1988 SSSC Spring Forum Focuses on Superconductivity

The Annual Spring Forum of the Solid State Sciences Committee of the National Academy of Sciences (SSSC) was almost entirely devoted to superconductivity, with particular emphasis on the new high temperature superconductors. Held in Washington, DC, March 10-11, this year's meeting was cosponsored by the National Materials Advisory Board of the National Academy of Engineering. SSSC chairman Prof. Herbert H. Johnson of Cornell University (an MRS councillor) and SSSC chairman-elect Bill R. Appleton of Oakridge National Laboratory (an MRS councillor and former MRS vice president) organized the program and cochaired the first day's activities.

Panelists at the 1988 SSSC Spring Forum (left to right): Roger Poeppel, Praveen Chaudhari, James Jorgensen, Victor Emery, David Larbalestier, and Robert Kamper.

Session I: Superconductivity and Materials Research and Engineering in the Federal Government

Speakers for the first session, on federal initiatives in superconductivity, were: Congressman David McCurdy of Oklahoma, Richard Nicholson of the National Science Foundation, Louis Ianniello of the Department of Energy, and Ted Berlincourt of the Department of Defense. Their remarks are summarized below.

Congressman David McCurdy, a member of the House Science, Space and Technology Committee, chairs the subcommittee that deals with materials issues. He called the rise in available funding for the new oxide superconductors during 1986 through 1988 "good news." On the other hand, he characterized the lack of a current national plan to coordinate activities in this R&D area as the bad news. Suggesting that a new administration might not be as enthusiastic a supporter of superconductivity as the present one, he emphasized that a well-formulated, comprehensive national program should be put in place now to assure continuity. Noting that a variety of agencies now independently direct funding, he comented that while "some diversity is good, too much diversity leads to chaos." McCurdy suggested that industry and academia be involved early in program development and that fundamental research properly balanced with technology must be supported. He warned against a too narrow direction by sources providing funds for basic research and also warned against creating a permanent distortion in other valuable research by reprogramming funds for superconductivity.

McCurdy pointed out that the President is looking for leadership coordination toward the Office of Science and Technology Policy and the National Critical Materials Council, which is charged with developing a national program plan for advanced materials. A five-year program with specified funding levels is anticipated. The Department of Energy is currently named as the supporter of basic and applied research for electric power, energy storage and transmission. The Department of Energy is designated as the development agency for sensors, microelectronics, and materials processing. The National Science Foundation is charged with supporting basic research, and the National Bureau of Standards is responsible for standards.

McCurdy's proposed legislation specifies a funding level of $120 million over five years, with $50 million for defense research and $70 million for the nondefense sector. He quipped that during the past two years he has been chairman of the materials subcommittee, "the materials area has always been considered the backwater." Now with the discovery of the high temperature superconductors, several other subcommittees are "trying to get in on the act." This level of enthusiasm, he said, is healthy, and negotiations among subcommittees can permit legislation to move forward.

The second speaker, Richard Nicholson, is the associate director for mathematical and physical sciences at the National Science Foundation. His central message was that the NSF has had a tumultuous budget year. Initial proposals to double the NSF budget over five years involved a 17% increase in the President's budget for 1988. This has deteriorated to approximately a 2% increase. The initial optimism and positive congressional response, he said, were based on accepting NSF's current activities as promoting national economic competitiveness and on recognizing the essential need to increase these ongoing activities. This motivation, he noted, was fueled by the nearly simultaneous discovery of the supernova and the new superconductors in February and March of 1987. Nicholson took special pride in reminding the audience that Prof. Paul Chu was working as a rotator for NSF during the year the discovery occurred. He emphasized that the NSF research funding style has given principal investigators considerable leeway to "follow their nose."

Somewhat in contrast to McCurdy's statement, Nicholson remarked that "a central coordinator would say that T_c hasn't moved more than 2 degrees in 15 years, why keep funding it now?" Subsequent speakers echoed the sentiment that cross-agency controlling coordination would be counterproductive.

The budget request for fiscal 1989 includes a 19% increase for NSF but, Nicholson said, he is only cautiously optimistic. The recent budget summit has restricted increases in discretionary programs to a total of 2%. Receipt by the NSF and other major scientific programs of their requested amounts in the administration's budget, would exhaust the 2%, leaving no increase for social programs. Indirectly referring to the current budget cutbacks and reducted grant amounts the NSF has been forced to implement during 1988, Nicholson said, "From the lesson learned in 1988, in 1989 we're not going to spend the money before we get it."

Louis Ianniello, deputy associate director for basic energy sciences, Office of Energy Research, Department of Energy, summarized superconductivity support activities in that agency. An internal energy materials coordinating committee (EMaCC) at DOE collects and reports on materials science funded through that agency. At present the bulk of supercon-

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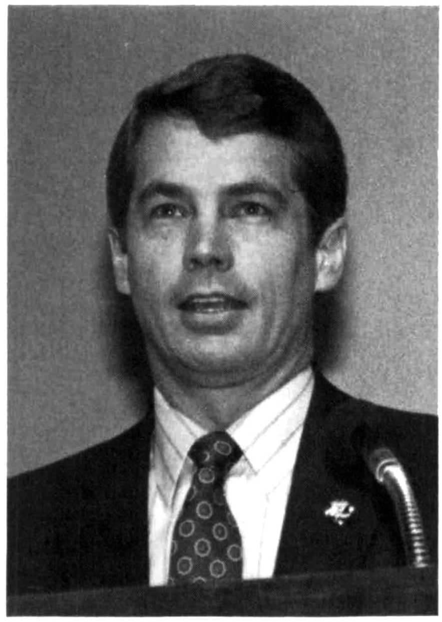
ductivity support comes from the Materials Sciences Division, with a small amount from Chemical Sciences and a little from Engineering. Ianniello described the types of research and development funded by DOE. Basic research includes theory, synthesis, processing, and characterization by neutron scattering and synchrotron radiation. Applications include energy conservation programs, such as transmission lines and fusion energy, high energy in nuclear physics accelerators, fossil energy, and defense programs. He also described several projects, including operating particle accelerators and demonstration transmission lines. Referring to the five DOE information exchange meetings [reported in the MRS BULLETIN in previous issues], he indicated they would continue the most recent embellishment—telecasting portions of the live proceedings.

After mentioning some recent technical developments, such as an 8 x 10^6 A/cm^2 critical current in the rf frequency range and the new thallium-based compound with a critical temperature of about 115 to 120 K, Ianniello described the funding breakdown within DOE for low temperature and high temperature superconductivity, including projections for 1989. The total budget for all superconductivity in 1989 is projected at $95 million. In addition the Small Business Innovative Research (SBIR) program received 125 superconductivity proposals by the deadline of January 22, 1987, that are now under review. Finally, Ianniello referred the audience to a panel report on the use of high temperature superconductors for particle physics using the superconducting supercollider as a benchmark. Al Narath of AT&T Bell Laboratories chaired the panel and the report is now available.

Ted Berlincourt, director of research and laboratory management at the Department of Defense, showed current and potential applications of superconductivity in general and of high temperature superconductors in particular. Included in the defense-related interests were magnetic launchers, ship propulsion, and superconducting electronics. A military system presently in the field operates on liquid helium for about one month. Liquid nitrogen, he said, would increase the operation time by a factor of 64.

A DOD panel on superconducting research and development was formed in June 1987. The panel's report recommended continuing activities in low temperature superconductivity and supporting research in areas particular to DOD interests, such as the effect of ionizing radiation on the new materials. Significant interest from the Strategic Defense Initiative Office in these materials is evidenced. The office has developed "technical insertion working groups" (TIWG) intended to determine ways to use the new technology.



U.S. Representative David McCurdy (Oklahoma), a member of the House Science, Space and Technology Committee.

Additional DOD interests include superconducting magnet energy storage (SMES), minesweeping, pulsed power, low frequency communication, free electron laser wigglers, magnetic shielding, particle beam accelerators, and power sources for directed-energy weapons. Electronics in sensors, filters, multiplexers, millimeter wave amplifiers, and infrared detection are also relevant. Berlincourt reminded the gathering that "the enemies of superconductivity are high currents, high temperature, and high fields. The new materials have already exceeded two of these benchmarks and there's hope that the third will be exceeded soon."

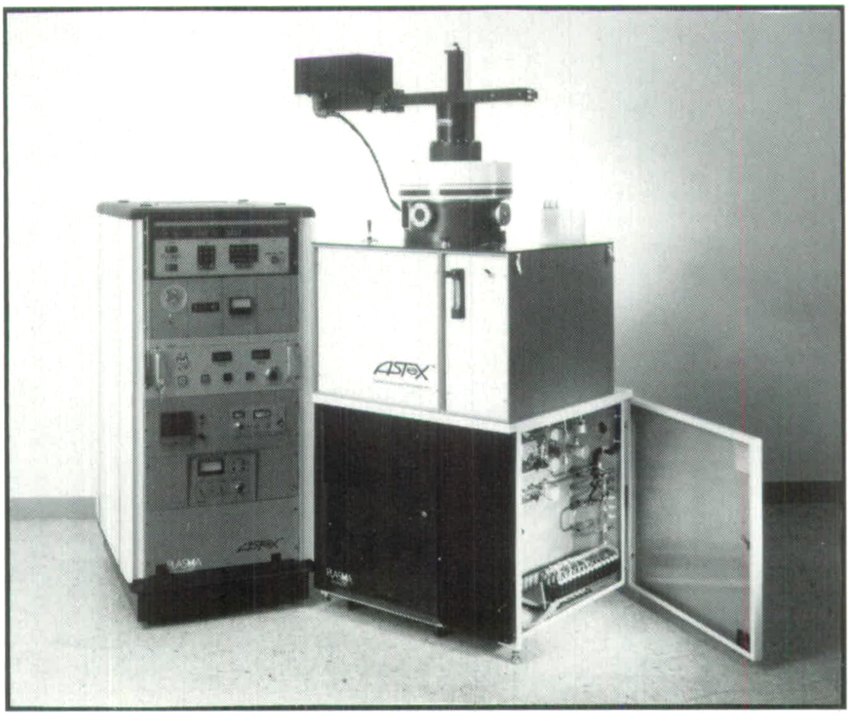
Session II: High Temperature Superconductivity—Research and Engineering

Four talks in the second session described the technical aspects of the superconductors. David Larbalestier of the University of Wisconsin surveyed the state of the entire field by summarizing the content of a COSEPUP report. He described the status of superconductivity before the recent discoveries as consisting of established industries around the world and some existing technologies in accelerators, in fusion, and in magnetic resonance imaging. A declining level of scientific interest and some proofs of principle which had not been picked up for commercialization, such as AC power transmission and magnetohydrodynamics, also characterized the pre-1987 era. In contrast, the situation today is one of enormous scientific interest. Major public and press interest, and hundreds of thousands of enthusiasts (compared to merely thousands before) now exist.

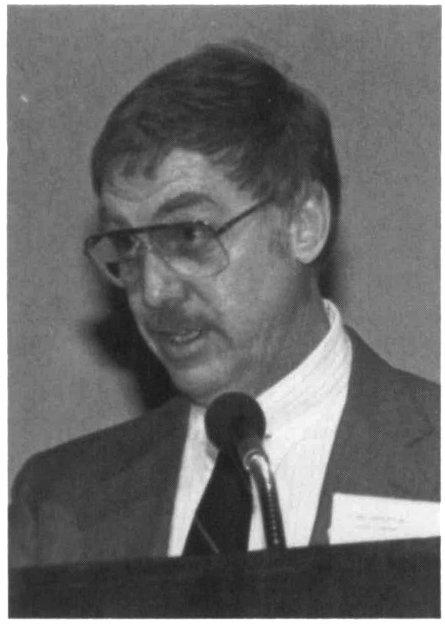
Larbalestier concentrated on the critical current issues surrounding the new superconductors and drew attention to the distinction between the magnetic and the transport measurements of that quantity. The magnetic is always considerably larger in the new materials, indicating that higher transport values may be possible.

Ted Geballe of Stanford University discussed the properties of high T_c superconducters. He particularly emphasized the anisotropy of the new oxide materials and properties near the transition temperature, such as the specific heat, magnetic susceptibility, and magnetization. He discussed determination of coherence lengths which show extreme anisotropy, being 2-3 Å along the c-axis and 14-16 Å in the basal plane. The resulting small coherence volume with a smaller number of electron pairs gives increased significance to fluctuation conductivity in these materials. Geballe described a form of the Y-Ba-Cu-O material which was fabricated at Stanford as a metastable phase in which the repeat distance along the c-axis is doubled and, rather than having stoichiometry 1-2-3-7, has 2-4-8-20. It has a transition temperature of 80 K and an additional set of copper-oxygen chains between the planes of barium atoms compared to normal 1-2-3 material. On annealing, the material reverts to the 1-2-3 structure with added stacking faults and shows properties different from unfaulted 1-2-3. The larger unit cell of the metastable material is reminiscent of the repeat sequence found in the new Bi-Sr-Ca-Cu-O superconductors.

James Jorgensen of Argonne National Laboratory described the structure of the high T_c superconductors based primarily on x-ray and neutron diffraction data. He discussed both Bi-Sr-Ca-Cu-O and the Y-Ba-Cu-O materials. While overall structure determinations are quite certain now, he said, anomalies in the behavior of the materials as a function of orthorhombic strain have yet to be explained. Another unexplained aspect of the behavior of the 1-2-3 material, he continued, is the variation of T_c as a function of oxygen stoichiometry which drops from 90 K to a 60 K plateau before dropping to zero at a stoichiometry of the order $O_{6.4}$. The 60 K plateau may be connected to the depopulation of oxygen sites which link



SSSC chairman Prof. Herbert H. Johnson of Cornell University.



SSSC chairman-elect Bill R. Appleton of Oak Ridge National Laboratory.

the copper chains to the copper planes. Jorgensen concluded by describing the structure so far known of the new bismuth-based superconducting material with an 80 K transition temperature. In addition to the 30 Å repeat distance along the c-axis, incommensurate modulations or supercells in the bismuth layers have been observed. No explanation for this behavior has been advanced.

Victor Emery of Brookhaven National Laboratory then described the state of theory, dividing theoretical approaches into the microscopic (essentially the Bardeen-Cooper-Schrieffer approach), and the phenomenological (the Ginsberg-Landau order-parameter approach). Emery discussed the kinds of experimental data any theory must account for. He included results from neutron scattering, muon spin precession, x-ray spectroscopy, and photoemission. Stating that only three types of electron couplings could account for superconductivity (namely, lattice phonons, spin magnons, and charge excitons, plasmons or density waves), he described the consequences of the three choices. From Hall effect and muon spin precession data, he concluded that only high energy excitations (> 0.5 eV) can explain the properties of the new materials, particularly the 1-2-3 material. It was difficult to imagine an interaction of that strength in the phonon or magnetic interaction case, but the charge polarization case did seem to provide that possibility. None of the possible interactions, however, has been ruled out at present. Finally, he pointed to the drawbacks of the Ginsberg-Landau order-parameter approach. Since that approach deals with expansions in powers of the reciprocal of the order parameter, volume terms depend on $1/(\text{large number})^3$ in normal superconductors. In the new materials, however, the very small coherence length, particularly in the c direction, causes the expansion to be in terms of $1/(\text{smaller number})^2$.

Session III: Studies Recently Completed

After opening remarks from Brian Frost of the National Materials Advisory Board, the third session comprised a description of ceramic processing techniques by Roger Poeppel of Argonne National Laboratory followed by a panel discussion including Brian Frost, David Larbalestier, James Jorgensen, Victor Emery, Praveen Chaudhari, Roger Poeppel, and Robert A. Kamper of the National Bureau of Standards.

Poeppel summarized the various means of ceramic casting and extruding using binder material and solvents with subsequent firing. He described the current mechanical properties in terms of fracture toughnesses and ultimate tensile strengths and projected some modest improvement in these. He indicated the great versatility of the known ceramic processing techniques. Results to date, however, are limited by the mechanical properties and the poor values of critical current in the granular fired material. He also described composite structures, such as powders cast on metal tapes and cermets formed with silver and 1-2-3 material, as ways to increase ductility and flexibility. Ultimate tensile strengths of 8-10 ksi and fracture toughness of 1 MPa-$m^{1/2}$ are present benchmarks. Critical currents in these cast materials are normally around 300 A/cm^2, too low for most applications.

Digressing somewhat, Poeppel described his experience with the huge degree of public enthusiasm that these discoveries have engendered. He said that, "if anything, these materials will contribute greatly to science education at the high school level," where he has seen a great increase in interest on the part of students and teachers alike. Contributing to this has been the proliferation of levitation kits. He explained that when he was displaying a small electric motor utilizing the new superconductors at the recent World Congress on Superconductivity in Houston, "scientists who came to the Argonne motor exhibit in the morning came back with their kids in the afternoon."

In a view to the panel discussion, Praveen Chaudhari from IBM Thomas J. Watson Research Center presented some recent IBM results on grain boundaries in thin films. Through deposition on large grain polycrystalline strontium titanate, the films of the ceramic oxide superconductor were made to have grain boundaries in identifiable locations, and circuit patterns were etched by laser ablation so that properties, intra- and inter-grain, could be measured. It was demonstrated that for grain-boundary tilts greater than approximately 10, when dislocation cores overlap, Josephson junctions are formed at the grain boundary and critical currents deteriorate. A byproduct of this research is the formation of SQUIDS using the grain boundaries in the as-deposited films.

Robert Kamper of the National Bureau of Standards described a large number of measurements performed at the Bureau on the new superconducting material and pointed out that NBS has been declared the "national research center for superconducting electronics."

The following panel discussion focused partly on comparing U.S. and Japanese approaches to research on the new materials. Japan, it was pointed, has established an international center of superconductivity technology in cooperation with major industries, both foreign and domestic. The center, excluding its laboratory component, has over 80 industrial members, each joining at a fee of 2 million yen per year. The vice president of the center, S. Tanaka,

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is also director of the technical laboratory. Over 40 companies have joined the laboratory, paying an entrance fee of 100 million yen and an annual fee of 12 million yen. Each company can send to the laboratory one or two researchers who remain on an individual company's payroll. Memberships in the center and the laboratory are open to industries worldwide. The Japanese, noted a discussion participant, have even published a comic book on superconductors in order to raise the public consciousness to the possible applications of the new materials.

The Solid State Sciences Committee Forum was rounded out by presentations from Praveen Chaudhari on the current status of the Academies' Materials Science and Engineering Study, from William D. Wilson of Sandia National Laboratories—Livermore on the NMAB study of the impact of supercomputing on materials science and technology, and from James J. Wynne of the IBM Thomas J. Watson Research Center on the SSSC's study of photonics science and technology assessment.

E.N.K.

Council on Superconductivity for American Competitiveness Testifies Before Senate Subcommittee

The Council on Superconductivity for American Competitiveness submitted a formal statement (February 26, 1988) to the U.S. Senate Subcommittee on Water Resources, Transportation and Infrastructure on S. 1794, the Federal Advanced Superconducting Transportation Act. The legislation is being sponsored by Senator Daniel P. Moynihan of New York.

Though magnetically levitated superconducting train transport could be "a very visible symbol for America's commitment to rejuvenate its competitive spirit," the CSAC statement "views S. 1794 with mixed emotions." "We support the intentions of S. 1794, but at the same time ask that the Senate focus attention on the need for an overall federal program that will keep the spotlight on superconductivity as a national priority," says the CSAC.

According to Kevin Ott, executive director of CSAC, keeping superconductivity a priority would include "expeditious consideration" by Congress of the Superconductivity Competitiveness Act of 1988. Transmitted by President Reagan to Congress on February 23, 1988, the act covers patent policy changes, joint cooperative development ventures, and access to information under the Freedom of Information Act.

The CSAC statement also advocates consideration by the House Committee on Science, Space and Technology of the National Superconductivity Competitiveness and National Security Act. Sponsored by Representatives Don Ritter of Pennsylvania and David McCurdy of Oklahoma, the bill calls for the formation of a national commission on superconductivity and authorizes $120 million each year for five years for R&D among various federal agencies.

In a final recommendation, the CSAC statement encourages the Senate "to continue support for those programs which could have a direct bearing on America's competitive posture in the long term, such as those programs funded by the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR)."

The CSAC is located at 1050 Thomas Jefferson Street NW, Sixth Floor, Washington, DC 20007; telephone (202) 965-4070.

NBS Budget Proposal Includes More Funds for Superconductor Research

The budget proposal for the U.S. National Bureau of Standards for fiscal 1989 proposes some increases. The electronic materials area includes $6.5 million (in addition to a fiscal 1988 increase of $4.8 million) to enable the NBS to provide U.S. industry with research findings and the measurement capability needed to develop and commercialize products based on the new high temperature superconductors. There is also $3 million for development of fiber-optic technology. ☐

ERRATA:

The name of Gholem-abbas Nazri (GM Research Labs) was inadvertently screened out of the Call for Papers copy for the 1988 MRS Fall Meeting (January issue, p. 67). Nazri is an organizer for Symposium M on Solid State Ionics. Also missing from the same page was the title of Symposium X, Frontiers of Materials Research.