Making New Materials with Nature's Help

Combining organic and inorganic processes may lead to such devices as biological sensors and synthetic muscle fibers

MATERIALS SCIENTISTS are quite practiced at making new compounds the old-fashioned way—by using chemistry to rearrange molecules and atoms, often under the brute force of high temperatures and pressures. But in the past few years, they have begun to experiment with a very different approach, one that uses the delicate biological processes of living things to produce various materials. So far, they like what they see.

"The potential is enormous," says Mark Alper of the Center for Advanced Materials at Lawrence Berkeley Laboratory and the Department of Molecular and Cell Biology at the University of California at Berkeley. "It [the field] is so broad that it's hard to say what the eventual applications will be, but it's clear they will be tremendous."

That tremendous potential was evident throughout a 3-day symposium at the fall meeting of the Materials Research Society in Boston, 27 November to 2 December, entitled "Materials Synthesis Utilizing Biological Processes." One researcher after another concluded that Mother Nature has a few things to teach scientists about making materials, both in terms of novel products and ways to make them.

Many natural materials, says Paul Calvert of the Arizona Materials Laboratories at the University of Arizona, have useful properties that researchers would like to imitate and improve upon—silk, tooth enamel, and the adhesive proteins that barnacles use to attach themselves to ship bottoms, for instance. And biological organisms often have ways of synthesizing materials that scientists cannot yet duplicate. Silk, for example, is an insoluble polymer, yet silkworms can somehow produce it in liquid form at room temperature and then spin it into long threads that solidify. Materials researchers would very much like to know how they do this, Calvert says. Calvert was a cochairman of the symposium along with Alper and Peter Rieke of Battelle–Pacific Northwest Laboratory in Richland, Washington.

Besides learning how nature rearranges molecules, materials researchers also hope to coax biological organisms to do some of their work. Vats of genetically engineered bacteria might be used to produce large quantities of materials in the same way that some drugs are made now. And several scientists at the symposium presented innovative ways to combine organic molecules with inorganic materials to make systems with unique properties.

■ Mark Bednarski from the Center for Advanced Materials and the University of California, Berkeley, gave a blueprint for a type of biological sensor made with organic molecules on a silicon surface. The sensor depends on long molecules that attach to silicon at one end and bind to various organic substances at the other. By coating a silicon surface with such molecules, Bednarski has produced an organic surface that will grab hold of certain bacteria that touch it, but not others. With the proper electronics attached, such an organic/inorganic composite should be able to serve as a detector that will sense various types of bacteria, viruses, or even drugs.

■ Several researchers at the symposium spoke of creating synthetic genes to make proteins with structures and properties different from those found in nature. Joseph Cappello of Protein Polymer Technologies Inc. of San Diego described the production of silk-like protein polymers using a man-made gene that had been transferred into bacteria. The goal, he said, was to make a synthetic polymer with some of the attributes of silk, including its strength and chemical resistance. By doing this with synthetic genes instead of natural ones, the company hopes to control the structure and properties of the polymer precisely—something that cannot be done with silkworms. The company has already produced batches of up to 500 grams of the polymer.

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■ At the University of Bath, England, Stephen Mann has used thin films of organic molecules to control and direct the growth of crystals. He puts a drop of surfactant on the surface of a supersaturated solution of calcium carbonate ($CaCO_3$), and the surfactant spreads out into a thin, monomolecular layer on top of the solution. The film acts as a template for the sheets of $CaCO_3$ crystals that form along the surface of the solution, and under the control of the monomolecular film, the individual grains in the crystal sheets have uniform particle size and are aligned in the same direction. "This is the first time that two-dimensional films have been shown to act as templates for crystal growth," Mann said. Eventually, he said, it should be possible to engineer all sorts of crystals—electronic, piezoelectric, and magnetic. "If you design the organic surface, you can tailor the physical and chemical properties of the crystal."

■ Dan Urry of the University of Alabama at Birmingham described a synthetic "muscle fiber" that contracts and relaxes in response to a change in chemical conditions. He worked with a polymer chain whose individual links each consisted of five amino acids in the sequence valine-proline-glycine-valine-glycine. This repeating sequence, which occurs naturally in the flexible protein elastin, contracts when the temperature is raised above about 30°C and relaxes again when the temperature is lowered. By modifying the polymer slightly, Urry produced a new material that instead contracts and relaxes in response to changes in the pH of the surrounding solution. Threads of this polymer, Urry says, can contract by more than 50% when the pH is lowered, and they can pick up weights thousands of times their own dry weight. These chemically activated "muscles" could have various uses in industry, he says, and because they are elastic, nontoxic, and biodegradable, they are a natural for medical implants for use with such tissue as ligaments and blood vessels.

■ Richard Blakemore of the University of New Hampshire in Durham has studied magnetic bacteria that accumulate iron from their surroundings into grains of iron oxide. Japanese companies have already filed several patents regarding the use of bacterially produced magnetic particles, he noted.

Alper says he was surprised to find out "how much work is going on, how well it's going, and how broadly it's based." The next 5 years, he adds, "are going to show a major increase in using biological processes to make materials." What will those materials be used for? It's still too early to tell, Calvert says. Biological processes offer a whole new set of tools with which to make materials, and researchers are still figuring out how to use them. ■ ROBERT POOL