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International Workshop on Ion Beam Modification and Processing of High T_c- Superconductors: Physics and Devices.

Sponsored by

The European Research Office of the U.S. Army

The NATO Scientific Affairs Division as a NATO Advanced Research Workshop

Program and Abstracts

Minster Lovell

9-12 April 1989

HARWELL

UK ATOMIC ENERGY AUTHORITY

ION BEAM MODIFICATION AND PROCESSING IN HIGH-T_c SUPERCONDUCTORS: PHYSICS AND DEVICES

Minster Lovell Mill, Oxford
9-12 April, 1989

R/D 6043-EE-03
DAJA45 88-M-0211

Sunday, 9th April, 1989

	Registration
19:00	Dinner
20:15	Colin English (Harwell) - Welcome
20:30	Ron Bullough (Harwell) - The relevance of fundamental / basic R&D in the AEA

Monday, 10th April, 1989

A. CURRENT UNDERSTANDING OF PHYSICS, MATERIALS SCIENCE AND DEFECTS
Chair: John Poate (AT&T Bell Labs)

8:45	John Poate (AT&T Bell Labs) - Scientific Objectives of the Meeting
9:00	John Rowell (Bellcore) - "Why is Superconducting Technology More Difficult the Second Time Around?"
9:45	Otto Meyer (Karlsruhe) - "Role of Ion Beams in Superconductor Research"
10:30	Break
11:00	Bob Dynes (AT&T Bell Labs) - "Transport Properties of High-T_c Superconductors"
11:45	H. Adrian (Technische Hochschule, Darmstadt) - "Irradiation Induced and Substitutional Disorder Effects in $YBa_2Cu_3O_7$"
12:15	Lynn Rehn (Argonne) - "Anomalous Thermal Vibrational Behavior in $(Y,Er)Ba_2Cu_3O_{7-\partial}$"
13:00	Lunch

B. CURRENT UNDERSTANDING (continued)
Chair: Harry Bernas (Orsay)

14:15	Alan Marwick (IBM) - "Irradiated Normal State Transport Properties"
15:00	Alice White (AT&T Bell Labs) - "Ion-Beam-Induced Damage in Thin Films of $YBa_2Cu_3O_{7-\delta}$"
15:45	Break
16:15	Marshall Stoneham (Harwell) - "Defect Phenomena in Perovskites and Related Oxides: Parallels Between Superconducting and Conventional Oxides"
17:00	Chris Van Haesendonck (Katholieke Univ. Leuven) - "Oxygen Disorder Effects in High T_c Superconductors"
17:30	Jerome LeSueur (Orsay) - "Irradiation Induced Depairing in YBaCuO"
18:45	Dinner

C. CURRENT UNDERSTANDING (continued)
Chair: Bernd Stritzker (Julich)

20:00	H. W. Weber (Atominstitut der Osterreichischen Univ.) - "Magnetization of Neutron Irradiated YBCO Single Crystals"
20:30	F. Rullier-Albenque (Lab. des Solides Irradies) - "Transport Properties in Low Temperature Electron Irradiated High-T_c Superconductors"
21:00	Georges Martin (CENS-SRMP) - "Stochastic Description of Compounds Stability Under Irradiation: Temperature, Flux and Cascade Size Effects"

Tuesday, 11th April, 1989

D. STRUCTURAL DISORDER, ANNEALING AND DIFFUSION
Chair: Alice White (AT&T Bell Labs)

9:00	Gerhard Linker (Karlsruhe) - "The Nature of Ion-Beam Induced Disorder in HTSC"
9:45	Steve Pennycook (Oak Ridge) - "Electron Microscopy of Defects and Interfaces in High-T_c Superconductors"
10:30	Break
11:00	Harry Bernas (Orsay) - "Irradiation Induced Amorphization of HT_c Superconductors"
11:45	G. van Tendeloo (Univ. Antwerpen) - "Electron Microscopy of High T_c Superconductors"
12:15	Mark Kirk (Argonne) - "Studies of Defect Structures Produced by Ion Irradiations in $YBa_2Cu_3O_{7-x}$"
13:00	Lunch

E. ION BEAM APPLICATIONS
Chair: Alan Marwick (IBM)

14:15	Greg Clark (IBM) - "Ion Beam Lithography of Thin Film High Temperature Superconductors"
15:00	Mike Nastasi (Los Alamos) - "Ion Implantation-Making and Doping of Superconductors"
15:45	Break
16:15	Wei-Kan Chu (Univ. of Houston) - "Ion Beam Research and Processing Program at the Texas Center for Superconductivity at the University of Houston"
16:45	Marie-Odile Ruault (Orsay) - "Formation and Evolution of Ion Beam-Induced Extended Defects in RBaCuO and BiCaSrCuO Supraconductors: In Situ TEM Studies"
17:15	Doug Chrisey (Naval Res. Lab.) - "Radiation Effects Research at the Naval Research Laboratory"

Wednesday, 12th April, 1989

F. DEPOSITION, MICROSTRUCTURE AND PHYSICAL PROPERTIES

Chair: John Rowell (Bellcore)

9:00	Venky Venkatesan (Bellcore) - "Perspectives on High Temperature Superconducting Electronics"
9:45	Richard Humphreys (RSRE) - "Laser Beam Patterning of $YBa_2Cu_3O_7$ Thin Films"
10:30	Break
11:00	Joachim Geerk (Karlsruhe) - "Superconducting Properties of HTSC Thin Films Prepared In Situ by Single Target Deposition"
11:45	Bernd Stritzker (Julich) - "Thin Film Preparation by Laser Ablation and Sputtering Without Post-Annealing"
13:00	Lunch

G. PROSPECTS AND FUTURE WORK

Chair: Otto Meyer (Karlsruhe)

14:00	Summary
16:00	End

"Why is Superconducting Technology More Difficult the Second Time Around?"

J. M. Rowell
Bellcore
Red Bank, NJ

Contrary to popular belief, at least that of the press, superconducting technology already exists. Its scope is impressive. High energy accelerators could not be built without superconducting magnets, whatever their available budget might be. Hospitals are adding magnetic resonance imaging systems to enhance both their diagnostic capabilities and the cost of patient care. High speed oscilloscopes using Josephson junction circuits are on the market, but are not being sold in large numbers. Sensitive instruments using SQUIDS have sold steadily for well over a decade, and are now in great demand. More exotic electronics applications are waiting in research laboratories and are being viewed seriously by the military. It appears inevitable that a train levitated by superconductivity magnets will be used routinely in Japan around the end of the century.

All this has been achieved without high T_c superconductors. The existing technology is based on a few key discoveries of the early 1960's, followed by twenty years of research, development and engineering of niobium based materials.

Given that the uses of superconductivity are so well-known, and the engineering requirements of the materials so well-defined, it must be puzzling to many that at least some of these applications are not yet utilizing the high T_c oxide materials. In this talk, I will attempt to summarize the key differences between the oxide superconductors and niobium alloys that have caused this delay in commercialization. These differences range from crystal structure and anisotropy, to the sensitivity of T_c to chemical doping, to the effects of damage and disorder on the transport properties. I will stress those physical properties which seem, at least to me, the most important for advancing the technology.

ROLE OF ION BEAMS IN SUPERCONDUCTOR RESEARCH

O. Meyer

Kernforschungszentrum Karlsruhe
Institut für Nukleare Festkörperphysik
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The application of ion beams with energies in the region of about 0.3 to 3 MeV for the analysis and modification of superconductors is reviewed. Rutherford backscattering spectroscopy (RBS) is widely used for the rapid determination of the composition in order to control and optimize deposition parameters during thin superconducting film synthesis. RBS combined with ion channeling is applied to study the growth properties of epitaxial films such as interface strain and disorder, intrinsic defects in the film and the surface quality of the films as well as of the single crystalline substrates used for deposition.

The superconducting properties of materials are strongly affected by chemical and structural disorder. Ion beams are used to modify the materials and study such effects in a controllable fashion either by producing radiation induced disorder (in this case the ions penetrate the material to be studied) or by doping (the ions are stopped and the composition of the material is varied).

The influence of disorder on the properties can thus be studied in a wide disorder range up to levels where phase transformations e.g. amorphization will occur. The controllable variation of the transport properties from metallic to insulating behaviour has been applied as a patterning technique to produce narrow bridges for critical current measurements and for the production of SQUID's. The sensitivity of SQUID's could be enhanced by ion irradiation.

Transport Properties of High-T_c Superconductors

R. C. Dynes
AT&T Bell Laboratories
Murray Hill, NJ 07974

Since the discovery of the High-T_c copper oxide superconductors many techniques have been used to probe and diagnose the materials. One of the most common of these techniques is electrical transport measurements. These measurements both in the superconducting and normal state have revealed some very unique properties; some of which are understood but many of which remain mysteries. I will review some of the more interesting features of the transport measurements which will set the stage for subsequent talks.

Irradiation Induced and Substitutional Disorder Effects in $YBa_2Cu_3O_7$

H. Adrian
Institut für Festkorperphysik, Technische Hochschule Darmstadt,
Hochschulstrasse 8, D-6100 Darmstadt, FRD

The effect of lattice defects introduced by low temperature irradiation with 25 MeV oxygen ions on superconductivity and electrical resistivity of thin $YBa_2Cu_3O_{7-\delta}$ films is reported. The experiments show that the sensitivity of T_c on irradiation depends strongly on the initial quality of the samples. Critical current measurements reported in literature [1,2] reveal that the defect induced decrease of T_c significantly contributes to the observed reduction of j_c (77K, B=0), whereas irradiation induced defects can even enhance j_c for $B \neq 0$. In order to elucidate the physical origin of the degradation of the superconducting properties by ion irradiation, we compare the results with the effect of chemical substitution. As a common feature one finds a strong negative temperature coefficient of the resistivity, whevever a significant decrease of T_c is observed. This indicates the defect induced localization of charge carriers which may be especially effective due to the 2-Dimensional character of the electronic properties.

1. A.E. White et al., Appl. Phys. Lett. 53, 1010 (1988).
2. B. Roas et al., preprint.

ANOMALOUS THERMAL VIBRATIONAL BEHAVIOR IN $(Y,Er)Ba_2Cu_3O_{7-\partial}$*

L. E. Rehn, R. P. Sharma, P. M. Baldo and J. Z. Liu
Materials Science Division
Argonne National Laboratory
Argonne, Illinois 60439

If destructive beam effects can be reduced sufficiently, ion channeling provides a powerful technique for extracting information on thermal vibrational properties from small, high-quality single crystals. A comparison of results from our recent ion-channeling studies in $YBa_2Cu_3O_{7-\partial}$ and $ErBa_2Cu_3O_{7-\partial}$ with available information from neutron diffraction studies of sintered specimens clearly shows the advantages of the channeling technique. Axial scans reveal a normal (Debye-type) temperature dependence between 40 and 300 K for thermal vibrations of the rare-earth and Ba atoms perpendicular to the c-axis. In contrast, a substantially stronger than normal temperature dependence is found for similar vibrations of the Cu-O rows, and a large anomalous change (~8% in the FWHM of the channeling dip) in Cu-O vibrations is seen across T_c. The large magnitude of the change at T_c suggests that the atoms located along the Cu-O rows become strongly coupled in the superconducting state.

*Work supported by the U. S. Department of Energy, BES-Materials Sciences, under Contract W-31-109-Eng-38.

IRRADIATED NORMAL-STATE TRANSPORT PROPERTIES

A.D. Marwick

IBM Research Division, T.J. Watson Research Laboratory,
Yorktown Heights, NY 10598

ABSTRACT

The effects of irradiation on the normal state properties of the high-Tc superconductors will be reviewed, with particular emphasis on changes in their electrical resistivity, and the applicability of concepts of charge carrier localization to the results will be discussed. Several groups have reported that the resistance of ceramic and thin film samples whose resistivity is initially in the mohm.cm range increases exponentially with dose when irradiated with neutrons, GeV ions, or MeV heavy ions. In-situ measurements have shown that the resistivity increase is exactly exponential for irradiation at room temperature with MeV ions heavier than oxygen [1]. Deviations from exponential that occur with lighter ions are due to annealing that takes place during the irradiation. For thin film samples of starting resistivity below 1 mohm.cm, two dose regimes can be distinguished. At low doses the resistivity of the films rises exponentially with dose up to a resistivity of around 10 mohm.cm, then the rate of rise increases.

[1] A.D. Marwick, G.J. Clark, D.S. Yee, R.B. Laibowitz, G. Coleman and J.J. Cuomo, Phys. Rev. B in press.

ION-BEAM-INDUCED DAMAGE IN THIN FILMS OF $YBa_2Cu_3O_{7-\delta}$

Alice E. White, K. T. Short, R. C. Dynes, J. M. Valles,
A. F. J. Levi, M. Anzlowar, and K. W. Baldwin,

AT&T Bell Laboratories
Murray Hill, NJ 07974

We have explored the effects of MeV ion irradiation on the electrical and structural properties of high quality, oriented thin films of $YBa_2Cu_3O_{7-\delta}$. At relatively low ion fluences (~4×10^{13} ions/cm^2), the superconducting critical current in the films is reduced by three orders of magnitude without substantial changes in T_c or $\rho(RT)$. At higher ion fluences, superconductivity is destroyed and the films go continuously through the metal-insulator transition. Although the resistivity varies by more than an order of magnitude, the Hall coefficient changes very little. This implies that the metal-insulator transition is a result of a reduction in mobility rather than a drop in carrier density. A quantitatively consistent picture of the data can be obtained using a simple model which assumes that the primary effect of the bombardment is to generate point defects which are insulating.

Defect Phenomena in Perovskites and Related Oxides: Parallels between Superconducting and Conventional Oxides

A M Stoneham

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Defects and defect processes in ceramic oxides control many aspects of their properties and preparation: electrical and optical properties, sintering and control of stoichiometry; mechanical properties and adhesion to substrates. In many respects the superconducting oxides resemble their conventional ceramic counterparts. In this talk I shall discuss what is known of defects and impurity states in oxides, especially perovskites, and compare what is known with the picture which is emerging for oxide superconductors.

The understanding of defects and interface properties in normal ionic oxides has been helped enormously by accurate atomistic modelling. It will appear that some useful predictions for superconducting oxides (which are clearly not simple ionics) can be made using 'reference crystal' models, in which certain classes of prediction are made as if these were purely ionics. These calculations are most useful in relation to ceramic preparation and processing, and can be used as a guide in relation to which sites are substituted, the way in which defects interact and organise locally, structure (including grain boundary and interface structure and, in principle, amorphisation) and defect processes of radiation damage and diffusion.

OXYGEN DISORDER EFFECTS IN HIGH Tc SUPERCONDUCTORS

Y. Bruynseraede, J.-P. Locquet*, J. Vanacken, B. Wuyts, C. Van Haesendonck and I.K. Schuller**; Laboratorium voor Vaste Stof-Fysika en Magnetisme, Katholieke Universiteit Leuven, B-3030 Leuven; * IBM Research Division, Zürich Research Laboratory, 8803 Rüschlikon, Switzerland; ** Physics Department - B019, University of California-San Diego, La Jolla California 92093, USA

It is now well established that the oxygen content and ordering plays a crucial role in the transport and crystallographic properties of high Tc materials. The properties of these superconductors depend in a delicate fashion on the precise preparation method and history, and it is therefore important to understand in detail the kinetics of oxygen evolution.
We present here a review of the effect of oxygen disorder in a large number of high Tc superconductors. The manipulation of the oxygen configuration in a controlled manner enables to establish a close link between superconductivity and crystal structure anomalies, charge transfer, etc. Topics such as chain and plain oxygen occupancy, oxygen diffusion and gradient effects in polycrystalline materials and single crystals, oxygen stoichiometry in thin films antiferromagnetic ordering, etc. will be discussed.

This work is supported by the Belgian I.U.A.P., G.O.A. and F.K.F.O. Programs and the U.S. National Science Foundation grant number 8803185 (at U.C.S.D.). International travel was provided by a NATO grant. J.V. is a Research Fellow of the Belgian I.W.O.N.L., B.W. is a Research Fellow of the Belgian F.K.F.O., C.V.H. is a Research Associate of the Belgian N.F.W.O.

Irradiation Induced Depairing in YBaCuO

J. Lesueur, P Nédéllec, H Bernas, JP Burger[*]

C.S.N.S.M. Bat 108 Université Paris Sud 91405 Orsay Campus France

**Hydrogène et Défauts dans les métaux UA 803 Bat 350 91405 Orsay Campus France*

We discuss ion beam irradiation experiments on $YBa_2Cu_3O_7$ thin films. A simple analysis in terms of separate intergranular and intragranular superconducting properties is proposed.

The details of the former vary from sample to sample, but the corresponding superconducting transitions display the power law dependence which is typical of phase locking in a Josephson junction network.

In order to deduce some intrinsic superconducting properties, we compare the irradiation fluence dependence of the superconducting (onset) critical temperature Tco with the Tc decrease induced by thermal oxygen desorption. This leads us to a quantitative depairing analysis of the Tco change which accounts for all results known to us. Some possible depairing mechanisms are discussed in the light of recent theories; the emphasis is on the specific role of disorder and, possibly, magnetism.

MAGNETIZATION OF NEUTRON IRRADIATED YBCO SINGLE CRYSTALS*

H.W.Weber, F.M.Sauerzopf and H.P.Wiesinger
Atominstitut der Österreichischen Universitäten, A-1020 Vienna, Austria
G.W.Crabtree and J.Z.Liu
Materials Science Division, Argonne National Laboratory, Argonne, Il. 60439, U.S.A.

YBCO single crystals with very sharp transitions at T_c were subjected to fast neutron irradiation in a reactor at ambient temperature. Until today, the following fluence levels have been reached: 0.3, 0.6, and 1.0 and 2.0 x $10^{22}m^{-2}$ (E > 0.1 MeV). All experiments were made in an 8T-SQUID magnetometer, and magnetization critical current densities evaluated on the basis of the Bean model. The general trend of the data, which agrees with our previous low-fluence low-field results, may be summarized as follows: In all cases, the critical current densities are found to *increase*, whereas the anisotropy of j_c, i.e. the ratio of critical current densities for fields parallel and perpendicular to the c-axis, *decreases* with neutron fluence. Detailed experiments on the temperature and field dependence of j_c show particulary interesting features, which will be discussed in terms of flux pinning potentials acting prior to and following neutron irradiation.

*Work supported in part by Fonds zur Förderung der Wissenschaftlichen Forschung, Wien, under contract # 6837, and by the U.S.Department of Energy, Basic Energy Sciences, Materials Sciences, under contract # W-31-109-ENG-38.

TRANSPORT PROPERTIES IN LOW TEMPERATURE ELECTRON IRRADIATED HIGH-T_c SUPERCONDUCTORS

F. RULLIER-ALBENQUE, H. VICHERY

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Sintered samples of $La_{2-x}Sr_xCuO_4$, $YBa_2Cu_3O_7$ and Bi-based compounds and single crystals of $YBa_2Cu_3O_7$ have been irradiated at low temperature by 2.5 MeV electrons.
For $YBa_2Cu_3O_7$, the T_c versus normal state resistance R curves are nearly the same in single crystals as in sintered samples. This indicates that T_c and R are mostly influenced by intragrain damage. The alteration of intergrain connections is reflected by the evolution of the transport critical current which exhibits a slight increase at very low defect concentration followed by a continuous decrease for higher doses.
Sensitivity to electron irradiation is about the same in $La_{2-x}Sr_xCuO_4$ and $YBa_2Cu_3O_7$ and is higher in the Bi-based system. Moreover in a given system, T_c is found to decrease faster in samples with lower initial value of T_c.

STOCHASTIC DESCRIPTION OF COMPOUNDS STABILITY UNDER IRRADIATION: TEMPERATURE, FLUX AND CASCADE SIZE EFFECTS

P. BELLON *AND G. MARTIN**
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**CENS-DTech-SRMP, 91191 Gif sur Yvette CEDEX, FRANCE.

ABSTRACT

Cascade size may affect phase stability under irradiation because of two distinct contributions: the replacement to displacement cross section ratio depends on the deposited energy density; ballistic jumps which tend to disorder ordered compounds occur by bursts (of size b), while thermal jumps which restore long range order occur one by one.

The latter effect cannot be handled by standard rate theory. A stochastic treatment of the problem, based on a Fokker Planck approximation of the relevant master equation is summarized. It is shown that the possible values of the long range order parameter under irradiation are not affected by the size b of the bursts, but that the respective stability of the former is b dependent. As a consequence, the stability diagram of phases under irradiation varies with b. Such a diagram is computed for the Ni_4Mo system where three structures are competing: the disordered solid solution, D1a and $LiFeO_2$ type ordering. A broadening by 100K of the stability domain of the short range ordered structure to the expense of the long range ordered one is predicted when increasing b from 1 to 100.

The stochastic potentials introduced in the present treatment are by no means free energies of some constrained state. They can however be computed in a mean field type approximation.

THE NATURE OF ION-BEAM INDUCED DISORDER IN HTSC

G. Linker

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Institut für Nukleare Festkörperphysik
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Disorder in high-temperature superconducting oxides introduced either by the preparation procedure (heating, cooling, doping, etc.) or in a specific manner by ion irradiation or implantation in most cases leads to a strong degradation of the transport properties, especially of the superconducting transition temperature. In some cases, however, e.g. with respect to the critical current density beneficial effects have been observed. The defect structure leading to such changes therefore is of large interest.

Defect studies in as-prepared and ion-beam treated material, mostly in YBaCuO, have been performed mainly by diffraction experiments (X-rays, neutrons), high resolution electron microscopy, and channeling analysis. The detected or assumed defect structures range from static distortions in the cation sublattice, disordering of oxygen in the chains or planes, trapped O_2, oxygen vacancies, change of stacking sequences, displaced Cu-atoms, dioxidation, etc., to phase transformations from orthorhombic to tetragonal or from crystalline to amorphous.

We present in this overview some of our results of ion beam (H^+, He^+, Ar^{++}) irradiation studies of LaSrCuO and YBaCuO thin films of different growth quality. The defects which appear of collisional nature are discussed in terms of lattice parameter changes, static displacements, or amorphous regions formation. In view of the variety of possible structural distortions a unique assignment of defects responsible for the T_c depressions appears difficult, but oxygen disordering seems plausible, especially taking into consideration annealing effects after low temperature irradiations.

ELECTRON MICROSCOPY OF DEFECTS AND INTERFACES IN HIGH-T_c SUPERCONDUCTORS*

S. J. Pennycook, M. F. Chisholm, R. Feenstra, D. Mashburn, and J. C. McCallum
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Oak Ridge, Tennessee 37831

The current status of high-resolution electron microscopy investigations of high-T_C superconductors will be reviewed including studies of bulk polycrystalline materials and epitaxial or oriented thin films. A new Z-contrast imaging technique using a high-resolution scanning transmission electron microscope will be described. This technique provides a directly interpretable image of the atomic structure and chemistry of defects and interfaces which is complementary to conventional high-resolution techniques. Images of the commonly observed planar defects in $YBa_2Cu_3O_{7-x}$ show clearly that these can exist in both interstitial and substitutional types. A study of the atomic structure and chemistry of low-angle tilt boundaries will be described. At low tilt angles the boundary consists of an array of partial dislocations but as the tilt angle increases these collapse into small amorphous zones. Z-contrast imaging gives a clear indication of the bounding plane and shows that the amorphous zones are chemically identical to the 123 composition. They are therefore formed by structural relaxation of the 123 material and not as a result of segregation effects in this case. Z-contrast images of substrate/film interfaces will be shown which demonstrate that although structurally sharp the interfaces are chemically diffuse. Preliminary experiments to study ion implantation damage and recrystallization will also be described.

*Research sponsored by the Division of Materials Sciences, U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

Irradiation induced amorphization of HT_c superconductors

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Abstract: At sufficiently high fluences (typically ~0.1 dpa for $RBa_2Cu_3O_7$ series and ~0.01 dpa for the BiCaSrCuOx series) the HT_c compounds are amorphized by ion beam irradiation and the amorphous state is an insulator.

We shall briefly review and discuss the information known to us regarding the nature of the damage produced by irradiating these materials, and the relation between the damage and phase transformations. Our provisional conclusion is that while irradiation-induced crystalline phase transformations are related to the displacement of specific atoms in the unit cell (the oxygen atoms in $RBa_2Cu_3O_7$, The Bi-O and/or Ca-O plane atoms in $BiCaSrCuO_x$), amorphization is related to the break-up of the "backbone" part of the structure: the heavy atoms in $RBa_2Cu_3O_7$ and the basic perovskite cell in the $BiCaSrCuO_x$. Thus amorphization and crystalline phase transformations (as well as disproportionation) compete in a given irradiation experiment: the net result depends on the collisional energy transferred and on the deposited energy density, as well as on the relative stability of the various possible phases.

A more definite conclusion, at least in $RBa_2Cu_3O_7$, is that overall amorphization and the metal-insulator (or even superconductor-non superconductor) transition are totally independent.

ELECTRON MICROSCOPY OF HIGH T_C SUPERCONDUCTORS

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Defects in the new superconducting materials definitely play an important role and their relation with the superconducting properties are far from trivial. We will report on the electron microscopy and electron diffraction results on a study of :

1) $YBa_2Cu_3O_{7-\delta}$ (T_C = 90K)
2) Bi-Sr-Ca-Cu-O (T_C = 110K)
3) Tl-Ba-Ca-Cu-O ($T_C \approx$ 125K)
4) Pb-Sr-(Ca-Y)-Cu-O ($T_C \approx$ 70K)

The first compound is crystallographically (by far) the most simple. Superconductivity is to be attributed to the orthorhombic (pseudo-tetragonal) phase. In the compounds with a high oxygen content (110) twinning is almost unavoidable. Inside the electron microscope the material can be heated into the tetragonal phase and cooled back to the room temperature orthorhombic phase. The (110) twins disappear and reappear completely reversible. A video movie of this transformation process reveals interesting details on this transformation process. Apart from these twin boundaries, intrinsically related to the structure, a number of other (sometimes very complex) defects can be characterized.

The Bi-Sr-Ca-Cu-O as well as Tl-Ba-Ca-Cu-O superconducting material is very often multi-phased. Depending upon temperature and composition one finds superconductivity at 20K (A-phase), 80K (B-phase) or 110K (C-phase). These different phases are based on the same building principle and only differ by the thickness of the perovskite-type lamellae, giving rize to c-repeat distances of 2.4nm (A-phase), 3.1nm (B-phase) and 3.7nm (C-phase). In some regions slabs with a 4.3nm unit cell are found. In some compounds periodicities of several tens of nm are found, double TlO layers alternate with single Tl-O layers while D block alternate with E (or C) blocks. The structure of these materials is incommensurably modulated and defects in the modulation are very common; they are studied in detail by high resolution electron microscopy.

Studies of Defect Structures Produced by Ion Irradiations in $YBa_2Cu_3O_{7-x}$*

M. A. Kirk, M. C. Frischherz, J. Z. Liu, L. L. Funk, L. J. Thompson, J. R. Wallace, E. A. Ryan, S. T. Ockers,

Materials Science Division, Argonne National Laboratory, Argonne, IL, 60439, USA,

and H. W. Weber,

Atomininstitut der Österreichischen Universitäten, A-1020 Wien, Austria.

Several experiments have been performed to investigate by transmission electron microscopy defect structures produced in $YBa_2Cu_3O_{7-x}$ by various ion irradiations in the Argonne High Voltage Electron Microscope-Accelerator Facility. The development of defect structures was followed as a function of dose up to amorphization under 1.5 MeV Ne^+ and 1.7 MeV Kr^+ irradiations at room temperature near two low index orientations of single crystals. Individual cascade defect structures were studied at low doses following irradiations by 85 keV Xe^+ at 300 K and 85 keV Kr^+ at 40 K (with changes upon annealing to 100, 170, 240 and 300 K), again in single crystals in two low index orientations.

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*Work supported by the U. S. Department of Energy, BES-Materials Sciences, under Contract W-31-109-Eng-38.

ION BEAM LITHOGRAPHY

OF THIN FILM HIGH TEMPERATURE SUPERCONDUCTORS

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Ion beam lithography was used to pattern the first thin film device fabricated from the high temperature superconductor $Y_1Ba_2Cu_3O_x$. The device prepared was a SQUID. The technology and physics of this technique will be described. The SQUIDs prepared by this technique will be compared to similar devices prepared by other lithographic techniques.

Ion Implantation-Making and Doping of Superconductors

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The application of ion implantation in the alloying and doping of high temperature oxide superconductors has recently been explored by several different research groups. Ion implantation alloying has been used to bring component deficient superconductors closer to stoichiometry by the implantation of Y or Cu ions. Ion implantation has also been used to dope superconductors with additional components such as F, H, and N. The impact of such ion implantation experiments on the quality and properties of high temperature superconductors will be reviewed and discussed.

Ion Beam Research and Processing Program At the Texas Center for Superconductivity At the University of Houston

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TCSUH is a multi-disciplinary research and development consortium, dedicated to the study of materials leading to the full-scale application of high-temperature superconductivity. Ion Beam Research and Processing Lab is one of the eight laboratories within the center. In this talk, an overview of TCSUH and an outline of the ion beam program will be described.

Formation and evolution of ion beam-induced extended defects in RBaCuO and BiCaSrCuO supraconductors: in situ TEM studies

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Abstract: We discuss low-dose, light and heavy-ion irradiations of high Tc superconductors performed at 15 K and 300 K in the CSNSM implantor-TEM set up. Extended defects were observed and their evolution under irradiation was studied in situ. In RBaCuO, our main conclusion is that while low damage density cascades (light ions) only produce stable extended defects at 15 K, high damage density cascades (heavy ions) produc^ resolved dislocationloopswhich interact with the twin boundaries. A videao recording of the latter effect will be shown. In the BiCaSrCuO samples which we have studied, we find no evidence of defect cluster formation under light ion irradiations.

Radiation Effects Research at the Naval Research Laboratory

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The modification of thin films of the recently discovered high temperature superconductors as a result of energetic particle bombardment is of interest to the Navy both to gain a fundamental understanding of radiation effects and defect phenomena in these materials, and as a demonstration of radiation hardness for possible applications of devices in natural or hostile space environments. Although the natural space environment is composed predominately of high energy electrons and protons many of our early radiation damage measurements, and those made at other laboratories, were made with slow heavy ions (1-20MeV, M>10amu) on the highest quality Y-Ba-Cu-O films available. Defining a radiation damage factor as $d(\Delta T_c)/d\phi$ and plotting this quantity versus the nuclear energy loss or displacement damage we found that approximately 1eV of displacement damage deposited per atom was required to destroy the superconducting (R=0) state; significantly lower values were found for poorer quality films. Since this time we have made detailed calculations of the displacement damage energy deposited by incident high energy electrons and protons to compare to existing data and amazingly it is found that this relationship is maintained over 6 orders of magnitude in nuclear energy loss. In addition we have made a careful study of the effect of irradiation temperature on radiation damage. This study demonstrated that films or devices operating at liquid nitrogen temperatures will be slightly more susceptible to radiation damage than will films operating at higher temperatures due to self-annealing.

PERSPECTIVES ON HIGH TEMPERATURE SUPERCONDUCTING ELECTRONICS

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ABSTRACT

The major challenges in making HTSC electronics viable are predominantly materials problems. Unlike their predecessors the metal oxide based superconductors are integratable with other advanced technologies such as opto- and micro- electronics. The materials problems to be addressed relate to the epitaxical growth of high quality films, highly oriented films on non-lattice matched substrates, heterostructures with atomically sharp interfaces for junctions and other novel devices, and the processing of these films with negligible deterioration of the superconducting properties. I will illustrate these issues with results based on films prepared in-situ by a pulsed laser deposition process. Films with zero-transition temperatures of 90k and critical current densities of 5*10E6 A/cm2 at 77k have been prepared by this technique. Ultra thin films, less than 100 A show Tc > 80k, supporting the idea of 2 dimensional transport in these materials. By the use of appropriate buffer layers films with Tc of 87k and Jc of 6*10E4 A/cm2 have been fabricated on silicon substrates. Sub micron structures with Jc > 2*10E7 at 10k have been fabricated. Results on nonlinear switching elements, IR detectors and microwave studies would be briefly summarized.

Laser Beam Patterning of $YBa_2Cu_3O_7$ Thin Films

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A high resolution patterning process is essential for assessing thin film High Tc superconductors as well as for making devices. We have adopted a laser ablation approach in order to be able to pattern material without degrading the properties. The technique offers adequate resolution (a few microns) and is convenient enough for routine work. We have used it to allow critical current density measurements to be performed on epitaxially orientated films without needing very large currents, to study the effect of high magnetic fields on critical current, and to correlate electrical properies with structural and compositional information.

SUPERCONDUCTING PROPERTIES OF HTSC THIN FILMS PREPARED IN SITU BY SINGLE TARGET DEPOSITION

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Thin films of ReBaCuO (Re = Y,Gd) and of BiCaSrCuO have been deposited onto Al_2O_3, MgO, $SrTiO_3$, Si and ZrO_2 substrates by planar and inverted cylindrical magnetron sputtering. The main advantage of this preparation technique is the high reproducibility allowing detailed and systematic studies of the film properties as a function of deposition parameters. Optimum deposition parameters were a high oxygen partial pressure of 2×10^{-1} Torr in an oxygen-argon mixture and substrate temperatures near 800°C. Except for the substrate Si the films grow highly textured on all substrates. For the 1-2-3 material zero resistance is obtained near 90 K for the case of textured growth. For Si the best film showed zero resistance near 84 K. High critical currents betwen 4×10^5 and 5.5×10^6 A/cm^2 were determined for films of the 1-2-3 material on the substrates MgO, ZrO_2 and $SrTiO_3$. On films on $SrTiO_3$ tunnel junctions with Pb and In could be prepared which showed a gap-like feature in their current-voltage characteristic. These junctions could be prepared with great reproducibility and experimental arguments could be provided which show that this gap-like feature is due to a superconducting density of states effect. Finally first results are presented on YBaCuO thin films which were deposited by a novel ablation device which uses a pulsed electron beam instead of the laser beam.

THIN FILM PREPARATION BY LASER ABLATION AND SPUTTERING WITHOUT POST-ANNEALING

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An overview is given on the methods used in KFA-Jülich for the in-situ preparation of $YBa_2Cu_3O_{7-x}$ - thin films which require no post-annealing. These methods are laser ablation and high-pressure sputtering. The resulting films have good superconducting properties (T_c > 90 K, $T_c \leq 1$ K, j_c (77 K) ~ $10^6 A/cm^2$). The different properties of the films are prepared by both methods are compared. In addition measurements of a macroscopic persistent current in these films are discussed.

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