FULLERENES

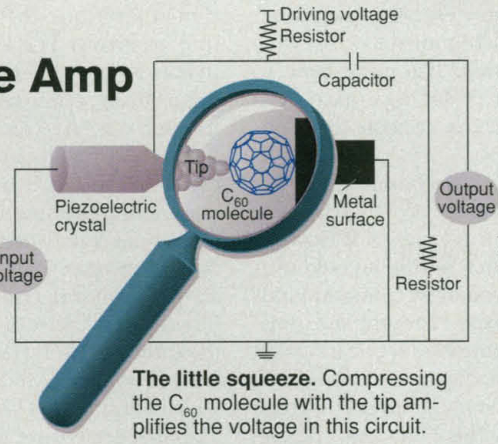
Trapped Buckyball Turns Up the Amp

In the dozen years since their discovery in 1985, the soccer-ball–shaped molecules of 60 or more carbon atoms now known as fullerenes have displayed a dazzling variety of tricks. Although real-world applications are still a way off, researchers have coaxed these "buckyballs" to become superconductors at low temperatures, emit light and carbon ion beams, and form many other compounds with different properties. Now, two European researchers have added something new to this list of talents: They have created an electromechanical amplifier from a single buckyball. "Nothing like this has been done before, and the experimental know-how to be able to do this is highly impressive," says Daniel Colbert of the Center for Nanoscale Science and Technology at Rice University in Houston.

This demonstration came about through a piece of serendipity. In 1995, Christophe Joachim of the CNRS Laboratory for the Study of Materials and Structures in Toulouse, France, and James Gimzewski at the IBM Research Laboratory near Zurich, Switzerland, tried to measure the electrical resistance of the basic fullerene molecule, C_{60}, using a scanning tunneling microscope (STM). This instrument can map out details of a surface with atomic accuracy by passing a current from an ultrafine tip to the surface and detecting changes in the current when the tip scans over it. The researchers used the STM tip to hold down a single C_{60} molecule on a metallic surface so they could measure the current through it. But they noticed, to their surprise, that the apparent resistance of the molecule changed drastically when they squeezed and deformed it with the STM tip. "We found this funny," says Joachim. "Why shouldn't we try to use it as an amplifier? we wondered."

So the team constructed a simple circuit based around the STM to demonstrate C_{60}'s ability to amplify an electrical signal. The key to the setup is the piezoelectric crystal that controls the distance of the STM tip from the surface. Such a crystal expands when a voltage is put across it. One loop of the circuit controls the voltage to the crystal, while a second loop passes a current down through the tip and the C_{60} molecule to the metal surface. Upping the voltage in the crystal circuit by 20 millivolts expands the crystal and moves the tip 1 angstrom (10^{-10} meters) closer to the surface, compressing the buckyball by about 15%. The resulting resistance change in the buckyball changes the voltage in its circuit by 100 millivolts. Hence, the input voltage to the crystal has been amplified by a factor of 5.

The researchers are now investigating other molecules in search of the same properties. "Perhaps we can expect a similar effect when you deform a nanotube; to my knowledge, nobody has tried this yet," says Gimzewski. They are also looking for other ways to compress the molecule. Possibilities include tiny actuators similar to the bimetallic strips used in thermostats, or molecules that deform in response to light, an effect known as photochromism. "The active element can consist of just one molecule," says Gimzewski.



The little squeeze. Compressing the C_{60} molecule with the tip amplifies the voltage in this circuit.

SOURCE: CNRS

Gimzewski's most recent work takes a step in this direction: He and his team have created a monolayer of bianthrone molecules on a copper substrate. These molecules change shape when irradiated by light. The team then attached C_{60} molecules to that layer and repositioned these molecules using an STM tip without destroying the monolayer—demonstrating for the first time that it is possible to move buckyballs around on top of a molecular monolayer. "Our research is now moving toward supramolecular systems, and this is one example of such a system—one type of molecule interacting with another type of molecule," says Gimzewski.

Practical applications are still far off, but "in a number of years, conventional microelectronics could run out of steam, and it is important to start now to look at possibilities from other directions," says Gimzewski. Colbert agrees: "The import is as a demonstration of things to come. We are going to look back in 5 or 10 years and consider these things as important demonstrations of our beginning to play in this playground."

–Alexander Hellemans

Alexander Hellemans is a science writer in Paris.

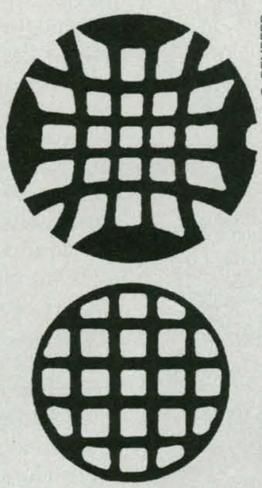
ELECTRON MICROSCOPES

Electron Mirror Gives a Clearer View

Optics researchers since Newton have known that any lens, no matter how well ground, suffers from flaws that will blur an image and add a rainbow fringe to its edges. Even the lenses in electron microscopes, which use beams of electrons instead of light to create images, can't escape these kinds of aberrations. Researchers long ago came up with corrective measures for light-focusing lenses. Now, a fix is in sight for electron microscopes as well, an Oregon team reports in the current issue of *Microscopy and Microanalysis*.

The fix—a corrective mirror developed by physicist Gertrude Rempfer and her colleagues at Portland State University—could increase the resolution of some high-powered electron microscopes by a factor of 5 or more. That's potentially enough to distinguish receptors on a cell membrane. "It's a technological tour de force," comments Jon Orloff, who works on electron optics at the University of Maryland.

It has been more than 250 years since Englishman Chester Moor Hall learned how to correct for the foibles of glass lenses. Glass brings different wavelengths of light, or colors, to focus at slightly different points, creating a blur of colors called chromatic aberration. Even light of just one wavelength won't focus perfectly, because rays passing through the edges of a lens bend too much, in what is known as spherical aberration. In 1732, Hall hit on the idea of passing the light through another lens that had the opposite defects and canceled out the aberrations.



G. REMPFER

Looking sharp. An electron image of the same screen, with *(bottom)* and without correction.

Rempfer and her colleagues looked for a similar solution to the aberrations introduced by the lens of an electron microscope, which consists of metal plates or magnetic or electric fields. Like a glass lens focusing light, electron lenses refract electrons of different energies by different amounts, causing the equivalent of chromatic aberration, and they suffer from a kind of spherical aberration as well. The Oregon team's solution is to send their beam of electrons into an electron "mirror," consisting of a hyperbolic electric field that bends the paths of the electrons even as it repels them.