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 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 BiFeO₃

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 1 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 BiFeO₃ (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