ing, that are not superconductors on their own, but rather exhibit superconductivity at the interface between them. The layer identified as essential to the superconductivity by the zinc-substitution experiment represents the second copper-oxide layer away from the interface.

The scientists found that the presence of zinc had no effect on the transition temperature at which superconductivity sets in, ~32 K (-241°C), except when placed in that particular layer. In the latter case, the scientists observed a dramatic drop in the transition temperature to 18 K (-255°C). The reduction in transition temperature provides a clear indication that that particular layer is the "hot" one responsible for the relatively high temperature at which superconductivity normally sets in for this material, according to the researchers.

"We now have a clean experimental proof that high-temperature superconductivity can exist, undiminished, in a single copper-oxide layer," Božović said. "This piece of information gives important input to our theoretical understanding of this phenomenon."

Božović said that, in the material he studied, the electrons required for superconductivity actually come from the metallic material below the interface. They leak into the insulating material above the interface and achieve the critical level in that second copper-oxide layer.

But in principle, he said, there are other ways to achieve the same concentration of electrons in that single layer, for example, by doping achieved by applying electric fields. That would result in high-temperature superconductivity in a single copper-oxide layer measuring just 0.66 nm.

From a practical viewpoint, this discovery opens a path toward the fabrication of electronic devices with modulated, or tunable, superconducting properties which can be controlled by electric or magnetic fields, said the researchers.

"Electronic devices already consume a large fraction of our electricity usage—and this is growing fast," Bozovic said. "Clearly, we will need less-power hungry electronics in the future."

Superconductors, which operate without energy loss—particularly those that operate at warmer, more-practical temperatures—may be one way to go.

According to the researchers, their layer-by-layer synthesis method and ability to strategically alter individual layers' composition might also be used to explore and possibly control other electronic phenomena and properties that emerge at the interfaces between layered materials.

Hierarchical Topographies Created by Controlled Evaporation of a Block Copolymer Solution

Hierarchically ordered materials tend to have unique physical properties. For instance, the lotus leaf has both micro- and nanostructures which contribute to its superhydrophobicity. To produce materials with useful properties such as superhydrophobicity, simple methods for making hierarchical materials must be established. Block copolymers provide a way of creating nano-patterned surfaces because of their ability to self-assemble into their constituent blocks. Zhiqun Lin, Suck Won Hong, and Jun Wang at Iowa State University have shown that controlled evaporation of a diblock copolymer solution creates a serpentine-like microstructure, which can further be processed to have nanostructures.

As described in the October 19 issue of *Angewandte Chemie International Edition* (DOI: 10.1002/anie.200903552; p. 8356), Lin and co-workers prepared a solution of polystyrene-*block*-poly(methylmethacrylate) (PS-*b*-PMMA) in toluene at a concentration of 0.13 mg/mL. The molecular weight of each block was 45.9 kg/mol and 138 kg/mol for PS and PMMA, respectively. This solution was held between a fused silica lens (1 cm diameter) and a silicon wafer by capillary forces. As the solution evaporated toward the center of the lens, concentric rings of the block copolymer were deposited on the silicon wafer surface. These rings had an undulating or "serpentine" morphology on the micron scale. The spacing between the characteristic features was approximately 20 μm and the height was approximately 100 nm. To further change the morphology, the researchers aged the films by exposing them to acetone vapor for up to 12 hours. After exposing the films to acetone vapor, the microtopography changed from "serpentine-like" to "mesh-like"—with distinct holes forming the "mesh-like" structure. At the nanoscale, atomic force microscopy and transmission electron microscopy imaging showed that the acetone vapor caused the polystyrene blocks to phase-segregate into hexagonally packed, cylindrical nanodomains ~39 nm in diameter. The surface chemistry was analyzed by x-ray photoelectron spectroscopy (XPS) and showed that aging the films with acetone vapor increases the carbonyl (O-C=O) signal at 289.1 eV relative to the hydrocarbon (C-C or C-H) signal at 285.0 eV.

The researchers attributed the "serpentine-like" microstructure to fingering instabilities which arise during progressive "stick-slip" motion of the three phase contact line as the solvent evaporates. The researchers propose that polystyrene initially forms at the top of the film due to its lower surface tension. XPS results demonstrated that the PMMA matrix reorients toward the surface after exposure to acetone vapor. This caused the polystyrene to form cylindrical nanodomains oriented perpendicular to the surface. Lin and colleagues propose that controlled self-assembly methods such as these allow for simple fabrication of hierarchical structures without using lithography.

Scott Cooper

How to Choose In-plane Ferroelectric Polarization States in Rhombohedral $BiFeO_3$

An international team of researchers have devised a way to reliably manipulate the ferroelastic polarization states of rhombohedral multiferroic materials that allows coupling to the strain and magnetic properties of these materials.

"The control of polarization switching to create different domain patterns with predefined in-plane domain orientations is key to applications which are based on the physical properties of domain walls or on the coupling of ferroic order parameters," said N. Balke of Oak Ridge National Laboratory in explaining the potential impact of their discovery.

As reported in the October 11 on-line issue of *Nature Nanotechnology* (DOI: 10.1038/NNANO.2009.293), the researchers used the electric field from a moving piezoresponse force microscope (PFM) tip to deterministically generate domain states in $BiFeO_3$ (BFO), including long-sought closure domains. Closure domains are ferroic domains of position and orientation such that flux lines from larger, adjacent domains close upon themselves (see, e.g, www.answers.com/topic/closure-domain). The tip motion that broke the rotational symmetry of the electric field was a crucial element that allowed the

https://doi.org/10.1557/mrs2009.206 Published online by Cambridge University Press