Fullerenes: Fill 'em up or move 'em out

Scientists studying those fanciful all-carbon molecules called fullerenes have started off the new year with still more twists in how these molecules might be put to work in new materials.

Biophysicists seeking to understand how plants convert solar energy into useful chemical energy have discovered that fullerenes can mimic nature by ferrying electrons across membranes. Other scientists have encapsulated simple metal crystals inside the giant hollow polyhedra that also form during the production of carbon nanotubes (SN: 7/18/92, p.36).

The giant fullerenes seem to develop around the metal, says Rodney S. Ruoff at SRI International in Menlo Park, Calif. To make these filled particles, Ruoff, Donald C. Lorents, and their SRI colleagues first drilled a hole into a graphite rod, then filled the hole with lanthanum oxide. They shot sparks from the rod to another electrode a millimeter away, causing the rod to vaporize. Then they sent the deposits that formed to Shekhar Subramoney at the Du Pont Co. Experimental Station in Wilmington, Del., for examination with a transmission electron microscope.

"Shekhar called me from the darkroom at Du Pont because he was so excited about the negatives he was developing," Ruoff recalls. The micrographs revealed a variety of nested carbon particles, many filled with crystals that turned out to be lanthanum dicarbide, he and his colleagues report in the Jan. 15 SCIENCE. Air's moisture destroys this carbide, but the carbon cages prevented that, they note.

SRI and Japanese researchers are encapsulating other materials, Ruoff adds. He hopes that giant fullerene "containers" will one day protect potentially useful air-sensitive materials. Also, chemists may be able to modify the filled carbon cages and incorporate them into polymers to create new materials, Ruoff suggests.

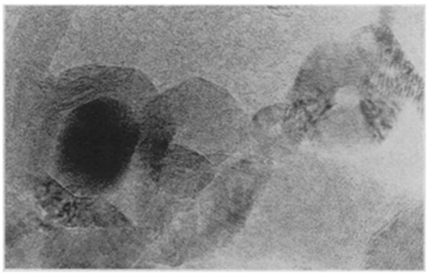
David Mauzerall of Rockefeller University in New York City takes a much different tack in putting fullerenes to work. He and Kuo Chu Hwang at Rockefeller study photosynthesis – in particular, how cells move electrons across membranes. This "charge transfer" ensures that when a donor molecule gets excited by light and lets go of an electron, that electron gets whisked away to someplace from which it cannot return. This transport and charge separation is important to successful energy storage for solar power, as well as to the survival of living organisms, Mauzerall says.

To mimic this process, the Rockefeller group and other researchers typically use various organic molecules to carry electrons from one side of a synthetic membrane to another. But Mauzerall decided to try fullerenes after noticing that their optical properties closely resemble those of light-activated porphyrins.

For their experiments, Hwang and Mauzerall mix the 70-carbon fullerene, C_{70}, with lipid molecules. Because they have a polar "head" and a nonpolar "tail," the lipid molecules arrange themselves into a two-layer film, with tails facing inward, trapping the carbon molecules. The researchers place two liquids – a light-sensitive one that donates electrons and another that can accept free electrons – on either side of this film.

Light from a slide projector bulb makes the light-sensitive liquid release electrons and makes the carbon molecules "photoactive" – more accepting of electrons. Thus light generates a current across the membrane.

"The fullerenes carry charges across membranes much better than porphyrins," says Mauzerall. This fullerene-based system is 40 times more efficient than the best synthetic charge-transfer system, the Rockefeller team reports in the Jan. 14 NATURE. The fullerene works quite fast – shuttling each electron in less than 20 microseconds, sustaining current for longer periods, and transferring more electrons before losing its photoactivity.



Ruoff et al./SCIENCE

Micrograph of empty polyhedra and a nested fullerene that encases a lanthanum-dicarbide crystal

Mauzerall and Hwang are now trying to determine whether a C_{70} ferries each electron or whether several C_{70} molecules straddle the membrane and, like stepping-stones, enable electrons to hop across.

– E. Pennisi

A surgical cure for long-lasting clots

A California team reports success with an experimental operation that removes life-threatening blood clots lodged in the lung's arteries. This condition afflicts an estimated 500 to 1,000 people in the United States each year, researchers say.

The clots in question form in veins in the leg. If part of such a clot breaks loose and gets into the bloodstream, it can reach the heart's right ventricle, which pumps venous blood into the pulmonary arteries. The body dissolves most clots trapped in these arteries; however, some clots take up permanent residence in the lungs. There they attract blood cells and debris, forming a rubbery clog impervious to drugs that dissolve fresh clots.

At first, the symptoms of the blockage are mild. A patient may notice episodic shortness of breath, especially upon exertion. Later, the breathing difficulties get worse. Eventually, patients with this disorder require continuous oxygen. At the same time, the right ventricle must work harder and harder to pump blood past the obstruction. If there is no treatment, the ventricle stops pumping effectively.

Kenneth M. Moser and his colleagues at the University of California, San Diego, School of Medicine have been working on a surgical correction for this condition. Now, Moser reports, they have performed the procedure on more than 400 people. In the risky days and weeks following the operation, 9 percent of those patients died, Moser says. In the most recent 150 cases, however, the death rate has dropped to 5 percent. Moser reported his team's data this week in Monterey, Calif., at a science writers seminar sponsored by the American Heart Association.

Although 5 percent is still too high, the surgery's record is much better than its alternative: Most of the patients would almost certainly have died without treatment, Moser says.

Despite the promising results, the surgery remains tricky. First, the anesthetized patient is put on a heart-lung machine that oxygenates his or her blood and then pumps it back into the body. Next, the surgeon isolates the lung's pulmonary artery and finds the clot.

At this point, the patient's body is cooled to 23°C, a temperature that puts it into a hibernation of sorts and protects brain cells and other vulnerable organs from damage caused by a lack of oxygen. The heart-lung machine is then stopped because the blood rushing through the arteries obscures the surgeon's vision. Finally, with tiny instruments, the surgeon carefully removes the clot from the artery wall.

People who make it through the postoperative period fare relatively well, Moser says. Ninety percent of patients enter the operating room with severe or total disability because of poor lung and heart function. Yet one year after surgery, most of them can resume work and other normal activities, he says. Not one has suffered a recurrence of the condition, he adds.

– K.A. Fackelmann