AAAS MEETING

A New Recipe for Superconductivity

Researchers in Japan and the United States have discovered a ceramic material that loses all resistance to electrical current at temperatures close to 120 kelvins, or −243°F. Until this finding, research on high-temperature superconducting materials had been stalled at roughly 90 K, the temperature at which yttrium-barium-copper oxides become superconducting (SN: 3/14/87, p.164).

The discovery marks a significant increase in the temperature at which superconductivity occurs. It gives experimentalists a new family of oxide compounds to investigate and theorists an extra piece for solving the puzzle of how high-temperature superconductors work (SN: 12/5/87, p.359). The new compounds may also be easier to process into useful forms for applications and potentially may carry larger currents when they operate at liquid-nitrogen temperatures (77 K).

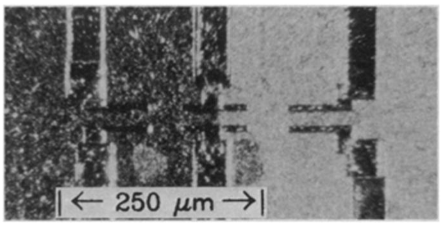
The new material contains the metals bismuth, strontium, calcium and copper, together with oxygen. A team of scientists at the National Research Institute for Metals in Tsukuba, Japan, last month reported finding one combination in which electrical resistance begins to fade at 130 K and reaches zero at 105 K. In the United States, Paul C.W. Chu of the University of Houston and his colleagues fabricated a similar material, containing aluminum in addition to the other elements, that achieves superconductivity at 114 K.

Within weeks, groups of researchers throughout the world were able to reproduce the Japanese results, to isolate the part of the material responsible for superconductivity and to work out its atomic structure. In contrast, previous observations of superconductivity at temperatures as high as the boiling point of water have been inconsistent or have failed to be reproducible (SN: 12/5/87, p.356).

"What we've seen in the last two to three weeks is a perfect example of a real, reproducible result," says John M. Rowell of Bell Communications Research in Red Bank, N.J. "As soon as the rumors about this new bismuth compound began to go around the world, it was reproduced extremely rapidly in many labs." The new findings and other recent experimental and theoretical work on high-temperature superconductivity were major topics this week at the meeting in Boston of the American Association for the Advancement of Science.

Based on preliminary results from researchers at IBM, Bell Communications Research and Du Pont, the new bismuth material appears to have a flaky structure, much like that of the mineral mica. It seems to be somewhat more flexible and less brittle than other superconducting oxides.

The new compounds typically contain elements in the following proportions: two parts bismuth, three parts strontium and calcium, two parts copper and just a little more than eight parts oxygen. At the atomic level, they have the characteristic layered sheets of copper and oxygen atoms typical of all the high-temperature superconductors identified so far. However, they lack the chains of atoms found in previous examples.



IBM Research Division

This micrograph of a thin superconducting film shows two adjacent grains, one lighter in color than the other. Measurements of critical current in three narrow regions marked by horizontal dark lines indicate that the critical current is smallest in the central region, which crosses a grain boundary.

The bismuth family of compounds also seems to be more stable and resistant to chemical attack than the superconducting oxides discovered earlier. "It's not as sensitive to processing conditions," says chemist Angelica Stacy of the University of California at Berkeley. "You can pull this one out of the furnace, and it will superconduct."

Compounds from the two previously discovered families of high-temperature superconductors — the lanthanum-strontium-copper oxides and the yttrium-barium-copper oxides — usually must be specially heat-treated to ensure they contain the right proportion of oxygen. They also react with water and carbon dioxide, readily losing their superconducting properties.

Researchers are also learning a great deal about the properties of the yttrium and lanthanum oxide families. "What we've discovered is not just a new kind of superconductor but a new kind of metal," says Philip W. Anderson of Princeton (N.J.) University. "The materials that become high-temperature superconductors are even stranger in many ways in their normal [metallic or insulating] state than they are in the superconducting state."

All of the materials are just barely electrical conductors. A slight change in the oxygen content or the proportion of a key element turns them into insulators. Even as conductors, because of their layered structure, these materials behave like a metal only in directions parallel to the layers. They act like a semiconductor in the perpendicular direction.

In fact, almost any effect that eliminates the material's superconductivity also destroys its metallic properties and turns it into an insulator, says Rowell. "This is in contrast to conventional materials, where superconductivity can be destroyed, say by magnetic impurities, but the material remains metallic."

"These materials don't look like the metals we're used to looking at," says Stacy. "If you magnify the material, it's composed of superconducting particles joined together in some fashion. If they're not joined in the right way, the material will not carry a lot of current."

Recently, scientists at the IBM Thomas J. Watson Research Laboratory in Yorktown Heights, N.Y., managed to measure the current carried by adjacent grains in a thin film of yttrium-barium-copper oxide grown on a specially prepared strontium titanate surface (see photo). They found that the maximum current the material could carry before losing its superconducting capability is lowest in regions including a grain boundary.

The IBM researchers also found a way to use the properties of such grain boundaries for constructing a new type of device for sensing tiny magnetic fields. Using a laser to etch appropriate patterns in two isolated regions that cross the same grain boundary, they were able to construct a new superconducting quantum interference device (SQUID) with a particularly simple structure.

Meanwhile, the search continues for novel metallic oxides, which may also turn out to be superconducting. "We need more examples of new types of superconductors," says Stacy, who is now studying several other copper oxides with unusual structures. "We have many years of interesting work," she adds. "I hope that by our systematic investigation of single-crystal compounds we'll discover new superconductors."

"We don't pretend that we have discovered the only [road to high-temperature superconductivity] that exists," says K. Alex Müller of the IBM Zurich Research Laboratory in Switzerland. Müller and Georg Bednorz discovered the first high-temperature superconducting oxides (SN: 10/17/87, p.244). Organic superconductors, consisting of long molecular chains, he says, could eventually turn out to be even more interesting than the oxides. — *I. Peterson*