SUPERCONDUCTIVITY

Physicists Scramble to Recapture the Magic

SEATTLE, WASHINGTON—Superconductivity researchers call it the "Woodstock of physics." Fourteen years ago, at the March meeting of the American Physical Society in New York City, thousands of physicists jammed a hotel ballroom until 3 in the morning to listen to 51 talks about the newly discovered high-temperature superconductors. Last Monday, the scene was repeated as over 1000 researchers gathered here for a session that lasted until 1 a.m. to compare notes on magnesium diboride (MgB_2). The newfound metallic compound superconducts at 39 kelvin, a temperature well below that of high-temperature superconductors but double that of its metallic kin.

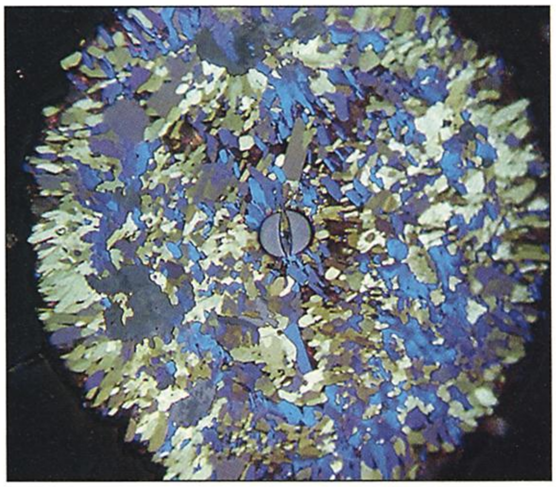
Although "Woodstock west" couldn't quite recapture the past magic, interest has been intense. "It's probably the most important discovery in superconductivity since the high-temperature superconductors," says Gerry Perkins, a physicist at Imperial College in London. Superconductivity in the material was first reported at a meeting only in January. Within a week, the news spread around the world. Dozens of groups dropped what they were doing and raced to understand why the material superconducts well above the temperature of other metal compounds, and to see if they could coax it even higher. And unlike 14 years ago, "we knew exactly what to do this time," says Jim Jorgensen, a superconductivity researcher at Argonne National Laboratory in Illinois.

A flurry of results started appearing last month on the Los Alamos National Laboratory physics preprint server (*Science*, 23 February, p. 1476), and the American Physical Society hastily organized a session to discuss the latest findings. In Seattle, just 2 months after the first report, 79 researchers presented papers in rapid-fire succession, with just 2 minutes each to present their results and 1 minute for questions. "Progress in the field has been very, very rapid," says Robert Cava, a superconductivity researcher at Princeton University in New Jersey. "The world has learned an awful lot about this material."

The lesson so far is that MgB_2 "seems to be a standard, old-fashioned superconductor," says Paul Canfield, a physicist at Iowa State University in Ames. Metal compounds conduct electricity without the usual electrical losses thanks to a mechanism first described in 1957 by John Bardeen, Leon Cooper, and Robert Schrieffer. Their BCS theory says that vibrations of the material's crystalline lattice cause electrons to overcome their usual repulsion of one another and surf through the material in pairs. Most theorists suspected that above about 20 K, additional vibrations in the lattice would cause these pairs to fly apart. The fact that MgB_2 works at nearly 40 K led some to suspect that a different type of glue must be holding electron pairs together. At the meeting, however, numerous teams described experimental evidence on the way MgB_2 conducts heat, transports electrical current, and behaves under pressure that makes it look like a familiar BCS superconductor.

"Generally, the consensus is we know what is going on," says Marvin Cohen, a theoretician at the University of California, Berkeley. Because of that, Cohen says, you could sense interest in the fundamental physics of MgB_2 deflating as the late-night meeting wore on. Adds Paul Grant, a superconductivity expert at the Electric Power Research Institute in Palo Alto, California: "I'll give it a half-life of about a year on the front lines of fundamental physics."

Even so, Grant and others say that interest in the more practical use of the material is just heating up. And it was in this area that some of the most exciting results at the meeting were revealed. Physicist David Larbalestier of the University of Wisconsin, Madison, reported that UW researchers led by Chang-Beom Eom had already made thin films of the material that conduct up to 10,000 amps per square centimeter. Although high-temperature superconductors can do more than 100-fold better, MgB_2 films need few of the tricks required to make high-temperature superconductors carry high currents. The reason, says Larbalestier, is that high-temperature superconductors are layered materials in which electrical currents zip through in flat planes. For the current to hop from one crystallite in the material to another, the crystalline lattices of the two grains must be nearly perfectly aligned. But MgB_2, like other metallic superconductors, doesn't require this same alignment, because superconducting currents can flow in any direction. That should make wires much easier to fabricate, Larbalestier says. In fact, his group has already made a nearly 10-meter-long wire of MgB_2 encased in copper, although for now the amount of supercurrent it can carry remains low. Still, Grant says, "it's a good start."



Power flower. MgB_2's multicolored grains, seen here under polarized light, are illuminating superconductivity research.

CREDIT: D. K. FINNEMORE/IOWA STATE UNIV.

Perkins revealed an equally welcome result on a way to prevent loss of superconductivity of the materials in high magnetic fields. For superconductors, magnetic fields are like Superman's kryptonite: They sap their power in short order. Magnetic fields initially penetrate superconductors in particular spots called vortices that look like tiny whirlpools of magnetic flux. If these vortices move around in the superconductor, they can dissipate electrical energy. Early results didn't bode well: The effect is particularly strong in MgB_2, potentially ruling out applications such as electrical motors that generate such fields.

To lessen this problem in other superconductors, researchers typically fire protons at a material or use other methods to create an array of defects in the materials' crystalline lattice. This disrupts the ability of the material to superconduct at these sites, a situation that is energetically favorable to vortices. As a result, the defects hold vortices in place, allowing the supercurrent to weave around them and continue through the material without shedding energy. At the late-night session, Perkins reported that his team had introduced defects into MgB_2 that sustain the ability of the material to carry a high electrical current in a magnetic field of 3 tesla, a field well above that found in many applications.

Even better would be to find new relatives of MgB_2 that carry supercurrents at still higher temperatures. Jun Akimitsu, a physicist at Aoyama Gakuin University in Tokyo, reported that adding beryllium to MgB_2 creates a new superconductor, but the temperature drops to 35 K. Still, most researchers are hopeful that better compounds may yet be found. Cohen says BCS theory suggests that the superconducting temperature of the material should go up if researchers can somehow expand the spacing of atoms in MgB_2's crystalline lattice. One way to do that, he says, is to substitute larger calcium atoms for magnesium. It hasn't worked yet. But Jorgensen, for one, believes there is good reason to hope. "What we have here is a remarkable science surprise. There surely must be more surprises ahead."

–ROBERT F. SERVICE