Inverse woodpile structure designed with extremely large photonic band gap

Since photonic band gap materials were first proposed over a decade ago, there have been intense efforts to develop a facile assembly route for creating 3D photonic crystals. These activities have focused predominantly on structures based on a woodpile architecture, in which dielectric rods are stacked in parallel arrays that are oriented orthogonal to one another between layers. Now, a team of scientists led by FS-MRL researchers, Paul Braun and Jennifer Lewis, that includes post-doctoral researcher Floren Garcia-Santamaria and graduate student Mingie Xu along with their collaborators, electrical engineering professor Shan-shui Fan at Stanford University and physicist Virginie Lousse at the Laboratoire de Physique du Solide in Belgium, have created the first inverse woodpile structure that possesses an extremely large photonic band gap.

The inverse woodpile structure is composed of a germanium matrix containing a periodic array of tubular holes, made possible by a unique and flexible fabrication technique that combines direct ink writing with a sequential templating approach. This advance was recently reported in a cover article published by the journal Advanced Materials.

To produce the germanium inverse woodpile structure, the researchers first created a polymer template by using direct-write assembly. This process employs a concentrated polymeric ink, dispensed as a filament to form the woodpile rods, from a nozzle approximately one micron in diameter. The nozzle dispenses the ink into a reservoir using a computer-controlled, three-axis micropositioner. After the pattern for the first layer is generated, the nozzle is raised and another layer is deposited. This process is repeated until the desired three-dimensional structure is produced. Next, the researchers deposited a sacrificial coating of aluminum oxide and silicon dioxide onto the entire structure. This bilayer coating enlarges the rods thereby increasing the contact area between them. The space between the rods is subsequently filled with germanium. Finally, the polymeric and oxide materials are removed, leaving behind a tiny block of germanium with an inner network of interconnected tubes and channels. The finished structure — built and tested as a proof of concept — consists of 12 layers and measures approximately 0.5 millimeters by 0.5 millimeters, and approximately 15 microns thick.

The direct-write template approach offers new design rules, enabling one to fabricate structures that cannot otherwise be made. This technique can also be adopted for converting other polymeric templates, such as those made by laser-writing or electro-beam lithography, into inverse woodpile structures. In addition to their potential as photonic materials, these interconnected, inverse woodpile structures could find use as low-cost microelectromechanical systems, microfluidic networks for heat dissipation, or biological devices.

This work is partially supported by DOE/BES Materials Sciences and Engineering Division through the FS-MRL Materials Research Cluster (MRC) on Programming Function via Soft Materials.
From the Director (cont. from page 1)

Each quarter, Advances introduces the researchers involved in the FS-MRL and highlights their recent accomplishments. Our research activities are extending the frontiers of materials science. Together, we are transforming fundamental scientific discoveries into technological advances in the areas of photonics, flexible electronics, superconductor devices, and energy materials (e.g., catalysts, fuel cells, and photovoltaics).

I hope that you enjoy learning more about the Frederick Seitz Materials Research Laboratory and our impact on the scientific community and society as a whole.

Jennifer A. Lewis
FS-MRL Interim Director

1st Annual Workshop on Advanced Materials Characterization

On May 23, the FS-MRL Center for Microanalysis of Materials (CMM) held its first annual workshop on Advanced Materials Characterization, which brought together nearly 200 participants from the university community as well as major industries, including Caterpillar. This one-day workshop consisted of eight tutorial lectures that highlighted techniques, such as atomic force microscopy (AFM), x-ray diffraction and reflection (XRD, XRR), x-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Auger electron spectroscopy (AES), secondary ion mass spectroscopy (SIMS), Rutherford backscattering (RBS), and near field and optical microscopy. These lectures were given by the FS-MRL staff scientists led by Ivan Petrov, Central Facilities Director, and workshop organizer Mauro Sardela (CMM).

The lectures were designed to introduce the fundamentals of each analytical technique, their strengths and weaknesses, and ways to combine various methods to extract the best possible complimentary information. There was a strong focus on practical applications and problem solving strategies required to effectively characterize a broad array of advanced materials, including electronic, nanoscale, structural, and optical materials.

The FS-MRL central facilities are partially supported by the DOE/BES Materials Sciences and Engineering Division through the Materials Research Cluster (MRC) program and by the University of Illinois.

Other Highlights

John Rogers has been named the 2007 Daniel C. Drucker Eminent Faculty Award winner by the Illinois Alpha chapter of Tau Beta Pi, the national engineering honor society. This award recognizes faculty in the College of Engineering who have received national or international acclaim for dedication to academic excellence through teaching and research and have made exemplary contributions to the understanding of their fields.

His research is supported by DOE/BES Materials Sciences and Engineering Division through the FS-MRL Materials Research Cluster (MRC) on Programming Function via Soft Materials.

The 67th Annual Physical Electronics Conference, including the prestigious Nottingham Prize Competition for best presentation based on doctoral research, was held at the FS-MRL on June 19-22. This topical conference focuses on the physics and chemistry of surfaces and interfaces in metals, semiconductors, insulators, and biomaterials. More than 100 researchers from around the world attended and presented their research. Tai Chiang, Ivan Petrov, and John Weaver served as the local organizers for the conference.

Please see http://cmm.mrl.uiuc.edu/PEC07/ for details.