Making new materials molecule by molecule

To dream of a new material, know how to design its molecular architecture and then build it up from molecular pieces — that would represent Eden for materials researchers, who now rely mostly on rules of thumb, trial-and-error and serendipity for developing new materials. A group of molecular engineers — scientists who think of molecules the way architects think of brick, wood and metal — has stepped slightly closer to this Eden.

Most attempts to engineer a new polymer, ceramic or metal alloy start with an existing material that has some of the properties of the imagined version. Substituting fluorine for chlorine atoms in certain polymers, for instance, can transform a polymer good for food-wrap into a tougher plastic.

A team of scientists at E.I du Pont de Nemours & Co. in Wilmington, Del., takes a different approach. Instead of spinning off variations of an existing material, they try to engineer new solid materials from scratch. Starting with molecular building blocks of their own design, the researchers are learning to precisely and rationally control how these blocks organize into crystal structures and macroscopic solid materials. Their envisioned payoff: a virtually limitless number of new materials that nature would never produce without laboratory assistance.

In back-to-back papers in the March 1 JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, the Du Pont researchers report progress toward their goal. In the first paper, chemists Paul J. Fagan, Michael D. Ward and Joseph C. Calabrese describe methods for making electrically charged, molecular building blocks in a variety of geometric shapes and sizes. In the second paper, they and former Du Pont researcher David C. Johnson, now at the University of Oregon in Eugene, explain how to assemble these blocks like Tinkertoys into what they call "molecular crystalline solids."

To make the blocks, the researchers combine a unique organometallic component (a positively charged compound made of carbon-based components and an atom of the metal ruthenium) with different-shaped compounds made of benzene rings (highly stable hexagonal arrangements of interbonded carbon atoms). The benzene compounds serve as geometric templates during the reaction with the ruthenium chemicals. The result: rod-like, triangular, tetrahedral, octahedral and zigzaggy molecules carrying units of positive charge localized at the molecules' vertices or corners.

In the second paper, the chemists report assembling these positively charged building blocks (cations) and negatively charged compounds (anions) into crystal lattices they can control with an electrode. Electrostatic interactions between the anions and cations serve as the glue holding the larger structures together as they grow into centimeter-sized crystals on an electrode surface. The cations' geometric shapes and the spatial arrangement of positive charges determine the details of the crystals' molecular structures by directing the surrounding anions to arrange only into certain "motifs." In one example, the researchers engineered a conducting solid by using bunches of rod-like cations to promote the stacking of "flat, pancake-like" anions, Fagan says.

"If we can learn how to rationally control the space between the molecules, we may learn how to build new solids that are semiconducting, conducting and superconducting," Ward adds. Other potential payoffs of controlling how molecules pack in a crystal include molecular-sized switches, wires and other devices for a future generation of computers that might be a thousand times smaller and a million times faster than today's electronic brains, remarks electrical engineer Barney S. Glavaski of Case Western Reserve University in Cleveland.

The ability to control the crystal structures of solids would open doors to a universe of new materials, says chemist Margaret C. Etter at the University of Minnesota in Minneapolis-St. Paul. Whether a material is soft, hard, transparent, opaque, flexible, brittle, magnetic, nonconducting or superconducting follows from the way its atomic or molecular building blocks pack into crystals. With further work by the Du Pont scientists and other molecular engineers, materials researchers may no longer have to rely on nature's choices of crystal-packing strategies, Etter says. *— I. Amato*

More cervical cancer in passive smokers

Women passively exposed to cigarette smoke run a higher risk of cervical cancer than those who remain relatively unexposed, researchers report. In addition, the findings bolster evidence that personal smoking boosts the risk of developing cervical cancer, which strikes about 13,000 U.S. women annually.

Martha L. Slattery at the University of Utah School of Medicine in Salt Lake City and her colleagues identified 266 cervical cancer patients and randomly picked 408 healthy women to act as controls. Interviewers asked participants about smoking, passive smoke exposure, sexual history, diet and other lifestyle differences. Evidence suggests a sexually transmitted virus causes cervical cancer, but smoking may make the cervix vulnerable to such infections, the researchers say.

Women passively exposed to smoke for three hours or more per day were nearly three times as likely to have cervical cancer as those not exposed to passive smoke, the researchers report in the March 17 JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION. Passive smoke exposure raised the cancer danger for nonsmokers and smokers alike, independent of other risk factors, the researchers say.

"This is the first adequate epidemiologic evaluation of the role of passive smoking in causing cervical cancer," says Peter M. Layde, director of the department of epidemiology at Marshfield (Wis.) Medical Research Foundation in an accompanying editorial. Although the study suggests an association between passive smoking and cervical cancer, further research must verify the finding, Layde says.

The team also examined the role of personal smoking habits, and found smokers more than three times as likely as nonsmokers to have cervical cancer.

The report reopens a decade-old controversy about the role of cigarette smoking in the development of cervical cancer. "It's pretty clear now that cervical cancer should be on the list of smoking-related cancers," says coauthor John W. Gardner, now at the Uniformed Services University of the Health Sciences in Bethesda, Md. Others are not so sure. Smokers' heightened risk of cervical cancer may be attributable to their greater likelihood of having multiple sex partners compared with nonsmokers, Layde notes.

— K.A. Fackelmann

AZT-resistant HIV seen

Marking a potentially significant setback in the battle against AIDS, the AIDS-causing virus, HIV, has in some patients become resistant to the only drug so far FDA-approved to combat the fatal disease. At least 11 AIDS patients who took zidovudine, or AZT, for at least six months now harbor HIV strains showing significantly reduced sensitivity to the drug in laboratory tests. The findings were made public this week by the drug's manufacturer, Burroughs Wellcome Co. of Research Triangle Park, N.C., in a letter to more than 8,000 physicians. Details will appear in the March 31 SCIENCE.

While the development of resistance was not entirely unexpected, it highlights an area of growing concern to researchers in the fledgling field of antiviral drugs (SN: 2/18/89, p.110). Researchers reviewing the data recommend no immediate changes in treatment. But once other AIDS drugs become approved, they say, combination treatments may help slow the development of drug resistance. Clinical trials of several such combinations are already underway. □