Supercurrent decay in high magnetic fields

The discovery of high-temperature superconductors opened up the possibility of fabricating superconducting magnets operating at liquid-nitrogen temperatures or higher. However, recent experiments on the effect of magnetic fields on these new superconductors indicate that the road to efficient electrical generators and magnetically levitated trains may be even longer and more difficult than expected. In particular, superconductors containing bismuth or thallium, which become superconducting at the highest temperatures yet achieved, show significant resistance to the flow of electrical current in the presence of a magnetic field, making them unsuitable in their present form for magnet applications.

"Until we understand this phenomenon, it's very unlikely that we are going to be able to make ... high-current magnets," says David J. Bishop of AT&T Bell Laboratories in Murray Hill, N.J. "The notion that in a few years we'll have a superconducting levitating train is foolish. It won't happen on that time scale."

When a superconductor is placed in a magnetic field and its temperature lowered below its superconducting transition point, it abruptly expels the magnetic field. This behavior is the basis for the Meissner effect, which allows a superconductor to levitate above a magnet.

In type II superconductors, including the recently discovered high-temperature materials, an external magnetic field begins to penetrate the material when the field exceeds a certain critical value. But the material's superconductivity isn't destroyed until the field exceeds another, higher value. In this intermediate regime, the penetrating magnetic field exists within the material in the form of separate filaments, or lines of flux, in the direction of the applied magnetic field. These flux lines generally form a regular pattern, or lattice, often pinned in place by impurities in the material.

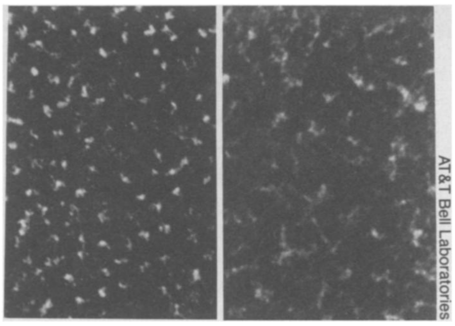
A true superconductor's electrical resistance is zero, and a current set up in a superconducting loop flows forever. However, in a type II superconductor, flux lines can shift in position, or "creep," interfering with supercurrent flow. Thus, the material has a finite resistance and dissipates energy. The surprisingly large amount of flux creep in high-temperature superconductors, even at relatively low temperatures, makes them unusual when compared with conventional superconductors.

Indeed, recent experiments show that in bismuth-containing materials, flux lattices are so fragile they become disordered, or "melt," at temperatures well below the material's superconducting transition point. For example, in the absence of a magnetic field, bismuth strontium calcium copper oxide is a superconductor below 86 kelvins (-304°F). But in a magnetic field, its flux lattice "melts" at 30 kelvins.

"For almost every application you can think of short of levitation experiments for high-school demonstrations, the flux lattice melting temperature is really the important temperature," Bishop says. Above that temperature, these materials show significant electrical resistance and are unsuitable for magnet applications.

The existence of flux "liquids" opens up new territory for theorists to explore. "There are all sorts of proposals on how one might understand what is happening as flux lines let loose, but there are still many questions," says Alexis P. Malozemoff of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y. One particularly perplexing problem is why the thin-film form of a superconductor usually sustains a much larger supercurrent than the bulk form of the same material. Another concerns how to pin down flux lines to allow supercurrents to flow unimpeded.

"Maybe there's some ingenious way of nailing flux lines in place," says David R. Nelson of Harvard University. For example, wandering flux lines may braid and entangle. "Pinning a few lines in a heavily entangled flux liquid would constrain the motion of an interlocking network of neighbors and might allow larger supercurrents to build up before flux line motion degrades them," he says. "But we really have to work out some hard theoretical problems before we can find the answers."



At 15 kelvins in a magnetic field of 20 gauss, magnetic particles (white spots) deposited on a superconductor surface to reveal the location of flux lines show that flux lines wander around more in a bismuth-containing material (right) than an yttrium-based compound (left).

Adds Sungho Jin of Bell Labs, "As it stands now, the bismuth compounds are probably inferior in terms of flux creep, but this is for a given material with a given structure produced in a certain way. That could change any day, any week. We have to have some faith that we will eventually overcome many of these problems by altering the chemistry, microstructure or processing." — *I. Peterson*

New accord would control waste exports

Leaders from 105 nations last week drafted the first international convention to control the export of hazardous industrial wastes. The result of 18 months of intense treaty negotiations — conducted under the auspices of the United Nations Environment Program (UNEP) — the accord represents a compromise. Many developing nations wanted a total ban on international exports of toxic industrial wastes. Over the past year, even UNEP officials have argued that international shipments of hazardous wastes should eventually cease.

One impetus behind the new accord is the growing number of tempting — but environmentally questionable — waste-disposal contracts offered to developing nations. According to UNEP, one Swiss company offered Guinea-Bissau the equivalent of $40 per ton to bury its toxic wastes — a deal that could have netted the African state $600 million, or more than 3.5 times its 1984 gross national product. While this deal never went through, many similar arrangements have. And with dumping costs at U.S. hazardous-waste landfills running up to $250 per ton, while incineration costs have climbed to $1,500 per ton, pressure exists for such offers to continue.

The accord, adopted March 22 in Basel, Switzerland, would require written permission from a potential recipient nation — and at least "tacit consent" from any nation through which a waste might be shipped. The convention would also prohibit exports in cases where exporters or recipients had questions about the safety of waste shipping or disposal.

While the United States is still formally scrutinizing the new convention and has yet to sign it, State Department officials say the administration supports the general philosophy underlying the pact. On March 10, President Bush announced his intention to seek U.S. legislation banning all exports of hazardous wastes except in cases where an importing country has provided assurances in advance that it can and will manage those wastes safely.

Ratification by 20 nations — the minimum needed to enact the new agreement — is expected to take a year or two. In the interim, the Nairobi, Kenya-based UNEP will set up a temporary waste-information referral service to aid developing countries. — ***J. Raloff***