Research News

Superconductor Claim Raised to 94 K

A joint effort by researchers at the University of Alabama in Huntsville and the University of Houston yields the first superconductor to operate above liquid nitrogen temperature

HARD on the heels of the surprising discovery of a new class of oxide compounds that become superconducting at temperatures in the neighborhood of 40 K comes the even more exciting prospect of superconductors that operate in liquid nitrogen (boiling point 77 K). The newest material, which is also an oxide but has a different composition and structure than its immediate predecessors, appears to remain fully superconducting up to 94 K. The first results were presented in a report published earlier this week by Maw-Kuen Wu of the University of Alabama in Huntsville, Ching-Wu (Paul) Chu of the University of Houston, and several co-workers, but the temperature quoted comes from more recent measurements.

It is hard to overstate the present level of enthusiasm and the burst of activity it has engendered in superconductivity laboratories. The last discovery of a new material with a record high superconducting transition temperature came way back in 1973, but the increase was a paltry one from 21 K to 23 K.

By last December, confirmation of the superconductivity above 30 K in a barium-lanthanum-copper-oxygen compound first reported by researchers at the IBM Zürich Laboratory in Switzerland was in hand, and a stampede was on among experimentalists to do as well or better and among theorists to explain the finding. One speculative model by Philip Anderson of Princeton University appears on page 1196 of this issue of *Science*. With the new report of superconductivity up to 94 K in a compound containing yttrium, barium, copper, and oxygen, investigators will barely have had enough time to catch their breath before throwing themselves back into the fray.

If the new material or related ones waiting to be discovered turn out to be manufacturable in a useful form, such as strong ductile wires for high-field magnets, electrical machinery, and power transmission lines, their technological impact could match their scientific importance. The replacement of liquid helium with liquid nitrogen or closed-cycle refrigerators that reach comparable temperatures could make the economics of superconductive devices sufficiently more attractive to spell the difference between go and no go in the hard world of commerce. In the past, superconductors with high transition temperatures have been hard and brittle, which has limited their usefulness. Presumably the projected economic benefits of a high-temperature superconductor would be enough to drive the research effort needed to solve such problems.

The ultimate superconductor would be one that operated at room temperature or above. In a statement released by the National Science Foundation prior to publication of the research report, Chu said that superconducting transition temperatures still higher than the current 94 K are very likely. Houston researchers have seen suggestive but so far unreproducible decreases in the resistivity of some samples at about 240 K.

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Researchers in superconductivity laboratories around the world have already begun to make the material for themselves and verify its performance. Although the Alabama and Houston researchers kept the composition of their new superconductor secret until the 2 March publication date of their report, a newspaper article in the 25 February *People's Daily* in Beijing, China, had already revealed the ingredients as found independently by a group at the Institute of Physics there.

Reproducing the material should be a simple and inexpensive matter, as it was with the barium-lanthanum-copper-oxygen superconductors, which were synthesized by a similar method. To make the new compound, yttrium oxide, barium carbonate, and copper oxide are heated in air to 1000°C to promote a solid-state reaction. The resulting material is then pulverized and heated again for several more hours. Next, the powder is pressed into pellets for sintering in air at high temperatures.

X-ray diffraction studies of samples prepared by this method showed that the material consists of at least two unidentified phases with the overall composition being $(Y_{0.6}B_{0.4})_2CuO_4$. In contrast, the barium-lanthanum-copper-oxygen superconductor has the approximate composition $(Ba_x La_{1-x})_2CuO_4$, where x is usually near 0.1, and a layered perovskite structure.

In the latter case, researchers in many laboratories realized immediately that substitution of other elements in the compound might generate higher transition temperatures. The first candidates were the group IIA metals strontium and calcium in place of barium. This substitution for a minority constituent introduces the smallest perturbation on the compound. Strontium in particular had a felicitous effect, raising the transition temperature to almost 40 K. With this experience in hand, the obvious question was, Would more daring substitutions fare even better?

According to Wu, in the course of a survey of this type, the Alabama and Houston researchers noticed a pattern in the variation of transition temperature with composition. The new superconductor was found from this pattern. At the moment, neither the physics nor the chemistry underlying the pattern is well understood. Nonetheless, the hope for finding still higher superconducting transition temperatures rests on following such empirically developed patterns because little guidance is available from existing theory.

In support of their claim for a transition temperature of 94 K, the Alabama and Houston researchers present the results of measurements that test the two main characteristics of superconductors, zero resistivity and the Meissner effect. The electrical resistivity showed a rapid drop with decreasing temperature that began at 98 K and became too small to measure at 94 K, suggesting a fully superconducting material at this temperature. It is not possible actually to measure a zero resistivity, however, and there are numerous instances in the literature of a sudden decrease in the resistivity of a material by several orders of magnitude owing to such phenomena as a transition from a nonmetallic to a metallic state.

The Meissner effect provides an independent and more stringent test of superconductivity because it is harder to mimic when the measurement is done correctly. When a metal in a constant (dc) magnetic field is cooled to below its superconducting transition temperature, it expels all magnetic flux lines from its interior. This effect shows up as a large negative magnetic susceptibility below the transition temperature. In addition to the published ac susceptibility measurements, dc measurements on samples taken to the Los Alamos National Laboratory indeed exhibited the expected large negative susceptibility.

Useful superconductors in large-scale applications must retain their properties not only at high temperatures but also in the presence of high magnetic fields and while carrying large electrical currents. The first measurements of the maximum or critical field at which the new Y-Ba-Cu-O compound remains superconducting suggest a critical field at 0 K as high as 180 tesla. In comparison, the critical field of lanthanum-copper-oxygen material containing either strontium or barium is estimated to be at least 60 tesla at 0 K. The presence of a high transition temperature and critical field does not necessarily imply a high critical current, however. The previous holder of the record for critical field, the compound $PbMo_6S_8$, has had disappointingly low critical currents.

It is too soon for theorists to have developed models for the new superconductor. The standard Bardeen-Cooper-Schrieffer theory of superconductivity contains two aspects. The first is that the superconducting state consists of electrons bound together in pairs known as Cooper pairs. The second is that the binding occurs by means of an interaction between electrons and lattice vibrations that generates an attractive force between the electrons involved. The transition temperature is the temperature at which thermal energy is sufficient to break up the Cooper pairs.

Stronger attractive forces between electrons than the electron-lattice vibration interaction can generate may be necessary to explain transition temperatures as high as 94 K. Several proposals for ways to produce such forces, including the magnetic interaction described by Anderson in this issue of *Science*, exist in the literature. ■

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ADDITIONAL READING

M. K. Wu *et al.*, "Superconductivity at 93 K in a new mixed-phase Y-Ba-Cu-O compound system at ambient pressure," *Phys. Rev. Lett.* **58**, 908 (1987).

Clinical Trials Planned for New AIDS Drug

U.S. researchers seek FDA approval to start testing peptide T in AIDS patients while the Swedish government has okayed a randomized controlled trial

A new anti-AIDS drug, which may prevent the AIDS virus from entering cells, is about to be tested in Sweden in a randomized, controlled, clinical trial. At the same time, researchers at the National Institute of Mental Health have applied to the Food and Drug Administration for permission to begin a 1-month phase one trial, which tests toxicity only. If that trial is successful, the group wants to follow it immediately with a randomized controlled trial in the United States.

Candace Pert

The Swedish investigators, led by Lennart Wetterberg of the Karolinska Institute, gave the drug, known as peptide T, to a group of four near-terminal AIDS patients last October. This was not meant to be a scientific study—the drug was given on a compassionate basis, Wetterberg explains. But the four men showed no ill effects during the month they received peptide T and, in fact, their symptoms abated. Their conditions have declined since the peptide was withdrawn, and the Swedish government has given Wetterberg and his colleagues permission to give these men the drug again for a period of 6 months. At the same time, the group will start testing peptide T against placebo in 36 AIDS patients.

Peptide T is the only potential anti-AIDS drug that is thought to work by preventing the virus from entering cells. Candace Pert of the NIMH, in whose lab it was discovered, explains that "it came out of left field and it sounded to some people too good to be true." But, she continues, other investigators are becoming convinced. "Skepticism is changing to excitement," she remarks.

Samuel Broder of the National Cancer Institute, says "the important thing is that there are data that suggest peptide T can interfere with binding [of the AIDS virus]. It is an interesting hypothesis and it can be tested at the clinical level. The clinical trial methodology will determine if it is useful."

Dean Mann of the cancer institute, who says that his preliminary data do not indicate that the peptide blocks the AIDS virus from attaching to cells, says he nonetheless has a "gut feeling" that peptide T prevents the AIDS virus from growing in cells. Pert's data indicate that when cells are treated with peptide T, the AIDS virus no longer replicates in them, although she did not measure viral binding directly.

The discovery of peptide T, says Pert, "came out of my lab's 15 years of studying peptides and peptide receptors and mapping receptor patterns in brains." Since AIDS patients often have neurological problems, including dementia, memory loss, and depression, Pert and her colleagues decided to look for evidence that the AIDS virus infects brain cells. When the AIDS virus infects lymphocytes, it enters the cells through the T4 receptor. So Pert and her associates decided to look for T4 receptors in the brain.

They and others found the T4 receptor in the brain, but what was most intriguing was the pattern of the distribution of the receptor. It looked to Pert, Joanna Hill and the others in the group exactly like the pattern of neuropeptide receptors, such as the opiate receptors which Pert and her colleagues had studied extensively. "As soon as we saw the pattern, we knew it was a neuropeptide receptor," Pert says. There was a great deal of binding in the amygdala, for example, the walnut-sized portion of brain that is just below the ears and that is "hard-wired with deep-seated emotional patterns—sex and violence," Pert explains. All neuropeptides bind in the amygdala, she says.

Pert and her associates then decided to try