Feverish Materialism in Snowy Boston

Materialism is never more in vogue than at the annual Winter meeting of the Materials Research Society, held traditionally in the thick of the Christmas buying season at Boston's hotel and shopping mecca known as Copley Place. About 4000 attendees convened there during the snowy first week of this month. Not only did they inject millions of dollars into Boston's needy economy, they also set an attendance record for the MRS, reflecting the growing role of materials R&D in the science and technology world. Among the attention getters were a passionate symposium on a puzzling form of highly porous silicon that emits light, a pair of nighttime show-and-tell sessions on fullerenes and fullerites—those cagey carbon-based Molecules of the Year and new materials that hold vast scientific and technological potential, and one of the first off-the-shelf, for-sale devices made with high-temperature superconductors.

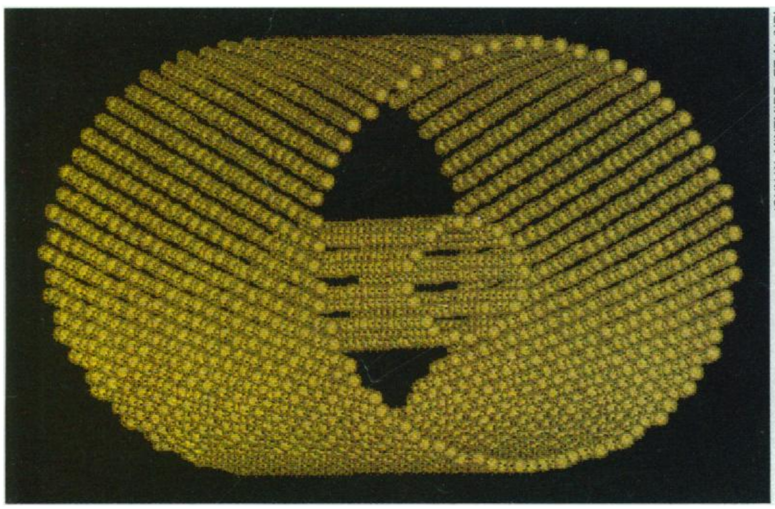
Fullerenes Still in Prime Time

Fifteen months ago when researchers in Germany and Arizona showed the scientific community how to make enough buckminsterfullerene to fiddle with in their labs, they lit a research wildfire that has spread across the world. It now routinely keeps conferees awake during evening "late-news" sessions at chemistry and materials meetings. The MRS meeting was no exception.

In Boston, a cluster of chemists, including Fred Wudl of the University of California at Santa Barbara and Donald Cox of Exxon's Corporate Research Science Laboratory in Annandale, New Jersey, outlined continued success in adding more types of chemical groups—including urethane groups, oxygen atoms, and hydroxyl groups—to the outside of fullerene's 60-carbon shell. These incremental advances open chemical routes to new families of fullerene-based chemicals and polymers.

And the first fruits of such work are already here: Douglas Loy and Roger Assink of Sandia National Laboratory in Albuquerque reported one of the first controlled polymerization reactions involving C_{60}. The specific product of the reaction, which involves C_{60} and paraxylene (a derivative of benzene), may not set the world afire: It's a brownish, cross-linked, and insoluble powder whose properties remain unknown. But the demonstrated capacity to carry out a controlled polymerization reaction with buckminsterfullerene could lead to materials with practical applications ranging from electrically conductive coatings to supports for chemical or biological catalysts.

Chemistry wasn't the only subject on the fullerene agenda at the MRS meeting. Materials scientists from Northwestern University reported that the frequency of laser light is doubled when it passes through a film of C_{60}—a property that could be important for optical communications and other photonic technologies in which light rather than electrons carry signals. Focusing on a different light-manipulating capability, Donna M. Brandelik of Science Applications International Corp. in Dayton said that C_{60}-based materials show promise as "optical limiters" for keeping the power of light that penetrates windows, goggles, or detectors to nondamaging levels. Such materials could be useful for protecting workers exposed to bright light, including doctors using surgical endoscopes and welders who need protection from the brilliant light emanating as searing metal joins metal, Brandelik says. Soldiers threatened by battlefield lasers also could benefit from optical limiters, noted James Lyndle of the Naval Research Laboratory in Washington, D.C. "You want a material that transmits well, but if a powerful light hits it, you want it to become opaque."



JOHN W. MINTMIRE, ET AL./NRL

Tubular carbon. *A pair of carbon tubes as envisioned by theorists.*

Absent at the MRS meeting were experimental replications of last October's head-turning report from Sumio Iijima at NEC Corp.'s Fundamental Research Lab near Tokyo, who reported making tubular versions of fullerenes with diameters in the nanometer range, lengths up to a micron, and structures that sometimes included multiple, nested carbon cylinders. Several theoreticians at the meeting, however, reported preliminary efforts in trying to predict the properties of such fullerene tubules, already conjectured to be superstrong. Calculations by theorist John W. Mintmire and his colleagues at the Naval Research Laboratory, for example, lead them to suspect that some versions of all-carbon tubules might behave like electrically conductive metals.

Also somewhat lower key than in the recent past was the topic of superconducting fullerene materials. One exception, though, came from Ray H. Baughman of Allied-Signal in Morristown, New Jersey. Last month he and his team reported in *Science* that mixtures of C_{60} and C_{70} containing thallium and rubidium ions became superconductive at 45 K or so, the highest temperature yet for any superconducting fullerene. Although Baughman acknowledged at the meeting that no other lab had yet succeeded in duplicating his results, he was hardly backpedaling. On the contrary, he embellished the claim by reporting he had made samples with superconducting transition temperatures in the 50 K region.

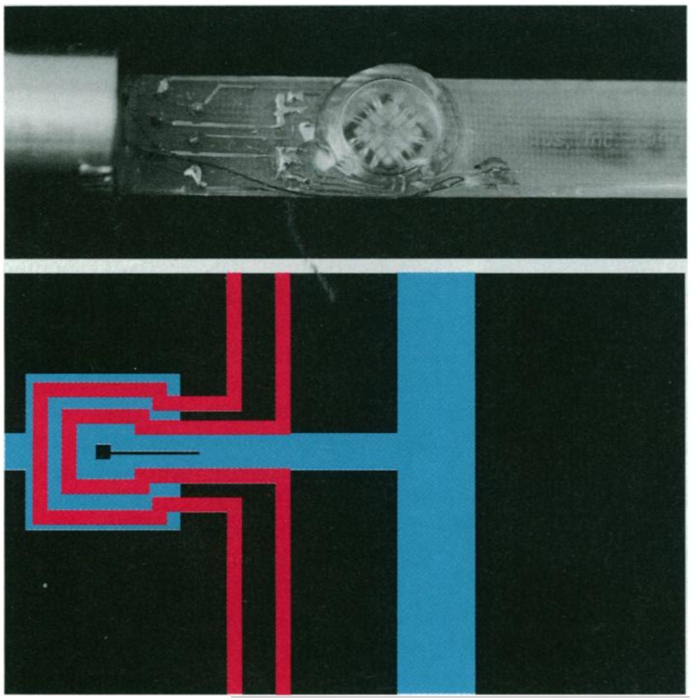
As these widely varying efforts suggest, the ferment surrounding fullerenes this year was sufficient to make them *Science*'s 1991 Molecule of the Year (see p. 1706). Will they earn the "Molecule of the Century" title? The scientific jury has about 8 years to assess that possibility.

This SQUID Ain't Sushi

Less than 5 years have passed since the field of high-temperature superconductivity (HTSC) began in earnest, yet one of the first electronic HTSC-based devices to go on sale was announced at the MRS meeting. For $1,500, Conductus Inc. in Sunnyvale, California, will send you (beginning in March) a complete "superconducting quantum interference device [SQUID]" system.

A SQUID is the most sensitive kind of sensor of magnetic fields. Company officials say Mr. SQUID, as the company calls its product, will find its place in undergraduate laboratories as an educational aid—though it is also capable of practical work, such as detecting metals behind walls. Educational or practical, producing Mr. SQUID is "quite a feat," says Alfred C. Anderson, an HTSC researcher at the MIT Lincoln Laboratory and one of the organizers of the traditionally large HTSC symposium at the MRS meeting. "It's amazing that after just 5 years people are making circuits that are fairly advanced and are now selling them."

At the heart of the system, whose potential applications range from geological surveying to nondestructive evaluation of materials to monitoring brain activity, is a superconducting loop of high-speed "Josephson junctions" made of thin layers of yttrium-barium-copper-oxide (the most studied HTSC materials). The arrangement converts hard-to-measure magnetic fields into electrical signals, which are far easier to monitor and process. In addition to the sensor, your $1,500 also buys a dewar flask to hold the liquid nitrogen needed to cool the magnetometer to its chilly operating temperature, an electronics package to help interpret signals, and a user's guide.



CONDUCTUS, INC.

Mr. SQUID. *The encapsulated detector mounted on a cryogenic probe and a drawing of its magnified sensing component.*

Conductus is not alone in the business of HTSC-based SQUIDS. An information technology company, F.I.T., in Bad Salzdetfurth, Germany, claimed in October that it was the first European company to sell such a device as a commercial product. And formidable competition in the SQUID business is bound to come from technology giants such as IBM, whose scientists have been at the forefront of SQUID R&D.

Silicon's Light Touch, Continued

Like a talented child, silicon keeps delighting its caretakers by showing off surprising new abilities. Its most tantalizing new accomplishment centers on its recently observed ability to emit light. When a network of minuscule pores is etched into silicon, and the material is irradiated with a laser or black light, or—as several groups reported at the meeting—prodded with electricity, it will emit light.

The first news of this new trick came last April, when British and French groups jointly announced at another MRS meeting that they had prepared glowing samples of silicon (*Science*, May 17, p. 922). Almost instantly, hundreds of researchers leaped in, trying to understand, optimize, and exploit the phenomenon. The motivation: Engineers already adept at processing silicon into electronic circuitry would presumably be able to integrate porous silicon into upcoming generations of photonic and optoelectronic technology much more easily than other light-emitting semiconductors, such as gallium arsenide.

Since that first report, many groups have reproduced silicon's "light touch." But major questions remain unanswered, including what drives the luminescence and how the porous silicon is structured. Leigh T. Canham and his co-workers at the Royal Signals and Radar Establishment in Malvern, England, whose team first reported the phenomenon in September 1990, argue that the etching leaves a structure so fine that quantum effects cause electrons confined within the silicon skeleton to shed their energy as light. By comparison, in bulk silicon crystals, those electrons almost always give off their extra energy as heat or vibrations of the crystal lattice rather than light.

Though many researchers found evidence to support Canham's quantum suspicions, others at the meeting had their doubts. They pointed to the possibility that chemical structures on the surface of the pores—or even impurities—might somehow be responsible for the luminescence. H.D. Fuchs and his co-workers at the Max Planck Institute for Solid State Physics found that laser-stimulated siloxene ($Si_6O_3H_6$)-based samples emit light of nearly the same intensity and wavelength range as the porous silicon. This suggests that silicon-hydrogen-oxygen compounds produced by chemical reactions during the etching process, rather than an unexpected quantum effect, could explain the surprising luminosity, said Fuchs at the meeting.

The heat—as well as light—that this field is generating was on display during 3 days of technical presentations, hallway and mealtime conversations, and a passionate panel discussion. "You walk around here enough and you can hear pretty much anything you want to hear," noted Michael Tischler of IBM's Thomas J. Watson Research Center.

In spite of the lack of theoretical and experimental consensus, efforts are moving ahead full blast to formulate practical silicon devices that emit light. "The proof of porous silicon will be in the devices that you can make of them," remarked Frederick Koch of the Technical University in Munich during the panel discussion. And research teams in the United States, Germany, Japan, and elsewhere have taken that challenge to heart. Fereydoon Namavar and co-workers at the Spire Corp. in Bedford, Massachusetts, for example, have made simple porous-silicon devices that they say behave like components in light-emitting diodes, used widely in commercial electronic products.

The field got even more colorful last week at the International Electronic Devices Meeting in Washington, D.C., when Rama Venkatasubramanian of the Research Triangle Institute in North Carolina reported that germanium, an elemental cousin of silicon, also can luminesce. When excited with green laser light, the researchers observed light in the red-to-orange part of the spectrum emanating from tiny needlelike structures, which they had chemically etched into the surface of germanium crystals. Said IBM materials scientist Subramanian S. Iyer at the Washington meeting (presumably without intending a pun): "It's an exciting business."

■ IVAN AMATO