Sixth DOE/BES Information Meeting on High T_c Superconductors Discusses Search for Higher Critical Current

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and Ellen O. Feinberg

The discovery of new materials and the search for higher critical currents were the main topics of the Sixth U.S. Department of Energy High Temperature Superconductivity Information Meeting. Sponsored by the Materials Science Division of the Office of Basic Energy Sciences of DOE, the meeting was one of a series that is providing a forum for coordinated high T_c information exchange among DOE-sponsored laboratory programs. Over 75 scientists attended the conference at the Ames Laboratory, Ames, Iowa, and at least 215 additional researchers at 17 sites participated via the NTU/AMCEE (National Technical University/Association for Media-Based Continuing Education for Engineers) satellite network.

The meeting was divided into five panels: (1) the status of the theory, (2) synthesis and structure of new materials, (3) properties of new materials, (4) role of flux creep and grain boundaries in critical currents, and (5) weak link effects in critical currents. The panels began following a brief, untelevised session. In order to accommodate the requirements of the teleconference, each panel consisted of a series of 10-20 minute presentations followed by a brief question-and-answer session. The television audience called in questions to which the panelists responded.

Highlights of the meeting include a report by Dave Hinks (Argonne National Laboratory) of a new protocol for doping $(BaK)BiO_3$, and a report by Duane Dimos (IBM Yorktown) of the critical current of isolated grain boundaries.

Panel I—Status of the Theory

Vic Emery (Brookhaven National Laboratory) gave an overview of new materials and the implication of these discoveries for theory. He divided these materials into two groups. The first was highly anisotropic materials based on Bi and Tl, which have structures dominated by copper-oxide sheets and transition temperatures up to 125 K. The second was isotropic perovskite structures based on $(BaK)BiO_3$, with T_c around 30 K. He outlined a series of careful experiments that will be needed to lay the groundwork for a full understanding of these two classes of materials.

Dwight Jennison (Sandia National Laboratories) presented a more detailed cluster calculation of screening of localized holes on the oxygen sites. Within this model, weak screening leads to localization and an electronically driven pairing.

Panel II—Synthesis and Structure of New Materials

Charles Torardi (Dupont Corporation) presented an overview of synthetic techniques for a wide range of new materials. He emphasized techniques to control the high vapor pressure of some components and methods to accurately control doping. He then briefly outlined the possibility of getting four or five copper-oxide sheets per unit cell.

Bruno Morosin (Sandia National Laboratories) discussed the role of cation disorder, the effect of oxygen vacancies, and the broad implications of structural changes. His studies were based primarily on x-ray, SEM, TEM, and microprobe analysis.

Bob Feigelson (Stanford University) described the pedestal growth method for preparing fibers of the Bi-Sr-Ca-Cu-O compound. [*See his article in this issue.*] In this method, a crystal is brought into contact with a laser-melted rod of material. Proper control of the seed extraction allows crystals to be pulled at the rate of about 1.5 mm per hour.

Scientists in at least 17 locations watched and participated via satellite as their colleagues gathered in Ames, Iowa to discuss recent research on high temperature superconductivity. Speaking here are (left to right) D. Jennison (Sandia National Laboratories), V. Emery (Brookhaven National Laboratory), and B. Harmon (Ames Laboratory).

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Panel III—Properties of New Materials

Lincoln Bourne (Lawrence Berkeley Laboratory) reviewed the isotope effect studies of the original La- and Y-based materials as well as the newer Bi- and Tl-based materials. In all the materials the isotope effect is rather small and in some cases, such as $Y_1Ba_2Cu_3O_7$, it is close to zero. The broad implication of these studies is that phonons often play a role but there are probably other pairing mechanisms that make a larger contribution.

Laura Greene (Bellcore) discussed the changes in structural and electronic properties of the high T_c superconductors that resulted from systematic doping. The doping is often found to control specific bond lengths and these bond lengths, in turn, are found to correlate highly with the occurrence of superconductivity.

Al Migliori (Los Alamos National Laboratory) focused on the occurrence of magnetism in these materials and discussed the connection of antiferromagnetism in the copper-oxide sheets to superconductivity. It is very common for phases close to high T_c materials to show antiferromagnetism, but the magnetic behavior is usually suppressed before superconductivity occurs. Many questions remain to be answered.

A highlight of the conference was Dave Hinks' (Argonne National Laboratory) report that doping in $(BaK)BiO_3$ can be achieved in a two-step process. Oxygen vacancies are first created in the $(BaK)BiO_3$ materials by heating it in flowing nitrogen to create a chemical potential to drive the K into the structure. Then the oxygen is replaced by slow-cooling the material in flowing O_2.

Panel IV—Role of Flux Creep and Grain Boundaries in Critical Currents

Alex Malozemoff (IBM Yorktown) reviewed recent experiments in the flux creep effects pervading the entire field of high T_c superconductivity. Because the coherence distance is so small, the pinning energy for vortices is only about 10 meV, a value comparable to kT_c. This means that creep will be a major factor in high T_c materials, and must be considered in many applications. He showed how flux creep can interfere with measurements of the upper critical field. The true H_{c2} values are much higher than values usually quoted from resistivity measurements.

Jim Kwak (Sandia National Laboratories) then discussed critical currents in Tl thin films. The critical currents measured by a rapid-pulse transport technique give a much higher apparent value of J_c than steady-state magnetization measurements.

Duane Dimos (IBM Yorktown) described a fundamental study of the changes in grain-boundary critical currents with misorientation angle, magnetic field, and temperature. Dimos and colleagues used laser oblation techniques to isolate a single boundary on a thin film and then studied the critical currents of the two adjacent grains and also that of the boundary. They showed that misorientation in the a-b plane, as well as misorientation along the c-axis, is detrimental to J_c.

Panel V—Weak-Link Effects in Critical Currents

Sue Babcock (University of Wisconsin-Madison) and Don Kroger (Oak Ridge National Laboratory) showed beautiful electron microscopy studies of grain boundaries and weak links. Bill Nellis (Lawrence Livermore National Laboratory) discussed dynamic compaction as a sample preparation technique. Ken Gray (Argonne National Laboratory) then summarized some of the most fundamental problems and limits in controlling J_c.

The time and place of the next DOE Information Meeting on Superconductivity have yet to be announced.

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