to the world and see what happens."

Purdue University physicist Ephraim Fischbach, who was a member of the group that first drew attention to the possibility of a fifth force last year when they published a reanalysis of the classic Eötvös experiment, says that these new results are quite interesting—but tenuous. "I would be happy when I get into bed tonight if there were one experiment in the world that showed the existence of a fifth force at a level at which I could believe it," he says.

Fischbach is hardly alone in that sentiment. Even now, physicists are awaiting the results of a fifth force study conducted in a borehole into the Greenland ice cap. That study involved researchers from Los Alamos, Scripps Institution, the University of California at San Diego and other institutions and companies. Meanwhile, another kind of experiment, an attempt to measure effects of gravity on antiprotons, has been approved for the CERN accelerator in Switzerland in 1991. ■ MONTE BASGALL

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Superconductor's Critical Current at a New High

A new processing technique brings the copper oxide materials much closer to practical applications; meanwhile, there are controversial hints of superconductivity at 500 K

IN the high-temperature superconductivity symposium at the Materials Research Society's recent fall meeting in Boston,* two announcements stood out.

In the first, a team of researchers at Bell Laboratories reported a new fabrication technique that increases the critical current of bulk superconductor by a factor of 1000 at 77 K; this brings the new copper oxide ceramic materials to within about one order of magnitude of the current capacity needed for magnetic resonance imaging and other large-scale applications of superconductivity.

In the second, Ahmet Erbil of the Georgia Institute of Technology laid out his controversial evidence for a possible observation of physics' new Holy Grail: superconductivity at room temperature.

The new fabrication technique was described at the meeting by Sungho Jin, Thomas Tiefel, Richard Sherwood, and Bruce van Dover, all of Bell Laboratories' Murray Hill, New Jersey, facility.

Their starting point was the family of yttrium–barium–copper oxide ceramics discovered last February. With a superconducting transition temperature of around 90 K, these so-called 1-2-3 compounds are still the only confirmed superconductors that can operate at the 77 K boiling point of liquid nitrogen, a cheap and universally available coolant. With their granular, polycrystalline structure, however, these superconductors have proved to be disappointingly feeble as current-carrying devices.

Even though their electrical resistance is zero below the transition temperature, their supercurrents still have trouble in passing from crystal to crystal. No one quite knows why this should be. Impurities at the interfaces, perhaps? Misalignment of the crystal lattices? But the reality is that the materials lose their superconductivity at very modest current densities, no more than a few hundred amperes per square centimeter. Moreover, their performance deteriorates rapidly as the external magnetic field increases. At a field strength of 1 tesla, which is typical of what the material would encounter in practical applications, the critical current is only 1 to 10 amperes per square centimeter. It needs to be more like 100,000 amperes per square centimeter.

"In the last 10 months, the low critical current has been the biggest problem in the field. Now we've broken out of the mold."

On the other hand, this limit is clearly not a fundamental one. Single crystals of the 1-2-3 compounds have exhibited critical currents in excess of 10,000 amperes per square centimeter, and thin films have attained 100,000 to 1 million amperes per square centimeter. In both cases, moreover, the performance is relatively unaffected by external magnetic fields. So the capability is there. The trick is to eliminate whatever internal imperfections have been holding the bulk materials back.

Jin and his colleagues have taken a giant step in that direction by changing the way they process the bulk material.

The standard technique is to press yttrium–barium–copper oxide powder into the desired shape and then sinter it—that is, heat the powder until the individual grains fuse together. Instead of simply leaving it at that, however, Jin and his colleagues do something that would be commonplace for a metallurgist, but that is almost unheard of in a ceramics laboratory: they take the sintered powder all the way to 1300°C and melt it. Then they put the sample through a proprietary cooling regimen to bring it back to room temperature. (They also have to restore the superconductivity with a final heat treatment that replaces oxygen atoms driven out of the crystal lattice during the previous processing. However, this latter step is standard and has to be done for sintered samples also.)

This "melt-textured growth" process yields bulk superconductor that is considerably denser than its sintered counterpart, which is about 15% porous on a microscopic level. More important, it creates new crystals and crystal boundaries. Jin and his co-workers find that the processed material now consists of needle-like crystals several hundred micrometers long. These crystals are elongated in the good conduction direction—the 1-2-3 compounds are highly anisotropic in their ability to superconduct—and they are well aligned with one another, at least locally. The result is that the material has a much higher critical current than before: 7400 amperes per square centimeter at zero magnetic field, and 1000 amperes per square centimeter at 1 tesla.

The new processing technique was discovered only a few weeks before the Boston meeting, and the Bell Laboratories researchers are understandably jubilant. "It's a new milestone," says Gilbert Y. Chin, director of the facility's materials research laboratory, where the research was done. "In the last 10 months, the low critical current has been the biggest problem in the field. People were getting discouraged, thinking there was

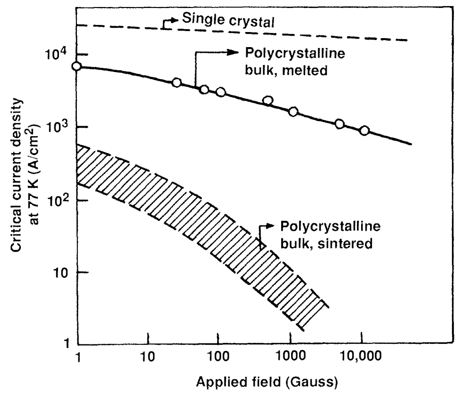
*Materials Research Society 1987 Fall Meeting, 30 November to 5 December 1987, Boston, Massachusetts.

something wrong with the bulk material. But now we feel we've broken out of the mold."

Looking to the immediate future, says Chin, the Bell Laboratories team would like to learn how to align the crystals with each other over macroscopic distances—a centimeter or more. That should increase the bulk critical current still further. Meanwhile, he says, they have not even had time yet to study the mechanical properties of the melt-processed material. The obvious next step is to see if it still suffers from the brittleness that plagues conventionally prepared materials, and whether it can be converted into usable wires.

If the meeting participants were generally enthusiastic about the Bell Laboratories result, their reaction to Erbil's evidence for room-temperature superconductivity was just the opposite. Not only were they skeptical of Erbil's astonishingly high transition temperature—500 K—but they were in no mood to listen to someone else cry wolf. In the 10 months since the 90 K materials were discovered, there have been several dozen reports of still higher transition temperatures—and none of them has ever been replicated. Indeed, many of the talks at the meeting were given over to the perils of wishful thinking, and to detailed studies of how these ceramics can go about fooling even the most careful experimenters.

That said, however, it was also true that no one could dismiss this newest claim lightly. Although Erbil is the first to point out that the Georgia Tech findings are pre-



A giant step. *This graph prepared by Shungho Jin and his colleagues at Bell Laboratories shows the poor critical current performance of the bulk, sintered superconductor, together with the much improved performance of samples prepared by the new melt-textured growth technique. The critical-current performance of single-crystal 1-2-3 superconductor is shown for comparison.*

liminary—he maintains he went public with them only because the rumors were getting out of hand—they definitely show that something unusual is happening. Moreover, his data have a consistency and reproducibility that earlier claims have lacked.

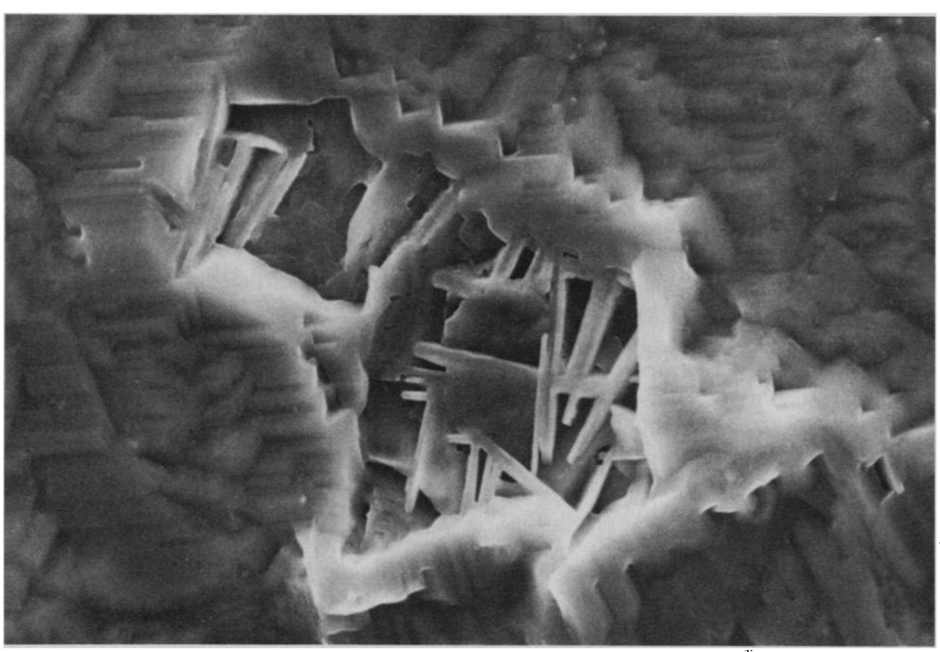
Erbil addressed one common complaint about previous claims by giving out the detailed recipe for his material. Basically it is a yttrium–barium–copper oxide compound prepared in the usual way, he said, except that it is deficient in copper. He and his students have prepared about a dozen samples so far. To a greater or lesser degree, the samples all show a drop in resistivity beginning at roughly 550 K and ending at roughly 450 K. They also seem to be fairly stable so long as they are not exposed to atmospheric humidity. "They are very moisture-sensitive," he told *Science*. "But if we exclude moisture, we've kept them for 3 weeks or so."

A sudden drop in resistivity is not in itself a proof of superconductivity, of course. However, the Georgia Tech group also claims to have seen evidence for flux quantization in the form of the direct-current Josephson effect. They likewise claim indirect evidence for the Meissner effect—a superconductor's compulsion to expel magnetic fields—in the form of a very slight diamagnetism in the samples. That is, bulk samples show a very slight tendency to be repelled by magnetic fields. Diamagnetism is not at all uncommon, says Erbil. However, "This is the first time it has been seen in this class of materials." If one attributes all the diamagnetism to the Meissner effect, he adds, then the superconductivity has to be concentrated in 0.03% of the material. This is qualitatively what one might expect if only a very few crystals in the bulk sample happen to have exactly the right structure for superconductivity.

At face value, at least, these findings do make an intriguing case for superconductivity. "I totally agree with my critics," says Erbil. "No one measurement is 100% proof. But taken all together, superconductivity is the only mechanism so far that explains them all."

However, it has to be said that the data are hardly ironclad. For example, the material's resistance does drop sharply around 500 K. But it does not go all the way to zero. Moreover, researchers at the National Bureau of Standards, where Erbil performed his diamagnetism experiments, point out that the values were upper limits at best. If this had been any other material, says bureau researcher Robert Shull, who worked with Erbil in making the measurement, "you'd say that the measurements found ***no*** superconductivity at room temperature."

In short, the issue is far from being resolved. Now that Erbil has given out the recipe for the material, other researchers will doubtless try to reproduce the Georgia Tech results in short order. Meanwhile, at IBM's Yorktown Heights laboratory, where Erbil worked before moving to Georgia Tech, materials research director Paul Horn draws what is perhaps the only safe conclusion at this point: "Ahmet has found an unusual effect that may not be an artifact—but it remains to be seen if it is superconductivity." ■ M. MITCHELL WALDROP



Bell Laboratories

Oriented crystals. *The new melt-processed growth technique produces needle-like crystals of 1-2-3 superconductor oriented in the direction of good conduction. In this electron micrograph, taken at a magnification of 5000, the crystals can be seen emerging from a surrounding matrix of superconductor in its granular form.*