High T_c Oxide Superconductors

M. Brian Maple, Guest Editor

This issue of the *MRS BULLETIN* is devoted to high T_c superconductivity. It is the sequel to a previous series of articles on the same subject which appeared in the *MRS BULLETIN* in January 1989. While the articles in the January 1989 issue emphasized the families of high T_c superconducting oxides known at that time, as well as novel processing techniques and thin films, the papers in this issue focus on the physical properties of high T_c oxide superconductors.

The quality of polycrystalline and single-crystal bulk and thin-film materials has improved to the point where researchers can now make reliable measurements of many physical properties representative of the intrinsic behavior of these materials. As a result, a broad spectrum of important issues such as the nature of the electronic structure, the type of superconducting electron pairing, the magnitude and temperature dependence of the superconducting energy gap, the behavior of fluxoids in the vortex state, etc., can be addressed meaningfully. Presently emerging is a consistent picture of the physical properties of the high T_c oxides, which will form the foundation to eventually developing an appropriate theory for the normal and superconducting states of these remarkable materials.

A key ingredient in achieving an understanding of the normal and superconducting states in the high T_c oxides is the underlying electronic structure—in particular, how it evolves as the insulating parent compounds are doped with electrons or holes to render them metallic and superconducting. The article by J.W. Allen and C.G. Olsen in this issue reviews direct and inverse photoemission spectroscopy studies of the electronic structure of high T_c oxide superconductors, with emphasis on distinguishing models for the normal state.

Infrared absorption is an effective method for studying the superconducting energy gap as well as the dynamics of highly correlated electron systems in the normal state. Since the penetration depth for electromagnetic radiation in the high T_c cuprates is about 1,500 Å, infrared measurements are essentially bulk probes in these materials. The article by Z. Schlesinger and R.T. Collins in this issue describes the current status of infrared studies of the superconducting energy gap and normal state dynamics of oxide superconductors.

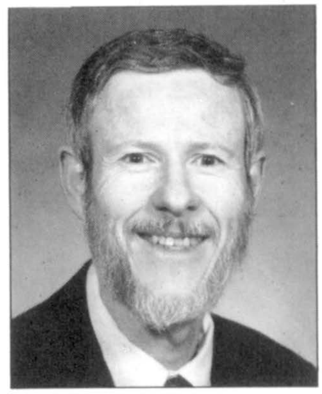
Electron tunneling has proven to be a powerful technique for measuring the superconducting energy gap and obtaining information about the electron-phonon interaction in conventional superconductors. The electron tunneling spectra of high T_c cuprates reveal a number of significant features, including a linear conductance in the normal state that is apparently associated with electron correlations, multiple structures which are presumed to be due to a gap (or gaps) in the electronic density of states, and features at high energies that are reminiscent of the phonon structures in conventional superconductors. The article by J.M. Valles Jr. and R.C. Dynes discusses electron tunneling measurements in the high T_c cuprates and bismuthates.

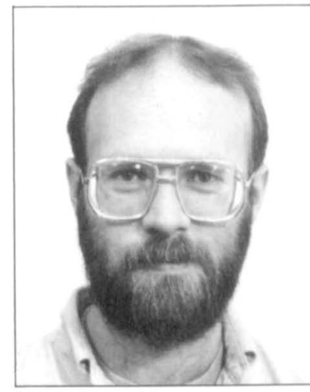
The behavior of fluxoids in the vortex state of high T_c oxide superconductors, a problem of fundamental interest, also has important implications for the performance of superconducting materials in technological applications. A.P. Malozemoff considers these issues in connection with the rich and complex magnetic field-temperature phase diagram of the high T_c oxide superconductors.

One of the most interesting of the high T_c oxides is $Ba_{1-x}K_xBiO_3$, which exhibits superconductivity near 30 K for $x = 0.4$. This material is distinctively different from the other high T_c oxides in the following respects: (1) it has a simple cubic perovskite crystal structure, (2) it does not contain copper, and (3) it does not exhibit antiferromagnetism in its insulating phase. The structural properties and various aspects of the superconducting state in the $Ba_{1-x}K_xBiO_3$ system are discussed in the article by D.G. Hinks.

An important recent development on the materials front is the discovery of electron-doped superconductors of the type $Ln_{2-x}M_xCuO_{4-y}$ (Ln = Pr, Nd, Sm, Eu; M = Ce, Th; $y \simeq 0.02$) for which $T_c \lesssim$ 25 K. These materials are particularly interesting because they are the first examples of high T_c oxide superconductors in which the charge carriers involved in the superconductivity appear to be electrons rather than holes that reside in the conducting CuO_2 planes. In the final article in this issue, I briefly review the superconducting and magnetic properties of these new electron-doped materials. □


M. Brian Maple


James W. Allen


Reuben T. Collins

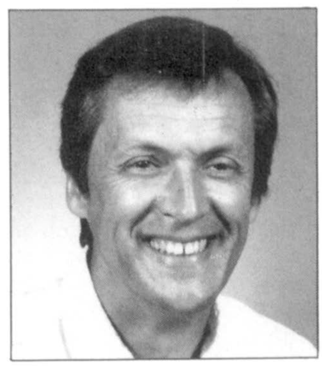
M. Brian Maple, Guest Editor for this issue of the MRS BULLETIN, is a professor of physics at the University of California, San Diego. He has a BS in physics from San Diego State University, and MS and PhD degrees in physics from the University of California, San Diego. His research interests include superconductivity, magnetism, valence fluctuation and heavy fermion phenomena, high pressure physics, surface science, and catalysis. Maple has co-chaired seven national and international scientific conferences. He has chaired the American Physical Society's Division of Condensed Matter Physics, and is co-editor of *Applied Physics A*. He serves on advisory and review committees for several national laboratories and is on the Executive Committee of the High Flux Isotope Reactor User's Group at Oak Ridge National Laboratory. He is a Fellow of APS, and a member of the American Vacuum Society, AAAS, and MRS. He was recently appointed to the Bernd T. Matthias Endowed Chair in Physics at the University of California, San Diego.

James W. Allen is a professor of physics at the University of Michigan. His research interests focus on the electronic structure of solids, with emphasis on the interplay of experiment and theory in systems with strongly correlated electrons. His experimental work includes optical and electron spectroscopy performed with laboratory and synchrotron radiation. He is a Fellow of the American Physical Society and a senior awardee of the Alexander von Humbolt-Stiftung.

Reuben T. Collins is a member of the research staff at IBM T.J. Watson Research Center. He received a BA in physics and mathematics from the University of Northern Iowa and a PhD in applied physics from the California Institute of Technology. Collins' research primarily involves the optical and electronic properties of semiconductors and superconductors, including inelastic tunneling and photoconductivity studies of semiconductor heterostructures and, more recently, infrared properties of high temperature superconductors.

R.C. Dynes is director of the Chemical Physics Research Laboratory at AT&T Bell Laboratories. The laboratory is responsible for research in the physics of new materials and novel configurations of materials with potential technological relevance. Dynes came to Bell Laboratories following a PhD in physics from McMaster University. He is a Fellow of the American Physical Society and the Canadian Institute for Advanced Research (CIAR), and a member of the National Academy of Sciences and MRS. His research has concentrated on studies of the physics of materials at low temperatures.

David G. Hinks is a chemist in the Materials Science Division at Argonne National Laboratory. He received a BS in chemistry from the Illinois Institute of Technology and a PhD in chemistry from Oregon State University. His current research interests are directed toward studying the structure of the high temperature superconducting oxides. Hinks is a member of MRS.

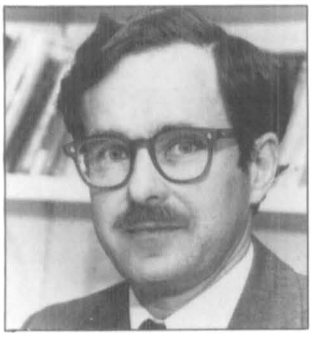

R.C. Dynes


David G. Hinks

Alexis P. Malozemoff is research division coordinator for high temperature superconductivity at the IBM T.J. Watson Research Center. He received a BA in physics and chemistry from Harvard University and a PhD in materials science engineering from Stanford University. After an NSF Postdoctoral Fellowship at the Clarendon Laboratory in Oxford, England, he joined IBM where he has held several positions. He received a Max Planck Fellowship, and his 110 publications in magnetism and superconductivity include two books and work on amorphous ferromagnets, spin glasses and, most recently, magnetic properties and applications of high temperature superconductors. He has chaired the Magnetism and Magnetic Materials Conference and its associated committees, and actively participates on a variety of national committees and advisory boards concerned with high temperature superconductivity.

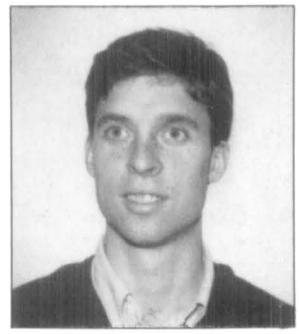
Clifford G. Olson is a senior physicist with the Ames Laboratory which is operated by Iowa State University for the U.S. Department of Energy. He has been involved in synchrotron-radiation-based research for the past 20 years using the storage rings Tantalus and Aladdin at Stoughton, Wisconsin. His current research interests involve high resolution photoemission studies of metallic systems, especially rare earths, heavy fermions, and high temperature superconductors.

James M. Valles Jr. is an assistant professor in the Physics Department and a member of the Materials Research Institute at the University of Oregon. He



Alexis P. Malozemoff

Clifford G. Olson



James M. Valles Jr.

Zack Schlesinger

received his PhD in physics from the University of Massachusetts and did postdoctoral work at AT&T Bell Laboratories for two years. Valles' research efforts include studies of the electronic and magnetic properties of high temperature superconductors and extremely disordered metals and conventional superconductors. He is a member of APS and MRS.

Zack Schlesinger is a member of the research staff at the IBM T.J. Watson Research Center. After undergraduate work at the University of California at Santa Barbara, he studied the propagation of infrared surface electromagnetic waves at Cornell University, receiving a PhD in physics in 1981. While on postdoctoral assignment at Bell Laboratories, he studied the far-infrared properties of two-dimensional electron layers at semiconductor interfaces. His current interests span the physics of conducting two-dimensional systems and high temperature superconductors. □