University of Wisconsin-Madison

Materials News

SPRING / SUMMER 2006

MATERIALS SCIENCE PROGRAM

In UW-Madison's interdisciplinary Materials Science Program, you will find opportunities to conduct unique graduate research in a range of areas and draw on the expertise of faculty from departments campuswide. Read about some of the program's activities here, E-mail Diana Rhoads at rhoads@engr.wisc.edu to learn more about materials science graduate study, or visit www.engr.wisc.edu/interd/msp.

Message from the Materials Science Program director

I'd like to share some observations of the MSP from my new, "insider" perspective. First and foremost is the extraordinary job my predecessor did. He re-organized the Materials Sciene Program (MSP); created a modern, flexible curriculum consistent with our interdisciplinary program; expanded the breadth of our materials' portfolio; and, especially, he eased me seamlessly into his role. Thanks John Booske!

Ray Vanderby, MSP director

A striking observation is the depth and breadth of excellence of UW-Madison's MSP. As evidence, consider a program that includes over 60 faculty from 12 departments (five of whom are members of the National Academy of Engineering); research opportunities in two NSF-sponsored centers (Nanoscience and Engineering Center and Materials Research Science and Engineering Center); technical support and instrumentation from three major facilities for materials fabrication and characterization (Wisconsin Center for Applied Microelectronics, Center for NanoTechnology, and Materials Science Center); energetic young faculty in emerging fields (e.g. nanoscience and technology, MEMS and bioMEMS, multiscale modeling, quantum circuits, biomaterials and tissue engineering); modern, well-funded faculty laboratories; and a large group of vibrant and talented graduate students.

A final observation is how exceptionally well suited UW-Madison is for interdisciplinary education and research. Our culture of open doors, fruitful discussions, and strong collaboration creates an ideal environment for the MSP. Please visit and see for yourself.

Controlling the speed of light

Nanostructured materials are a unique class of materials with wide-ranging applications in drug-delivery systems, nanoelectronics, electro-optics and photonic band-gap materials.

Assistant Professor Padma Gopalan (above) investigates nanostructured polymer composites with electroactive molecular subunits. She explores the structure-property relationship in electro-optic materials, which can control the speed of light through electric-field-induced changes in their index of refraction.

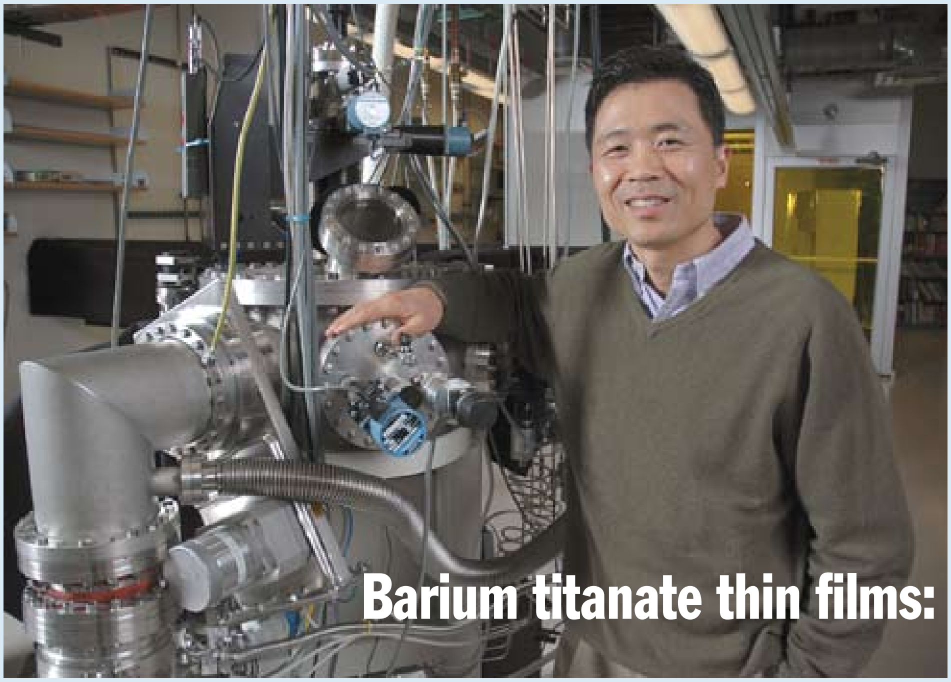
Electro-optical materials are important to applications such as fiber-optic data transmission, analog video transmission, and millimeter wave signal generation. Electro-optic polymers offer unique possibilities for complete opto-electronic integration and efficient, flexible, active optical devices.

Electro-optic activity is enabled through blending a nonlinear optical chromophore with a polymer host, and applying an electric poling field to impose orientational order on dipolar chromophores. Although such polymers can be made today, there is little fundamental understanding of the interface between the chromophore and polymer host.

Gopalan is applying a systematic approach to controlling the morphology of the material through chemical design and correlating the morphology to observed activity. These studies will provide basic information on rational design of next-generation electro-optic materials.

As part of the project, Gopalan is creating an educational and outreach program that will incorporate her work into the undergraduate instructional laboratories, including creating a polymer course with a major emphasis on nanostructured electronic polymers. An extended outreach program will be aimed at female high school students and minority colleges, including improved materials-science training of high school students and teachers, and mentoring female graduate and undergraduate students.

Barium titanate thin films: the perfect mismatch



Professor Chang-Beom Eom and his team grew a material of slightly larger atomic structure upon a slightly smaller substrate. Eom engineered strain into barium titanate (BaTiO3) thin films, giving the material ferroelectric properties that could lead to cleaner, smaller, faster and more efficient memory and electro-optic devices.

The ability of ferroelectric material to store information resides in its arrangement of atoms, with each structure holding a bit of information. This information changes every time the material receives a pulse of electricity, basically switching the arrangement of atoms. These materials have great appeal to the semiconductor industry because, as memory devices, they can be rewritten more than 1,000 trillion times. Flash memory, such as that used in digital cameras and cell phones, can be rewritten about 100,000 times.

Ultimately, ferroelectric materials might be used to create computers that don't need to "boot up" when restarted because unlike the technology used in desktop computers, ferroelectrics have built-in electronic memory that does not disappear when the power is shut off.

Eom's new strain-engineered BaTiO3 is significant because unlike other widely pursued ferroelectric candidates, BaTiO3 contains no lead or bismuth that would complicate its introduction into semi-conductor fabrication facilities or pose environmental toxicity issues. But even more impressive are the dramatic improvements in transient temperature and remanent polarization.

Hard like diamond, pliable like metal

Unlike other exceptionally hard materials, nanostructured ceramic materials tend to bend rather than break, meaning they could be shaped into extremely long-lasting yet lightweight parts for everything from automobile engines and high-speed machining tools to medical implants in the body. But they are also notoriously difficult to engineer, because as their name implies they possess a grain structure that falls into the nano-size range of molecules and atoms.

In a massive computer simulation involving 128 computer processors and nearly 19 million atoms, Assistant Professor Izabela Szlufarska and colleagues at the University of Southern California recently demonstrated the precise atomic mechanisms that explain why these ceramics—some of the hardest substances known—also exhibit unusual pliability.

To understand, at the atomic scale, how nanocrystalline silicon carbide deforms under force, the researchers performed a simulation in which they pressed a tiny virtual probe, called an indenter, into the material's surface and watched how the atoms moved in response. Initially, the grains deformed and then sprang back as a unit, an illustration of the material's hardness. But as the probe pressed deeper and exerted greater pressure, the researchers witnessed a surprising shift in the material's response. At a specific indentation depth, the grain boundaries began to yield, allowing individual grains to rotate and glide independently under the probe's force.

The team published its results in the August 2005 issue of *Scence.* Its work could speed the design of materials that approach the hardness of diamond yet remain pliable enough to be worked like metal.

Izabela Szlufarska

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The Materials Science Program is administered through the UW-Madison College of Engineering.
Produced by: Engineering External Relations / Editor: Jim Beal / Design: Phil Biebl