ray diffraction data from steels to study transformation kinetics at the level of individual grains. The researchers' results are published in the November 1 issue of *Science*.

The principal transformation reaction in carbon steels is from the high temperature fcc austenite to the low-temperature bcc ferrite. The solubility of carbon in ferrite is lower than in austenite, resulting in the enrichment of carbon in the remaining austenite. At lower temperatures, the carbon-enriched austenite decomposes into pearlite, which is a lamellar structure of ferrite and orthorhombic cementite. In addition, other complex nonequilibrium structures such as bainite and martensite

could also form. In this study, a steel sample was annealed at 900°C for 10 min to form the austenite phase and then continuously cooled to 600°C for 1 h. X-ray diffraction data was obtained in the synchrotron source with a typical time resolution of 10 s. The growth behavior of individual ferrite grains and pearlite colonies were monitored using the diffraction spot intensities.

The results indicated that the activation energy for ferrite grain nucleation was at least two orders of magnitude smaller than that predicted by the thermodynamic models. The growth curves of the grains appear to confirm the parabolic growth model but also show three fundamentally different and distinct types of growth. The researchers were able to distinguish between the four types of grain growth which are (in order of reducing temperature): grains not interacting with neighboring grains, grains continuing to grow with the same crystallographic orientation into another phase, grains that indirectly interact, and grains that directly interact with neighboring grains.

This innovative experimental technique and the resulting insights can be incorporated into nucleation and growth models for the processing of steels in order to tailor the properties of the final product. A detailed knowledge of austenite decomposition kinetics in steel can lead to the development of new steel grades and optimization of processing conditions to yield high-quality steels with superior properties.

GOPAL R. RAO

Dolphin Skin Offered as Model for Nanoparticle Coating

Karen L. Wooley, professor of chemistry at Washington University in St. Louis, has noted how the shape and texture of dolphin skin prevents marine creatures from clinging. The observation fits into her study of finding ways to mediate interactions between biological systems and synthetic materials, designing chemical functionalities, or groups of atoms that either promote or discourage binding between them.

During the Council for the Advancement of Science Writing’s New Horizons in Science 40th Annual Briefing, held October 27–30 at Washington University, Wooley said that the key to her antifouling agents is their three-dimensional topography, which mimics such naturally occurring hydrodynamic surfaces as the skin of a dolphin. Using high-powered electron microscopy, researchers have found that dolphin skin, for all its seeming smoothness, is slightly rippled on the nanometer scale. Still, these ripples are not large enough to hinder movement through the water but are small enough that they leave few niches for marine creatures to grip.

“For a long time, antifouling work was geared toward making super-smooth surfaces,” Wooley said. “It was thought that if the surfaces were super-smooth and had less surface energy, then the organisms couldn’t attach.”

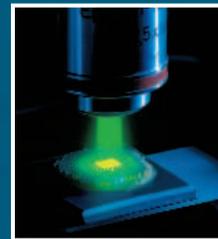
Wooley formulated the idea of mixing two normally incompatible polymers—a hyperbranched fluoropolymer and a linear polyethylene glycol—and allowing them to phase-separate into distinct domains, one interspersed in the other. Cross-linking would then solidify the mixture, she said, thus creating a heterogeneous coating that, upon close examination, reveals treacherous nanosized terrain composed of mountains and valleys, ranging from hard to soft, hydrophilic to hydrophobic.

Wooley hypothesizes that if the coating’s surface features are in the same size-regime as the secreted adhesive protein put out by marine organisms, then the protein will be unable to bind sufficiently to maintain attachment.

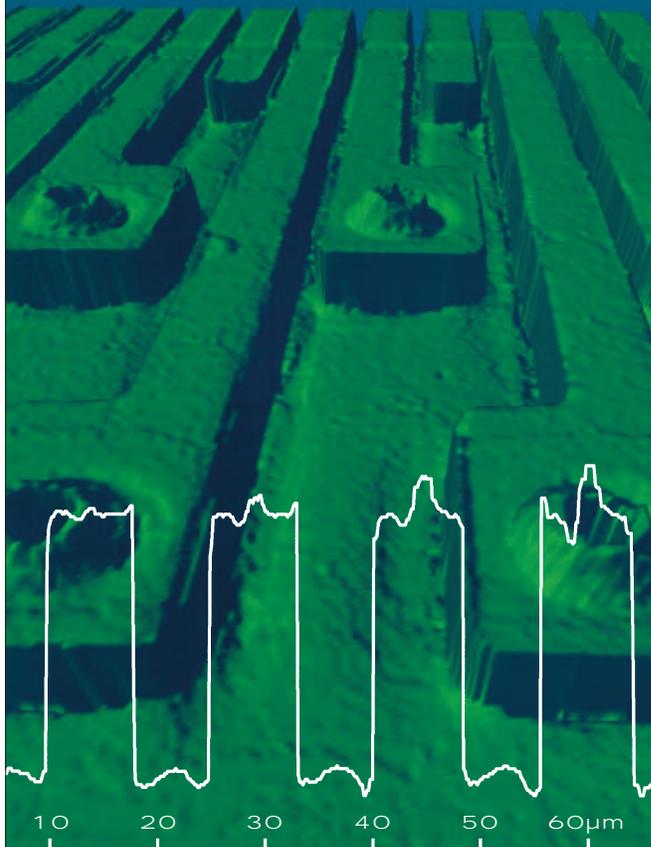
“When the polymer surface is first prepared, it looks like a bunch of submicroscopic mountains, but when it’s placed under artificial sea water, the entire surface swells and gives us this inverted structure,” Wooley said. With this concept, she said, researchers can control the size of the surface features and determine whether that influences the attachment of marine organisms. Such antifouling coatings may inhibit barnacles and other marine organisms from attaching to, and ultimately corroding, ship hulls. □

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