Chemistry

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Plastics that leave no space unfilled

Many cars, planes, tennis racquets and other modern accoutrements come off assembly lines at least partly built with composite materials composed of a plastic reinforced with, say, carbon or glass fibers. These composites often are tougher, lighter, more impact resistant and more easily formable than the metal, glass, wood and other materials they replace.

A team of chemists, engineers and materials scientists at the General Electric Co. in Schenectady, N.Y., has come up with a process for making high-strength, recyclable composites that can be shaped after they are made. "These are fundamentally new materials," claims John W. Verbicky, manager of GE's Chemical Synthesis Laboratory.

The newness lies in the composites' plastic component. Typically, the interwoven molecular architectures underlying plastics form from smaller precursor molecules that link into huge, stringy polymer molecules. But the linearity of these molecules makes them tangle up and leads to melts of the polymeric material that resist flowing into the smaller spaces within a composite's reinforcing fibers. The GE scientists devised a way of forming the polymer network from circular, rather than linear, precursor molecules, which readily flow into and infiltrate the reinforcing fibers. Once the molecules are in place in and around the fibers, a catalyst opens their rings and latches them into polymer networks.

The process uses thermoplastics such as polycarbonate and polyetherimides, which engineers can reshape with heat treatments even after the initial polymerization reaction. Most existing composites involve thermosetting polymer resins that take on an unalterable shape once polymerized. The processing advantages of the new composites could help manufacturers reach previously inaccessible market niches in the automotive, aerospace and construction industries.

Self-assembling molecular receptors

In the crowded chemical brew of every living cell, molecular and atomic subunits find each other and assemble into functioning enzymes, ribosomes — the organelles that link amino acids into proteins — and other cellular occupants. The elegance and efficiency of this self-assembly tactic, which cells mastered billions of years ago, has long captured chemists' admiration. Yet not until about a decade ago did scientists begin emulating the process in their laboratories.

For the most part, such efforts have focused on large components that combine to form even bigger molecular systems, which bind, for instance, charged atoms such as sodium or potassium ions. Scientists hope to use these so-called ionophores for such purposes as scavenging and removing sodium ions from complex solutions while leaving other kinds of ions behind.

Now, chemist Alanna Schepartz of Yale University and chemistry graduate student Jason P. McDevitt, who began the project as a Yale undergraduate, report developing self-assembling ionophore systems out of much smaller molecular subunits. The systems' simplicity should allow finer structural and functional control than is possible with large systems, Schepartz says.

Nickel ions dissolved in chloroform serve as attractants for the molecular components also in the solution, she explains. The ring-shaped part of two of these molecules sticks to the nickel ion. Oxygen-containing molecular arms, whose length the chemists can control, stem from each ring and reach toward each other to form variously sized enclosures that embrace different ions with differing readiness.

In future studies, Schepartz says, she expects to design peptide-containing receptors by attaching short amino acid sequences to the rings.

Preventing postsurgical tissue 'gluing'

"It's very common for women who have had gynecological [surgery] to experience increasing pelvic pain as they grow older," says Eugene P. Goldberg, director of the University of Florida's Biomedical Engineering Center in Gainesville. Most learn their pain results from "adhesions" — patches of tissue that respond to abrasion from gauze, sponges and surgical instruments by fusing to each other during the normal wound healing process. While these adhesions can cause decades of discomfort, they usually do not threaten life.

The same is not true of adhesions that develop in patients surviving open-heart surgery, Goldberg notes. Adhesions in the membrane lining the heart can not only seriously compromise heart function but also complicate the physician's job — and the chances of survival — if the patient needs surgery again. And roughly 70 percent of abdominal-surgery survivors develop adhesions, which can prove similarly lethal if they cause intestinal blockages that are not surgically corrected.

Goldberg and his co-workers now report that hyaluronic acid, a natural, biodegradable constituent of cell membranes, can ward off adhesions in animals when applied to healthy internal tissues that will be exposed to surgical implements when surgery starts.

Hyaluronic acid coatings limited adhesion development to between zero and 20 percent of treated rats in one series of tests involving more than 350 animals. In contrast, 50 to 75 percent of the rats whose tissues were merely irrigated with Ringer's lactate — a standard technique — developed serious adhesions. In a related series of studies involving 60 dogs undergoing cardiac surgery, the results were more striking: zero adhesions in one hyaluronic acid group, compared with 100 percent adhesions for animals irrigated with Ringer's lactate.

"There are currently no clinically reliable local or systemic treatments for suppressing adhesion formation," Goldberg's group notes. However, hyaluronic acid "appears promising for the general prevention of surgical adhesions — and especially for preventing adhesions of the fragile tissues of the abdominal and thoracic cavities." Goldberg notes that Boston-based Genzyme Corp. — which has a new process to produce the acid — will soon begin human trials.

Cataract surgeons use a gel-like form of the same substance when implanting synthetic lenses. But the 0.4 milliliter of 1 percent hyaluronic acid solution they use for each implantation comes from a rooster-comb extract and costs about $70. That would be prohibitively expensive for adhesion prevention, which may require a third of a liter of solution. Genzyme's new process should dramatically reduce hyaluronic acid's cost.

Radon's sticky temperament

The degree to which radon sticks to the materials it touches can vary dramatically, "though we don't fully understand why," says Stephen D. Schery at the New Mexico Institute of Mining and Technology in Socorro. His new studies show the radioactive gas is about 100 times more likely to bind to masonite, clay and certain wood-based building materials than to quartz sand, fired brick, cinderblock or sheetrock. That's important, he found, because the presence of highly absorbing materials in soil or buildings can "greatly slow the passage of radon through them," limiting what escapes to contaminate indoor air. But even for a given material, Schery is finding that the higher its moisture or temperature, the less likely radon will adhere. For example, he has observed that a 10°F increase in temperature can halve radon's sorption to some materials.

These findings suggest that scientists designing radon barriers may need to tailor the choice of materials — and their thickness — to the average ambient temperature and humidity in which they will be used.