SYMPOSIUM E

Materials for High-Temperature Superconductor Technologies

November 26 – 29, 2001

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*Invited paper
SESSION E1: NEW SUPERCONDUCTORS I. MgB<sub>2</sub>
Charles D. Keffer and Christensen
10:00 AM

POTENTIAL ELECTRIC POWER APPLICATIONS FOR MAGNESIUM DIBORIDE. P. Gran, EPRI, Palo Alto, CA.

The newly developed superconductor, MgB<sub>2</sub>, has significant potential for a number of electric power applications, even though its critical temperature, T<sub>c</sub>, is "only" 39 K. In recent months, there has been rapid improvement in the critical currents and the properties crucial to deployment in power devices, which rival NbTi at 4.2 K, and equal or surpass many of the high temperature superconducting copper oxide perovskites in the 20-25 K range. Moreover, substantial progress has been achieved in reducing the electric current density, with thousands of amperes in current densities that appear economically feasible to commercial production. In this talk, we will review several opportunities to exploit these developments for transformer, motor and electric cable applications, and discuss a visionary power delivery system centered on MgB<sub>2</sub>-based dc cable cooled by gaseous or liquid hydrogen taking both electrical and chemical energy to the end user.

9:30 AM

IRON-CLAD MgB<sub>2</sub> SUPERCONDUCTOR WIRING. S. Jin, J. McHenry, B. van Dover, Agere Systems/Lucent Technologies, Bell Labs, Murray Hill, NJ.

The recent discovery of the 39K superconductivity in magnesium diboride presents a new possibility for significant bulk applications, especially in view of the weak-link-free characteristics of the grain boundaries and high critical currents observed in MgB<sub>2</sub>. The only useful bulk superconductors need to be fabricated in metal-clad wire configuration and must have high transport current critical density. The fabrication of tensiometric MgB<sub>2</sub> wires having an acceptable density, 39K superconductivity, and high critical currents is a challenge because of the difficulties associated with the volatility and reactivity of magnesium and brittleness of MgB<sub>2</sub>. Metal-clad processing of MgB<sub>2</sub> is a convenient, practical method of overcoming these problems. Recent work demonstrated the successful fabrication of iron-clad MgB<sub>2</sub> superconductor wires exhibiting desirable characteristics, with the transport J<sub>c</sub> as high as 85,000 A/cm<sup>2</sup> at 4.2K. In this talk, we will discuss the current status of processing parameters, composite wire structures, grain boundary characteristics, and critical current behavior of the MgB<sub>2</sub> wires will be described. Various approaches of microstructural modifications to induce coherence-length-scale defects and higher density of flux-pinning sites will also be discussed. 1. J. Noguera et al., Nature 410, 63 (2001). 2. D.C. Larbalestier et al., Nature 410, 186 (2001). 3. D.K. Finnemore et al., Phys. Rev. Lett. 86, 2420 (2001). 4. S. Jin et al., Nature 410, 926 (2001).

10:00 AM

HALL EFFECT IN SUPERCONDUCTING MgB<sub>2</sub> FILMS AND RELATED MATERIALS. B. L. Jr., P. Prasad, H. C. S. He, J. Christen, D. M. McHenry, Oak Ridge National Laboratory, Oak Ridge, TN.

We have investigated the temperature and magnetic field dependence of the Hall coefficient of high-quality MgB<sub>2</sub> films (T<sub>c</sub> = 38.0 K) in both the normal and superconducting states. Our results show that the normal-state Hall coefficient R<sub>H</sub> is positive and increases with decreasing temperature, independent of the applied magnetic field. Below T<sub>c</sub>, R<sub>H</sub> decreases rapidly with temperature and changes sign before it reaches zero. The position and magnitude at which R<sub>H</sub> changes a minimum depends on the applied field. Quantitative analysis of our data indicates that the Hall response of MgB<sub>2</sub> behaves very similarly to that of high-T<sub>c</sub>, cuprates: 1/R<sub>H</sub> = x T and cot R<sub>H</sub> x T<sup>n</sup> in the normal state, and a sign reversal of R<sub>H</sub> in the mixed state. This suggests that the B-Layers in MgB<sub>2</sub>, like the Cu-O planes in high-T<sub>c</sub>, cuprates, play an important role in the electrical transport properties. Results obtained from related materials will also be presented.

10:45 AM

DIRECT OBSERVATION OF NM-SCALE Mg- AND B-OXIDE PHASES AT GRAIN BOUNDARIES IN MgB<sub>2</sub>. R.P. Klee, J.C. Ihde, and C.S. Browning, Department of Physics, University of Illinois at Chicago, N.S. Regia and J.R. Cava, Department of Chemistry and Princeton Materials Institute, Princeton University, Princeton, NJ.

The discovery of superconductivity in MgB<sub>2</sub>, with a record breaking transition temperature (T<sub>c</sub> = 39 K) for "conventional" superconductors, has sparked an enormous research effort to understand its structure-property relationships. One aspect of MgB<sub>2</sub> that has particular technological importance is that the grain boundaries in the polycrystalline materials studied so far do not appear to significantly decrease the overall critical currents. The grain boundaries are so wide that the considerable tape-like or needle-like MgB<sub>2</sub> grains in a polycrystalline MgB<sub>2</sub> sample by the combination of Z-contrast imaging and electron energy loss spectroscopy in the TEM/STEM. Specifically, we find that there is no oxygen detection within the bulk of the grains (within the few percent detection limits of our techniques) but significant oxygen enrichment at the grain boundaries. Furthermore, the boundaries are found to consist of two distinct boundary types containing BO<sub>3</sub> planes with a width of ~4nm (i.e. smaller than the coherence length) and a second containing a BO<sub>3</sub> - MgO<sub>6</sub> (BO<sub>3</sub> - BO<sub>3</sub> - BO<sub>3</sub>) trilayer ~1.5nm in width (i.e. larger than the coherence length). Such boundary features indicate that although J<sub>c</sub> is high overall, the structure-property relationships at grain boundaries in MgB<sub>2</sub> are a complex function of processing conditions, and that control of the oxygen content at grain boundaries will be essential for attaining optimal bulk critical currents.

11:00 AM

SUPERCONDUCTIVITY IN MgCN<sub>1</sub> - UNCONVENTIONAL OR ORDINARY? E.L. Close, T. He, M.A. Haywood, M.K. Hass, E.A. Regen, Dept. of Chemistry, Princeton University, Princeton, NJ; Q. Huang, NIST Dept of Neutron Research, Gaithersburg, MD, and Dept. of Materials and Nuclear Engineering, University of Maryland, M.D.; A.P. Ramirez, Center for Neutron and Thermal Physics, Los Alamos Nat. Lab., Los Alamos, NM.

The discovery of superconductivity in MgCN<sub>1</sub> has stimulated a great deal of research into its characteristics of its physical properties. Since then after that material was discovered, we discovered superconductivity at 8 K in the non-oxide perovskite MgCN<sub>1</sub>. The low superconducting transition temperature makes it inappropriate for consideration for real applications, and the relatively low T<sub>c</sub> suggests at first sight that is may not be a very interesting material. However, the very large proportion of Ni in the compound suggests that magnetic interactions may play a role in the superconductivity. Its structural and chemical relation to the superconducting quasi-one-dimensional borocarbides is also of interest. Some very interesting proposals have been made by theorists concerning what may be going on in this material. Here we will report our latest results designed to probe the nature of the superconductivity in MgCN<sub>1</sub> by a variety of chemical substitutions and microscopic characterization methods.

11:30 AM

MICROSTRUCTURE AND PHASE DEVELOPMENT IN MgB<sub>2</sub>. D.J. Miller, D.G. Hicks, Materials Science Division, Argonne National Laboratory, Argonne, IL.

We have studied the microstructure and phase development in MgB<sub>2</sub> bulk ceramics. Samples were prepared by high-pressure annealing of dense boron pellets in the presence of Mg. The sequence of phase development was studied by controlling the time of annealing. In the first samples, porous particle boundaries that limited cooling were present and a network of amorphous grain boundaries are commonly observed. Amorphous grain boundaries have been reported in samples prepared by other means and an evaluation of the growth process suggests these regions act as a reservoir for impurities. The progression of phases follows that predicted by the phase diagram, but equilibrium throughout an entire pellet is difficult to achieve. These results will be presented together with possible alternative routes for processing. This work was supported by the U.S. Department of Energy, Basic Energy Sciences-Materials Sciences, under contract #W-31-109-EN-38.38.

11:45 AM

ANISOTROPY GRAIN MORPHOLOGY AND CRYSTALLOGRAPHIC TEXTURE IN POLYCRYSTALLINE MgB<sub>2</sub>. SUPERCONDUCTORS. X. Song, S. Bobroczki, J. Jiang, L.D. Coolen, X. Y. Cui, A. Gurevich, A.A. Polyanskii, S. Pot pinchik, C.B. Eom, E.E. Hellstrom and D.C. Larbalestier, R. Cava, SL Brod, P.C. Canfield, and D.K. Finnemore; "Applied Superconductivity Center & Department of Materials Science and Engineering University of Wisconsin-Madison; N.S. Regia and J.R. Cava, Department of Chemistry, Princeton University, Princeton, NJ; "Department of Physics and Astronomy, Iowa State University, Ames, IA.

The microstructure of electromagnetically characterized bulk MgB<sub>2</sub> sintered MgB<sub>2</sub> filament and MgB<sub>2</sub> thin film,
was studied using transmission electron imaging and diffraction techniques with a view toward understanding the effect of microstructures on magnetic properties. An epitaxial thin film on a substrate of [100] MgB2 was found to show highly interconnected regions of the superconductor. This work, however, suggests that MgB2 films are sensitive to the processing conditions and the composition. We will discuss these results and their implications for the development of high-field superconducting devices.

2:30 PM #E2.3
IN-SITU DEPOSITION OF SUPERCONDUCTING MgB2 FILMS
N. A. Stelmashenko, V. N. Taranets, M. Kambhala, N. Hazi Baha, D. A. Cardwell, M. G. Blamire, IBC in Superconductivity, University of Cambridge, Cambridge, UNITED KINGDOM

The discovery of superconductivity in MgB2 has been followed by many papers reporting attractive thin film properties. In most cases it is the Mg-rich bulk sintered target that we have been able to grow superconducting MgB2 films from Mg-rich targets at temperatures below 400°C. This paper reports the deposition method, optimization, spectroscopy of the sputter plume, and structural and electrical characterization of the films.

2:45 PM #E2.4
SUPERCONDUCTING AND MICROSTRUCTURAL PROPERTIES OF MgB2/Mg NANO-COMPOSITES. Qi Li, G.D. Gu, Y. Zhu, and M. Smajgara, Brookhaven National Laboratory, Upton, NY

A study is presented of superconducting and microstructural properties of bulk MgB2/Mg composites. Advanced TEM investigation revealed that the composites are very dense, consisting of sinterized MgB2 and Mg grains, with a range of Mg:B ratios from 20-101 (10%, Mo). Both magnetization and transport measurements were performed for superconducting property characterizations. We found that the composite carried over critical current density of 1 Ma/cm2 at 4.2K and self-field. Based on the results, we can expect that the properties of this material will be superior to the pure MgB2 sample.

3:30 PM #E2.5
THE SYNTHESIS AND PERFORMANCE OF MgB2. R.L. Meng, X.H. Chen, D. Pham, J. Cmaida, B. Lorenz, J.K. Mean, Y.Y. Sun, Y.Y. Xue and C.W. Chu*, Dept. of Physics and Texas Center for Superconductivity, Univ of Houston, Houston, TX. Also at Hong Kong Univ of Science and Technology, HONG KONG

The relatively high transition temperature, the small anisotropy, and the negligible grain boundary effects on the superconducting properties of the newly discovered MgB2 suggest that the compound may hold great promise for both large- and small-current applications. Unfortunately, the density, microstructure, electrical connectivity, and surface morphology of the MgB2 samples, which define the performance of the superconducting devices, remain beyond control. We have examined systematically the influence of various synthesis conditions and identified the critical parameters affecting the above properties. For instance, microstrain and lattice parameters have been found to be effective measures of the quality of the samples. These and other results, together with their effects on the transport and magnetic properties of MgB2, are to be presented and discussed.

4:00 PM #E2.6

MgB2 thin films were co-evaporated on sapphire substrates by pulsed
 INNER DEPOSITION (PLD), followed by post-annealing in mixed, reducing gas, Mg-rich, Zr-gettered, environments \([\text{Ar} \sim \text{He}] / \text{Ar} \sim 10 \text{~mbar} \) at 750°C and 550°C. The target, which is 5 cm in diameter and 1 cm thick, is loaded to 30K, 3A (20K, H=0) in the range 3x10^6 A/cm^2 to 3x10^6 A/cm^2, and irreversibility fields \(H_i \approx 20 \text{~K} \) of 4 to 6.2 T. An inverse correlation was found between \(T_c\) and \(H_i\). The films had grain sizes of ~1-1.1 μm and a thin-spinodal phase was observed, with a transition temperature of 550°C annealed film. \(111\) oriented \(\text{MgO}\) was also observed. Mg coating of films during crystallization appeared to improve film \(T_c\).

**SESSION E3**

**HIGH TEMPERATURE SUPERCONDUCTORS**

Chair: Terry G. Hoeljesinger and Kamil Safarov

**Tuesday, November 27, 2001**

**Room 200** (Hynes)

**8:30 AM **

**E3.1**

**BOND-LENGTH FLUCTUATIONS IN THE COPPER OXIDE SUPERCONDUCTORS**

John B. Goodenough, Texas Materials Institute, The University of Texas at Austin, Austin, TX.

The phase diagram of \(La_{2-x}Sr_xCuO_4\) is interpreted. From the virial theorem, it is argued that the cross-over from localized to itinerant electronic behavior in the range 0 < \(x < 0.3\) is characterized by fluctuations between two equilibrium Cu-O bond lengths. Cooperative local fluctuations give rise to one-hole correlation scales of 5 to 6 copper centers on the undoped side, to strong-coherence fluctuations in an electron-electron correlated side. Spinodal phase segregation between an antiferromagnetic, insulating parent phase and the superconductive phase occurs in the undoped, intermediate and metallic overdoped phase on the other side of the phase diagram. Ordering of the fluctuations into a travelling bipolaronic charge-density/spin-density wave of composition \( \pm 1/6 \) yields herring bone symmetry (\(x^2 - y^2\)) coexisting with light electrons; the high-temperature superconductive pairs are condensed out from the heavy fermions.

**9:00 AM **

**E3.2**

**DEVELOPMENT OF BSCCO-BASED HIGH TEMPERATURE SUPERCONDUCTING TAPE PRODUCTS**

Alessia Orto, Bill Carter, Ralph Mason, Ron Parrella, Eric Pettit, Bill Riley, Jeff Schreiber, Yinling Huang, American Superconductor Corporation, Westboro, MA.

\(Bi_2Sr_2CaCu_2O_8+(n=0,1)\) (BSCCO) multifilament superconducting tape technology has provided key progress on attributes required for specific large-scale applications. Key attributes include mechanical robustness and strain tolerance, performance including transport current density and ac loss, and piece length supported by splicing technology. Long length production capability now yields an average engineering current density (77K, 1 μm2, self-field) exceeding 13.8 kA/cm2, with equivalent critical currents in excess of 115 A, representing a very significant increase over the past 18 months. Short length development activity in support of long length production has demonstrated that significant BSCCO cost/performance improvements are possible, and BSCCO's potential is still far from fully tapped. Key among these has been the experimental demonstration of critical current in excess of 170 A (77K, 1 μm2, self-field) in tape samples with the same architecture and geometry as long length product. This paper will report on the properties and microstructure of experimental and production BSCCO tapes.

**9:30 AM **

**E3.3**

**IMPROVED CRITICAL CURRENT DENSITY OF Ag-Cu-CLAD Bi-2223 TAPES BY CONTROLLED PROCESSING**


Applied Superconductivity Center, University of Wisconsin, Madison, WI.

The processing of long length Ag-clad [Bi,Pb]2Sr2Ca2Cu3O10-x (Bi-2223) tapes is a complex, multi-parameter process which typically involves 2 heat treatments with one intermediate rolling. The key to improving the performance of the Bi-2223 tapes is to improve their electrical connectivity, which is compromised by weak link pinning regions or lower Tc intergrowths, by insulating second phases, by cracks or by porosity, or by filament smearing. A fundamental component of the problem of poor connectivity is the tendency of Bi-2223 tapes to swell as they convert from Bi-2212 to Bi-2223 and thus for the mass density to decline strongly. Our detailed density measurement on monocore Bi-2223 tapes shows that the retrograde densification during the first heat treatment depends greatly on the precursor powder pretreatment and that some treatments produced rising density during the first heat treatment, thus resulting in higher critical current density in the final product. On the other hand, the effects of a post Bi-2223 formation anneal was systematically investigated in monocore Bi-2223 tapes by microstructural observation and superconducting property measurement. It was found that annealing at 750°C in 0.075 atm O2
Controlling phase development and optimizing grain-to-grain connectivity are the primary material issues that affect the performance of Bi-2223 multilayered tapes. The current protocol for processing Bi-2223 involves the in situ formation of the primary phases from a suitable mixture of precursor phases. As such, the phase development during the first few minutes of heat treatment determines to a large extent the efficiency of primary phase development, competing secondary phase development, texture evolution, and grain connectivity. The main connection is that x-ray electron microscopy, detailed compositional and microstructural data were obtained from partially and fully processed Bi-2223 tapes. Defects in these tapes were either structural, compositional, or a combination of the two. They were introduced into the filament microstructure either intrinsically through the normal evolution of phases to form the Bi-2223 phase or extrinsically by various aspects of the thermo-mechanical processing. Relationships between the defect structures and transport properties will be discussed.

10:30 AM *E3.5 CRYSTAL GROWTH AND SUPERCONDUCTING PROPERTIES OF Bi2Sr2CaCu2Oy (Bi-2223) SINGLE CRYSTALS. Kansuke Shimizu, Takehiko Okabe, Shigeru Horii, Kenji Otsuchi, Junichi Shimoyama and Koji Kishio, Dept. of Superconductivity, Graduate School of Engineering, Univ. of Tokyo, Tokyo, JAPAN.

Bi2Sr2CaCu2Oy (Bi-2223) is one of the most important materials for practical application of superconducting wires. However, its substantial properties have not been well understood mainly due to difficulty in the synthesis of large single crystals enough to perform precise studies. Therefore, we have attempted to grow Bi-2223 single crystals by the floating zone method with an extremely slow growth rate of -0.005mm/h in order to clarify their basic properties, and successfully obtained large single crystals with the largest crystal size of approximately 3 x 2 x 0.1mm3. Through the X-ray diffraction analysis and DC susceptibility measurement, the grown crystals were confirmed to be the almost single phase of Bi2223 with very few intergrowth of Bi2212 phase. Their carrier doping state was systematically controlled in wide range from underdoping to overdoping by post annealing under various conditions, temperature and P(O2). Tc's of the crystals varied from 80K (underdoped) to 103K (overdoped) via 110K (optimally-doped). The second peak effect was observed in magnetization hysteresis loops taken around 30K under H//c. The peak field, Hc2, monotonically increased from 300 to 1100Oe as the carrier doping level H//c increased. Tc's of the crystals were measured by the conventional resistivity measurements. Abrupt resistivity drop was observed under fields below Hc2, suggesting the first order phase transition of the flux line system. These characteristics are similar to those observed in the Bi-2212 single crystals. Further results of the X-ray diffraction analysis of Bi2223 single crystals with various carrier doping levels will be discussed including the irreversibility line and surface barrier effect from a viewpoint of electromagnetic microscopy.

11:45 AM *E3.9 REAL-TIME DEGRADATION STUDY OF HgBa2Ca2Cu3O8+δ SUPERCONDUCTING FILM USING SCANNING PROBE MICROSCOPY TECHNIQUES. R.S. Aga Jr., Y.Y. Xie and J.Z. Wu, Univ. of Kansas, Dept. of Physics and Astronomy, Lawrence, KS.

All high-temperature (high-Tc) superconductors are susceptible to moist environment. The mechanism behind this degradation process is not yet well understood or even described. We present our experimental results in observing the real time degradation process of HgBa2Ca2Cu3O8+δ (Hg-1212) single crystals. We implemented several scanning probe microscopy (SPM) techniques to image different time evolving properties of the sample. In our experiment, we used a commercial atomic force microscope system and a home-built combined microwave/optical scanning near-field probe. The scanning probes capture data from the exposed samples at regular time interval. This enabled us to have a real time observation of surface topography, morphology and resistivity maps of the samples as they reacted with the humid environment (T=20°C, RH=60%). We used this information to describe the mechanism behind the degradation of Hg-1212. The duration of sample exposure was two days. In this time frame, a typical sample would acquire residual resistance of about 0.0008% at 100 K (Tc=120 K) and would exhibit a broader superconducting transition due mostly to the formation of impurities.

SESSION E4: HIGH TEMPERATURE SUPERCONDUCTORS II

Chairs: Judy Z. Wu and Raghu N. Bhattacharya
Tuesday Afternoon, November 27, 2001
Room 200 (Hyenas)

1:30 PM *E4.1 HIGH-TEMPERATURE AND HIGH-PRESSURE PROCESSING ROUTES OF Bi2(Pb/2223)Ag TAPES FOR HIGH CURRENT

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APPLICATIONS G. Giannini, R. Pascari, C. Beneduce, B. Seber, E. Walker and R. Flükiger, Department of Condensed Matter Physics (DPMC), University of Geneva, SWITZERLAND.

The necessity to improve the transport properties of PIT processed Bi$_2$Pb$_x$(Sr$_2$Ca$_{2-x}$Cu$_{1-y}$O$_{2+y}$) tape has driven us to search for alternative processing routes and compositions. It was found that the equilibrium constant can be decreased by lowering the temperature and increasing the duration of the processing step. This technique was used to reduce the critical current in these tapes, and the results are discussed in the following sections.

2:45 PM E4.4
DIFFUSION EQUATIONS OF CATIONS AND ANIONS IN FABRICATION OF HgBa$_2$Ca$_2$Cu$_2$O$_{x+y}$ SUPERCONDUCTING FILMS USING CATION-EXCHANGE PROCESS. Y. Y. Xie, J. Z. Wu, University of Kansas, Lawrence, KS.

We report the experimental test results on the study of the diffusion dynamics of Hg (Tl) cations and oxygen ions during the formation from Tl$_2$Ba$_2$Ca$_2$Cu$_2$O$_{x+y}$ to Tl$_2$Ba$_2$Ca$_2$Cu$_2$O$_{8+y}$ (Hg-1212) films. Different Tl-$
u$ vapor annealing times and post oxygen annealing times were used to convert epitaxial Tl-2223 superconducting films into Hg-1212 films and to optimize the oxygen content in the films. The Tl-$
u$ vapor annealing was carried out at $\sim 700^\circ$C from several to 720 minutes, and oxygen annealing at $\sim 300^\circ$C from 2 to 12 hours. Two time constants were found. A nearly complete Tl to Hg cation exchange can be obtained in a period as short as 45 minutes, an order of magnitude shorter than what has been used. The diffusion of ions (oxygen), on the other hand, takes several hours or longer depending on the processing conditions. The optimal level of Hg-1212 films prepared using a shortened Tl-$
u$ vapor annealing time (96-180 minutes) and an extended oxygen annealing time (>4 hours) has zero resistance transition temperature $T_c$ of 120 K and critical current density $J_c$ close to 1 MA/cm$^2$ at 100 K in self-field magnet. These $T_c$ and $J_c$ values fall among those reported for high-quality Hg-1212 epitaxial films, which motivates us to employ these modified experimental conditions for development of Hg-1212 coated conductors since a smaller heat budget could minimize the interfacial reaction between the substrate and the film. The results on Hg-1212 coated conductor will also be discussed.

3:30 PM E4.5
SUPERCONDUCTING THALLIUM OXIDE AND MERCURY OXIDE FILMS. R. N. Bhattacharjee, Richard D. Blaugher, National Renewable Energy Laboratory, Golden, CO; Zengwen Xing, Judy Z. Wu, Department of Physics and Astronomy, University of Kansas, Lawrence, KS.

The primary technical challenge that must be satisfied to permit high-temperature superconductor (HTS) wire or tape in superconducting magnets or power-related applications is the successful demonstration of a low-cost, high-field, high-current-carrying wire or tape with good mechanical properties. In this paper, we report the results of a study of thallium-bismuth and mercury-based oxide superconducting oxides are excellent candidates because of their high transition temperature reaching to 130 K and unique features in their growth morphology. In general, the approach to the growth of thallium superconducting oxide films has been towards a low-temperature process, typically in the fabrication of large non-planar devices. Electrodeposition is a potentially low-cost, non-vacuum process that has the ability to easily deposit superconductor films or tapes on conducting substrates up to 15 microns. Electrodeposited films of all the oxide superconductors have been demonstrated. The thallium system emerging as most promising. Previously we reported on a two-layer electrodeposition process of thallium oxide superconductors that showed transport critical current density above 10$^4$ A/cm$^2$ at 77 K in zero field on LAO substrates. We were not successful of forming the 1221-Tl$_2$Bi$_2$CO$_{2+x}$ phase on Ag, Ag/Pd (105 Pd), and also on textured Ni. The Tl-2212 or Tl-1212 phases lack good magneto-field-dependent properties. A recent study by Wu et al. [J. Z. Wu, S. L. Yin, and Y. Y. Xie, Appl. Phys. Lett., 74, 1468 (1999)] showed that the thallium-oxide exchange of thallium oxide on Hg$_2$-2212 was complete within 4 hours for all these substrate materials. The Tl-2212 or Tl-1212 phases lack good magneto-field-dependent properties. A recent study by Wu et al. [J. Z. Wu, S. L. Yin, and Y. Y. Xie, Appl. Phys. Lett., 74, 1468 (1999)] showed that the thallium-oxide exchange of thallium oxide on Hg$_2$-2212 was complete within 4 hours for all these substrate materials. The Tl-2212 or Tl-1212 phases lack good magneto-field-dependent properties. A recent study by Wu et al. [J. Z. Wu, S. L. Yin, and Y. Y. Xie, Appl. Phys. Lett., 74, 1468 (1999)] showed that the thallium-oxide exchange of thallium oxide on Hg$_2$-2212 was complete within 4 hours for all these substrate materials.

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One way to improve Jc in magnetic field is to create flux-pinning centers. Random MgO nanorods and carbon nanotubes embedded in bulk superconductors have been reported to enhance flux pinning, though the enhancement is not recent. We attempted to use well-aligned carbon nanotubes as flux-pinning centers in thallium-based thin films to enhance Jc. Synthesis of thallium-based thin films with well-aligned carbon nanotubes has been achieved successfully. Primary results are very promising. The combination of different size and density of well-aligned carbon nanotubes in different superconductors or thin films are being investigated. Superconducting properties of these superconductors with aligned carbon nanotubes will be reported.

4:15 PM E4.7
METASTABLE SUPERSTRUCTURES IN
Ru2Sr2Gd1,4Ce0.6Cu0.4O10-δ SUPERCONDUCTOR BASED ON TEM OBSERVATION AT ROOM TEMPERATURE. Li Yang, J.M. Vieira, Averio Univ, Dept of Ceramic and Glass Engineering, Averio, PORTUGAL, Kabin Tang, Guo Jiu Zou, Structure Research Lab, Univ of Science and Technology of China, Hefei, PR CHINA.

Three types of metastable modulations in Ru2Sr2Gd1,4Ce0.6Cu0.4O10-δ were identified by electron diffraction and reported in this paper. The modulations are sensitive to the irradiation of the electron beam and the sample storage time. After several minutes' exposure to the electron beam, type 3 modulation with the period in the [110] direction in the [110] direction is enhanced, and coexists with type 1 with $\tau_1=0.605\text{nm}$ oriented in the [100] direction and type 2 with $\tau_2=0.544\text{nm}$ oriented along the [110] direction. The intensity of the type 2 modulation, with $\tau_2=0.544\text{nm}$ oriented along the [110] direction, is enhanced when it coexists with type 1 for type 4 modulation. However, when the sample is observed after 6 months storage, only type 2 modulation appears, and its intensity varies from one grain to another. It should be noted that no components of modulation along [001] have been detected, and no differences in the orientation of the modulation within the accuracy of the x-ray diffractometer in all the cases. Having the tetragonal symmetry [14 mm] with $a=0.384\text{nm}$, $c=2.86\text{nm}$, the structure of Ru2Sr2Gd1,4Ce0.6Cu0.4O10-δ resembles that of YBa2Cu3O7 by inserting a fluorite type Gd1,4Ce4O10 layer instead of the Y layer and Ru ions residing in the Cu[1] site. CuO2 layer and RuO2 layer coexist as structural constituents in one unit cell. It has been proved that, in this compound, superconductivity is confined to the CuO2 layer while magnetism is due to the RuO2 layer. The metastable modulations display the interaction between the two layers from the structural point of view. Superconductivity and magnetism may exist simultaneously in unconventional superconductor Ru2Sr2Gd1,4Ce0.6Cu0.4O10-δ, and they are decoupled from each other. Li Yang gratefully acknowledges the support from Research Contract PRAXIS/P/CTM/13142/98.

4:30 PM E4.8
TRANSPORT PROPERTIES OF Hg(Re)Ba2Cu3Oy SINGLE CRYSTALS. Shigeru Horii, Shinich Ueda, Keisuke Kamejo, Kenji Oyama, Jun-Ko Shimaguna, Koji Kushiro, Univ of Tokyo, Dept of Superconductivity, Tokyo, JAPAN.

Hg$_2$Ba$_2$Cu$_2$O$_y$ (Hg1223) Phase shows the highest $T_c$ of approximately 135K under ambient pressure among all superconductors, but its electrical stability and flux pinning performance are poor. We have revealed these disadvantages became clear by substitution of Re for Hg from systematical measurements of Hg(Re)Ba$_2$Cu$_3$O$_y$ polycrystaline samples. Further, recently, several groups reported growth of Hg(Re)Ba$_2$Cu$_3$O$_y$ single crystals. However, using single crystals, fundamental physical properties of this phase have not been understood yet. In this study, we have successfully grown high quality Hg(Re)Ba$_2$Cu$_3$O$_y$ single crystals in a Bi2RuO$_3$ crucible which is inductive to the flux liquid, and checked transport properties of the crystals with several carrier-doped conditions. For $n$-grown crystals, we observed superconductivity of $T_c$ of 113K and metallic behavior in a whole temperature range below room temperature from inplane resistivity measurements. On the other hand, a hump-like behavior was observed from out-of-plane resistivity. Further, a sharp superconducting transition at 113K was also picked up, suggesting that intergrowth of 122 and 211 structures are from inplane resistivity measurements. The intergrowth behavior was observed from $T^*$ measurements as well, suggesting a result of TEM observation. In this present study, we show inplane and out-of-plane resistivity, magnetoresistance and Hall effect for crystals with several carrier-doping conditions, and systematically discuss changes of electronic magnetic anisotropy by Re-doping in Hg-system.
indicate that several electron states such as charge stripes and oxygen ordering are coupled to the underlying lattice instabilities re interpreted in terms of magnetic or incommensurate \( La_2CuO_4 \) and \( La_2Sr_1/2NiO_4 \) new dielectric transitions are observed, at common temperature 32K and 285K, that are signatures of local lattice octahedral instabilities present in these high-dimensional compounds. The results reveal new aspects of the phase diagram of the perovskite cuprates and nickelates. Preliminary results of microwave illumination on thin film \( MgB_2 \) reveal \( R \), that is higher than that of \( YBa_2Cu_3O_{x+y} \). Detailed microwave analysis of \( MgB_2 \) film in comparison with HTS will be presented.

E5.5

HEAVY-ION DAMAGE TO MAGNESIUM DIBORIDE FILMS: ELECTRICAL TRANSPORT, CURRENT CHARACTERIZATION.


The use of magnesium diboride in superconducting magnets, transmission lines, or other large-scale applications depends upon the transport-current characteristics of this material in magnetic field, and how they compare to the properties of conventional and high-temperature superconductors. Thin films of boride grown on sapphire substrates by pulsed laser deposition were exposed to \( Mg \) vapor to produce 0.5-μm thick layers of the metallic compound \( MgB_2 \). Four-terminal measurements of their voltage-current relations, \( E-J \), were carried out before and after exposure to \( B_0 = 1 \) T and higher doses of 1-Gev \( U \) ions. These doses lowered critical temperatures \( T_c \) and \( \Delta \Theta \) by 2-10% in the 1-T field, respectively. \( T_c \) and \( \Delta \Theta \) reveal the soft-field critical current density, \( J_c \), mostly by a factor of 2.5; higher doses added little. Unexpectedly the irradiation slightly reduced critical current densities in the presence of applied magnetic field greater than \( 0.1 \) T. The radiation effects upon thermally assisted flux flow (TAF) resistivity revealed by the \( E(J) \) slopes measured at temperatures near \( T_c \), will be discussed.

Research sponsored by the U.S. Department of Energy under contract DE-AC05-00OR22725 with the Oak Ridge National Laboratory, managed by UT-Battelle, LLC.

E5.6

FLUX PENETRATION AND DYNAMICS AT RF IN SUPERCONDUCTING \( MgB_2 \). E. Nyguen, N. Hakim, P.V. Parimi, S. Sridhar, Physics Department, Northeastern University, Boston, MA.

Radio frequency penetration depth of polycrystalline \( MgB_2 \) has been measured and from the data the lower critical field \( H_{lc} \) has been obtained. The \( H_{lc} \) (T) determined from the experiment has a BCS-like temperature dependence, but the theoretically estimated \( H_{lc} \) does not show an exponential dependence expected for BCS-like superconductors for \( T < T_c \). The pinning force constant \( \alpha(T) \) is found to be two orders of magnitude higher than that of polycrystalline \( YBa_2Cu_3O_{x+y} \) suggesting a marginal contribution from grain boundaries. The critical current density is however lower than that of single crystal \( YBa_2Cu_3O_{8+\delta} \). Field dependent penetration depth reveals an intermediate field scale \( H_{lc} \), that lies between the upper and lower critical fields. This has been discussed in terms of softening of flux lattice and unusual temperature dependence of condensate fraction, Work supported by ONR and NSF.

E5.7

THE EFFECT OF SHEATH MATERIALS ON THE SUPERCONDUCTIVITY OF \( MgB_2 \). W. Zhu, J.R. Cava, IREQ, Hydro Québec, Varennes, Québec, CANADA.

Several sheath materials, such as silver-palladium alloy, inoxel, and tantalum, have been used to fabricate \( MgB_2 \) tapes. The tapes are made with PIT method and heat treated at various conditions in argon under 1 atmosphere. The microstructure and phase compositions of the tapes are examined by electron microscope and X-ray diffractometer. Current-voltage relations are characterized by the four-probe method at the temperatures of liquid helium and above. Resistive critical temperatures are measured by SQUID magnetometry. It is found that tantalum sheath has no effect on the \( T_c \) of the material; but the silver-palladium sheath decreases the \( T_c \) and also the current of the tape. A method to destroy the superconductivity completely under certain circumstances is proposed.

E5.8

LITHIUM INSERTION IN SUPERCONDUCTING MAGNESIUM DIBORIDE. Emma Labarba, Aninha Morais Ortona, E. Morais and M. A. Almeida-Franco, Laboratorio de Quimica del estado Síldio, Facultad de Ciencias Quimicas, Universidad Complutense, Madrid, SPAIN.

Ever since superconductivity was discovered in \( MgB_2 \) [1], work has been performed in different directions so as to modify and, eventually, improve its already remarkable superconducting properties [2]. We highlight here the investigation of several compounds and alloys of \( MgB_2 \) via Soft Chemistry, by means of both an electrochemical cell and the usual chemical reactions in solution, e.g. \( MgB_2 - x \) Li \( \rightarrow Li_x MgB_2 + x \) \( B_4C \). By this procedure, we have observed that lithium can be intercalated in varying amounts that are reflected in the unit cell volume and also in some superstructure lines appear. Concomitantly with these structural modifications, we have also observed that \( T_c \) seems to decrease. Work supported by CICTT, Projects: CT96-0729 References: 1. Nagamatsu, J., Nakaue, N., Murakami, T. and Akimitsu, J., Nature 410, 63 (2001) 2 Hinks, D.G., H. and Jorgensen, J.D., Nature 411, 457 (2001) 3. There is a very useful web page concerning this type of materials: http://www.batn.gov

E5.9

SUPERCONDUCTIVITY, SUPERSTRUCTURE, AND STRUCTURE ANOMALIES IN \( Mg_{1-x}Al_{x}B_2 \). J.Q. Li, L. Li, F.M. Liu, C. Dong, J.Y. Xiang and Z.X. Zhao, National Laboratory for Superconductivity, Institute of Physics, Chinese Academy of Sciences, Beijing, PR CHINA.

The appearance of a superstructure is identified to play a key role for the modifications in both superconductivity and structure transitions in the \( Mg_{1-x}Al_{x}B_2 \) system. This superstructure occurs along the c-axis direction, and can be well interpreted by Abrikosov ordering. The optimal composition of the superstructure phase is \( MgAlB_2 \), a superconductor with \( T_c \approx 12K \). Raman spectrum of \( MgAlB_2 \) gives rise to a sharp peak at around 341 cm\(^{-1}\). Brief diagrams illustrating the superconductivity and structural features of \( Mg_{1-x}Al_{x}B_2 (0<x<1) \) materials are presented.

E5.10

SUPERCONDUCTIVITY AND CRYSTAL LATTICE OF \( MgB_2 \) UNDER HIGH PRESSURE. Jie Tang, A. Matsushita, K. Togano, National Institute for Materials Science, Tsukuba, JAPAN; Li-Cheng Qin, JST-ICRP Nanosubstitute Project, Tsukuba, JAPAN; H. Kito, H. Ihara, Electrotechnical Laboratory, Tsukuba, JAPAN.

Magnetism diboride \( MgB_2 \) shows the highest transition temperature \( T_c \) among the binary superconductors. We have investigated the superconductivity and crystal lattice of \( MgB_2 \) under high pressure up to \( 10 \) GPa. Four-probe measurement of the transition temperature \( T_c \) shows a linear decrease at a rate of \( 1.03 \) K/GPa following the equation \( T_c = 38.6 - 0.13P \). The material synthesized under 3 GPa pressure shows a very narrow transition width and this transition width stayed unchanged even under high pressure. The crystal lattice shows an anisotropic compressibility measured from in situ X-ray diffraction under hydrostatic pressure up to 10 GPa using a diamond-anvil cell and its bulk modulus was deduced to be \( 172 \) GPa from our measurement. It is much more compressible along the c-direction than the a/b direction. This is attributed to a weaker inter-plane bonding along the c-axis in comparison with a stronger in-plane bonding perpendicular to the c-axis. The pressure effect on \( T_c \) is well explained within the framework of the classical BCS theory based on the electron-phonon coupling mechanism.

E5.11

THE NATURE OF SURFACE OXIDES ON MAGNESIUM DIBORIDE. Chandana Menegro and Michael Trenary, University of Illinois at Chicago, Dept of Chemistry, Chicago, IL, Yu Pedneo, Academy of Sciences of Ukraine, Institute for Problems of Materials Science, Kiev, UKRAINE.

The recent discovery of superconductivity at 39 K in magnesium diboride \( MgB_2 \) by Akimitsu and co-workers has stimulated a great deal of interest in this compound. Most of the recently published papers have focused on synthesis methods, measurements of bulk properties, and theoretical aspects of superconductivity in \( MgB_2 \). Here we report on the nature of the surface oxides present in polycrystalline \( MgB_2 \) samples as determined with high resolution X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES). The samples used in our study have a critical temperature of \( 39 \) K as revealed by magnetic susceptibility measurements. X-ray diffraction (XRD) shows that the samples are comprised of both crystalline and amorphous phases. The surface oxides were characterized with XPS by examining the B 1s, Mg 1s, Mg 2s and Mg 2p regions. A product of Lorentzian and Gaussian functions was used to fit the spectra. The B 1s peak shows two components, one of which is assigned to \( B_2O_3 \). The other is due to the B oxides of \( MgB_2 \). Some element B may also be

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E5.12 STRUCTURAL CHARACTERIZATION OF POLYCRYSTALLINE PEROVSKITE MgCu2NiO4 SUPERCONDUCTOR. X. Song1, S.E. Bullock2, L.D. Cooley3, J. Jiang4, A. Polonsky5, and D.C. Larbalestier6,7,8.

The newly discovered superconductor MgCu2NiO4 exhibits a systematic change in its superconducting behavior at a lower temperature. This suggests a transition from a grain-boundary flux pinning just below Tc, to pinning by a nanometer-scale distribution of core pinning sites at low temperature. Scanning electron microscopy, transmission electron microscopy (TEM), and channeling imaging were used to study the microstructure of a polycrystalline MgCu2NiO4 sample on different length scales. Scanning electron microscopy revealed about 10 mm diameter grains whose boundaries were generally lined with residual graphite. TEM revealed an about 200 nm sub-grain structure separated by a network of dislocation walls (i.e. low angle grain boundaries). Selected area diffraction patterns recorded along various zone axes from single sub-grains showed that the perovskite MgCu2NiO4 was the primary phase. Additional weak spots in the diffraction patterns indexed consistently as a second phase with a simple cubic unit cell with lattice parameter of 0.47 nm, but at unknown structure. The second phase also observed as a minor second phase constituent in X-ray diffraction patterns of the material, indicating that it is not present only as a thin surface layer on the TEM samples. The diffraction patterns show that this phase must contain a cubic to cubic orientation relationship with the primary MgCu2NiO4 phase in spite of the lattice mismatch of the lattice parameters. More patterns observed by high-resolution TEM suggest that the second phase is finely dispersed. These patterns are generated most through the sample and confirm a phase of no perceptible effects, even though the volume fraction of the second phase by X-ray appears to be small. This fine scale nanostructure is qualitatively consistent with the strong flux pinning exhibited by the compound.

E5.13 OBSERVATION OF VORICIES AND COLUMNAR DEFECTS BY 1-MV LORENTZ MICROSCOPY I. Hiroa Kanazawa1, Osamu Kaminuma1, Tsuyoshi Matsuda1, Ken Hirada2, Akira Tonomura1, Satoru Ootsuka3, Minoru Sassa4, Yuri Nakayama5, Jun-i Chiyo6, Tetsuo Hasegawa6, and Kouichi Kikumoto6.

An understanding of the dynamical behavior of individual vortices (magnetic flux lines) in a Type-II superconductor is important for developing practical applications of superconductivity, because the vortex flow generates heat and breaks down the superconducting state. There are no techniques, however, for observing the dynamics of vortices except for Lorentz microscopy using a field emission electron microscope [1]. Here we present the first observation of vortices using newly developed 1-MV field emission electron microscope [2] whose world highest brightness is 2 x 10^14 A/cm²/s.

In case of vortices in high-temperature superconductor Bi2Sr2CaCu2O8±δ (Bi-2212), the observable specimen thickness with a 300kV microscope is about 200 nm or maximum due to the limited penetration ability of electrons [3]. While 1-MeV electrons can penetrate the 400-nm-thick specimen whose size is similar to the vortex diameter (twice the penetration depth of Bi-2212). Higher contrast and detailed images of the vortices are able to be observed by the new microscope.

A single crystalline of Bi-2212 was grown by the standard floating zone technique whose critical temperature Tc was about 85 K [4]. The thin film was prepared by 200kV electron beam with density of 5 x 10^16 ions/cm² (corresponding to 1 G) whose irradiation direction was tilted by 70 degrees from the axis of Bi-2212 in order to obtain elongated size and enhanced contrast of the projected columns. Such a low dose was chosen in order to specially deposit a single ion in a sputter system installed at the beam line of the Tandem accelerator of the Japan Atomic Energy Research Institute (JAERI). Then prepared thin film was set on a low-temperature stage of the electron microscope with a temperature difference of 100 K from the electron beam. Finally, simultaneous observation of single vortex and columnar defects has been carried out successfully by Lorentz microscopy, and their interactions have also been investigated.


E5.14 OBSERVATION OF VORICIES AND COLUMNAR DEFECTS BY 1-MV LORENTZ MICROSCOPY II. Osamu Kaminuma1,2, Hiroa Kanazawa1, Tsuyoshi Matsuda1, Ken Hirada2, Akira Tonomura1, Satoru Otsuka3, Minoru Sassa4, Yuri Nakayama5, Jun-i Chiyo6, Tetsuo Hasegawa6, and Kouichi Kikumoto6.

The individual vortices in Bi2Sr2CaCu2O8±δ (Bi-2212) thin film with thickness of 400 nm and columnar defects produced by irradiation of 245 MeV Au ions were simultaneously observed by Lorentz microscopy using newly developed 1-MV field emission electron microscope [1]. To obtain clear images of column defects and their pinning effect for individual vortices [2], the thin films were irradiated to 70 degrees tilted to the specimen normal with extremely sparse dose (0.05 ions/μm²).

There are two kinds of vortex image in a Lorentz micrograph; one is a columnar image which is ordinary vortex image in our many experiments, mother is elongated image with lower contrast. Numerical simulation [3] reveals that the elongated image is caused by vortex penetrating the film perpendicular to the film plane and the elongated contrast corresponds to vortex trapped along tilted column. It means that we are successfully obtained the information of the vortices inside superconductors. Furthermore, we found that the elongated image change their contrast depending on temperature. From their images and their dynamical behavior, we considered of vortex features at the columnar defects as follows: (1) Above 14 K to the critical temperature, (elongated contrast), the vortices were trapped along tilted columnar defects.

(2) From 12 K to 19 K (from elongated contrast to globular one), the vortices change their direction along the column to perpendicular to the film plane.

(3) Lower than 12 K (globular contrast), the vortices was stand up perpendicular to the film plane.

These phenomena are considered that strong, high density and small pinning sites exist and become effective at lower temperature than 12 K. Then columnar defects seem to lose their pinning force and vortices at the columnar defects stand up perpendicularly. Precise investigation of the pinning mechanism is significant for the practical applications of the high-temperature superconductor.

E5.16 EFFECT OF NANO-SIZED MGO ADDITION ON MICROSTRUCTURAL DEVELOPMENT AND SUPERCONDUCTING PROPERTIES OF 61 MULTILAYER BSCCO 2223 TAPES. Jeong-Woong Ko, Jaimoo Yoo, Shin-Chul Kang, Hae-Doo Kim, Korea Institute of Machinery and Materials, Materials Engineering Dept., Changwon, Kyeongnam, KOREA; Hyunsuk Chung, Ajou Univ., Division of Mechanical and Industrial Engineering, Suwon, KOREA.

The effect of inert second phase on microstructural development and superconducting properties has been studied in order to increase Jc under magnetic field. In this study, nano-sized MGO particles were homogeneously mixed with BSCCO 2223 precursor using planetary ball milling and ultrasonication and then 61 multilayers BSCCO 2223/MGO tapes were fabricated by PIT method. Microstructure and phase were analyzed by XRD, SEM and DTA. The critical current density was measured under magnetic field at 77K. Homogeneous distribution of MGO particles in BSCCO 2223 matrix led to increase in Jc under magnetic field.

E5.17 BSCCO CERAMICS WITH MICROINCLUSIONS OF THERMODYNAMICAL PHASES OF COMPLEX COMPOSITION: Phael E. Kuzin, Yuri D. Dey working, Vasili V. Lennokov, Marina A. Mekhonova, Andrey S. Karpov, Moscow State Univ., Dept. of Chemistry, Moscow, RUSSIA; Martin Jansen, MPI Institut fuer Festkoerperforschung, Stuttgart, GERMANY.

Critical current density in BSCCO superconductors is strongly restricted on account of their low flux pinning ability. A promising way to solve this problem is connected with producing superconductor matrix containing a certain number of effective pinning centers. In the present work an original approach was elaborated in order to create submicron precipitates of thermodynamically compatible phases in the BSCCO matrix. Systems Bi2Sr2CaCu2O8+δ (A = Mg, Al, In, Zr, Sn, P) were investigated and several A-containing oxides were found to be thermodynamically compatible with the Bi-2212 superconductor. The superconductor composites were prepared via melt-processing of either homogeneous precursors containing all the components or a mixture of two finely ground oxide precursors. The inclinations size, shape and spatial distribution depended on preparation conditions and nature of the dopant A. The inclinations of submicron ground particles (A = Mg, Al, Zr, Sn) and whiskers (A = Sn, P) were obtained by calculation of chemical reaction between two oxide precursors to form micro-sized particles with complex shape such as hollow performed shells, serrated or w-tile-like grains. The dopant Bi2Sr2CaCu2O8 was then inserted into the Bi-2212 matrix. The composites exhibited Tc above 90 K and enhanced flux pinning at elevated temperatures in comparison with undoped superconductors.

E5.18 Abstract Withdrawn.

E5.19 INTRINSIC JOSEPHSON JUNCTIONS ON HIGH QUALITY BSCCO THIN FILMS GROWN BY MOCVD. Kamilya Endo, Hiroshi Ito, Hiroshi Aoki, Junji Itoh, National Institute of Advanced Industrial Science and Technology, Nanoelectronics Research Institute, Ibaraki, JAPAN; Koji Kajimura, Japan Society for the Promotion of Machine Industry, Tokyo, JAPAN.

Much attention has been focused on intrinsic Josephson junctions observed in BSCCO single crystal from the point of view of Josephson characteristics control of artificial junctions and findings of new barrier materials as well as high frequency applications in the THz region. In order to improve integration for device applications, it is very important to fabricate Josephson junctions on high-quality thin films. We report on the successful preparation of intrinsic Josephson junctions on high-quality BSCCO thin films grown by MOCVD. The surface of the grown films were very smooth with a roughness of the order of half unit cell. In addition, there were no apparent grain boundaries, which offers a strong advantage for the improvement of integration. A typical 1-V characteristic in the c-axis direction of a BSCCO film at 4.2K shows multiple resistance branches. The number of branches is consistent with the number of junctions calculated from the height of a mean structure. This indicates that BSCCO films consist of a series array of (SrCu2O2) layer / [SrSe2O2 layer] / (SrCu2O2) layer). The investigation of round precipitates with sizes of about 6 nm. The relatively fast decomposition of the Pr-doped solution was caused by annealing under reduction conditions (500 °C, N2 atmosphere). This work was supported by the National Program "High-strength problems of condensed matter" (subprogram "Superconductivity", #06079), National Program of leading scientific school support (#04-15-74455), Russian Foundation for Basic Research (#05-02-2314).
superconducting and intrinsic Josephson junction property measurements. The prospect of use of Hg,Pb,PE film in electronic device applications is under investigation. This work is partially supported by CREST, Japan Science and Technology (JST) Corporation, Japan.

E5.24
PREPARATION OF [Ba$_2$Cu$_2$O$_5$[$\text{CO}_3$]]$_{1/2}$[$\text{AcO}_2$]$_{1/2}$ (A = $\text{Sr, Ca}$) FILMS BY MBE TECHNIQUE. Yutaka Adachi, Yoshio Misumi, Isao Sakanouchi, Higimi Haseda, Koichi Tokumitsu, Advanced Materials Laboratory, National Institute for Materials Science, Tsukuba, JAPAN.

[Ba$_2$Cu$_2$O$_5$[$\text{CO}_3$]]$_{1/2}$[$\text{AcO}_2$]$_{1/2}$ superconductors containing oxycarbonate blocks as a change reservoir have been prepared on SrTiO$_3$ using the molecular beam epitaxy technique. First, thin films of the oxycarbonate cuprate Ba$_2$Cu$_2$O$_5$ have been prepared on SrTiO$_3$ (001) using NO$_3$ as an oxidant and CO$_2$. The films have been grown at 50°C substrate temperature. At higher substrate temperature or lower CO$_2$ pressure Ba$_2$Cu$_2$O$_5$ was formed instead of Ba$_2$Cu$_2$O$_5$[$\text{CO}_3$], and the thin films become amorphous at lower temperature. XRD and RHEED observations indicated that Ba$_2$Cu$_2$O$_5$[$\text{CO}_3$] grew along the (001) crystal orientation on SrTiO$_3$(001) with following epitaxial relationship:

$$\text{Ba}_2\text{Cu}_2\text{O}_5\text{[CO}_3\text{]}_{1/2}\text{[AcO}_2\text{]}_{1/2}/\text{SrTiO}_3(110) \text{ and Ba}_2\text{Cu}_2\text{O}_5\text{[CO}_3\text{]}_{1/2}\text{[AcO}_2\text{]}_{1/2}/\text{SrTiO}_3(110)$$

The depth profile of SIMS indicated the incorporation of carbon into the films. As-grown films behaved a semiconductor property in electrical measurement. No evidence of superconductivity has been observed down to 5K. Secondly, the oxycarbonate cuprates and infinite layers have been alternately stacked. It was confirmed that Ba$_2$Cu$_2$O$_5$[$\text{CO}_3$]$_{1/2}$ was inserted between several unit cells of SrCu$_2$O$_2$.

E5.25
REVERSIBLE CONVERSION BETWEEN Hg$_2$1212 AND Tl$_2$1212 SUPERCONDUCTING THIN FILMS IN CaION EXCHANGE PROCESSES. Zhongwen Xing, J.Z. Wu, University of Kansas, Dept. of Physics and Astronomy, Lawrence, KS.

In a recently developed ion exchange process, Tl$_2$-based high $T_c$ superconductors are used as "precursors" that are converted to Hg-based high-temperature superconductors when Tl ions are replaced by Hg cations, leaving the overall structure of the lattice nearly unchanged. We report in this paper that such a conversion between TlHgBa$_2$Cu$_2$O$_6$-2$\delta$ (Tl$_2$1212) and HgBa$_2$Cu$_2$O$_6$ (Hg$_2$1212) is completely reversible and the direction of the conversion is determined by the population ratio of the Tl and Hg cations. The experiment was composed two steps. In step 1, Hg$_2$1212 film was annealed in Tl vapour at 740°C - 760°C to convert it to Tl$_2$1212 films through ion exchange. In contrast, a control film of amorphous TlBa$_2$Cu$_3$O$_7$ became TlHgBa$_2$Cu$_2$O$_6$ (Tl$_2$1212). In step 2, the Tl$_2$1212 film was annealed in Hg vapour to form the Hg$_2$1212 films through ion exchange. The quality of the Hg$_2$1212 film is almost identical to the starting Hg$_2$1212 film. The resistance transition temperature ($T_c$) is close to 120K and critical current densities ($J_c$) of the Hg$_2$1212 film is 1.88A/cm$^2$ - 27K in zero field. This demonstrates that the conversion between Hg$_2$1212 and Tl$_2$1212 is reversible and the "1212" crystalline structure is stable during the ion exchange.

E5.26
NON-STOICHIOMETRY IN La$_2$CuO$_4$ THE La$_{2+2}\text{Cu}_{-4}\text{O}_{4.4}$ SOLID SOLUTION. Georges Debens*, Krzysztof Ruterbusch*, Glenn Taylor* and Brent Thompson*, Concordia Univ, Department of Chemistry and Biochemistry, Laboratory of Solid State Chemistry and M"ossbauer Spectroscopy, Laboratories for Inorganic Materials, Montreal, Quebec, CANADA; bPedagogical University, M"ossbauer Spectroscopy Laboratory, Cracow, POLAND.

"Useful" doping of La$_2$CuO$_4$ high $T_c$ superconductor have usually been restricted to substitution on the lanthanum site, usually by $\text{M}^{2+}$ divalent cations [alkaline earth metals], and this also resulted in non-stoichiometry on the oxygen site, which is further modified by the additional oxygen resulting from the oxidation of some Cu(II) to Cu(III) by annealing under oxygen. Most substitutions on the copper site, usually by transition metals, have resulted in a drastic decrease of $T_c$. Recently, we have carried out a 10% substitution of copper by tin(VI), to give stoichiometric La$_2$Cu$_{1-x}$Sn$_x$O$_{4.4}$, where ideally $x=0.10$ if all the copper is in the 2 oxidation state. Microwave absorption measurements showed that, contrary to earlier substitutions on the copper site, 10% substitution by tin results in no decrease of $T_c$, which actually increases by 1K. We have now carried out an investigation of the material obtained versus the substitution fraction x. It was found that the La$_2$Cu$_{2-x}$Sn$_x$O$_{4.4}$ solid solution exists for $x < 0.12$. *M"ossbauer Spectroscopy shows that all the tin is in the same form, and that at least two kinds of tin are present, with the coordination of one being much more distorted than the other.

E5.27
INFLUENCE OF LATERAL CRITICAL CURRENT DENSITY DISTRIBUTIONS ON AC TRANSPORT LOSSES FOR Ag-SHEATHED (Bi,Pb)$_2$223 MULTIFILAMENTARY TAPES WITH DIFFERENT FILAMENT ARRANGEMENTS. H. Igaki, H. Ikeda, Shusuke Suzuki, Pingxing Zhang, Aki Oota, Toyoohshi University of Technology, Dept of Electrical and Electronic Engineering, Aichi, JAPAN; Hiroyuki Fujimoto, Railway Technical Research Institute, Tokyo, JAPAN.

The influence of the lateral critical current density ($J_c$) distributions on AC transport losses in selffields of 77 K have been investigated on Ag-sheathed (Bi,Pb)$_2$223 multifilamentary tapes with different filament arrangements. Two deformation methods were applied to prepare the wires with different filament arrangements, one is an ordinary drawing process by using round die, another is a rectangular deformation by a Turk's Head with four roller machine. Finally, the ordinary one-axial rolling process and heat treatments were applied to make all the multifilamentary tapes. The self-field distributions on the tape surface measured by scanning Hall probe depends on the configuration of each tape, because the lateral $J_c$-distributions are strongly influenced from the non-uniformity of the filament deformation in tapes caused in the rolling process. The measured AC transport losses of each tape are nearly independent of frequency between 50 and 500 Hz, indicating that the main contribution to losses comes from the hysteresis loss in the superconductor filaments. However, there is significant dependence of the loss values on the filament arrangements in each tape. Using the theory of Norris, these results are explained by calculating the results for the shape of field-free-core and flux-penetration regions, varying with filament arrangements and non-uniform lateral $J_c$-distributions.

E5.28
NEW DAMAGE MORPHOLOGIES AND THEIR FORMING MECHANISM IN HEAVY ION IRRADIATION. Daixing Huang, Superconductivity Research Laboratory, ISTEC, Tokyo, JAPAN; Yukichi Sasaki, Japan Fine Ceramics Center, Nagoya, JAPAN; Yuichi Ishihara, Engineering Research Institute, University of Tokyo, Tokyo, JAPAN.

238MeV Au and 180MeV Fe ion beams were used to bombarded Bi$_2$Sr$_2$CaCu$_2$O$_x$ (Bi2212) single crystal slices (∼30µm thick) at room temperature using a Fandem machine. Conventional transmission electron microscopy observations were performed to analyze the damage evolution along the ion traces. Located in between the two typical irradiation-induced defect morphologies, parallel columnar defects and disordered cascade defects, we found three new types of transverse defect morphologies, large-angle-deflected columnar defects, cascade-defect-dotted columnar defects, and ordered cascade defects. Based on the analysis of the ion-energy deposition process along the ion traces, the formation mechanisms of these three new types were suggested. The columnar defect size was measured systematically along the ion traces using high-resolution electron microscopy, which leads us to study the ion velocity effects on the irradiation damage conveniently in a single ion-target system. In this system, the complicated influences on the irradiation damage due to the different target materials and the different ion species can be neglected. Then, a novel method was suggested by simply considering the dependence of damage efficiency on ion velocity, which can further minimize the influence of the ion effective charge and let us understand the pure influence of ion velocity in the irradiation damage process. The application on the Au-1112214 system shows that there is a critical velocity $V_c \sim 0.05 \text{c}$ (c, the velocity of light) at which the damage efficiency is maximum. This is a general phenomenon confirmed by reanalyzing the published previous data. From this observation, the irradiation damage process can be divided into two stages: the ion velocity controlled stage and the energy-density threshold controlled stage. In the Fe-irradiated sample, we found the long columnar defects with constant column size and the low threshold of stopping power for generating columnar defects. Combining with the Au irradiation data, a model is suggested which can explain the specific phenomena existed in the Fe-irradiated sample.

SESSION E6: YBCO COATED CONDUCTORS I
Chair: Robert A. Hulsey and Stephen R. Foltyn
Wednesday Morning, November 28, 2001
Room 200 (Hyenas)

E6.30 AM E6.1

A top priority of our government is to improve the energy delivery infrastructure. According to the report issued May 2001 by the
National Energy Policy Development (NEPD) Group, a group chaired by Vice-President Dick Cheney. "For the electricity we need, we must be ambitious. This is an enormous task of repair, upgradation, and expansion if we put these connections in place, we'll go a long way to avoiding future blackouts." The U.S. Department of Energy (DOE) leads the U.S. national effort to develop high-temperature superconducting HTS wires and to demonstrate and apply these ceramic, oxide-type superconducting power applications using the best wires available today.

Superconductivity is an important aspect of our nation's energy future that the report recommended that the U.S. should 'expand the Department of Energy's programs and development of high-temperature superconductivity.' Prototype superconducting power cables that will help upgrade our power grid when commercialized later this decade are being developed at places such as Lawrence Livermore, Georgia Tech, and Detroit, Michigan. Research and development remains, however, if the superconducting wires are to have the electrical performance and low-cost features necessary for U.S. companies to fully commercialize transmission, distribution, and generation technology that will help eliminate the blackouts in our urban areas and strengthen our grid. The industry-led Second Generation Wire Initiative is exploiting breakthroughs at Los Alamos and Oak Ridge national laboratories that promise unprecedented current carrying capacity in HTS wires. The most recent progress in the U.S. development of HTS "coated conductor" and in fielding prototype applications will be presented.


Since 1993 Los Alamos has been working to advance the performance levels and demonstrate the commercial feasibility of coated conductors consisting of YBCO deposited on flexible metal. We have concentrated extensively on the use of ion beam assisted deposited (IBAD) - as pioneered in 1991 by Fujikura Ltd. and Lawrence Berkeley National Laboratory - and pulsed laser deposition (PLD) for the textured template and superconductor, respectively. In 1995 we demonstrated conductors with critical current density of 1 MA/cm². More importantly we also showed that this 3.5 cm wide-tape with 600 A/cm² thickness of 5 microns or more and have demonstrated the potential to reach 600 A/cm² in a cm-wide tape. Second, because of its evolutionary texture development, IBAD and YSZ is the costliest step in our process. This economic issue has been addressed by using STI embedding. In support of our industrial partners, we are developing a new facility with reel-to-reel tape transport systems to scale these successful processes up to lengths of 1-100 meters.


The structure of grain boundaries in YBa2Cu3O7-δ (YBCO) thin films deposited on [001] tilt STO bicrystal substrates has been characterized by transmission electron microscopy (TEM). It was found that the YBCO film boundaries were meandering along the relatively straight substrate boundaries. High-resolution lattice images indicated that the microstructural meandering of the film boundary essentially consisted of many straight segments of facets at the atomic scale. The observed facets correspond to low-index crystallographic planes in each of the adjacent grains. The orientations of the facets tend to have small deviation angles (~2°) from the designed template boundary. The closure failure formed by the crystallographic planes of the facets in the two crystals compared with the misorientation angles are generally less than 2°. The factors controlling the formation of facets are discussed based on a three-criterion facetting model.


A novel thin film deposition technique based on pulsed electron beam is presented in this paper. Pulsed Electron-beam Deposition (PED) is a process in which a pulsed (100 ns) high power electron beam (approximately 1000 A, 15 keV) is incident on the surface of a target fabricating stoichiometric thin films. Deposition, PED, of YBa2Cu3O7-δ film starts by depositing YBa2O4, the substrate, Pulsed Electron-beam Deposition (PED), in the case of Pulsed Laser Deposition (PLD), provides a unique platform for depositing thin films of complex materials on a variety of technologically important planes. Transmission electron microscopes between 1.5 nm/pulse can be achieved by this method. In contrast with PLD, where the ablation process is critically dependent on the optical absorption coefficient of the film, PED, the ablation depends only on the range of electrons in the target. For most of the solid state materials, this range is of the order of a few microns. Due to this unique difference in the beamsolid interaction mechanism, PED is expected to extend the range of materials that can be deposited in thin films. Our group will present data obtained on epitaxial high-temperature superconducting (YBCO) films with superconducting transition temperatures in the range of 85-88 K and transition widths at 0.5 K. We will also present data on other oxide films relevant to superconducting technologies. We will compare the relative merits of this new deposition technique with relatively mature PLD technique.
11:00 AM E6.7
DEPOSITION OF YBCO THIN FILM ON METALLIC SUBSTRATES BY A SOL GEL METHOD. Dongbu Shi, Yongli Xu, Shawn McClelen, and Relva Buchman, Dept. of MSE, University of Cincinnati, Cincinnati, OH; Lumin Wang and Shawn Wing, Dept. of Nuclear Engineering and Radiological Science, University of Michigan, Ann Arbor, MI.

A unique Sol Gel process has been developed without using fluoride in our laboratory for the deposition of YBCO thin films on metallic substrates including silver and silver alloy for conductor development. On single crystal substrates such as LAlO3 and YSZ, the growth has been found to be epitaxial. Both rocking curve XRD and HRTEM experimental results have shown consistent structural behaviors of the thin films that the YBCO growth is coherent with the lattice structure of the substrate. Transport resistivity measurements have shown sharp Tc's in these sol gel thin films indicating their high qualities. The growth mechanisms and sol gel chemistry will be discussed in this presentation.

11:15 AM E6.8
NANOPARTICLE FORMATION FROM Y2BaCuO5−x FOR POTENTIAL FLUX PINNING MECHANISM. Paul N. Barnes, P. Terry Murray, Tim Haugan, Propulsion Directorate, Air Force Research Laboratory, Wright-Patterson AFB, OH; Richard Rogov, Glen P. Pettit, Department of Engineering Physics, Air Force Institute of Technology, Wright-Patterson AFB, OH.

An initial report of nanoparticle formation from by laser ablation of Y2BaCuO5−x (YBCO) will be presented. The nanoparticles were created by irradiating a target of bulk YBCO with a KrF excimer laser in a pulsed laser deposition setup used for making thin film YBCO. Background pressures of 5 Torr O2 were used. The nanoparticles ranged in size from 3 to 5 nm for the conditions used with a laser energy of 50 mJ per pulse. Characterization of the linear plasma was performed using optical emission spectroscopy. Although the visible plasma was very transient, it was used to create the nanoparticles, the plasma remained collisionally dense at the high pressure and low laser energy used. Use of the nanoparticle formation for flux pinning will be discussed.

SESSION E7: YBCO COATED CONDUCTORS II
Chair: Warren Rebeiz and J. Parman Pramanick
Wednesday afternoon, November 28, 2001
Room 200 (Hynes)

1:30 PM E7.1
PHASE AND MICROSTRUCTURE EVOLUTION OF HIGH Tc YBCO Films with CURRENT DENSITY TEA-MOD YBCO COATED CONDUCTORS. Yutaka Yasui, Takeshi Araki, Haruhiko Kurosaki, SeckBeom Kim, Tozakura Yukihisa, Shigehisa, Shinichi Hiramaki, Superconductivity Research Laboratory, Nagoya, JAPAN; Yasumasa Haga, Takashi Shoji, Nippon Kogyo, JAPAN; Yuki Shishida, Yuki Kishimoto, Tokyo University, Tokyo, JAPAN; Takeshi Kachi and Tsukasa Hiramatsu, Japan Fine Ceramic Center, Nagoya, JAPAN.

We have obtained high Jc values for TEA-MOD processed YBCO, for example, 7.8 MA/cm2 on LaAO3/cm2 substrates and 2.5 MA/cm2 on metallic Nb2O5 substrates. Using resistivity measurements during firing up to 800°C, AEM and TEM studies, phase change has been investigated for the high Jc TEA-YBCO samples. Precursors consisted of fine CuO and amorphous Y2BaCuO5−x was further oxidized in the firing of a low pressure oxygen atmosphere at a temperature as low as 600°C and then seemed to be transformed into Y2O3 at 670°C. Moreover, the microstructures formed in an early stage and a terminate stage at 800°C differed each other. The former was considered to be more textured and uniform structure than the latter and that the interface region near the substrate was estimated to have higher Jc than the above mentioned Jc of 7.8 MA/cm2 and 2.5 MA/cm2.

2:00 PM E7.2

Progress made in the fabrication of high-Jc tapes by epitaxial deposition of YBCO on rolling assisted biaxially textured substrates (RABITS) is reported. A high critical current density of 4.4 MA/cm2 at 77K, selffield was obtained on a single crystal Nb foil made by a modified RABITS approach. Similar results are also obtained for intragrainular, transport Jc measurements on typical epitaxial YBCO films on RABITS. This provides a significant motivation for improving the texture of the metal template used in the RABITS process. Recent progress made in developing substrates with improved textures will be reported. Buffer layer deposition on such substrates and the improvement of controlling surface segregation of impurities for obtaining high quality epitaxial films will be discussed. It has been suggested that Czogoldy may mitigate the effects of grain boundaries in coated conductors. We summarize here our results on Czogoldy of grain boundaries in the YBCO films on RABITS. It is also of interest to grow thick YBCO films with high Jc/width. Efforts of fabricating thick YBCO films on RABITS with buffer deposition will be summarized. Mechanisms of Je reduction with increasing YBCO thickness will be discussed. Lastly, a status report on real-to-real fabrication of meter long YBCO samples using the BU2/THF process on RABITS will be given. Research sponsored by US Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Power Technologies, Superconductivity Program under contract DE-AC05-00OR22944.

2:30 PM E7.3
COATED CONDUCTORS WITH HIGH STRENGTH BIAXIALLY TEXTURED Nb ALLOY SUBSTRATES. Bernd de Boer, Vadimneni S. Sarma, Laura Fernandez G., Norman Regen, Joerg Eickemeyer, Bernhard Holzapfel, HFW Dresden, Institute of Metallic Materials, GERMANY; W. Pruesser, THYVA GmbH, GERMANY.

To increase the overall current density of the YBCO coated conductor either the film thickness can be increased or the substrate thickness can be reduced. Unfortunately the superconducting film quality deteriorates with increasing thickness and therefore the total current is decreased. The reduction of the substrate tape thickness is limited by the material strength. By enhancing the strength, the tape thickness can be further reduced and thereby the current density of the coated conductor is improved. The metallurgical ways of strengthening RABITS kind of substrates materials are limited by the necessity of the very strong cube texture. In this contribution two feasible ways of substrate strengthening are proposed. By solid solution strengthening the yield strength can be enhanced up to a factor of four in comparison to pure ni. The strengthening is limited by the solute concentration at which the cube texture deteriorates. Besides strengthening, Cu and Varies in Ni reduce the Curie temperature below 77K. This is necessary for ac applications. The formation of Cu or V oxides at the surface before cooling is prevented by the PVD of a thin Ni layer in HV. Another way of strengthening is by introducing finely dispersed particles into the tape matrix. In order to maintain a strong cube texture the particles have to be formed after the recrystallization annealing by internal oxidation of solute Al. The room temperature yield strength of these tapes reaches up to five times the value of pure Ni. A further enhancement of the strength is possible by combining solid solution hardening with particle strengthening. Also these tapes have been coated with a Ni layer before buffer and YBCO deposition. Counting of the tapes have been carried out by PDL or thermal coevaporation.

2:45 PM E7.4
X-RAY DIFFRACTION MAPPING OF YBCO SUPERCONDUCTING TAPE ON A FIBER-MOSTRUCTURAL SCALE. E.J. Peterson, Los Alamos National Laboratory, Superconductivity Technology Center, Los Alamos, NM; U. Peckwinkle, B.N. Harrington, Bruker AXS, Inc. Madison WI; F.M. Mueller, D.J. Brown, C. Testa, M.E. Hawley, J.Y. Coulter, R.P. Flexon, P.N. Arndt, and D.E. Peterson, Los Alamos National Laboratory, Superconductivity Technology Center, Los Alamos, NM.

In the production of second-generation superconducting tapes, the quantification of substrate and superconductor in-plane texture by x-ray diffraction has been found to be one of the best ways to predict the final tape current transport performance. However, it is also possible to obtain crystallographic information regarding superconductor oxygen stoichiometry, crystal disorder, textures and overall crystal quality through the analysis of x-ray diffraction peak positions, intensities, and shapes. With the advent of 2-dimensional x-ray detectors and focused x-ray sources it is possible to collect this information on a relatively fine spatial scale and in reasonable time frames. We present here the results of mesoscale (approximately 1 mm resolution) x-ray diffraction mapping over 3.3 cm x 1 cm region of YBCO coated conductor tape that had been produced by combined IHAD/PDL techniques. The x-ray diffraction mapping results are compared to images of the supercurrent paths, as obtained using a magnetic field scanning technique. Correlations are made with regard to features in the diffraction maps and the supercurrent images.
Epitaxial thin films of YBa$_2$Cu$_3$O$_7$ (YBCO) have been deposited and patterned on (100) SrTiO$_3$ and (110) NdGaO$_3$ substrates. Wet etchants used in conventional photolithography react too quickly with YBCO thin films, resulting in undercutting of patterned structures. We have implemented a technique to pattern thin films from lines without wet etching. Chromic acid-etching solutions have been substrates and subsequently patterned. YBCO is then deposited by pulsed laser deposition, which results in an epitaxial YBCO film on patterned areas and randomly oriented YBCO deposited on chromium. An annealing step is required for the chromium to diffuse through the undesired YBCO in order to render those sections insulating. Rutherford Backscattering Spectrometry performed after annealing confirms Cr-diffusion up through the undesired YBCO areas. YBCO lines patterned with this technique exhibit resistivity and critical temperatures similar to those of the unpatterned films. As we decrease the width of the YBCO lines, the effect of the edges, where there is chromium-reaction material, on transport becomes more pronounced. The patterning technique and the profile of superconducting versus non-superconducting materials at the edges will be explored.

3:30 P.M. #ET7.6

**SCALE UP OF YBCO COATED CONDUCTOR PROCESSES AT IGC-SUPERPOWER. V. Schmannick, IGC-SuperPower, Schenectady, NY**

IGC SuperPower has established pilot-scale facilities for scale up of coated conductor processes to manufacturing. These facilities have been designed to provide high quality processing of substrates, buffer layers, and superconducting layers over time periods of a week. To enable continuous processing over long time periods and with high throughput, the processing equipment has been designed for providing substantial capabilities of operating simultaneously, with independent deposition zones, and ratings for continuous, long operation cycles. Using a reel to reel polishing equipment, tens of meters of substrates have been polished continuously with a high degree of surface finish. Uniform in-plane texture has been achieved in lengths of buffer layers deposited on these substrates. High current densities have been attained in YBCO deposited on the buffered substrates. The overall activities on scale-up of Coated Conductor processes at IGC SuperPower will be summarized in this presentation. Part of the work was performed under a CRADA with Los Alamos and Argonne National Labs.

4:00 P.M. #ET7.7

**PROGRESS IN YBCO COATED CONDUCTORS. Suresh Annavarpu, Martin Rupich, Cees Thieme, Qi Li, Sky Cui, Nguyen Nguyen, Sharon Lu, Wei Zhang, Darren Verebelyi, Joe Lynch, and Elliot Thompson, American Superconductor, Westborough, MA.**

Progress in the development of economically and technologically viable YBCO coated conductor is reported. Bi-axially textured metal substrates have been fabricated using rapid quenching and textured processing. Epitaxial buffer layers have been deposited on deformation textured metal substrates using a combination of reel-to-reel electron-beam evaporation, metal-organic deposition and magnetron sputtering. Epitaxial YBCO films have been deposited on lengths of buffered textured substrates using a reel-to-reel solution deposition process. Structure property relationships will be presented and critical issues for future progress will be identified.

4:30 P.M. #ET7.8

**THE PROGRESS ON LOW-COST, HIGH-QUALITY, HIGH-TEMPERATURE SUPERCONDUCTING TAPES DEPOSITED BY THE COMBUSTION CHEMICAL VAPOR DEPOSITION PROCESS. Shaan S. Shoup, Marvin K. White, Steve L. Krebs, Adam C. King, Dave S. Misto, Tim H. Campbell, MicroCoating Technologies, Inc., Chandlee, GA; Ken R. Murken, Seung Hong, Byun, Bolek Piecuch, Oxford Superconducting Technology, Carteret, NJ; M. Parashankar, Hans M. Christen, Hong Ying Zhai, Oak Ridge National Laboratory, Oak Ridge, TN.**

The innovative Combustion Chemical Vapor Deposition (CCVD) process is a non-vacuum technique that is being investigated to enable next generation products in several application areas. One such area is high-temperature superconductors (HTS). In combination with the Roll-In-Assisted Bi-Yttria Stabilized Zirconia (RABITS) technology, the CCVD process has significant promise to enable low-cost, high-quality lengths of YBCO coated conductor. The CCVD technology has considerable potential to overcome many of the shortcomings of currently industrial vapor deposition techniques while yielding equal and/or better quality coatings at a lower cost. As a result, capital requirements and operating costs are reduced to levels tenfold when compared to competing vacuum-based technologies (e.g. sputtering and PVD). The ability to deposit this film in the open atmosphere enables continuous, production line manufacturing.

Consequently, throughput potential is far greater than with conventional thin-film technologies, most of which are generally restricted to batch processing. Such advantages can help decrease the cost of fabricating HTS tape over traditional deposition technologies and thus meet DOE’s target cost goals for making HTS tape competitive with copper. The CCVD technology has been used to deposit both buffer layers as well as YBCO superconducting layers. A buffer layer architecture of strontium titanate and ceria has been deposited by CCVD on textured nickel substrates and optimized to appropriate thicknesses and microstructures to provide templates for growing YBCO with high critical current density values. Films of YBCO superconductors have been grown on single crystal substrates with critical current densities over 1 million amperes per square centimeter. Work is currently proceeding to combine both the buffer layer and superconductor technologies to produce high-quality coupons of HTS tape made entirely by the non-vacuum CCVD process. An update on the progress made towards scaling the CCVD process will also be given.

**SESSION B8: POSTER SESSION**

Chairs: Venkat Schmannick and Suresh Annavarpu

**Wednesday, November 28, 2001**

8:00 PM

Exhibition Hall D (Hynes)

**EB 1**

**A FLUX PINNING MODEL FOR CRITICAL CURRENTS AT LOW-ANGLE GRAIN BOUNDARIES. D. Agnoli, Naval Surface Warfare Center, White Oak, MD; S.J. Pennycook, Oak Ridge National Laboratory, Oak Ridge, TN.**

Determination of the factors that limit the current carrying capacity of low-angle grain boundaries is critical for improved performance of wires and tapes. In the high angle regime the exponential drop in critical current has been successfully modeled as transmission through a continuous Josephson junction. With a width less than a YBCO structural unit description of grain boundary atomic structure [1], at lower angles, however, the situation is more complicated in the boundary comprises an array of discrete dislocation cores. Previous models have used a geometric approach [2] or a Gamble-Junction formulation [3] to predict the angular dependence and are appropriate where the coherence length is large compared to the dislocation spacing in the boundary. However, in the technologically important low field, low temperature, low anode regime, flux pinning is expected to determine the critical current. We present flux pinning calculations [4] for the two limiting descriptions of the bad zone around a grain boundary dislocation, the strain model and the band-bending model. We find significant differences in the angular dependence of critical current that provides insight into the origins of the very different experimental results reported by different groups and also into the improvement in critical current possible through doping. Critical currents parallel to the boundary are predicted to be close to the depairing limit in agreement with recent experiments. [1] N.D. Browning, J.P. Bubic, P.D. Nelli, D.P. Norton, M.F. Chisholm and S.J. Pennycook, Physica C 294 [1998] 189. [2] M.F. Chisholm and S.J. Pennycook, Nature 351 [1991] 47. [3] A. Gurevich and E.A. Pashitski, Phys. Rev. B 57 [1998] 13878. [4] D. Agnoli, C.S. Pande and R.A. Marcus, Phys. Rev. B 52 [1995] 16237.

**EB 2**

**NEW CONDUCTIVE BAD BUFFER FOR HTS APPLICATIONS. Karolin Thiele, Silhyere Sievers, Herbert C. Freyhardt, Institut für Materialphysik, Universität Göttingen, GERMANY; Jürgen Huck, Jörg Hoffmann, Zentrum für Funktionswerkstoffe GmbH Göttingen, GERMANY.**

The use of bi-axially textured yttria-stabilized zirconias (YSZ) thin
films deposited by an ion-beam-misted deposition process (IBAD) as a buffer layer for HTS has been widely studied and coated conductors of up to 1 µm in length have been successfully prepared. Two points require further investigation: Firstly, the IBAD mechanisms are not fully understood. Therefore, it is important to follow the texture evolution of IBAD-YSZ films during film growth in detail and to use other IBAD techniques for comparison. Secondly, and therefore, a gold sand is necessary for protecting the HTS film in case of switching to the normal state; an electrically conductive buffer would act as a bypass for the electrical current itself. Both conditions are known to be fulfilled with a new electrically conductive buffer material that can be textured by an IBAD process and which serves as a suitable template for YBCO. Bi-aspect texturing buffer layers were deposited by an IBAD process. The deposition conditions (e.g. ion-beam parameters and the angle of incidence) were varied to optimize the in-plane texture. Investigations on TEM and X-ray of the texture evolution of these IBAD films during film growth were carried out. There are results which can be explained by mechanisms similar to IBAD-YSZ, such as in-plane texture improvement with increasing film thickness, but also findings which are contrary to the ones obtained for YSZ, such as etching rates and dependences on the incident beam angle. An in-plane texture of 15° FWHM for a 900 nm thick film has been achieved. The quality of the buffer has been proven by the subsequent deposition of YBCO-films deposited by pulsed laser deposition and thermal evaporation. So far, ntype of 0.31 MA/cm² (77K, Jt) has been observed. Part of this work was supported by the German BMFT.


Superconducting YBa2Cu3O7−δ thin films were processed by means of in-situ ultrasonic pyrolysis, on single-crystal oxide substrates. Growth temperatures lower than 900°C have been utilized to spray nitrate precursors. Epitaxial growth of bi-axis oriented (110,6°) 1.5 micron films has been achieved, with Jc’s of 2-3.5 x10⁶ A/cm² at 77K, with growth rates of ~0.2 micron/min.

ES.9 STUDY OF NGO FILMS GROWN ON PURE N, Ni-Cr AND Ni-V SUBSTRATE FOR THE FORMATION OF A BUFFER LAYER COMPONENT FOR REBCO COATED CONDUCTOR. Z. Lockman, R.L. MacManus-Driscoll, Imperial College, London, UNITED KINGDOM; M. Goldshleger, R. Nast, Forschungszentrum Karlsruhe, Technik und Umwelt, GERMANY; B. De Boer, Institute of Metallic Materials, IFW Dresden, GERMANY

In this work, thermal oxidation of rolling assisted bi-axis textured substrates with different Ni, Ni-Cr, Ni-V alloyed compositions has been studied. It was possible to form predominantly cube-textured NGO for both short and long annealing times with a drop of the texture for intermediate times. The texture evolution with time is related to competing nucleation and growth processes on the bare substrate and on the developing NGO surface. For the thin oxide, the best texture was obtained on Ni, 13%Cr and for longer oxidation times the best texture was obtained for pure Ni and Ni-V.

ES.10 INITIAL GROWTH STUDIES OF REBaCuO THIN FILMS. Guus Rijken, Victor Leeu, Mark Huijben, Martijn Dekkers, Sybok Perlemoen, Horst Rogalla, Dick J.A. Blank, Univ. of Twente, Low Temperature Div and MESA Research Inst., NETHERLANDS; Sara Bal and Gustav van Tendeloo, EMAT, Univ. of Antwerp, BELGIUM

Depending on the deposition method, like standard pulsed laser deposition, block-by-block and interval deposition, the structural properties of REBaCuO thin films have been investigated. As is known from literature, the initial growth plays a crucial role in the occurrence of phase boundaries, grain boundaries, pseudo-modal growth and oxidation process. Using well-defined (single terminated) substrates, this initial growth has been studied in situ using high pressure reflective high energy electron diffraction and exactly X-ray diffraction. Atomic Force Microscopy, Transmission electron microscopy and Electron Microscopy. In this contribution an overview is given of the data obtained using these different growth techniques. Besides the above-mentioned properties, special attention will be paid to cation disorder. Furthermore, insights into the preparation of superconducting properties as well as surface morphology.

ES.11 BREAKING OF Cu-O CHAINS IN PbBa2Cu3O7 Upon ALO-DOPING. Mingji Jin,” Q.Y. Chen”, C.L. Chen”, Chong Wang”, Y.S. Song”, Hye-Won Seo”, Lizi Yuan”, W.K. Chu”, Udom Tiptrakun”, T.P. Chen” and K.S. No”. Texas Center for Superconductivity and Dept. of Physics, Univ. of Houston, TX; Dept. of Physics, Univ. of North Dakota, ND; Dept. of Mat. Science and Eng., Korea Adv. Inst. of Sci. and Tech., Taejon, SOUTHERN KOREA

We have vacuum-deposited α- and (110) oriented PbBa2Cu3O6+x thin films on (001) LaAlO3 and (110) SrTiO3 substrates by sputtering and pulsed laser deposition. From the temperature dependence of resistivities for both the target and the films it was found that the former conductance was affected by the variable range phonon mediated hopping mechanism. This suggests that ALO-doping in this material has given rise to extensive impurity scattering in the band gap, turning the oxide into a good conductor, especially at low temperatures. The resistivity of the doped PBCO is higher than the pure PBCO, ranged from ~124 Ω.m at room temperature to about five orders of magnitudes higher at ~30K. The electronic structure of the samples was studied through measuring the optical absorption coefficient and band gap, and defect states energies were inferred. Then the soft x-ray emission spectra were obtained for pure and ALO-doped PBCO thin films. The shift in Cu O peak position and the change of Cu O/La intensity ratio in soft x-ray emission spectra after ALO doping indicate the change of Cu-O banding in the lattice due to the partial A1 substitution. Also, the Raman spectra for pure and ALO-doped PBCO thin films were obtained. An additional peak near the typical oxygen peak was detected in the ALO-doped PBCO thin film. This occurs as a result of the broken symmetry of Cu-O chains caused by the partial replacement of the A1 atoms with the Cu ions on the Cu-O chains, indicating that the A1 atoms primarily substitute the Cu sites on the Cu-O chains.

ES.12 STRAIN, NON-STOICHIOMETRY AND DOPING AT LOW ANGLE GRAIN BOUNDARIES IN YBCO. G. Duscher, Oak Ridge National Laboratory, Oak Ridge, TN and North Carolina State University, Raleigh NC; M. Kim, C. Cantoni, D.K. Christen, Oak Ridge National Laboratory, Oak Ridge TN; A. Franceschetti, S.T. Pantelides, and S.J. Pennycook, Oak Ridge National Laboratory, Oak Ridge TN, and Vanderbilt University, Nashville TN.

The origin of the non-superconducting zone around dislocation cores in YBCO has been probed by a combination of atomic-resolution Z-contrast microscopy, electron energy loss spectroscopy (EELS) and first-principles theory. As in the case of the model perovskite SrTiO3, EELS and theory both show that grain boundaries in YBCO are intrinsically non-stoichiometric. This is the origin of band-bending. Hole depletion is seen up to 2 nm from the cores, even in relatively strain-free regions. We show further that Ca segregates to the dislocation cores without changing the atomic arrangement. The strain field is therefore identical to the undoped boundary, but changes are found in the extent of the hole depletion. These results show that at least in the specific samples studied, band bending is the main factor in determining the non-superconducting zone, and implies significant potential for improvements in critical current through doping. [1] M. Kim, G. Duscher, N.D. Browning, K. Schilling, S.T. Pantelides and S.J. Pennycook, Phys. Rev. Letts. 86 (2001) 4056.

ES.13 FAST MOD PROCESSING OF YBCO FILMS. Igor Selmenyev and Michael J. Cima, Massachusetts Institute of Technology, Dept. of Materials Science and Engineering, Cambridge, MA

Coated conductors using epitaxial thin films of YBa2Cu3O7−δ (YBCO) high temperature superconductor will only be widely used in large-scale electrical devices if the YBCO can be grown relatively fast on different substrates. Films of YBCO were prepared on lanthanum aluminate (LAO) single crystals and CeO2-buffered YSZ single crystal substrates by metal organic deposition (MOD) process. MOD has many advantages over different techniques. MOD is flexible and can be used to deposit chemically uniform films on large areas and exhibits relatively high growth speeds of films. A difficulty with MOD process is, however, the first low temperature anneal when liquid solution deposited on a substrate is converted to an oxide film. A new method was developed that drastically decreases the low temperature anneal time from hours to approximately 15 minutes. This method was used for the deposition of 0.6-micron thick films. Films prepared by this method have strong α-ax orientation and exhibit good electrical properties and Jc of 1 MA/cm². An additional decrease of conversion time of YBCO films can be reached by using lower-temperature during high temperature conversion. Low temperature furnace was built for those purposes. Conversion of films in vacuum speeds the conversion due to the elimination of any mass transfer limitations in the gas phase. Production of high critical current density films required that the water partial pressure be carefully controlled during the conversion reaction. This method was successfully applied. Films that carried more than 1 MA/cm² were prepared by using this method.
Grain boundaries in YBa$_2$Cu$_3$O$_7$ (YBCO)-based coated conductors can significantly affect the current transport properties; therefore, the study of such boundaries and their interactions with flux-bearing vortices is critical. It has been shown that small-angle [001] tilt boundaries with (100) grain boundary planes that are 5° - 7° misorientation, the boundary dislocations begin to close off the supercurrent transport in the conductor. We have shown previously that small-angle [001] tilt boundaries with (110) grain boundary planes exhibit partial grain boundary dislocations separated by stacking faults. Interestingly, these grain boundary structures have twice the number of dislocations and shorter core channel widths than Frank's geometric rule predicts. In contrast, the latter effect on controlled samples, single (110)-oriented grain boundaries were fabricated on Y$_2$O$_3$/ZrO$_2$ (YSZ) ceramic substrates. Pulsed laser deposition was used to deposit ≈ 300 nm of YBCO on ≈ 20 nm of CuO on these bicrystal with boundary angles from 0° to 45°. Transport property measurements, as well as results of a transmission electron microscopy study will be presented.

Earlier, we achieved twin refinement in mult-textured growth (MTG) YBCO by combining the effect of PtO$_2$ doping and increase of isothermal annealing temperature from 450°C to 680°C. By increasing annealing temperature, the twin boundaries in MTG YBCO are greatly refined, with twin spacing of 1900 Å at annealing temperature of 450°C to 540 Å at annealing temperature of 680°C. The superconducting properties significantly improved: critical current density $J_c$ and maximum flux pinning force $F_p$ can be enhanced by 200% from $J_c$ of 0.800 A/cm$^2$ to 3.020 A/cm$^2$ at 77 K and 1 T, and from $F_p$ of 1.17 x 10$^4$ N/m to 3.35 x 10$^4$ N/m. Recent study has shown that the processing of YBCO by quenching and melt growth QMG method can further enhance twin refinement and increase superconducting properties. Twin structures studied by TEM reveal that, for samples annealed at the same temperature, twin boundaries are more refined in QMG than those of MTG. The twin spacing is 10% - 20% lower in QMG samples. The maximum flux pinning force can be enhanced by 100% in QMG samples. The critical current density is also improved from 12,500 A/cm$^2$ for MTG sample oxygenated at 500°C to 25,390 A/cm$^2$ for QMG oxygenated at the same temperature.

The so-called Ba$_2$ process for YBa$_2$Cu$_3$O$_7$ coated conductor fabrication shows great promise, but still obstacles remain to fabricating 5μm thick films because of the onset of formation on non-crystalline-aligned crystallites. To understand the mechanisms involved requires an understanding of the thermodynamics of the (Y,Ba) oxide-fluoride and (Y,Ba)Cu$_2$O$_3$ (the "T-phase") transitional phases which have recently been discovered by detailed studies at BNL of the Ba$_2$ process using transmission electron microscopy. Shell models of interatomic bonding were used to calculate lattice energies, Delye temperatures, and other parameters required to estimate the Gibbs free energies of the oxide-fluoride and T phases as a function of temperature as well as fluoride and oxygen partial pressures. The relative stability of the transitional phases and their effect on the nucleation of c-axis or a-axis YBCO crystallite will be discussed.

A multiphase thin film structure of YBa$_2$Cu$_3$O$_7$ (YBCO) superconductor intercalated with non-superconducting YBa$_2$CuO$_4$ (1211) phase was studied for the purpose of increasing the T$_c$ of the YBa$_2$Cu$_3$O$_7$ superconductor. Initial results showed significant improvement for T$_c$ in applied magnetic fields, e.g. over 100% higher at 0.5-2 T, 77 K. A multi-layer structure of 35 layers of (~80) nanometer YBa$_2$Cu$_3$O$_7$(YBCO) was fabricated by (248 nm) pulsed laser deposition at 300 mTorr O$_2$ pressure and 785°C substrate temperature. This multilayer structure showed superimposed improvement in flux-pinning at 4 to 77 K. However, for the unintercalated process, the T$_c$ of the composite was reduced from 87 K to 92 K for pure 123 phase. This multilayer film showed no cracking and unusual surface smoothness, probably as a consequence of the multilayer growth process. The significance of these results for long length applications of coated conductors will be discussed.

A new method for x-ray microbeam diffraction has been developed to study the crystallographic alignment (texture) and strain in each layer of YBCO films. Since x-rays penetrate all layers, while microbeam diffraction simultaneously provides CCD line patterns from each layer of the multilayer film. Analysis of these patterns yields real-space maps of the local lattice structure, crystallographic orientation, and the strain tensor with micron-scale resolution. The advantage of this x-ray method is that the microbeam patterns are compared with electron backscattered patterns (EBSP). Our orientation results show that the successively deposited layers are not strictly epitaxial, rather, each heteroaxial layer exhibits a tilt toward the surface normal. The tilt behavior of YBCO film at high growth temperature can be described by aledge growth model which incorporates both elastic deformation at steps and interfacial misfit dislocations. Note that tilt is desirable in applications since it results in the grain boundary misorientation angles and enhances Tc. Strain results show that the microstrain, like the misorientation angle of the grains is consistent with thermal contraction.

YBCO layering was achieved by depositing YBa$_2$Cu$_3$O$_7$ thin films on YSZ substrates. The high T$_c$ YBCO films were highly c-axis oriented and well-crystallized, as shown by X-ray diffraction θ/2θ scan and rocking curves, showing a peak for 0.2°. Buffered YBCO thin films are superconducting at 1 T = 88 K with improved crystallinity, as observed from X-ray diffraction of different samples. Moreover, the buffered superconducting thin films possess an extremely smooth surface (roughness less than 1.5 nm) and a strained Krastanov growth mode was observed under atomic force microscopy. The X-ray diffraction patterns of the buffered YBCO thin films on YSZ substrates are improved, as shown by X-ray analysis of the polycrystalline thin films. The buffer is necessary to reduce the buffer layer thickness to the desired thickness and to improve the c-axis orientation of the YBCO film. The buffer layer also provides strain relief and reduces the thermal mismatch between the YBCO film and the YSZ substrate.

A careful study of the ECo material showed that the use of ECo as an insulating interlayer would result in a dramatic improvement of electrical transport and surface interfacial condition of superconducting YBa$_2$Cu$_3$O$_7$ (YBCO) thin films grown on yttrium stabilized ZrO$_2$ (YSZ) substrates. The high T$_c$ YBCO films are highly c-axis oriented and well-crystallized, as shown by X-ray diffraction θ/2θ scan and rocking curves, showing a peak for 0.2°. Buffered YBCO thin films are superconducting at 1 T = 88 K with improved crystallinity, as observed from X-ray diffraction of different samples. Moreover, the buffered superconducting thin films possess an extremely smooth surface (roughness less than 1.5 nm) and a strained Krastanov growth mode was observed under atomic force microscopy. The X-ray diffraction patterns of the buffered YBCO thin films on YSZ substrates are improved, as shown by X-ray analysis of the polycrystalline thin films. The buffer is necessary to reduce the buffer layer thickness to the desired thickness and to improve the c-axis orientation of the YBCO film. The buffer layer also provides strain relief and reduces the thermal mismatch between the YBCO film and the YSZ substrate.

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processing yield, volatility of PhO can lead to changes in stoichiometry. Most recently, interest in MgS-based superconductors has led to the investigation of the impact of pressure on the processing of these materials. For all such systems, it is important to consider phase equilibria as a function of the appropriate partial pressures. Equilibrium partial pressures over selected systems have been measured in our laboratory using gas chromatography. We have also used solution calorimetry to measure selected heats of formation, which can be directly related to vapor pressures. These data provide an important handle in designing the thermodynamic phase diagram of a system. A comprehensive understanding of the solidification behavior of RE123 materials should be optimized independently for improving critical current performance in each system.

**ES.16**

**PHASE RELATIONS IN THE Ba-R-Cu-O (R = Nd, Sm, AND Y) SYSTEMS.** Winnie W. Ng, Julia Suh and Lawrence Cook, Ceramics Division, NIST, Gaithersburg, MD.

Phase diagram provide guidelines for processing of high-temperature superconductors. There is a need for phase diagrams of the second-generation coated conductors prepared under reduced conditions. These flexible coated conductors are based on the lanthanum yttrium copper oxide and the lanthamide substituted materials. The phase diagrams of the carbonate-free Ba-Nd-Cu-O, Ba-Sm-Cu-O, and the Ba-Y-Cu-O systems were constructed under atmospherically controlled conditions (purified air and 1% O2). A special experimental procedure was used for preparing BaO scarring material and for the handling and heat-treatment of samples. A discussion of the crystal chemistry and phase relations of phases found in these systems will be presented. A comprehensive comparative analysis of selected superconductors prepared under different atmospheric conditions will be summarized.

**ES.17**

**THE EFFECT OF PHOTODOPING ON THE LOCAL STRUCTURE OF YBCO (0.3, 0.94) FILMS.** A. Yu. Ignatov, T.A. Tyson, L. M. Deng, NJIT, Dept. of Physics, Newark, NJ.

We report on c-axis polarized Cu K-edge x-ray absorption measurements of YBa2Cu3Oy films [0.3 and 0.94]. Optimally doped sample [y 0.94] do not show any appreciable change in its local structure at photon doses up to 1022 em2. In contrast, XANES of the underdoped sample [y 0.3] shows changes that are reminiscent of those found with oxygen doping. Cu K-edge multiple-scattering experiments on YBa2Cu3Oy.5 suggest that the observed experimental behavior can be understood assuming local ordering of O(1) on the chains. We also studied relaxation of photodoped states by measuring resistance and XANES spectra vs. time after photodoping. Changes of major XANES features could be scaled to the resistance. EXAFS analysis indicate that, on average, the Cu(1)-O(4) and Cu(2)-O(4) distributions tend to broaden in photodoped states. Fits to the experimental data suggest a double-peak Cu(1)-0.01 distribution with a typical separation between the peaks of 0.15 A. Though the c-axis measurements do not probe the electronic and magnetic structure of the CuO planes directly, EXAFS data in line with a microscopic model suggest partial photoinduced diffusion of O1 atoms from a mostly disordered uniform arrangement to a locally ordered states where they group into short-range chains of [O1-Cu-O1]. Preliminary Cu K-edge EXAFS results, enabling local probe around Cu(1) sites, will be presented. This work is supported by NSF Career Grant DMR-9733862.

**ES.18**

**HOW TO OPTIMIZE CRITICAL CURRENT PERFORMANCE OF RE123 MATERIALS BY CONTROLLING OXYGEN CONTENT.** Junsichi Shimagawa, Shigeru Hori, Kenji Osachi and Kohji Kishio, Department of Superconductivity, University of Tokyo, Tokyo, JAPAN.

In order to optimize the critical current performance of RE123 materials, such as coated conductors and bulk magnets, post-annealing under suitable conditions is especially important, because resulting oxygen defect concentration determines Tc, pinning sites and electromagnetic anisotropy. Oxygen nonstoichiometry of RE123 compounds have been carefully studied before 1990, however, more quantitative information has been required for the recent RE123 materials. Therefore, in the present study, oxygen nonstoichiometry of RE123 compounds with various RE elements was precisely measured as functions of temperature and P(O2). And dependence of their superconducting properties, such as Tc, irreversibility field and Jc, on oxygen content was systematically studied. Thermodynamic measurements of the underdoped bulk specimen were performed using an electro-microbalance. Thermodynamic quantities, ho and so, were calculated from the nonstoichiometry data. Superconducting properties of sintered bulk, melt-sintered bulk and single crystals with various oxygen contents were measured by using a SQUID magnetometer.
ES 23
SPATIAL DISTRIBUTION ANALYSIS OF SUPERCONDUCTING TRANSITION TEMPERATURE IN EPIXTAL YBa2Cu3O7 FILM USING VARIABLE TEMPERATURE SCANNING LASER MICROSCOPY. E. Seo and C. Kwon, Department of Physics and Astronomy, University of Utah, Salt Lake City, UT; B.H. Park and Q.X. Jin, Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, NM.

We have investigated spatial distribution of superconducting properties using Variable Temperature Scanning Laser Microscope (VTSLM). The scanning laser microscope is a “hot spot” scanning technique where a laser beam is scanned across a sample to create a local heating of the sample and the resistance response of the beam is measured from the sample using a lock-in amplifier with respect to the position of the beam. We used an epitaxial YBa2Cu3O7 film photolithographically patterned to a 300 nm wide and 2.0 mm long bridge. Since the voltage response, $\delta V(x,y)$ is proportional to $dR/dT(x,y)$, we obtain the spatial distribution of superconducting transition in VTSLM images. In the resistive transition region, we find a strong correlation between the VTSLM images and the resistance of the sample. With decreasing resistance, the area with large $\delta V(x,y)$ shifts towards the ends of the bridge. This indicates that the resistive transition is not uniform and both ends of the bridge have lower transition temperature ($T_{c}$). VTSLM images taken below superconducting transition temperature and near the critical current ($I_{c}$) show that the resistive areas appear initially at both ends of the bridge. VTSLM technique enables us to image the local superconducting properties and to identify the weaker superconducting areas. The effects of laser output power, bias currents, and thermal linkage between the sample and the sample block will also be discussed.

ES 26
ABSTRACT WITHDRAWN.

ES 27
LOCAL STRUCTURE OF SUPERCONDUCTING MATERIALS: HALOGENATED YBCO AND MgO, L.M. Deng, A.A. Ignatov, T.A. Tyson, NJIT; Dept. of Physics, Newark, NJ; M. Croft, Dept. of Physics, Rutgers University, Piscataway, NJ; H.J. Cyna, Dept. of Chemistry and Princeton Materials Institute, Princeton University, Princeton, NJ.

The recovery of superconductivity by chlorination, iodination and bromination was investigated in underdoped single crystal YBCO. The spatially resolved local structural changes in halogenated samples have been measured by x-ray absorption spectroscopy (XAFS) and compared to those in normal crystals. The local structure about the Y, Ba, Cu and Br/C(I)/I lattices was determined. Evidence for charge transfer was derived from the near edge spectra (XANES). We address the issue of the incorporation of Br/C(I) into the lattice and discuss the recovery of superconducting material in these studies. In addition, we also investigated the local atomic and electronic structure on the new perovskite superconductor MgCa2O5 in order to examine the role of local distortions. This research is supported by the National Science Foundation Career Grant DMR-9733602.

ES 28
LATROX CONDUCTIVE BUFFER LAYERS ON BIAxially TEXTURED Cu FOR COATED CONDUCTORS. Kyung Il Kim, Mitach Patel, and David Norton, University of Florida, Department of MSE, Gainesville, FL; John Buhl, Brian Sales, Matthew Chisholm, Ayug Talga, Chaudin Cantoni, and David Christen, Oak Ridge National Laboratory, Oak Ridge, TN.

In recent years, significant effort has focused on HTS coated conductors based on Rolling Assisted Biaxially Textured Substrates (RABiTS). For a functional conductor, it is likely important to provide a suitable conducting shunt for traversing current around localized breaks in the superconducting film. With metallic substrates, shorting the superconducting film to the substrate via a conducting buffer layer is one approach being considered. While much of the interest has focused on Ni and Ni-based alloys, other biaxially textured metals present intriguing advantages. In particular, copper is attractive as it is non-magnetic and exhibits a higher conductivity than Ni at 77 K, thus providing better fault suppression for HTS substrates. Unfortunately, little is known about the epitaxial growth of oxides on Cu. Epitaxial growth of oxides on Cu present major challenges due to the large difference in thermal expansion coefficient between conducting oxides. In this talk, we will describe the growth of LaTiO3, which is a metallic pseudoperovskite, as a suitable conducting buffer layer on Ni and Cu for YBa2Cu3O7 growth. Oxide film growth is explored using reactive sputtering deposition and pulse laser deposition. Characteristics of the films will include X-ray diffraction and scanning electron microscopy.
In addition, we will describe properties of superconducting films deposited on the buffered substrates.

**ES.29**
Abstract Withdrawn.

**ES.30**
HTQTD PHASE AND BUFFER LAYER CONSIDERATION FOR HIGH RATE IN-SITU YBCO DEPOSITION. Tsuyoshi Ohnishi, William Jo, Ann Marshall, Jeong-uk Huh, Robert T. Hammonds, and M.R. Bend. Kent State University, Geophysical Laboratory for Advanced Materials, Stanford, CA; Richard E. Erickson, 3M Corporation, St. Paul, NM.

We are developing a high rate (up to 10 mm/s), in-situ YBCO film synthesis process using an electron beam deposition method with a view toward coated conductors for electrical power applications. It seems that Bi2Ca2O6-Og liquid flux is important in growing not only bulk critical but also film form of Bi2Ca2O6 [1]. We have also confirmed the effectiveness of the liquid phase to grow high Jc YBCO in our high rate in-situ deposition. In this talk, optimization of the liquid phase, i.e., composition and formation temperature, based on thermodynamic stability and lowering melting point with doping will be presented. Growth of buffer layers suitable for the liquid phase assisted film growth on artificial textured metal tapes will be also discussed. [1] M. Kawasami, D.B. Choi, T. Itto, K.S. Yun, and H. Koizum. Proceedings of the third symposium on atomic scale surface and interface dynamics. I, 1999: 151.

**ES.31**
INVESTIGATION OF MAGNETIZATION LOOPS IN ULTRATHIN YBCO FILMS. Lyubov Delima, Ivan Linichuk, Ilse Inost, Dept. of Solid State Electronics. S. Petersburg, RUSSIA; Erkki Likhitens. Univ. of Turku, Wibuti. Phys. Lab. Univ. of Viscan, Dept. of Physics, FINLAND; Konstantinos Traoi, Ilse Inost, Dept. of Solid State Physics. S. Petersburg, RUSSIA.

The interest in fabricating high-quality ultrathin YBCO films is associated with their fundamental HTSC properties and possible microwave and microelectronic applications. The investigation of magnetic hysteresis loops in HTSC materials is a widely used tool to estimate the critical current density and its dependence on magnetic field. Yielding information about superconducting properties relevant to applications. We study magnetization loops in strip-shaped YBCO films with a thickness about 10 nm, deposited on a Si/SiO2 substrate with and without a YBaCu3N6O3 buffer layer. The zero resistance critical temperatures of the films studied are Tc = 74.7±8 K. The magnetization loops are measured in magnetic fields of up to 1 T applied perpendicular to the film surface in the temperature range of 2.5-50 K. The critical current density determined from the opening of the hysteresis loop is in the order of (1 x 10^7 A/cm^2) at 2.5 K and 0K. It is field independent up to 1 T and decreases down to 10^7 A/cm^2 at 1 T. Magnetization M(B) of all the samples is found to show a sharp minimum (dip) around zero magnetic field. The width of dip is 0.01 T. The anomaly of M(B) behavior occurs in the same field range where an anomaly of ac surface impedance Z(B) of thin YBCO films has been found recently. In the framework of the 2D limit of the critical state model, this dip of M(B) can be associated with anomalous weak links having a non-Franz-Hue-cker-like field dependence of the critical current.

**ES.32**
ENHANCEMENT OF FLUX PINNING IN MELT TEXTURED Y1−xNdXBaCuO4−x SUPERCONDUCTORS. Guixiong Qiu, Yuri Xing, Institute of Metal Research, Chinese Academy of Sciences, Shenyang, CHINA.

The textured Y1−xNdxBaCuO4−x superconducting samples have been fabricated by the modified MTG method. XRD analysis shows that the samples have good orientation along the [100] direction. Nd substituted Y1−x substituted Y1−x samples are homogeneous and it has little effects on the samples microstructure. The field dependence of the irreversibility temperature in various MTG Y1−xNdxBaCuO4−x samples at 60K is 8 K, the Tc of the ZFC curves were measured by a dc SQUID magnetometer. It was found that the magnetization of FC curve is very small compared with the ZFC curve. This means the pinning force acting on the flux are very strong. The irreversibility line of the samples show that small amount of Nd substitution can enhance the flux pinning properties of these YBCO superconductors especially in higher fields. The irreversibility temperature of the sample with the substitution amount of 0.01 is increased by 8 K compared with the sample of zero substitution in high fields; in very low fields, the Tc is almost the same. We believe that the substituted areas have poor superconducting property with the matrix. When the substitution amount is small, it has little effects to the FC curve. In large fields, the few substituted areas in the sample lost their superconductivity and then they can act as flux pinning centers in the sample. So introducing a second phase, which has a similar crystal structure with the main phase, into high Tc superconductors may be a prospective way to improve their flux pinning properties.

**ES.33**
Abstract Withdrawn.

**ES.34**
MECHANICAL PROPERTIES OF CUBE TEXTURED Ni/Nil.5%Al COMPOSITE TAPES FOR HTS COATING APPLICATIONS. Y.S. Sarma, Bernd de Boer, Bernhard Holzapfel, Institute for Solid State and Materials Research, Dresden, GERMANY.

The development of mechanically stronger (~0.5 MPa yield strength) highly textured substrates is of great technological importance for increasing the engineering current density of the coated HTS conductor tapes. Nickel is frequently thought to be a candidate for this improvement of our excellent oxidation resistance and ability to form strong cube texture after heavy rolling and annealing. However nickel is very soft (yield strength ~0.1 MPa). The mechanical properties can be increased through solid solution and precipitation strengthening methods. However the addition of alloying elements in larger amounts (eg. Cr, V, Al) required for solid solution strengthening results in deterioration of cube texture. A more promising method to improve strength is through internal oxidation of Ni-Al alloy. Results on the internally oxidized Ni-1.5% Al and Ni-2.5% Al alloys show that yield strength levels of the order of 200 MPa can be achieved through this method in 40µm tapes. To avoid the formation of Al2O3 at the surface which is detrimental for further deposition, Ni-NiAl-1.5%Al composite tapes are prepared by rod in tube hot extrusion and further hot and cold rolling to 40 and 80 µm thickness. The tapes were characterized to texture and the texture was investigated. Further the tapes will be internally oxidized to obtain Al2O3 precipitation for increasing the strength. The present paper reports the texture development and mechanical properties of these composite tapes.

**ES.35**
IMAGING TRANSPORT CURRENT DISTRIBUTION IN HIGH TEMPERATURE SUPERCONDUCTORS USING ROOM TEMPERATURE SCANNING LASER MICROSCOPE. C. Kwon, S. Seo, and B.E. Klein, Department of Physics and Astronomy, California State University-Long Beach, Long Beach, CA; B.H. Park and Q.X. Jin, Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, NM.

We report the feasibility of room temperature scanning laser microscope (RTSLM) for the study of high temperature superconducting films. The scanning laser microscope is a “hot spot” scanning technique where a laser beam is scanned across a sample to create local heating, and the voltage response, ∆V(y), due to the laser beam is measured from the sample using a lock-in amplifier with respect to the position of the beam. RTSLM images from SmBa2Cu3Ox and YBa2Cu3O7 thin films show that the ac voltage response exists only in the section of the bridge where the transport current produces a voltage drop. A photolithographically defined 60 µm x 60 µm void in a 300 µm wide bridge was clearly visible in a RTSLM image giving the spatial resolution smaller than 60 µm. In addition, the void disturbs the transport current distribution beyond it, generating an elongated domain void of 60 µm x 85 µm with the longer side along the direction of current flow in the RTSLM image. Our results indicate that the RTSLM is a useful tool to investigate the transport current distribution in high temperature superconductors.

**ES.36**
THE EFFECT OF MAGNETIC FIELD ON THE ANOMALOUS MICROWAVE Q OF YBCO-ON-MGO RESONATORS. S.H. Park, Department of Electrical Engineering and Computer Sciences, MIT; Cambridge, MA and Air Force Research Laboratory, Hanscom AFB, Bedford, MA; D.E. Orton, MIT Lincoln Laboratory, Lexington, MA; J.S. Dewey, Air Force Research Laboratory, Hanscom AFB, Bedford, MA; G. Dresselhaus, Department of Physics, MIT, Cambridge, MA and Air Force Research Laboratory, Hanscom AFB, Bedford, MA; M. Dresselhaus, Department of Physics, MIT, Cambridge, MA.

Several reports of anomalous microwave surface impedance in YBCO thin films have appeared in the literature. The anomaly consists of a decrease in both the real and imaginary parts of the surface impedance as either the microwave power or the dc magnetic field is increased. We have previously observed an increase of Q as the microwave power is increased for both YBCO and niobium resonators on MgO substrates at low temperatures. This effect closely resembles the reported anomalous surface impedances. In this study we measured the Q vs microwave power in a resonator in a function of dc magnetic field up to 0.1 T for temperatures between 5 and 70 K. The
measurements were done at a frequency of 3.7 GHz in a suspended microstrip resonator. The external DC magnetic field was perpendicular to the plane of the YBCO film. The power was varied from 55 to 18 dBm. The anomalous $Q$ behavior was not affected by the magnetic field. The anomaly was much less pronounced at 20 K than at 5 K and completely gone at 70 K. The anomalous $Q$ behavior was present on all samples and bulk YBCO/aluminate substrates. We conclude that a low-temperature nonlinear dielectric loss in the MgO is the source of the anomalous $Q$. The absence of any magnetic field dependence rules out magnetic origin.

We will discuss the various mechanisms that could explain this previously unobserved nonlinear dielectric loss. This work was supported by the Air Force Office of Scientific Research.

**E8.37**

**DEVELOPMENT OF HTS RF DEVICES USING SINGLE-DOMAIN YBCO FOR WIRELESS TELECOMMUNICATIONS.** Dong-Ki, Shih, Yong-Doo, Xu, Alain, and David, Dep. of Electrical & Computer Engineering and Computer Science, and Dept. of Physics, University of Cincinnati, Cincinnati, OH.

Using a novel laser technique, unique RF devices have been designed and developed using single-domain YBCO for wireless telecommunication. The uniqueness of these devices lies on the 3-D architecture of the single-domain structures. In contrast to the thin film devices with 2-D patterns, the newly designed RF cavities and circuitry utilize the processing freedom in the development of 3-D structures. These advantages will enable the design of lightweight, tunable, and compact RF devices in base station filters. In this presentation we will show current experimental results in single-domain YBCO growth, device design, and RF property characterization.

**SESSION E9: YBCO COATED CONDUCTORS III**

Chair: Martin W. Rapich and Victor A. Moroni

**Thursday Morning, November 29, 2001**

Room 201 [Hynes]

**8:30 AM #E9.1**


Inclined substrate deposition (ISD) offers the potential for rapid production of high-quality biaxially textured buffer layers suitable for YBCO-coated conductors. We have grown biaxially textured MgO films by ISD onto single-crystal Si(111) wafers. Laminated, textured grain structures with a roof-tile-shaped surface were observed in these films. X-ray pole figure analysis revealed that the [100] planes of these ISD-MgO films are tilted at an angle from substrate normal. A small rhombohedral cell with half maximum (FWHM) of $\pm 0.5^\circ$ was observed on MgO films deposited at an inclination angle of $55^\circ$. YBCO films were grown on ISD-MgO buffered Hasselloy substrates by pulsed laser deposition. We obtained a critical current density of $\approx 1 \times 10^6$ A/cm$^2$ at 77 K in self-field on 0.5-mm-thick, 0.5-cm-wide, and 1-cm-long samples. Details of ISD-MgO film fabrication and characterization, as well as the results of YBCO deposited on the ISD-MgO buffer layer, will be presented.

**9:00 AM #E9.2**

**CONTINUOUS YBCO - TAPE COATING BY THERMAL EVAPORATION.** Halflermann, Werner, Fraunhofer IZM, Dresden, Germany; F. Reimann, A. Wagner, J. E. Geelhaar, H. de Kiefer, H. Fischer, G. Fischer, T. Heumann, R. Auer, D. Rehbach, A. D. Be'er, A. A. Beimler, Oxford Superconducting plc, UNITED KINGDOM.

Currently, due to simultaneous large area coating thermal evaporation allows the highest YBCO volume deposition rates among various coating techniques. The simultaneous large area deposition translates into long deposition length when the deposition area is closely filled up with metal tape. On short RABITS samples thermal evaporation has already established critical current densities in excess of 1 MA/cm$^2$ at 77K. Recently, the deposition technique has been scaled up using a multi-turn tape winders for a simulataneously coated length of about 4 meters of 1 cm wide tape. The red to red tape deposition system is designed for long term continuous operation based on vapor composition control by atomic absorption spectroscopy and in situ reliable evaporation sources. In the initial setup the system has been able to reproduce the above results on small samples. The first results on continuously moving tape substrate containing up to a length of several meters will be reported.

**9:30 AM #E9.3**

**CONVERSION KINETICS OF OXYFLUORIDE-DERIVED YBCO FILMS.** Michael J. Cima, Igor Selzlemy, and Adina Gopal, Massachusetts Institute of Technology, Dept. of Materials Science and Engineering, Cambridge, MA.

Films of YBa$_2$Cu$_3$O$_{7-\delta}$ (YBCO) were prepared on lanthanum aluminate [LAO] single crystal, buffered (500 nm Y$_2$O$_3$, 50 nm CeO$_2$) Na$_x$-single crystal substrates and O$_2$-buffered YSZ single crystal substrates by metal-organic deposition (MOD) process. Glassy films were converted to epitaxial YBCO films, by heating in wet atmosphere of N$_2$/O$_2$ mixture. A novel technique was used to determine kinetics of conversion of films from glassy state to crystalline YBCO films. The concentration of residual fluoride in the partially converted films was examined using fluoride ion selective electrode. Influence of different factors on the conversion rate of the oxyfluoride films, including high and low vapor pressure of water, temperature and substrate materials, of this conversion method was investigated. Results obtained with the electrode measurements were compared to results obtained by X-ray analysis and in situ resistivity measurements. Analysis of data received by different techniques showed that fluoride concentration measurement method is a fast and accurate method that can be successfully used for the investigation of conversion kinetics of the films. Based on the fluoride analysis of the growth rate at different temperature activation energy was estimated as 2.6 eV. This result was compared to theoretical, thermodynamic calculations.

**9:45 AM #E9.4**

**DEVELOPMENT OF A HIGH RATE, ECONOMICALLY VIABLE BUFFER DEPOSITION PROCESS FOR YBCO COATED CONDUCTORS.** M. Porada, T. Ayagi, B.W. Kang, S. Sultanpouri, P.M. Mier, A. Benetti, D. Kratzer, and D.K. Christen, Oak Ridge National Laboratory, Oak Ridge, TN.

A low-cost, high rate, reactive sputter deposition process has been developed to fabricate epitaxial YSZ buffer layers on O$_2$-buffered Ni (100) substrates. For fabricating high current YBCO conductors on practical substrates, present experience suggests that the buffer layer thickness should be at least 200 nm to 500 nm. In the standard RABITS architecture of YBCO (sputtered)/ YSZ (sputtered)/ Co$_3$O$_4$ (electrode)/N$_2$, the typical deposition rate for YSZ from an oxide source is 0.5 A/sec. But for providing long lengths of buffered Ni substrates, we need deposition rates in the order of 20-30 A/sec. We have recently sputter deposited YSZ layers epitaxially on electron-beam-coated buffered Ni substrates at reasonably high rates from an alloy target. YBCO films with a J$_c$ of over 1 MA/cm$^2$ at 77K and self-field have been obtained using pulsed laser deposition on reactively sputtered YSZ layers and O$_2$-coated layers. We will discuss in detail issues related to scale-up of reactivity sputter deposition process.

Supported by the U.S. DOE, Division of Materials Sciences, Office of Science, and Office of Power Technologies—Superconductivity Program, Office of Energy Efficiency and Renewable Energy. The research was performed at the Oak Ridge National Laboratory, managed by U-T-BEG, LLC for the USDOE under contract DE-A05-8601R2725.

**10:00 AM #E9.5**

**A NEW COMMERCIAL-VIABLE METHOD OF FABRICATING ROBUST OXIDE BUFFER LAYERS FOR YBCO SUPERCONDUCTING TAPE.** Ilwoo Kim, Scott A. Barnett, John Rechner, and Sinuk Samanin, Applied Thin Films Inc., Epsenhan, IL, Amit Goyal, Oak Ridge National Laboratory, Oak Ridge, TN.

A novel technique has been developed for fabricating oxide buffers for YBCO coated conductor application. We have demonstrated smooth, crack-free YBCO films on various buffer layers with various techniques. The technique relies on the use of low temperature deposition of YBCO on top of the buffer layer to enable growth of high quality YBCO films. Buffer layers have been deposited on these substrates with Pulsed Laser Deposition. YBCO films with or without intermediate layers have been grown on YBCO films. X-ray diffraction and high resolution transmission electron microscopy were used for characterization of the large area coated conductors. The buffer layers significantly enhance the superconducting properties of the coated conductors.

**10:30 AM #E9.6**

**ENGINEERED MICROSTRUCTURES AND TRANSPORT PROPERTIES IN YBCO COATED CONDUCTORS.** Terry Holesinger, Brandy J. Gibbons, J. Yates Coulter and Stephen R. Foyt.

Each process used to deposit or make the bi-axially textured template,
additional buffer layer(s), and the superconductor creates interfaces along which defects or interfacial reactions may result. These defects can be detrimental to the transport properties of the superconducting film. Defects within the films and their corresponding transport properties have been correlated in differences in composition and thickness of the underlying buffer layer materials. We show how this knowledge can be used to maximize critical current densities and engineer specific stack designs to improve transport properties in applied fields.

11:00 AM *E0.7

PHASE RELATIONSHIPS IN THE Bb-Y-Cu-O disproportion system
Winny Weng-Ng, Lawrence Cocks, Igor Levin, Mark Vazdin, Julia Sull, James Clfile, Ceramics Division, NIST, Gaithersburg, MD; Ron Feenstra, Solid State Division, Oak Ridge National Laboratory, Oak Ridge, TN.

Recently methods using e-beam co-evaporated Bi-2212-Y-Cu0 precursor films on RABiTS, followed by post-annealing in the presence of water vapor, have demonstrated the potential of producing high quality, long length Bi2212-0 superconductors. However, the details of phase equilibria and the phase evolution of the Bi-2213 phase in the multi-component Bi2212-CuO-5-OH system, are not completely understood. It is important to determine the role of liquid specifically, whether an intermediate fluoride-containing low-temperature liquid forms, and whether its formation plays a role in governing the formation of the Y-213 phase. We accomplished the design and setup of the experimental apparatus (automated controlled furnace, DTA, preparation of BiOx), and sample handling procedure necessary for atmospheric-controlled experiments. Since the interplay of phase equilibria and kinetics is important in this system, we have investigated the melting equilibria involving Y-213 under reduced processing temperatures, and have also successfully employed the in situ high-temperature x-ray diffraction to follow the phase formation of the Y-213 phase, starting from amorphous Bi2212-Y-Cu films supplied by ORNL. Results of the melting equilibria and phase formation of Y-213 in the presence of water vapor will be discussed.

11:30 AM E0.8

EFFECT OF SULFUR SURFACE STRUCTURE ON NUCLEATION OF OXIDE SEED LAYERS ON TEXTURED METALS FOR COATED CONDUCTOR APPLICATION

RABiTS technology is based on epitaxial deposition of oxide buffer layers on a textured metal surface. This process is intrinsically complex because of the different chemical and electronic nature of the two surfaces involved. Changes in the atomic structure and free energy of the metal surface determined by chemisorbed species can have a dramatic influence on the seed layer nucleation and ultimately determine the film crystallographic orientation. We have shown that 90% of the CuSe substrates are characterized by a bicrystal (2x2) superstructure formed by sulfur, and that this superstructure is responsible for the (200) epitaxial growth of YSZ on the metal layer. We will investigate further the mechanism of formation of (2x2) CuSe on Ni substrates and its effect on the nucleation of other oxide seed layers such as YSZ and STO. We will present a study of the surface structure and oxidation conditions in bisnally textured Ni alloys such as Ni-3% W and Ni-13% Cr and will address the possibility of oxide seed layer nucleation directly on the Ni-13% Cr surface. Preliminary data on epitaxial cubic on cubic growth of STO on 100<100> textured Cu will be also discussed. Deposition of perovskite buffer layers on Cu is a very interesting approach for coated conductor applications because 1) Cu would provide a non-magnetic substrate less reactive with oxygen than Ni-13% Cr, and 2) a RABiTS architecture consisting of Cu and perovskite conducting buffer layers will provide thermal stability to the YSZ tape without the need for an additional cap layer. Therefore, the results of the tape engineering and critical current density study will be presented. Research sponsored by the U.S. Department of Energy under contract DE-AC05-00OR22725 with the Oak Ridge National Laboratory, managed by UT-Battelle, LLC.

11:45 AM E0.9

THEORETICAL MODELS OF SPACE CHARGE STRAIN FIELDs, AND Cu DOPING AT BOUNDARY IN V9Bi2Cu2OY, YBi2Cu3O7-, AND WELICHITOUS LAYERS
C.P. Kuebler, New York University, New York, NY; H.B. Su, SUNY- Stony Brook, Stony Brook, NY.

In this paper we will discuss statistical thermodynamic and kinetic modeling of the origin of space charge and broadening effects at tit boundary in YBi2Cu3O7- and the effects of Cu doping upon them. Model sets of interatomic forces used to calculate the energetics of surface reconstruction and defect clusters as well as their energies of binding to grain boundary dislocations. Open system thermodynamics, including stress effects, will be used to model equilibrium states of Cu segregation, oxygen content and degree of order at various temperatures and oxygen partial pressures. Kinetic considerations and non-equilibrium states will be discussed.

SESSION E10: YBCO COATED CONDUCTORS IV

Chair: U. (Rihana) Balasubramanian and Kazumasa Misumoto

Thursday, November 29, 2001

Room 200 (Hynes)

1:30 PM *E10.1

SURFACE-OXIDATION EPITAXY METHOD FOR CRITICAL CURRENT CONTROL OF YBCO COATED CONDUCTORS
Kazumasa Misumoto, Kyoto University, Kyoto Materials Science, Kyoto, JAPAN; Izumi Harabum, NIST, Superconductivity Research Laboratory, Nagoya, JAPAN.

The principle and application of surface-oxidation epitaxy (SOE) method, which is one of the methods for preparing long-length biaxially textured template for coated conductors, are discussed. Biaxially oriented surface-oxidized NiO/Ni tape of 50 micrometer in width has already been produced by SOE in-plane texture (dekaplan) of the NiO layer was 12.15 degrees throughout the whole length of the tape. Though biaxial orientation mechanism in the NiO layer on the cube-textured Ni tape is not yet clear, the difference of the growth rate of different NiO crystal planes to be a requirement of the orientation. In the initial stage of SOE process, (001)NiO grains and (111)NiO grains coexist. However, the (001) grains coalesce and bury (111) grains, and eventually covers all Ni surfaces. The (001)NiO grains grow by keeping epitaxial growth with (001)NiO surface so that the biaxial orientation of NiO layer realizes. Large Jc improvement in YBCO films deposited SOE-NiO tapes have been obtained by using 50 micrometer QO cap layer on bare NiO surface. The smooth flatness of NiO was greatly improved, since a surface roughness of MgO for NiO is excellent. MgO was also very effective in diffusion prevention of the Ni element. On the other hand, control of the exact YBCO film deposition condition is necessary in order to form high Jc YBCO films on MgO, because the YBCO grains with cubic-on-cube and with 45 degrees rotated orientation are easy to coexist. Consequently, SrTiO3, Bi2212, YSZ, etc., which have better lattice match to YBCO than that of MgO, were examined as the new material for cap layer. YBCO deposition condition will be this is very important for fabricating long coated conductors.

2:00 PM *E10.2

CHARACTERIZATION OF THE CHEMISTRY AND PHYSICS OF COATED CONDUCTOR EMBODIMENTS BY MOLECULAR SPECTROSCOPY AND SYNCHROTRON X-RAY METHODS

Molecular spectroscopy and synchrotron x-ray diffraction/aethering methods are being used to investigate the microstructural and phase chemical properties of coated conductor specimens prepared by a variety of fabrication pathways. These structures included stacked and seeded substrates, deposition of seed layers, pulsed laser deposition of buffer and YBCO layers, and metal-organic deposition of YBCO. The purpose of the studies is to determine how interfacial physics and chemistry influence the nucleation and propagation of biaxial texture, the development of strain from layer to layer (substrate through to superconductor), and, ultimately, the current carrying capacity of the conductor. Defect structures in the superconductor layer and the presence of second phases were examined in each case. This presentation will report on (1) the application of Roman microscopy as a primary characterization tool for analysis of the YBCO layer (the technique detects/determines and gives spatial information concerning cation disorder, defect structures, impurity phases, c-axis alignment, approximate YBCO oxygen stoichiometry, and the nature and approximate magnitude of strain fields); (2) the implementation of synchrotron x-ray reflectivity methods to examine the surface roughness and epitaxy of unseeded and seeded substrates, including the detection of sub-micron oxide films on textured metal substrates, the determination of surface roughness parameters before and after seed layer deposition, the measurement of substrate and seed layer grain size, and the examination of mosaic distributions; and (3) the use of molecular spectroscopy and x-ray diffraction methods in combination to measure the thickness of buffer layers and to determine the nature and magnitude of strain fields at buffer layer/substrate interfaces. Work performed at the Argonne National Laboratory was sponsored by the U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy, as part of a DOE program to develop electric power technology, under Contract W-31-109-E-4838.
2:30 PM E10.3

Transport current pathway information is useful for improving the current conduction of high temperature superconducting tapes because it can be correlated with data from other characterisation techniques such as spatially-resolved X-ray Analysis, to optimize tape production methods. The current density (J) pathways can be determined by inverting magnetic field data measured at the surface of the superconductor, but care must be taken to avoid subtle errors in the inversion process. We have developed improved inversion techniques that allow us to compare the spatial dependence of the current densities with a variety of different defects present in superconducting tapes. In particular, our methods more adequately treat the high-wave-number noise inherent in these inversion processes. We will compare directly the spatially resolved vector paths of J with X-ray data. The correlation is high. This improved inversion process should lead to improved YBCO coated conductor tapes.

2:45 PM E10.4
MANIPULATING THE NUCLEATION AND GROWTH OF REBCO ON THIN FILMS. Guus Rijnders and Dave H.A. Blank, Univ of Twente, Low Temperature Div, MESA Research Inst, Enschede, THE NETHERLANDS.

The nucleation and growth of the cuprate high Tc material, especially the REBa2Cu3Ox compounds, has been subject to many studies in the last ten years. In the case of deposition techniques such as pulsed laser deposition (PLD) or sputter deposition mainly the growth mode was studied. Depending on the growth conditions, a multiple layer 2D or spiral growth has been observed introducing grainboundaries and increased roughening of the film surface. This limits applications based on multi-layer technology. Starting with atomically smooth substrates, i.e. TiO2 terminated strontium titanate, the initial growth of REBa2CuOx+y using high-pressure RHEED is studied. With standard PLD conditions, the RHEED intensity drops significantly during the initial growth and nucleation of sub-unitcell blocks is observed by AFM and TEM [1]. As a consequence, defects such as are present in the film. In this presentation growth manipulation using a new growth method, pulsed laser intercalation of sub-unit cell, will be discussed. With this technique, control and modification of nucleation and growth are possible. Special attention will be paid to the perovskite stacking sequence at the interface with the substrate and its impact on the occurrence of amphi-phase boundaries during film growth. [1] S. Bla, G. Rijnders, D.H.A. Blank, G. van Tendeloo, Physica C 355 (2001) 225.

3:00 PM E10.5
FABRICATION OF HIGH J, YBCO COATED CONDUCTORS USING SOL-GEL BUFFER LAYERS ON NICKEL AND NICKEL ALLOY SUBSTRATES. S. Subramanian, M. Paramesh, W. Kang, T. Ayyag, A. Goyal, P.M. Martin, and D.K. Christen, Oak Ridge National Laboratory, Oak Ridge, TN.

Sol-gel processing of La2BaCu2Ox (LZO) buffer layers on biaxially textured Ni3 W alloy substrates using a continuous reel-to-reel dip-coating unit has been studied. The epitaxial LZO films obtained have a strong cube texture and uniform microstructure. The effect of increasing the melting speed on the texture, microstructure, and the carbon content retained in the film were studied. On top of the LZO films, epitaxial layers of Yttrium Stabilized Zirconia (YSZ) and Ceria (CeO2) were deposited using rf sputtering, and YBCO films were then deposited using pulsed laser deposition. The density (Jc) of 1.9 MA/cm2 at 77K and self-field and 0.34 MA/cm2 at 77K and 0.5T have been obtained on these films. These values are comparable to those obtained on YBCO films deposited on alumina deposited buffer layers, and the highest ever obtained using solution seed layers. The use of these solgel films as single buffer layers for coated conductor processing has been explored. Critical current density of 0.2 MA/cm2, on textured nickel substrates at 77K and self-field, has been measured on these samples. Microstructural analysis of these samples reveals the presence of significant amount of nickel oxide. The processing thicker, denser LZO buffer layer to combat the problem of nickel oxidation using modified solgel synthesis is currently being explored. The results obtained from this process will be discussed in detail.

This research was sponsored by the U.S. DOE, Division of Materials Sciences, Office of Science, Office of Energy Efficiency and Renewable Energy, Office of Basic Energy Sciences, Office of Energy Efficiency and Renewable Energy, and Office of Basic Energy Sciences. This research was performed at the Oak Ridge National Laboratory, managed by UT-Battelle, LLC for the USDOE under contract DE-AC05-00OR22725. Sincere acknowledgements also extended to Oak Ridge Associated Universities for making this work possible.

3:30 PM E10.6
FABRICATION OF REBCO COATED CONDUCTORS BY LIQUID PHASE EPITAXY. Xiaojing Qi, Zaolin Lockman, Masoud Sciere, and Judith L. MacManus-Driscoll.

Liquid phase epitaxy (LPE) has been used to grow mixed REBCO (RE=Y, Yb, Er) thick films for coated conductor applications. Growth on single crystal substrates has produced very encouraging results. T's of 91 K and J's close to 1 MA/cm2 have been achieved in several micrometer thick films, with a growth rate of 1 µm/y. However, the growth of REBCO thick films on metallic substrates in much more difficult. There is an urgent need to find a suitable metallc substrate and its buffer layers, which can meet the special conditions of the LPE growth. The most important requirements of these buffer layer and substrate materials are a close lattice match and resistance to corrosion by the flux. In this presentation, we will report the results of LPE growth of mixed REBCO's on RE2CuO4 on surface corrosion epitaxy Ni0 on RbTiS Ni substrates. Each processing step is highly scalable.

4:00 PM E10.7
PEAK EFFECT AT MICROWAVE FREQUENCIES IN SWIFT HEAVY ION IRRADIATED Y-123 THIN FILMS - INVESTIGATION OF VORTEX DYNAMICS. Tanmulkar Bunkerjee, R. Pinto, TIFR, Dept of CMP & MS, Mumbai, INDIA; Avinash Bhangale, Institute of Science, Dept of Physics, Mumbai, INDIA; Pravin Raj, University of Birmingham, School of Physics and Astronomy, UNITED KINGDOM; D. Kanghita, Nuclear Science Centre, New Delhi, INDIA.

The vortex dynamics at microwave frequencies in Y-123 films has been studied. We observe a peak in the microwave (4.8 GHz) surface resistance in some films in magnetic fields (up to 0.8 T) whereas a few films do not show a pronounced peak in their surface resistance. This is associated with the 'peak effect' phenomenon and reflects the order-disorder transition of the flux-line lattice near the transition temperature [1]. Introduction of artificial pinning centers like chromium defects as a result of irradiation with 200 MeV Ag ions leads to the suppression of the peak in films exhibiting 'peak effect'. Interestingly, a peak is seen to develop in those films that initially did not show a peak in the surface resistance before irradiation. These results and the dynamics of the vortices at microwave frequencies for the unirradiated and irradiated films will be discussed. [1] A.R. Bhangale, P. Rayadhurhi, S. Surkar, T. Bunkerjee, S.S. Bhagwan, V. S. Sirishkumar and R. Pinto, Phys. Rev. B(Rapid) 63, (2001) 180510R.

4:15 PM E10.8
PHASE STABILITY, MICROSTRUCTURE, AND CRITICAL CURRENTS OF YBCO FILMS BY THE IN-SITU E-BEAM METHOD. William Jo, T. Ohnishi, J.U. Huh, R.H. Hammond, and M.R. Bensky, Geballe Laboratory for Advanced Materials, Stanford University, Stanford, CA.

Synthesis of YBa2Cu3Oy~ films by the in-situ e-beam method is promising for manufacturing scale-up of coated conductors, since it allows deposition with large area, high rate, and thick growth due to low pressure and, a finding that is under certain conditions the growth is via a liquid flux. Formation of stable YBa2Cu3Oy~ at low pressure (5x10^-5 torr) results from a thermodynamic stability driven by atomic oxygen added to molecular oxygen. Growth temperature is also found to be an essential parameter to determine phase stability of the films. From TEM studies, layer-by-layer and /or island growth have been observed. It is found that critical currents of the films show a strong dependence on microstructure: high critical currents 3 ~ 5 MA/cm² in faulted island in low pressure growth and 5 MA/cm² in high pressure layer-by-layer structures. The faulted microstructure is believed to supply enough pinning centers of vortices and be transparent for oxygen diffusion while layer-by-layer structures show larger lattice constant, indicating that they are oxygen-deficient. Growth on metal tape substrates with high Tc and high rate is a challenge because of reaction and diffusion at the high temperature needed so far for the liquid flux assisted growth. At lower temperature the challenges are different and will be discussed.

4:30 PM E10.9
CLEANING, REFINING, TRANSPORT CURRENT EFFECTS IN 1 C M YBCO COATED CONDUCTORS. G.W. Brown, M.E. Hawley, Structure-Property Relations [MST-8], Los Alamos National Laboratory, Los Alamos, NM; E.J. Peterson, J.Y. Coulter, P.C. Doremus, P.N. Arendt, S.R. Fellyn, Materials Science and Technology Center [MST-STC], Materials Science and Technology Division, Los Alamos National Laboratory, Los Alamos, NM.
An important aspect of YBCO coated conductor progress is the identifcation and elimination of isolated regions of low $J_c$, that have been found in otherwise high $J_c$ tapes. In the past these regions have been observed with 4-point probe measurements taken at 1 cm intervals along the tape length. Now we have been able to characterize these regions in greater detail using low temperature scanning magneto-resistance microscopy to map the current pathways in the defective region. These results help us to identify the extent and overall nature of these defects in terms of their effect on the current flow, the property of interest we wish to optimize. In this work we have imaged 5 cm long sections from "good" and "bad" regions of a 1 meter long YBCO coated conductor. The current density map from the "good" region had the expected edge-peaked structure, similar to that found in our previous work on high quality test samples grown on single crystal substrates. The map from the "bad" region showed the current density to be confined to half the width of the conductor with some additional defects and inhomogeneities in the adjacent broader current flow regions. The implications of these structures as well as general correlation of their details with spatially resolved x-ray analysis and electron microscopy results will be presented and discussed.