Invention and Outreach:

The Center for the Science and Engineering of Materials

THE CENTER FOR THE SCIENCE AND ENGINEERING OF MATERIALS (CSEM), under the direction of Professor of Chemical Engineering Julia Kornfield (BS '83, MS '84), celebrated its first anniversary this past September. Established with a $9.6 million multi-year grant from the National Science Foundation, the Center addresses both research and educational aspects of polymeric, structural, photonic, and ferroelectric materials that will be necessary to solve critical societal needs of the twenty-first century. The Center pioneers a number of exotic and futuristic materials and applications such as liquid metals, responsive gels, and tiny medical sensors.

The Center draws its researchers principally from EAS—but also from the Division of Chemistry and Chemical Engineering. The four major research thrusts are in the areas of biological synthesis and assembly of macromolecular materials; bulk metallic glasses and composites; mesophotonic materials; and ferroelectric thin films. "I have really enjoyed catalyzing connections," notes Professor Kornfield. "It has been wonderful to watch relationships develop between scientists that had little interaction before the Center existed. It's impossible to predict now how these connections will develop, but they will almost certainly lead to unique and unanticipated collaborations as the Center moves forward."

The biosynthesis initiative is led by David Tirrell, McCollum-Corcoran Professor and Professor of Chemistry and Chemical Engineering, and Chair of the Division of Chemistry and Chemical Engineering. Research efforts include the use of artificial proteins to make polymers with exquisite control of properties, and responsive polymers and gels for biomedical and industrial applications, including materials for entrapment of cells in tissue engineering or biosensors.

The team investigating glassy metallic alloys is led by Bill Johnson (PhD '75), the Ruben F. and Donna Mettler Professor of Engineering and Applied Science. This group pursues basic science and new engineering strategies that will lead to custom-designed materials with desirable characteristics such as ultrahigh strength, exceptional elasticity, and ease of fabrication into complex parts.

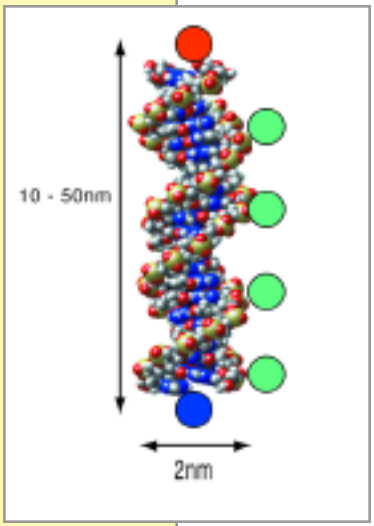
The effort toward mesophotonics is led by Harry Atwater, Professor of Applied Physics and Materials Science. Mesophotonic devices are optical components and devices sized at or below the wavelength of light. Future applications include engineered optical probes for biology and medicine, and photonic devices that could replace certain electrical devices in telecommunications and computing.

Everybody knows that it is impossible to propagate light through structures smaller than the wavelength of light... but CSEM researchers have belied this conventional wisdom, showing propagation of light along waveguides whose lateral dimensions are a few nanometers (a few percent of the wavelength of light). The key is to exploit the tendency for electromagnetic excitations to "hop" between electric dipoles, such as fluorescent dye molecules or metal nanoparticles.

Researchers in the mesophotonics group, led by Professor of Applied Physics Harry Atwater, have demonstrated propagation of light through two types of subwavelength-scale waveguides. The first is a DNA-based waveguide in which a fluorescence excitation hops from an optical donor molecule bound to one end of the DNA backbone to an acceptor molecule at the other end through dye mole-

CSEM Director, Julia Kornfield, and a student at the March outreach program for high-school minority youth. More than 100 students attended.

cules tethered at intervals in between. These fluorescence-resonant-energy-transfer waveguides have so far demonstrated that light can take several hops between molecules bound to DNA, and this "movement" can be extended to many hops along a longer waveguide.



The second nanoscale waveguide structure is called a "plasmon wire," which is a chain of metal nanoparticles along which light hops from one particle to another. Light can even propagate around sharp corners and through nanoscale networks—all of which are impossible in conventional optical waveguides. So much for conventional optical wisdom!

Valerie Villareal is studying the stability of hydrogels (aggregated fluoroalkyl-ended polyethyleneglycol) for applications in capillary electrophoresis. She and her mentors (Professor Julie Kornfield at Caltech and Professor Frank Gomez at CSULA) are hoping to show that drugs (or other components) can be immobilized in the hydrogel and that the hydrogel can also serve as a sieving matrix. Rob Lammertink (a Caltech postdoc, pictured at left) is also working on this project.

Kaushik Bhattacharya, Professor of Applied Mechanics and Mechanical Engineering, is leading research to create microactuators based on high-strain ferroelectrics. The team's integrated simulation and experimental approach promises to reveal the microscopic basis of large strain behavior in this class of materials.

Along with the flurry of research activities that the Center enhances, major outreach efforts have been made to bring under-represented minorities to campus for special seminars, tours, and learning activities. The CSEM Undergraduate Research Fellowship Program hosted seven students from California State University, Los Angeles (CSULA) during the past year. These students, working with faculty mentors from both CSULA and Caltech, have been pursuing research in various laboratories.

In March, CSEM hosted a two-day outreach program for high-school minority youth. More than 100 high-school students from science and technology programs throughout the Los Angeles area had a stimulating first-hand exposure to cutting-edge work in materials science, technology, and mathematics. Particularly exciting was a presentation created by CSEM scientist Mario Blanco and Native American artist Rosemarie McKeon exploring the connections between science and Native American life. Blanco and McKeon connected scientific concepts and diagrams to art and cultural concepts, interpreting from multiple perspectives how one might understand the molecular representation of the structure of matter. "The creation of the Center really jump-started campus-wide discussion about outreach efforts that take advantage of Caltech's special strengths and the demographics of the Southern California region," observes Kornfield. "It has allowed this NSF MRSEC [Materials Research Science and Engineering Center] to be part of something bigger. As the Center was growing up, there were numerous outreach efforts on campus that did not connect. The Center was created at a time when the situation was ripe for coordination of more ambitious outreach efforts, which has enabled us to substantially expand upon the programs we had proposed. For example, we had proposed an annual workshop for a dozen high-school students and it grew into a program for a hundred with help and support from other organizations at Caltech."

For more information on CSEM activities, visit their website at
http://www.csem.caltech.edu