SYMPOSIUM C
Recent Advances in Superconductivity—Materials Synthesis, Multiscale Characterization, and Functionally Layered Composite Conductors

March 29 - April 1, 2005

Chairs

Terry Holesinger
Los Alamos National Laboratory
MS G755
Los Alamos, NM 87545
505-667-2911

Teruo Izumi
SRL-ISTEC
1-10-13, Shinonome, Koto-ku
Tokyo, 135-0062 Japan
81-3-3536-5711

Judith L. MacManus-Driscoll
Dept. of Materials Science & Metallurgy
University of Cambridge
Pembroke St.
Cambridge, CB2 3QZ United Kingdom
44-1223-334-468

Dean Miller
Argonne National Laboratory
Bldg. 223
9700 S. Cass Ave.
Argonne, IL 60439-4108
630-252-4108

Winnie Wong-Ng
National Inst of Standards and Technology
Bldg. 223, Rm. A205
100 Bureau Dr.
Gaithersburg, MD 20899
301-975-5791

Symposium Support
Applied Superconductivity Center/University of Wisconsin
Argonne National Laboratory
Center for Applied Superconductivity/Los Alamos National Laboratory
Oak Ridge National Laboratory

Proceedings to be published online
(see ONLINE PUBLICATIONS at www.mrs.org)
as volume 868E
of the Materials Research Society
Symposium Proceedings Series.
This volume may be published in print format after the meeting.

* Invited paper
One salient feature of a superconductor is the expulsion of magnetic flux below its transition temperature $T_c$. A Type II superconductor will be in the Meissner state (MS) with an equilibrium diamagnetic moment $M_\text{eq}$, and $M_\text{eq}$ is smaller than its lower critical field $H_L$. A distinct $dM_\text{eq}/dH>0$, on the other hand, is expected either under higher $H$ or in the spontaneous vortex state (SVS), which has been predicted when superconductivity and ferromagnetism coexist and the internal field is greater than the $H_L$. The magnetic properties of powder samples of different particle sizes and a single crystal of rutheno-cuprates have been systematically examined. Here we report the observation of a novel superconducting state in the polycrystalline and single crystalline superconducting ferromagnetic rutheno-cuprates below $T_c$, where: (1) magnetic field expulsion does exist, albeit the effect is very small, (2) the spontaneous vortices occur; (3) $dM_\text{eq}/dH$ is negative and $H$-independent up to an apparent $H_L$, reminiscent of the MS; and (4) this effect persists below $T_c$ but varies with the particle size of the single-grain powders. These are in strong contrast to what is typically expected of either MS or SVS. We attribute these to the combination of the anisotropic superconductivity, the fine granularity of the compounds, and the unusually long penetration depth, which make the polycrystalline and single crystalline rutheno-cuprates a naturally occurring mesoscopic superconducting system with device implications.

9:00 AM C1.2

1Materials Science, California Berkeley, California; 2Dept. of Materials Science, Univ. California Los Angeles (UCLA), Los Angeles, California.

Recent diffraction studies have shown the existence of lattice modulations in yttrium barium cuprates (YBCO). We show that these modulations are caused by the ordering of O-Cu-O chains in the CuO planes. Remarkable agreement is illustrated in the case of underdoped YBCO between experimental diffraction patterns of diffuse intensity and satellite intensity obtained from ab initio electronic structure calculations. It is suggested that the "stripe" structure of magnetic excitations observed by inelastic neutron scattering originates in the underlying oxygen order.

9:15 AM C1.3
Structure and Superconducting Properties of Bi-2223 and Bi-Pb-2223 Single Crystals. Enrico Giannini1, Alexandre Piriou1, Nicholas Clanton2, Nicolas Musolino1, Roman Gladyshevskii2 and Rene Flukiger1.

1DPMC, University of Geneva, Geneva, Switzerland; 2Ivan Franko National University of Lviv, Lviv, Ukraine.

The structure and superconducting properties of both Pb-free and Pb-doped Bi-2223 single crystals have been investigated. Large and high-quality crystals were grown by using the newly developed Vapour-Annulated Travelling Solvent Floating Zone method, which allowed us to grow crystals containing volatile doping elements, like Pb. The homogeneity of the crystals was enhanced by post-annealing under high pressure of O2 (up to 40 MPa at $T = 500^\circ$C). Sharp superconducting transitions (as high as 1.1 K and as sharp as $\Delta T \approx 1$ K) were obtained in crystals having a sizes up to 3 x 0 x 0.1 mm3. The structure of both Pb-free and Pb-doped Bi-2223 was refined for the first time from single-crystal X-ray diffraction (XRD) data. The unit cell of the average structure is pseudo-tetragonal with $a = 5.4210(7), b = 5.413(6)$ and $c = 37.010(7)$ Å, and $\alpha = 5.356(1), b = 5.413(1)$ and $c = 37.042(11)$ Å, for the Pb-free and the Pb-doped phase, respectively. An incomensurate modulation in the direction of one of the short cell vectors has been defined (q ~ 0.21 a*), however, the structure can be conveniently described in a supercell with a 5-fold volume ($a = 27.105(4)$ Å). With respect to the ideal average structure, one additional oxygen atom for ten initial O was found to lie in a cavity parallel to the BiO layers. The Cu sites were found to be partially occupied by Bi atoms, the amount of the substitution achieving $\approx 8$% and $\approx 5$% in the Pb-free and Pb-doped Bi-2223 phase, respectively. The magnetic properties of the superconducting state were widely investigated. The superconducting anisotropy was found to be $\approx 50$, more than three times as lower as in Bi-2212. As a consequence, the irreversibility fields are higher and the magnetic relaxation times are lower than in the Bi-2212 phase. The lower
Effect of Impurities in MgB2 on Thermodynamic Properties.

Lawrence L. Cook, Ralph Klein and Winnie Wong-Ng; Ceramics, NST, Gaithersburg, Maryland.

In the course of a thermodynamic study of MgB2, we have measured vapor pressures over several samples using the Knudsen effusion vacuum thermogravimetric technique, and measured the standard enthalpies of formation on the same samples using isoperibol solution calorimetry. While we found a large variation in the measured enthalpies, vapor pressure differences between the samples were much less. Second phase impurities in the samples were at low levels, and ranged from absent to barely detectable by powder X-ray diffraction. Certain of the samples, after partial vaporization, showed presence of PM*C2.4. These samples show higher HC2 as a solid.

**11:45 AM C2.8**

### SESSION C2: Fundamental Issues for Coated Conductors

**1:30 PM C2.1**

Progress and Barriers in Developing High Temperature Superconductor Wires. **Dean E. Peterson**, Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, New Mexico.

Most power applications of High Temperature Superconductors (HTS) depend on production of wires with appropriate properties and costs. Tremendous progress has been made during the past 15 years towards viable conductors. First generation BSCCO tapes are already commercially available for prototype power applications. Second generation coated conductors are now being fabricated in hundreds of meter lengths that exhibit critical currents in excess of 100 amps at 77 K. Several technical barriers remain to be solved before these new YBCO tapes will be produced in kilometer lengths with appropriate properties for large scale power applications. This review will summarize the status of high temperature superconducting wire development and discuss promising technical approaches as well as research opportunities. The presentation will focus on Los Alamos IBAD Coated Conductors to exemplify development of these scientifically and technologically important materials.

### 2:00 PM C2.2

Progress of Long Length PLD-YBCO Conducted and IBAD, PLD and/or O2 Substrate, and Jc Improvement in a Magnetic Field. **Yutaaka Yamaida**, Tomosumi Watanabe, Kazuhiro Takahashi, Masayuki Kunihi, Takumi Murugou, Seiki Miyata, Akira Ibi and Yu Shihara; **Nagoya Coated Conductors Center, ISTEC-SRL, Nagoya, Aichi, Japan**; **Division of Superconducting Tape and Wire, ISTEC-SRL, Tokyo, Japan**.

Activity at SRL-Nagoya Coated Conductor Center (NCCC) is presented for the production of a 100 m class long buffered substrate and a few tens meters YBCO coated conductor using reel-to-reel IBAD and PLD systems. A 220 m long IBAD and a 100 m long CeO2 capped substrate have been successfully and stably produced. Furthermore, the PLD-CeO2 method succeeded in obtaining a high degree of 3 degrees of bi-axial texturing, which is close to a single crystal level and is considered to increase an Ic. A new PLD system called the Multi-PLD (Multi-Plume and Multi-Turn PLD) successfully achieved a 46m long YBCO conductor with a high Ic over 180A. The production rate was so rapid that each run of YBCO deposition was carried out at 12m/h for 4 times deposition. Also, Ic and Jc in a magnetic field are being improved by the study of thickness dependence on a magnetic field and RE-BCO materials. This study made it clear that Ic in a magnetic field has a crossover for the thickness and, then, it showed an optimum thickness for Ic in a given magnetic field. Furthermore, RE element such as Gd has a superior magnetic dependence of Ic, compared to YBCO. These effects are considered to help us efficiently develop a high Ic conductor used in a magnetic field.

### 2:30 PM C2.3

Continuous Preparation of Pulsed Laser Deposited YBCO on IBAD-MgO for Coated Conductor Applications. **Brady J. Gibbons**, Paul Dowden and Vladimir Matusa; **MST-STC, Los Alamos National Laboratory, Los Alamos, New Mexico**.

The Superconductivity Technology Center at the Los Alamos Research Park has focused on continuous processing of second generation coated conductors. Our process includes steps for continuous electropolishing of Hastelloy C276 substrate tape (1 cm x 0.1 mm), continuous thin-film assisted deposition (IBAD) of a bilayerly textured MgO template layer, and continuous pulsed laser deposition (PLD) of oxide buffer layers and the superconductor (YBa2Cu3O7). We are currently producing YBCO-based coated conductors using a 50 mm thick LaMnO3 (LMO) buffer layer. The in-plane texture improves from 8-10° in the MgO to 3° in YBCO. We have attained YBCO performance of over 350 A (at 75 K) in lengths over 1 m (for a 3 µm thick YBCO film). YBCO is deposited in a multi-zone heater that allows for an engineered heating power profile as the YBCO film is deposited. The premise is to account for the change in the emissivity of the tape surface as the YBCO film becomes thicker. Using this heater we are able to grow thicker YBCO layers and maintain high Jc values over longer lengths. More detailed studies of using this "engineered" profile will be presented. This work is funded by the Department of Energy Office of Electric Transmission and Distribution.

### 3:15 PM C2.4

Realization of High Performance Coated Conductors by Advanced TFA-MOD Process. **Tero Iinuma**, Hiroshi Fujita, Yui Aoki, Ryo Teranishi, Koichi Nakao, Yumio S. Matsuda, Suteohara Nomoto, Yutaka Kito, Yutaka Yamaida, Akira Yajima, Takeshi Saitoh and Yuh Shihara; **1SRL-ISTEC, Koto-ku, Tokyo, Japan**; **2Asahi Ceramic, Ltd., Koto-ku, Tokyo, Japan**; **3Fujikura Ltd., Koto-ku, Tokyo, Japan**.

The TFA-MOD process is expected to be suitable as a low cost method due to its simple process and high performance. However, in order to produce the coated conductors for the applications, the several factors such as higher Ic, long tape etc. should be realized. In this paper, the recent progresses in our group on R&D of coated conductors by TFA-MOD process are reviewed. In order to obtain high Ic, the optimization of the growth conditions both for calcinations and crystallization steps was investigated. Through the investigations, it was clarified that a low heating rate in the calcination step and high Ic20 with a low heating rate in the crystallization step are important for a high Ic value in thick films. The extremely high Ic value of 415 A was obtained by applying the above results to highly textured buffered substrates. On the other hand, the gas flow was controlled precisely by using a simulation technique for a uniform long tape processing. In the case of the low gas flow rate in our reel-to-reel system which has a transverse gas flow system, it was predicted by the calculation that the stagnant gas region with high HF concentration exists in the leeward part in the furnace. This could be a reason for the non-uniform reaction not only in the width direction but in the longitudinal one. Then, the long tape fabrication was carried out in the high gas flow condition, and the uniform performance with the high Ic value of 119 A as an end-to-end one was realized in the 8.9m long tape. This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) as Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications.

### 3:45 PM C2.5

Progress in Scale Up of Applications-Ready Coated Conductors at Superpower. **Yenkat Selvanarayanan, Yi-Yuan Xie, Allan Knoll, Yinlin Chen, Yijie Li, Xiaoming Xiong, Jodi Reeves, Yunfei Qiao, Ping Hou, Tom Salaga and Ken Leness; SuperPower Technologies for Superconductivity Applications.

The progress in the scale-up of applications-ready coated conductors at Superpower is presented. The work has been focused on the development of coated conductors for high current fault current limiter (FCL) and magnetic energy storage (MES) applications. The FCL coated conductor is currently operating in the 15 kA application in New York. The MES coated conductor is currently in operation at 1.2 TFL. The work presented includes the design, manufacturing, testing, and application of coated conductors for these high current applications. The presentation includes a discussion of the challenges and solutions encountered during the development process, as well as the current status and future plans for these applications-ready coated conductors.

SuperPower is scaling up coated conductors for use in HTS device applications. In addition to high critical currents over 100 m lengths, our program is focused on developing applications-ready coated conductors. All steps of our coated conductor manufacturing process are conducted in pilot scale facilities, examples of producing maximum piece lengths of 100 m. Achievement of high throughput in every process stage is an important focus of our program. Linear speeds of at least 10 m/h are used in every process step. High-field performance has been substantially improved using rare-earth substitution. Lower losses have been achieved by producing multilayered conductors using an industrial photolithography process. Conductors are produced in practical 4 mm widths by slitting, where the critical current has been unaffected. A unique surround stabilizer structure, wherein a copper layer is electroplated completely around the conductor, has been developed. Over-current measurements show the effectiveness of the ground copper stabilizer structure. Superior bend strain, tensile strain, and tensile stress properties have been measured in our 4 mm wide conductors with surround stabilizer. A 1 m long cable was fabricated for the first time ever with 4 mm wide conductor. AC losses measured in this cable show very low values, which are substantially lower than that measured in cables made with first-generation HTS conductors. Pancake coils and racetrack coils have been fabricated with our coated conductor for magnet and rotating machinery applications. This work was partially supported by the U.S. Air Force through funds from Title III, AFRL, and AFOSR and the U.S. Department of Energy. This work was partially conducted under CRADAs with Los Alamos National Laboratory and Air Force Research Laboratory at Wright Patterson Air Force Base.


The Second Generation (2G) YBCO Coated Conductor wire development effort at American Superconductor has transitioned from demonstrating the technical feasibility and evaluation of potential manufacturing processes to development of a commercially viable 2G YBCO coated conductor manufacturing technology. In turn meter lengths of 2G wire with critical currents exceeding 200 A/cm-width (77 K, self-field) have been available from AMSC for the past year. The current homogeneity and the mechanical robustness of AMSC's 2G wire has enabled its successful testing in prototype demonstrations, including coils and cables. AMSC's 2G manufacturing approach, based on the RABITS/MOD-YBCO technology, is now focused on increasing the processing width and length to enable the high-rate, low-cost manufacturing of 2G wire that meets the electrical, mechanical, thermal and environmental requirements of targeted commercial and military applications. The RABITS/MOD-YBCO manufacturing approach allows for the performance of the wire for specific customer applications. In addition the MOD YBCO process allows the controlled introduction of defects into the YBCO, enabling optimization of the wire performance for applications with different temperature and field requirements. In this presentation we will review the performance and properties of AMSC's RABITS/MOD-YBCO 2G wires in relation to requirements for targeted commercial applications and discuss the progress of AMSC's 2G Pilot scale manufacturing effort.

4:45 PM C2.7 Improvement of Multi-plume and Multi-turn (MPT) PLD for YBCO Coated Conductor. Tomonori Watanabe, Reiji Kuriki, Takeharu Kato, Seiki Miyata, Atsuko Ibi, Yukiko Yamada, Yuh Shiibara, Takeharu Kato and Tsukasa Hirayama; 1Nagoya Coated Conductor Center, ISTEC-SRL, Nagoya, Japan; 2Division of Superconducting Tapes & Wires, ISTEC-SRL, Tokyo, Japan; 3Japan Fine Ceramics Center, Nagoya, Japan.

Enlargement of deposition area is one of the problems to be solved to achieve high rate deposition of YBa2Cu3Ox (YBCO) layer by pulsed laser deposition (PLD) for long coated conductor fabrication. We introduced a reel-to-reel PLD system, in which the optical system was designed so that the laser beam scanned YBCO targets during deposition and produced plural and discrete plumes (multi-plumes) to enlarge the deposition area along the tape substrate transferring direction. Reel-to-reel tape transferring system was designed so that the substrate was transferred through multi-turn loops, and turns around a substrate heater for 3 times (multi-turn), to enlarge the deposition area across the substrate transferring direction. Using this multi-plume and multi-turn (MPT) PLD system, we have investigated a high rate deposition of YBCO with high critical current (Jc) on the "self-epitaxial" PLD-CeO2 cup layer, which indicates drastic improvement of the in-plane grain alignment, on the ion beam assisted deposition (IBAD)-Gd2Zr2O7 (GZO) buffered Hastelloy tape. Multi-plume, which used in this study were 4 plumes with laser repetition frequency of 40 Hz each, was able to achieve YBCO layer growth with high deposition rate of 90 Hz, which is higher than conventional PLD system. The YBCO layer was grown with a-axis oriented grain growth. Adding this temperature adjustment to the MPT-PLD, an increase of YBCO layer growth rate of 100% was achieved in a 10 cm long conductor. Furthermore, we applied MPT-PLD, with deposition temperature adjustment, to produce long YBCO coated conductor. Then, a 45-58 m long YBCO layer was successfully deposited in excess to the end-to-end Jc reached 182 A. The multiplication of Jc and length achieved high value of 8.34 kA m. Our efforts to fabricate longer YBCO coated conductor will be reported. This work was supported by New Energy and Industrial Technology Development Organization (NEDO) as Collaborative, Research and Development of Fundamental Technologies for Superconductivity Applications.

SESSION C3: Functionally Textured Metal/Oxide Coated Conductor Composite Templates

Chairs: Tolga Aytug and Teruo Izumi

Wednesday Morning, March 30, 2005

Room 2000 (Moscone West)


The Los Alamos second-generation coated conductor architecture utilizes superconducting YBCO films on a biaxially textured MgO template produced by ion-beam-assisted deposition (IBAD) on polycrystalline metal substrates. YBCO films grown using this architecture have been shown to exhibit transport critical current properties equivalent to films grown on single crystal substrates.[1] When compared with other IBAD materials, MgO displays superior texture vs. thickness properties. However, it has been criticized for requiring ancillary layers not required by the other IBAD materials. In this talk, we discuss the functionality of these layers and how they fulfill and improve upon roles played by the other, much thicker, alternate IBAD materials. Radiation damage anisotropy experiments of MgO will also be described. The results imply a mechanism for the formation of biaxially textured IBAD MgO. They also suggest possible IBAD improvements, which when tested, proved to broaden the IBAD processing window.[2] S. R. Folykin, P. N. Arendt, Q. X. Jia, H. Wang, J. L. MacManus-Driscoll, S. Kresskott, R. F. DePaula, L. Stan, J. R. Groves, and P. C. Dowden, App. Phys. Lett., 82 4513 (2003).


It is presently recognized that a sharp substrate texture is key for obtaining critical current densities approaching single-crystal values in coated conductors. Nevertheless, many questions remain about the evolution of grain boundaries from substrate to buffer layers to superconductor, and the effect on Jc, of particular types of misorientations. In RABITS, each substrate grain boundary can be regarded as the superimposition of a [001]-tilt, a [100]-tilt, and a [100]-twist boundary, and the global texture is commonly described in terms of these three misorientations. In particular, the majority of bulk layers deposited on textured metal substrates by various techniques duplicate more or less faithfully the substrate crystal alignment, some materials have been found to develop a much sharper out-of-plane texture. These materials offer the opportunity to distinguish the effects of the out-of-plane and in-plane texture on Jc. When a TiN seed layer is employed, the out-of-plane misorientation of the buffer layers XRD FWHM decreases down to ~ 3 degrees, while the in-plane misorientation remains equal to the substrate value of ~ 7 degrees. We will report on the growth and structural characterization of TiN-based buffer architectures deposited by PLD that have consistently shown tilting of the c-axis towards the direction of the sample surface normal. We will address the extent and the mechanism of such tilt, as well as the modifications of the grain boundary distribution, using x-ray microbeam measurements and electron backscattering diffraction maps in which in-plane and
out-of-plane components of the local misorientation are separated. We will also discuss the effect of such texture improvement on Jc.

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.

9:30 AM C3.3 Influence of the Substrate Temperature on the Texture of MgO Films Grown by Ion Beam Assisted Deposition, Liliana Stano, Paul N. Ansolidt, Raymond F. DePaula, Igor Usov and James R. Cromer, Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, New Mexico.

The variation in substrate temperature during the ion beam assisted deposition (IBAD), which employs the use of energetic ions to bombard the growing film, could influence quality of the crystalline texture of the MgO films. Therefore, the investigation of the texture dependence on temperature is necessary to determine the optimum temperature for MgO growth. Also, determining the ion to molecule ratio window (the acceptable deviation from the optimum ion to molecule ratio) for different substrate temperatures establishes the optimal MgO deposition conditions. For each fixed deposition temperature, a set of samples was produced by varying the ion assist beam current from sample to sample while keeping the deposition rate constant. In this way, the ion to molecule ratio was modified and the range for achieving well-ordered MgO films was determined. This investigation of the MgO texture dependence on the substrate temperature reveals that the best in-plane alignment is obtained at ~25°C. At this temperature, MgO films with in-plane orientation distribution full width at half maximum of less than 1° have been attained. MgO films deposited at temperature higher than 100°C have broad in-plane alignment. Although, the deposition at the lowest temperature (~150°C) did not improve the in-plane texture, the ion to molecule ratio deposition window for achieving in-plane textured films was the largest. As a trend, the ion to molecule ratio deposition window decreases with increasing substrate temperature. This is especially important for continuous IBAD MgO depositions where less restrictive conditions are desired.

10:15 AM C3.4 The Atomic Scale Properties of Interfaces in High-Tc Materials and Layered Composites, Nigel D. Browning 1, 2, Rolf Erni 3, James P. Buhman 4, Robert F. Klie 5, Stephen J. Pennycook 6, 7, Sokrates T. Pantelides 8, 9, and Alberto Frassetto 10.

1Chemical Engineering and Materials Science, University of California, Davis, California; 2National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, Berkeley, California; 3Department of Materials Science and Engineering, University of Washington, Seattle, Washington; 4Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee.

Grain boundaries have long been known to play a critical role in determining the transport properties of high-Tc superconducting materials. With the introduction of layered oxide composite systems for the next generation of wires, other interfaces have also begun to assume similar levels of importance. For both the highly studied grain boundaries and the newer hetero-interfaces, characterizing the atomic scale properties such as the interface structure (e.g. the formation of interface phases), composition (e.g. segregation and diffusion), and local bonding (electronic properties) is the key to understanding the overall transport properties as a function of processing conditions. The ability to perform this characterisation is afforded by the combination of atomic resolution Z-contrast imaging and electron energy loss spectroscopy (EELS) in the scanning transmission electron microscope (STEM). The recent technical innovations of aberration correction (higher spatial resolution) and monochromation (higher energy resolution) have extended modern STEMs to the point where direct correlation of the experimental results with density functional theory is now possible. Through a combined experiment and theory approach to characterizing interfaces, the basic foundations of crystal chemistry (doping) and the transport models for interfaces in high-Tc materials can be examined. In this presentation, the latest developments in microscopy for the characterization of interfaces high-Tc materials will be presented. These techniques will be applied to analyze the morphology of interfaces in a layered composite and used at the highest energy and resolution to discuss segregation and doping effects at undoped and Ca-doped YBa2Cu3O7-d grain boundaries.

10:45 AM C3.5 Crystal Chemistry of Interfaces Formed Between Two Dissimilar Structures. Fred F. Lange and David Andeen; Materials, UC Santa Barbara, California.

Without a doubt, when one crystalline material is allowed to nucleate and grow on another, special crystallographic relations are discovered that would not be predicted with any current theory. There are many examples where different lattice parameters can actually be used to explain special crystallographic relations. Recently, the authors have discovered that the two simple rules of crystal chemistry can be used to understand some special crystallographic relations between two dissimilar structures, and thus different lattice parameters can actually be used to explain special orientation relations between two dissimilar structures. The examples chosen are ZrO (wurtzite) that epitaxially on (111) MgAl2O4 (spinel), TiO2 (anatase) on (100) LaAlO3 (perovskite) and TiO2 (rutile) on (R-plane) Al2O3 (sapphire), ZrO2 (fluoride) on basal plane Al2O3 (sapphire), and SiO2 (Cristobalite) on basal plane Al2O3 (sapphire). In addition to these basic concepts, methods for experimentally discovering special relations, and generating YBCO coated conductors for exploring special orientations that minimize the misfit strain will be discussed.

11:15 AM C3.6 Stability of Chemically Deposited Buffer Layers for YBCO Coated Conductors. Md. S. Bhuiyan 1, 2, M. Paranthanlan 1, S. Sathyamurthy 1, D. Lee 3, S. Kang 3, A. Goyal 3, and K. Salama 3; Oak Ridge National Laboratory, Oak Ridge, Tennessee; 4University of Houston, Houston, Texas.

It is extremely important to develop a low-cost coated conductor fabrication method for electric-power applications. We have developed a chemical solution deposition (CSD) process, to deposit oxide buffer layers on biaxially textured Ni-W (3 at.%) substrates. CeO2 and Y2O3 seed layers were grown by MOD technique and in the case of CeO2 sharper out-of-plane and in-plane textures were achieved compared to the underlying texture of the Ni-W substrate. A new set of single rare earth niohthioplane, RE (RE = La, Ce, Nd, Sm, Eu, Gd, Ho, Y and Yb) buffer layers have been developed for the growth of superconducting YBa2Cu3Oy~4 (YBCO) films. Using CSD, smooth, crack-free and epitaxial RE3NiO7 films were grown on cube textured Ni-W substrate. YBCO films with critical current densities exceeding 1 MA/cm2 at 77 K and self-field were achieved on these solution buffers using pulsed laser deposition. This demonstration promises a route for producing low-cost all-solution buffers for second generation YBCO coated conductors. This work will be presented as part of Bhuiyan Ph.D. dissertation. Research supported by the Department of Energy, Office of Electric Transmission and Distribution, and Air Force Office of Scientific Research. This research is performed at the Oak Ridge National Laboratory, managed by UT-Battelle, LLC for the USDOE under contract DE-AC05-00OR22725.

11:30 AM C3.7 Chemical Solution Deposition of Perovskite Buffers Layers for Superconducting Applications. Scott Fillery 1, Quanxi Jia 1, and Frederick F. Lange 1; 1Materials Department, University of California Santa Barbara, Santa Barbara, California; 2Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, New Mexico.

Chemical solution deposition of Lanthanum Manganite (LMO) thin films has been achieved on Ion Beam Assisted Deposition (IBAD) MgO substrates provided by Los Alamos National Laboratory. Solutions of Lanthanum acetate and Manganese acetate were refluxed in acetic acid and methanol to produce a spin-on solution of varying concentration. Heat treatments at between 1000 and 1100 deg. C included water vapor, measured at between 0.5 and 0.9 ml/hr, to allow LMO film stability and inhibit Ni oxidation. Suppression of MgO(02) at temperatures below 400 deg. C was achieved by delaying water input to higher temperatures. X ray diffraction shows epitaxy of (020) Lanthanum Manganite thin films on the (002) IBAD MgO substrates. LMO film thicknesses were measured at 90 nm using a stylus profiler on channels formed by stamping self assembling, the Octadecyltrichlorosilane (OTS) monolayers prior to film deposition. Similar perovskite structures have also been investigated on IBAD MgO substrates and will be discussed in conjunction with the above research.

11:45 AM C3.8 Solution Deposition and ex-situ Vacuum Conversion of Epitaxial YBCO/SrTiO3/NiW RABiTS Coated
A variety of solution deposition routes have been reported for processing epitaxial YBCO film coated conductors on metal tape substrates. We have taken an extension of these methods toward long-length, epitaxial film all-solution deposition routes to enable biaxially-oriented YBa2Cu3Oy (YBCO) coated conductors. Recent results are presented detailing an all solution deposition approach to coated conductors with critical current densities J (77K) = 1 MA/cm² on rolling-assisted, biaxially textured, (200) oriented Ni-W alloy tapes, using SrTiO3 (STO) or SrTiO3.86 Nb2O3 (Nb-STO) buffer layers processes to enable growth of STO on NiW without formation of NiO or W2O5, will be discussed, as well as defect chemistry approaches to limit oxygen diffusion in STO and Nb-STO. Recent results with J, values up to 1.7 MA/cm² have been obtained using Advanced Conductor Corporation (AMSC) solution-deposited YBCO on SrTiO3/NiW, with L = 139 A/cm-width. Current limitations to all-solution deposition processes will be discussed, including the influence of substrate quality and buffer layer/substrate lattice mismatch. Kinetics of vacuum conversion will be discussed for 0.25-1.0 micron thickness YBCO films. Sandia is a multidivision laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

SESSION C4: Interface Dynamics in Layered Heteroepitaxial Oxide Films
Chairs: Claudio Cantoni and Paul Clem
Wednesday Afternoon, March 30, 2005
Room 2000 (Moscone West)

1:30 PM *C4.1
Abstract Withdrawn

2:00 PM *C4.2

The atomic stacking sequence at the substrate–film interface plays an essential role in the heteroepitaxial growth of REBa2Cu3Oy. During initial growth, the interface configuration influences the surface morphology and structural properties of the film, due to the formation of antiphase boundaries (APBs) by coalescence of islands with different stacking sequences. In this study, the interface configuration is accurately controlled by both the terminating atomic layer of the SrTiO3 substrate and the stoichiometry of the first unit cell layer. By using this capability the number of APBs and, therefore, the in-plane ordering is tuned, allowing the study of its influence on the structural and electrical properties of the YBa2Cu3O7 film. The critical temperature Tc is depressed by increase of the in-plane ordering, which strongly indicates that the presence of APBs in the sample favors the oxygen in-diffusion. Furthermore, the correlation between the structural properties of STO(001) substrates and the twinning in YBa2Cu3O7 thin films grown by pulsed-laser deposition is studied using x-ray diffraction with reciprocal space mapping. The vicinal properties, i.e., angle and in-plane orientation, play a significant role in the anisotropic strain starting at the interface between substrate surface and film, and affect the twin behavior of YBa2Cu3O7. On substrates having an 110°-in-plane orientation of the step edges, a completely preferred twin pair is observed if the vicinal angle is equal to the migration length of the atomic species in the growth process of the film. For precipitate-free films, the width and height of the twin boundaries are completely precipitate-free. These films exhibit a detwinning as the vicinal angle increases. For a -1.10° a maximum detwinning, i.e., monocrystalline film is obtained.

2:30 PM C4.3

We have established a coordinated set of characterization methods that can be applied to coated conductor specimens to help identify the underlying causes of poor performance. The key to this approach is to utilize complementary techniques that measure local superconducting properties, phase formation, microstructure, and texture. We have used the coordinated application of magneto-optical imaging (MOI), Raman microscopy, and site-specific microstructural characterization using focused-ion-beam (FIB) sectioning and transmission electron microscopy (TEM) to study meter-length coated conductor tapes. These studies have pinpointed specific microstructural and chemical defects which can be correlated with poor Ic performance on coated conductors. The key aspects of this coordinated characterization approach will be outlined and detailed studies that illustrate the role local defects play on transport properties will be presented and discussed. Work at Argonne National Laboratory is supported by the U.S. Department of Energy, Offices of Science and of Electric Transmission and Distribution under Contract W-31-109-ENG-38. Electron microscopy was carried out in the Electron Microscopy Center at Argonne National Laboratory, which is supported by the Office of Science.

3:15 PM *C4.4
A New Approach using Artificial Substrates for Growth of High-Quality Precipitate-Free HTS Thin Films, Toward Electronic Device Applications. Krzysztof Endo, Petr Badica, Hiroshi Sato, and Hiroshi Aoki; Nano-technologies Research Institute (NRI), National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan; 2Institute of Laser Technology, Tohoku University, Sendai, Japan; 3National Institute of Materials Physics (INCBFM), Bucharest, Romania; 4Correlated Electron Research Center (CERC), National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan.

For successful fabrication of electronic devices, high quality thin films are required; controlled and uniform thickness and properties, certain morphology and alignment, low and uniform roughness, device fabrication area completely without precipitates are several key limiting parameters. All of them are even more important for sandwich-type structures and superlattices exhibiting through the stacked layers certain effects, e.g., Josephson or Andreev (tunneling, other) and/or for integrated devices. In particular, the last criterion is increasingly difficult to be realized for ultra thin films and/or films of multi-component materials showing segregation problems. For the first time, we have succeeded in the growth of high-quality thin films with clean and completely precipitate-free surface, suitable for device applications, by applying a new concept and method to the substrates. The concept consists in generation of artificial steps of controlled height and width, and desired shape on the surface of the substrate. The width of the step is chosen so that it is equal to the double of the migration length of the atomic species in the growth process of the film. If precipitates occur, they will be selectively gathered to the step edge where the free energy is lowest. Using this new approach, we have successfully obtained by MOCVD high-quality precipitate-free Bi-2223 and Bi-2223/Bi-2212-superlattice thin films on (001) SrTiO3 substrates with artificial steps of controlled width and height. These as-grown films have been further used to fabricate patterned intrinsic Josephson junctions, which are not only instructive models for future artificial SIS junctions, but also good candidates for high frequency applications in the THz region. Completely precipitate-free films offer a strong advantage for integration, and generate new possibilities for the device fabrication.

3:45 PM *C4.5
Transmission Electron Microscopy Studies of YBCO Films on Biaxially Textured Buffer Layer Deposited by Pulsed Laser Deposition. Takaharu Kato, Hirokazu Sasaki1, Tomonori Watanabe, Akira Iida, Hiyori Ita1, Yasuhiro Iijima1, Kazunori Kudoh1, Yasunori Sotou1, Shigeru Shintani1, Kenji Hasegawa1, Yutaichi Yanada1, Takashi Snatch1, Tetsu Izumi, Yukichi Sasaki, Tsuhaon Hirayama, Yuk Ishihara1,2, and Yuichi Ikubara1,2; Materials Research and Development Laboratory, Japan Fine Ceramics Center, Nagoya, Japan; 2SRL-Nagoya Coated Conductor Center, ISTEC, Nagoya, Japan; 3Material Technology Laboratory, Fujikura Ltd., Koto-ku, Tokyo, Japan; 4SRL-Division of Superconducting Tapes and Wires, ISTEC, Koto-ku, Tokyo, Japan.

Thick YBCO films with high Jc values were deposited by pulsed-laser deposition (FLD) on Hastelloy with buffered biaxially textured layers. Both cross-sectional and plan-view TEM specimens of the YBCO films were prepared, and then the microstructural characterization of the films was examined by transmission electron microscopy (TEM). The YBCO films less than 1µm thick were predominantly composed of c-axis oriented grains, however, a-axis oriented grains were occasionally found. Since screw dislocations perpendicular to the substrate were observed in the c-axis oriented grains, the grains were considered to grow spirally. It was found that the a-axis oriented grains nucleate on the biaxially textured buffer layer, and grew larger with the increasing thickness of the YBCO film. We found that c-axis and a-axis oriented grains coexisted in the thick YBCO films beyond 1µm from the buffer layer and formation of many gaps between the YBCO grains. In addition, both Y-rich phases and cupper oxides were formed at the interface between a-axis and c-axis oriented grains. Since those phases or the gaps are considered to reduce the Jc values of the YBCO film, it is, therefore, important to find out the optimum fabrication conditions to suppress both the nucleation of Y-rich grains, Y-rich phases or cupper oxides and the formation of the porous microstructure.
structure. Acknowledgment: This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) as the Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications.

4:15 PM C4.6

EuBa2Cu3O7 (Eu123) films show some unique properties such as an excellent surface morphology, a high transition temperature, and an interesting field-dependent critical current density, which are important for thin film devices and coated conductor applications. In our earlier studies, we found that by inserting a certain REBa2Cu3O7 (RE123, RE = Dy, Y, etc.) seed layer, the process window for high performance Eu123 can be significantly expanded. In this presentation, we report our comparative studies of the microstructures of Eu123 films on SrTiO3 substrates with different seed materials. We have used high-resolution X-ray diffraction (HRXRD) to investigate the micro-domains and dislocation densities of the films. We will also discuss the effect of the microstructures on the superconducting properties of Eu123 films.

4:30 PM C4.7

We examine the evolution of biaxial texture during ion-beam assisted deposition (IBAD) of MgO using reflection high-energy electron diffraction (RHEED), in situ ion scattering, x-ray diffraction and transmission electron microscopy. The IBAD-MgO templates on metal tape are used for second generation high-temperature superconducting wire, also known as coated conductors. We find that the texture development is very sensitive to the nucleation surface conditions, both chemical species and surface morphology. In the best cases an in-plane texture of 3.5 degrees and an out-of-plane texture of 1.5 degrees are attainable. We are utilizing a methodology of presenting data in terms of IBAD texture contour plots where we collect data as a function of ion-to-molecule ratios and film thickness. The striking conclusion from the data is that the texture development for different ion-to-molecule ratios can be scaled with the cumulative ion damage normalized to deposited MgO material. We discuss the results in terms of possible mechanisms for IBAD-MgO biaxial texturing and relationship to other IBAD texturing processes. This work is funded by the Department of Energy Office of Electric Transmission and Distribution.

C5.3
Textured Oxidation Protection Coatings on Copper and Copper-Alloy Substrates to be used in Coated Conductor Applications. Chakrava Karumas1,2, Paul N. Barnes2, Nicholas A. Yust3, Andrew D. Chayen2 and Srinivas Suthiran3,2; 1University of Dayton Research Institute, Dayton, Ohio; 2PRPG, AFRL, Wright-Patterson AFB, Ohio; 3National Research Council, National Academy of Sciences, Washington DC, District of Columbia.

Copper or copper based alloys are an attractive, less costly alternative to Ni-based alloys as substrate materials for YBa2Cu3O7-δ (YBCO) coated conductor applications. Use of a thermally conductive copper substrate will have the benefit of conducting the heat away from a localized hot spot and hence acting as a quench protection stabilization component of the coated conductor when used with suitable buffer layers. If the YBCO layer is electrically connected to the copper substrate via conducting buffer layers, then the addition of a copper current shunt can be avoided. These advantages can make copper a superior substrate for the dc conductor. In addition, copper substrates are non-magnetic and provide for reduction in losses resulting from transient fields, although eddy current losses may be a competing factor. As cubic texture can be developed in copper or copper-iron substrates with good lattice match with buffer layers and YBCO, the rolling-assisted biaxial textured substrates (RAIBTs) approach can be used to process coated conductors. However, the oxidation of copper and copper-iron substrates has been a problem to process long length YBCO coated conductors successfully. Deposition of oxidation protection layers on copper is an attractive approach to address this problem. However, the protective layer should have a good lattice match, provide oxidation protection, remain effective (diffusion into copper considerations), and should be non-magnetic. In this study, non magnetic Ni-20% Cr, and Pt coatings have been applied onto cubic textured Cu and Cu-Fe alloy substrates by DC magnetron sputtering to develop substrates with good texture and high oxidation resistance. Texture development and oxidation protection were investigated for films deposited at different deposition parameters.
Particles by a Metal-Chelate Decomposition Method. Hiroki Fujii1, Kiyoshi Ozawa2, Takayuki Nakane1, Hiroaki Kummer1 and Hitoshi Yanaguchi3; 1SMC, NIMS, Tsukuba, Japan; 2NEL, NIMS, Tsukuba, Japan; 3MAS, NIMS, Tsukuba, Japan.

Co/Sm-doped Y-Ba-Cu-O particles of different compositions were prepared by a metal-chelate decomposition method. The solution of each metal-oxide was mixed with NFA (nitrofluoracetic acid) solution. After mixing these solutions and subsequent stirring, these solutions were decomposed by H2O2 at 60 °C or 70 °C. The composition of the precipitates depended on the initial composition of the solutions and the reaction temperature. The composition of the precipitates was closer to that of the solutions when heated at 70 °C. The precipitates with the compositions of Y:Ba:Cu=1:2.3:1 and 1:2.4:1 were obtained when the precipitations were performed at 85 °C in air. YBa2Cu3O7 (Y-123) formed as a single phase, and its particle size was ~200 nm. The particle size decreased to ~50 nm when heated at 900 °C. On the other hand, YBa2Cu4O8 (Y-124) formed in the air. The critical temperatures of Y-123 and Y-124 were 90 K and 80 K, respectively.

C5.6
Superconducting YBCO Films Prepared by Electrodeposition and Spray Pyrolysis. Sovannary Phok, Priscilia Spagnol, Tapas Chaudhuri and Raghu Biattacharya; NREL, Golden, Colorado; 1Basic Science-Superconductivity Group, National Renewable Energy Laboratory (NREL), Golden, Colorado; 2Physics, University of Colorado, Boulder, Colorado.

Electrodeposition (ED) is a low-cost, non-vacuum deposition process that can easily deposit uniform films on large non-planar substrates. In this paper we report successful bi-axially textured electrodeposition of Ir on Ni and Ni-W substrates. Ir metal is well known for its excellent oxidation and corrosion resistance among platinum group elements, and also the lattice mismatch of cubic Ir is very close to that of CeO2 and Ni. Our main goal is to produce a Ni-W alloy substrate, using ED deposition of thin Ir film. The films were deposited in a vertical cell in which the electrodes (both working and counter) were suspended vertically from the top of the cell. The ED experiments were performed at 65 °C without stirring the solution. The ED precursors were prepared at ~5.2 V from 15 minutes on both Ni and Ni-W substrates. In this paper we report successful bi-axially textured electrodeposition of Ir on Ni and Ni-W substrates. The Ir metal is well known for its excellent oxidation and corrosion resistance among platinum group elements, and also the lattice mismatch of cubic Ir is very close to that of CeO2 and Ni. Our main goal is to produce a Ni-W alloy substrate, using ED deposition of thin Ir film. The films were deposited in a vertical cell in which the electrodes (both working and counter) were suspended vertically from the top of the cell. The ED experiments were performed at 65 °C without stirring the solution. The ED precursors were prepared at ~5.2 V from 15 minutes on both Ni and Ni-W substrates. The Ir metal is well known for its excellent oxidation and corrosion resistance among platinum group elements, and also the lattice mismatch of cubic Ir is very close to that of CeO2 and Ni.

C5.7
Preparation and Characterization of Oxide Superconducting Electrodeposited YBCO Buffer Layers for YBCO Superconductors. Priscila Delega Spagnol1, Tapas Chaudhuri and Raghu Biattacharya; NREL, Golden, Colorado. Bi-axially textured YBa2Cu3O7-δ films have been fabricated by non-vacuum electrodeposition and spray pyrolysis techniques. Electrodeposited YBCO was prepared on sputtered copper/single crystal substrates. Electrodeposition was carried out at constant voltage and the deposition was completed only in few minutes. The thickness of the as-deposited films was in the range of 0.5 to 1 μm. The optimized sputtered copper layer thickness was about 200 μm on SrTiO3. In spray pyrolysis method, the solution is sprayed directly on LaAlO3 substrates. The substrate temperature is about 100 °C. The thickness of the as-deposited films was in the range of 0.24 to 0.31 μm. The electrodeposited and spray deposited films were annealed at temperatures ranging from 800 °C to 920 °C under various flowing gas mixtures. XRD analysis revealed that processed electrodeposited and spray deposited films were bi-axially textured where YBCO grains were well oriented along c-axis and in the (a,b) plane. The critical current density for these type of films already reached 0.5 MA/cm2 at 70 K and 0 T.
However, this TFA-MOD process requires long time (over 10 hours) especially in the calcination process for each single coating. In our previous work, we shortened the calcination time, we developed a new precursor solution that consisted of yttrium- and barium-trifluoroacetates, and copper naphthenate. We call the process using this new precursor solution as an "advanced TFA-MOD process." The heating rate in the advanced TFA-MOD process was achieved to be 25 times faster than the conventional process, maintaining a high Jc property. In this work, we have investigated the calcination process on both microstructures and superconducting properties for optimization of the advanced TFA-MOD process. Increase of the heating rate makes the surface microscopic morphologies of the precursor films rougher, and Jc values lower. In the case of the high heating rate, formation of large pores and segregation of Cu atoms were observed in the precursor films. The maximum values of the HF gas generation rate during calcination became higher as the heating rate was increased. The crystallinities of the YBCO films increased with increasing the heating rate in the calcination. Consequently, it became clear that the increase of the heating rate caused the rapid HF gas generation leading to degradation of the surface microscopic morphologies, formation of pores, film thickness, crystal growth, and reduction of Jc values. Additionally, the effects of Cu-segregation were also investigated. This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) for Collaborative Research and Development Fundamental Technologies for Superconductivity Applications.

C5.12 Improvements in Critical Current with Second Phase Additions to MgB2. Sook Kien Chen1,2, Yue Soon Jang1,2, Man Park1,2, Seung Jin Ryu1 and Jin Ho Choy2,3; 1School of Chemistry, Seoul National University, Seoul, South Korea; 2NanoScience, Ewha Womans University, Seoul, South Korea; 3Asahi Denka Kogyo Co., Ltd., Tokyo, Japan.

Recently we have studied Hc2 as a function of proximity to the MIT, and aton1ic force microscopy (AFM) analyses were accomplished. Instead, various empirical correlations have been noted and used with moderate success. Alternatively, band theory can be used to estimate Tc on a case-by-case basis. We demonstrate empirically that several different classes of superconducting oxides enable us to open a new chapter in the development of nano-hybrid with various functions. Recently, we were successful in preparing a novel high-Tc superconducting micro-wires and films from the nano-hybrid exfoliated superconducting colloids by electrodeposited superconducting deposition method (EPD). In order to prepare such novel superconducting colloidal suspension, the high-Tc bismuth cuprate superconductor, Bi2Sr2CaCu2O8+y or Bi2Sr2Ca2Cu3O10+y, should first be intercalated with mercury iodide molecules and subsequently with organic salt intercalates. Exfoliation of Bi-based superconductor has then been achieved from organic salt intercalates. In order to study the successful exfoliation of layered high-Tc superconductors, powder X-ray diffraction (XRD), transmission electron microscopy (TEM), and atomic force microscopy (AFM) analyses were accomplished. Moreover, we found that the surface property of the resulting nanosheets in acetone solvent is slightly positive with a potential of 25mV. Such a surface property allowed us to apply these colloidal particles as a novel precursor to the fabrication of superconducting thin, and thick films. As a great advantage, the present exfoliated nanoparticles are not limited to shape and scale of substrate thanks to the nanoscale dimension. At a point of this view, high-Tc superconducting thin films and micro-wires on silver substrate were fabricated by EPD method. Directional growth along c-axis and connectivity between wires were remarkably improved by subsequent heat treatment. Such an epitaxial growth was further confirmed by field-emission scanning electron microscopy (FE-SEM), and TEM. Consequently, the resulting films and wires show reasonable critical current density (Jc) and their thickness can be controlled in proportion to the regulation of time.

C5.14 Behavior Te and Hc2 Near the Metal/Insulator Transition. Michael Oosfksy1,2, Robert J. Soulen2, Gerald T. Woods2 and William F. Egeliollef;3 1C5.13

The discovery of superconductivity in MgB2 with a transition temperature of 40 K has attracted the attention of the scientific community for two main reasons: the technological applications of this material and the new insights that such a simple structure could bring to superconductivity theory. Efforts to improve the superconducting properties of MgB2 have included doping with elements such as V, Cr, C, Al, Cu and Ag, but the results varied for different groups. An explanation for this behavior is that the transport properties of MgB2 have a strong dependence on the sample preparation conditions, and in particular, the incorporation of impurities. Different phases of oxygen precipitates have been characterized and it has been found that the presence of oxygen in MgB2 systematically changes the electronic structure of the boron atoms. From the different phases of
oxygen precipitates found in MgB2, those forming coherent superlattice structures of MgB2-MgB2O, were studied in more detail by first-principles calculations. This is in contrast to the other phases of oxygen precipitates, has been reported to increase the upper critical fields and critical current density but without decreasing the critical temperature of MgB2. This effect is reflected by the low critical temperatures calculated for coherent oxygen precipitates with different concentrations of oxygen using density functional theory. These low critical temperatures explain the behavior of the oxygen precipitates as pinning centers and highlights the importance of the superconducting properties of MgB2. Additionally, due to the presence of two carrier species given by the boron and magnesium states in MgB2, a low energy plasmon mode was proposed theoretical. This work presents the first experimental evidence of this plasmon mode, which has a quadratic dispersion, \( \omega = q^2 \).


The bulk synthesis of the superconducting compound MgB2 is studied between 770 and 1025 °C, using Mg in liquid or vapor form and B in powder or fiber form. The formation of the MgB2 phase is monitored as a function of time \( \textit{in situ} \) by scattering of high-energy synchrotron x-rays. Reaction rates vary significantly depending on the form of the boron (fibers vs. powders), but show little differences when using Mg as liquid or as vapor. These reaction rates are much faster than those published for reaction between Mg vapor and B thin films, which may be due to the increases in surface area created by cracks from the large volume expansion during formation of MgB2 on the macroscopic boron fibers or powders.

C5.19 Substitution of Zr and Nb in MgB2 Bulk Superconductor. Mohit Rattia, Michael D. Sumption, Xuan Peng and Edwards W. Collings; Materials Science and Engineering, The Ohio State University, Columbus, Ohio.

The effects of zirconium diboride (ZrB2) and niobium diboride (NbB2) doping on the microstructure and superconducting properties of bulk MgB2 superconductor have been investigated. The samples were prepared by powder-composition and in-situ sintering of pure Mg and B doped with 7.5 mol% of ZrB2 and NbB2 respectively. Although additions of ZrB2 and NbB2 have been found to decrease the critical temperature (Tc) by about 2 K a profound increase in the upper critical field Hc2 and the irreversibility field Hip has been observed suggesting that small amounts of Nb and Zr have substituted for Mg in the bulk composition leading, it has been suggested, to relative change in electronic diffusivities in the superconducting band. High-resolution TEM studies were performed to confirm the substitution. Along with the increase in Hc2 and Hip a consistent increase in critical current density over the entire superconducting temperature range (up to 30K) has also been observed, indicating also the presence of significant increase in the density of flux pinning sites. This observation was confirmed by pinning force calculations (Fp) and the XRD studies, which showed the presence of small second phase ZrB2 and NbB2 precipitates.

C5.20 Abstract Withdrawn

C5.21 Electric-Field-Induced Modulation of the Magnetic Penetration Depth of Undoped Superconducting La2-xSrxCuO4. Alain Rufenacht, Jean-Pierre Locquet, Jean-Fumpeyrie, Daniel Caimi, and Piero Martinelli; 1Institut de Physique, Universite de Neuchatel, CH-2000 Neuchatel, Switzerland; 2IBM Research Division, Zurich Research Laboratory, CH-8803 Rueschlikon, Switzerland.

A study of the electric-field-induced change of the in-plane magnetic penetration depth \( \lambda_{ab} \) of an undoped \( \text{La}_{2-x}\text{Sr}_{x}\text{CuO}_4 \) (LSCO) ultrathin superconducting film is reported for the first time. Using MgB2, a two superconductor (TSC) film architecture, this LSCO film was grown epitaxially on a 12 UC thick normal (\( x = 0.4 \)) LSCO buffer layer deposited on a monocrystalline SrLaAlO4 (SLAO) substrate. This almost homoepitaxial deposition method minimizes degradation of the film structure at the interface, thereby allowing a considerable reduction of the minimal thickness needed to superconductivity in LSCO films [1]. This is essential to achieve a significant carrier modulation in a electric-field-effect device. A calculation structure was the photolithographically patterned after growing on top of the superconducting film a 15 nm thick HfO2 insulating layer with a dielectric constant \( \epsilon \approx 15 \) and a Pt gate electrode. After processing a superconducting transition (zero resistance) at \( T_c \approx 11K \) was observed. The inverse kinetic inductance \( 1/L_c \propto T_c^{-2} \) of the LSCO superconducting film was inferred from the mutual change of a drive-receive two-coil system caused by the screening currents flowing in the film [2] in response to an ac excitation of 30 kHz. Both the temperature (down to 0.5 K) and

C5.15 Development of the HPCVD Process for MgB2 Film Fabrication. Alexei V. Pogrebnyakov, Abhishek Jain, Daniel Lamborn, Joan Redwing and Xiaoping Xu; 1Department of Materials Science and Engineering, The Pennsylvania State University, University Park, Pennsylvania; 2Department of Physics, The Pennsylvania State University, University Park, Pennsylvania; 3Department of Chemical Engineering, The Pennsylvania State University, University Park, Pennsylvania.

\( \textit{In situ} \) growth of high quality MgB2 films was demonstrated using Hybrid Physical-Chemical Vapor Deposition in which evaporated Mg and thermally decomposed diborane gas (B2H6) serve as precursors. Using this method, high quality MgB2 films were fabricated, which have residual resistivity values as low as 0.26 \( \mu \)cm and critical temperature, \( T_c \), values exceeding those of bulk and other film samples. Epitaxial multilayer structures were also grown comprising MgB2 and other conducting and insulating films. In the present implementation of the HPCVD system, the Mg source is placed around the substrate on an inductively-heated susceptor and both are heated to \( \sim 700^\circ \text{C} \) which is needed to provide a sufficient Mg vapor pressure. This configuration imposes limitations on the substrate size, and prohibits independent control of substrate and source temperatures. A new HPCVD reactor design was implemented which includes a separately heated Mg source boat and substrate holder in a vertical geometry. The effect of substrate temperature on the growth rate and superconducting properties was investigated. In the deposition temperature interval studied (650 – 720°C), the growth rate increases exponentially with increasing \( T_s \), and the \( T_c \) values of MgB2 films on SiC substrates remain over 41 K.


The bulk synthesis of the superconducting compound MgB2 is studied between 770 and 1025 °C, using Mg in liquid or vapor form and B in powder or fiber form. The formation of the MgB2 phase is monitored as a function of time \( \textit{in situ} \) by scattering of high-energy synchrotron x-rays. Reaction rates vary significantly depending on the form of the boron (fibers vs. powders), but show little differences when using Mg as liquid or as vapor. These reaction rates are much faster than those published for reaction between Mg vapor and B thin films, which may be due to the increases in surface area created by cracks from the large volume expansion during formation of MgB2 on the macroscopic boron fibers or powders.

C5.13 Oxygen precipitates in MgB2 and other conducting and insulating films. In the present study, the behavior of the oxygen precipitates as pinning centers and highlights the importance of the superconducting properties of MgB2. Additionally, due to the presence of two carrier species given by the boron and magnesium states in MgB2, a low energy plasmon mode was proposed theoretical. This work presents the first experimental evidence of this plasmon mode, which has a quadratic dispersion, \( \omega = q^2 \).
Electronic Structures of YN12-xCo2B2C Superconductors Studied by Photoemission and Photoabsorption Spectroscopy.

Li-Sheng Hsu1 and M.-D. Lui2; 1Department of Physics, National Taiwan University, Taipei, Taiwan.
2Department of Physics, National Chung Hsing University, Taichung, Taiwan.

The electronic structures of five polycrystalline YN12-xCo2B2C (x = 0, 0.05, 0.1, 0.15, and 0.2) borocarbide superconductors were studied by photoemission and photoabsorption spectroscopy. The resonant photoemission spectra (RESPES) around the Ni 2p3/2 absorption edge were used to study the 6-eV valence-band (VB) satellite of Ni. The Ni and Co k-edge x-ray absorption near edge spectra (XANES) for these metallic compounds were compared with those of Ni and Co powder and foil, respectively. One can see clearly the transition from photoemission - to Auger-like behavior around the Ni 2p3/2 absorption edge. The Ni and Co partial DOS’s for these five compounds locate at 4-6 eV higher energy above the Fermi level than those for the corresponding elements, which was also confirmed by theoretical calculation.

SESSION C6: Buffer Layer Processing for Metal/Oxide Coated Conductor Composites

Chairs: Jan Evetts and Fred Lange
Thursday Morning, March 31, 2005
Room 2000 (Moscone West)

8:30 AM *C6.1 Chang-Beom Eom

Abstract Not Available

9:00 AM C6.2 Thickness Effects of SrTiO3 Buffer Layers on Superconducting Properties of YBa2Cu3O7-δ Coated Conductors.

Haiyan Wang1, Stephen R. Foltyn1, Paul N. Arendt1, Quanxi Jia1, Judith L. McNamara-Driscoll1,2 and Xuefeng Zhang2; 1Los Alamos National Lab, Los Alamos, New Mexico; 2Materials Science Division, Los Alamos National Lab, Los Alamos, New Mexico.

A thin layer of SrTiO3 has been successfully used as a buffer layer to grow high quality superconducting YBa2Cu3O7-δ (YBCO) thick films on polycrystalline metal substrates with a biaxially oriented MgO template produced by ion-beam-assisted deposition (IBAD). Using this architecture, 1.5-μm-thick YBCO films with an in-plane mosaic spread in the range of 2.5°-4° in full width at half maximum and critical current density over 2×106 A/cm² in self-field at 75 K have been achieved routinely. We have demonstrated that the pulsed laser deposition growth conditions of SrTiO3 buffer layers, such as growth temperature and oxygen pressure, have strong effects on the superconducting properties of YBCO.1 In this talk, the interesting thickness effects of SrTiO3 buffer layers on the properties of YBCO are discussed in detail. The critical current density of YBCO films increases dramatically when the thickness of the SrTiO3 buffer layer reaches optimum. Microstructure studies including transmission electron microscopy (TEM) and scanning electron microscopy (SEM) were used to explore the microstructure and growth mechanisms of SrTiO3 thin films deposited at different thickness and to further understand their effects on the growth and properties of YBCO films. Cross-sectional TEM studies reveal that SrTiO3 has a good lattice match with YBCO and clean and sharp interfaces with both MgO and YBCO, which further proves that SrTiO3 is a promising candidate as the buffer layer for high performance superconductor coatings. [1] H. Wang, S. R. Foltyn, P. N. Arendt, J. L. McNamara-Driscoll, X. Zhang and P. C. Dowden, J. Mater. Res., 19, 1899 (2004).

9:15 AM *C6.3 Pulsed Laser Deposition of Bi-axially Textured YSZ/CoO2 Films on Electrodeposited Ir/Ni-W Tapes for YBCO Superconductors.

Tapas Chaudhuri, Priscilla Spagnol, Raghu Bhattacharya and Sovannary Phok: Basic Science Center, National Renewable Energy Laboratory, Golden, Colorado.

Ir film is a potential candidate for conducting buffer layer on Ni-W tapes used for YBCO superconductor. We have developed in our laboratory electro deposition of Ir on Ni-W tapes. To complete the buffer structure it was imperative that Bi-axially textured YSZ/CoO2 layers be grown on these substrates. This paper reports the deposition of YSZ/CoO2 layers by PLD on Ni-W tapes electroplated with Ir. The PLD system consisted of a standard chamber (NeoCera) and an excimer KrF laser (Lambda Physik, ñ248 nm) operated at 200 mJ with a fluence of 2-3 MJ/cm² at the target kept at 8 cm from the substrate holder. Layers of YSZ and CoO2 were deposited sequentially on Ir/Ni-W substrates. Two different approaches were investigated: in one the substrate temperature and in another the environment for ~50 nm seed layer of YSZ was varied. The layers were characterized by XRD and AFM. When YSZ and CoO2 layers were deposited on Ir/Ni-W at 775 to 800 °C in 10-4 Torr of oxygen, the layers had both (111) and (200) orientation. The (111) orientation was more pronounced at and above 850°C while (200) orientation dominated below it. This was marked change when a seed layer of YSZ was deposited by deposition temperature was fixed at 800 °C and different seed layers were first deposited in H2/Ar (0.3 Torr) O2 (1-0.4 Torr) and vacuum (~0.6 Torr). The H2/Ar prepared YSZ films with (111) with a small (200). O2 gave films with mixed (111) and (200) while YSZ films grown in vacuum was (200) oriented. The XRd studies revealed that the Y layers are Bi-axially textured with phi ~ 5° and omega ~ 80°. The surface roughness measured by AFM is about 5 nm.

9:30 AM C6.4 Development of Ho-123 Coated Conductors.


We have been developing Ho-123 thin films by using pulsed laser deposition (PLD) method. Ho-123 shows high Jc up to 5MA/cm² in the case deposited on single crystal substrates such as sapphire and LAO. In this work, based on our PLD technique, Ho-123 coated conductors have been developed on flexible metal tape substrates. Oxide buffer layers such as YSZ and CeO2 have been deposited on textured Ni-alloy tapes. A basic technique of the formation of buffer layer was investigated, and hetero-epitaxial buffer layer of CoO2 / YSZ showed excellent texture plane alignment with the delta phi value in the range of 5 to 7 degrees. Surface roughness (Ra) was several nm and the surface was almost flat with few particles. Ho-123 film deposition was conducted on the buffer layers by PLD method. Samples less than 0.2 μm thick showed Jc (77.3 K self field) over 2 MA/cm². Sample with 1.4 μm in thickness showed Jc (77.3 K, self field) over 1MA/cm². In another sample, Jc was 190MA/cm². X-ray (103) pole figure of Ho-123 shows in-plane texture of approximately 6 degrees. This demonstrated fine epitaxial Ho-123 growth on CeO2 / YSZ / NiO textured Ni-alloy tape. SEM photograph of Ho-123 layer revealed relatively smooth film morphology with some particles. Furthermore, Jc-B characteristics at 4.2 K under the high magnetic field up to 30 Tesla were evaluated. Jc (4.2 K, 30 T) was 1.3MA/cm² when the external magnetic field was applied parallel to the tape surface. Concerning the results of the long length conductors, high Jc of 14 MA/cm² was achieved for 30 cm long by using multi-layer formation of superconducting layer. High production speed was also achieved by using industrial large scale excimer laser. A part of this work was supported by NEDO as Collaborative Research and Development of Fundamental Technology for Superconductivity Applications. The authors would like to thank Dr. T. Tsuchide and Dr. N. Banno of NIMS for Jc measurement under low temperature and high magnetic field.
Buffer layers play a key role in second generation YBa2Cu3O7-δ (YBCO) coated conductors. The purpose of the buffer layers is to provide a growth on and diffusion barrier between the substrate to the superconductor layer. Important buffer layer characteristics are to prevent metal diffusion from the substrate into the superconductor, as well as, to act as oxygen diffusion barriers. The most commonly used RABiTS architectures consisting of a starting template of biaxially textured Ni-W substrate with a seed layer of Y2O3, a barrier layer of YSZ, and a CeO2 cap. In this three layer architecture, the buffer layers were grown using physical vapor deposition (PVD) techniques. We have developed a low-cost, non-vacuum, chemical solution deposition process to grow highly aligned oxides buffers on textured Ni-W substrates. Using an all solution buffer architecture comprising of La2Zr2O7 and CeO2, we demonstrated the growth of high performance YBCO films with an Ir (critical current) of 140 A/cm-width. This process could potentially decrease the cost of the conduction. We will report in detail about results achieved on all solution buffers. Supported by the U.S. DOE, Division of Materials Sciences, Office of Science, and Office of Electric Transmission and Distribution. The research was performed at the Oak Ridge National Laboratory, managed by UT-Battelle, LLC for the USDOE under contract DE-AC05-00R22725.


Ex-situ growth techniques are the subject of an intense research in order to get low cost high-critical-current YBa2Cu3O7-δ (YBCO) coated conductors (CC). In particular, the main goal is to obtain all chemical CC where superconducting YBCO is grown by the so-called trifluoroacetates route (TFA) and the buffer layers are grown by metalorganic deposition (MOD). To that end, several oxides have been successfully grown by MOD that can be potentially used as intermediate (as for example, La2Zr2O7, BaZrO3, ...) or cap (CeO2, SrTiO3) buffer layers. On the other hand, progresses made on the optimization of TFA-YBCO growth have been impressive in the last years and the critical currents reported on single crystals or on vacuum buffer layers largely exceed the target value of 1 MA/cm2 at 77K in self-field. Most of the studies have been focused on improving the in-plane texture of both the YBCO and the buffer layers. However, there is still a lack of studies on the role of the interface quality between the different MOD layers and the final superconducting properties of the CC. For example, it is known that several buffer properties can dramatically affect the critical current as for example, surface roughness or lattice matching with YBCO. These properties can be tuned by modifying the processing conditions of buffer layers but, for the optimization of their microstructure it is important to fully understand the relationship between the different parameters. In this work we will report recent progress in the control of the interface quality between buffer layers and TFA-YBCO thin films and how it influences the critical current of the CC. For this, TFA-YBCO films have been deposited on SrTiO3 and CeO2 buffer layers. Normal state resistivity and critical currents of the superconducting films have been taken as figures of merit to assess the growth quality of the different buffer layers structures. We will show the dependence of Jc on the microstructural evolution of these buffer layers under different processing conditions, as for example, growth temperature and reaction atmospheres and the modification of the interface quality through post-annealing treatments. We will compare also with our results on vacuum deposited CeO2 buffer layers on RABiTS and IBAD metallic substrates. The microstructure of the samples has been characterized by XRD, SEM, AFM and in-situ Raman measurements. We will also analyze the magnetic field dependence of the critical current and the possible influence of buffer layer microstructure on the pinning forces in YBCO thin films will be discussed. This work has been supported by the European Union through the Growth project SOLSULET (G5RD-CT-2001-05550).


In this meeting we will report on non-vacuum deposition of buffer layers and YBCO superconductor. Electrodeposition process is used for buffer layer deposition of Ir, CeO2, and Y2O3. Both electrodedeposition and physical vapor deposition are used to prepare YBCO superconductor. We choose Ir as buffer layer because of its excellent oxidation and corrosion resistance properties among platinum group elements, and also the lattice mismatch of cubic Ir is very close to that of CeO2 and Ni. Optimization of the growth of the YBCO film, while transferring the biaxial texture from the substrate to the superconductor layer. Important buffer layer characteristics are to prevent metal diffusion from the substrate into the superconductor, as well as, to act as oxygen diffusion barriers. The most commonly used RABiTS architectures consisting of a starting template of biaxially textured Ni-W substrate with a seed layer of Y2O3, a barrier layer of YSZ, and a CeO2 cap. In this three layer architecture, the buffer layers were grown using physical vapor deposition (PVD) techniques. We have developed a low-cost, non-vacuum, chemical solution deposition process to grow highly aligned oxide buffers on textured Ni-W substrates. Using an all solution buffer architecture comprising of La2Zr2O7 and CeO2, we demonstrated the growth of high performance YBCO films with an Ir (critical current) of 140 A/cm-width. This process could potentially decrease the cost of the conduction. We will report in detail about results achieved on all solution buffers. Supported by the U.S. DOE, Division of Materials Sciences, Office of Science, and Office of Electric Transmission and Distribution. The research was performed at the Oak Ridge National Laboratory, managed by UT-Battelle, LLC for the USDOE under contract DE-AC05-00R22725.

11:45 AM • C6.9 Phase Equilibria for Coated-Conductor Research. Winnie Kwai-wah Wong-Ng1, Lawrence Cook1, Zhi Yang2, Igor Levin1, Julia Frank1 and Ron Feenstra2; 1Cermics Division, NIST, Gaithersburg, Maryland; 2Solid State Sciences, ORNL, Oak Ridge, Tennessee; 3Solid State Sciences, ORNL, Oak Ridge, Tennessee.

Continued global research in high Tc superconductors has lead to the promise of a wide variety of industrial applications, including power distribution, energy storage, and advanced motors and magnets. To implement these applications, the availability of coated conductors of large length, and high performance wire/tape and cable is critical. Phase diagrams are commonly regarded as road maps for the optimization of processing. We have focused our efforts on phase equilibria studies of Ba2RCu3O6+x (R=lanthanides and Y) systems under atmospheric-controlled conditions and high temperature conditions. A phase diagram for the Ba2YCu3O6+x system will be discussed. A phase diagram for the Ba2R2Cu3O6+x system will be discussed.

SESSION C7: Recent Advances in RE-123 Film Epitaxy

Thursday Afternoon, March 31, 2005

Room 2000 (Moscone West)
As YBCO-based coated conductor approach the commercialization phase, a few long-standing issues have become prominent, one of which is the rapid decrease in critical current density (Jc) as the coating is grown thicker. This problem creates a "diminishing returns" effect that has generally limited critical current (Ic) for centimeter-wide tapes to a few hundred microamperes at liquid nitrogen temperature. We have analyzed this problem and have developed a simple model for the variation of current density within a thick film that produces excellent agreement with experimental results. One aspect of the model is that Jc is abnormally high near the YBCO-substrate interface - predicts that additional interfaces within the YBCO layer would significantly raise the average Jc of a coating. We have tested this hypothesis by alternately depositing YBCO and thin CeO2 interfaces to create a few hundred nanometer-thick multiple heteroepitaxial interfaces. Our tests used samples with nickel-alloy substrates and a textured MgO coating produced by ion beam asperity formation. This was followed with a SrTiO3 buffer layer and a number of 0.4-0.6 μm YBCO layers separated by ~40 nm CeO2 layers, all layer-deposited. The results were striking: Films with Ic values in excess of 600 A/cm-width (75.4 K, self field) were routinely produced, with many exceeding 1000 A/cm-width. The highest Ic-to-date is 1400 A/cm-width obtained in a coating with six YBCO layers and five CeO2 interlayers having a total thickness of 3.5 μm and a Jc of 4.0 MA/cm2. This achievement demonstrates that thick YBCO films can be produced with the high Jc levels previously only available in thin films, enabling the fabrication of 1000 A/cm tape with much less YBCO than the 5-10 mm thickness that would otherwise be required. The multilayer design itself is scalable to continuous process tape and is expected to result in an order of magnitude enhancement of Jc, with many exceeding 1000 A/cm-width produced, with many exceeding 1000 A/cm-width. 

The composition of the liquid layer is maintained during growth, and the optical properties of the YBCO during growth and the optical properties of the YBCO during growth and the optical properties of the YBCO during growth. FTIR allows us to study the relationship between phase stability, growth morphology, and transport properties. These samples are characterized by XRD and NMR measurements. Further details of the phase stability and growth morphology (supersaturation) are accessed using an ambient controlled X-Ray hot stage. [1] T. Ohnishi, et al., Supercond. Sci. Technol. 17 (2004) 1215-1223. 


2.30 PM C7.4
Ultra-fine Multilayer Structures of YBa2Cu3O7 / 
EuBa2Cu3O8y for Coated Conductors. Terry G. Heegsanger, Quanxi Jin, Paul Dowden, Boris Maiorov and Leonardo Civalle; Los Alamos National Laboratory, Los Alamos, New Mexico.

The use of multilayer structures has been suggested as an approach to further improve the performance of the HTS layer of a coated conductor. A method is described here for the production of ultra-fine multilayer structures by pulsed laser deposition for stationary and moving substrates. Multilayer structures with periods of less than 10 nm have been grown on individual single-crystal and IBAD MgO templates. Continuous processing of ultra-fine multilayers on lengths of IBAD MgO has produced Ic values in excess of 200 A/cm-width.

3:15 PM C7.5
Growth of Thick High Critical Current YBa2Cu3Oy Films by HLPE. Jan Kvetos, Ahmed Kurusmov and Judith MacManus-Driscoll; Materials Science, University of Cambridge, Cambridge, United Kingdom.

A range of hybrid liquid phase epitaxy (HLPE) processes will be described that enable high rate ‘liquid assisted’ growth of epitaxial YBa2Cu3Oy as well as certain other oxide films without the many disadvantages of classical LPE[1]. Since growth occurs by diffusive transport of Y through a liquid flux layer of thickness ~100 nm the problem of an aggressive flux is minimized, also there is no requirement to maintain a precise undercooling and nucleation on multilayer substrates, so a seed layer is essential. The flux layer may be pre-deposited onto the substrate by various means including vacuum and non-vacuum techniques. Many different process configurations are possible and the working window for high Jc films appears to be wide. A range of oxygen partial pressures have been used and deposition has been carried out at both low pressures and atmospheric pressure. The composition of the liquid layer is maintained during growth, and the optical properties of the YBCO during growth. 

The multilayer design itself is scalable to continuous process tape and is expected to result in an order of magnitude enhancement of Jc, with many exceeding 1000 A/cm-width. Films 1-3 micron thick with Jc ~90 K and a transport critical current density Jc > 2 MA/cm2 have been grown on a range of single crystal substrates as well as on high density textured metallic tapes. In this work we have studied growth of transport critical currents as high as 400 A per centimeter width in YBa2Cu3Ox films on RABiTS Ni-alloy tape with NiO/SrTiO3 buffers. XRD and HRTEM studies indicate that the films are highly textured and contain a distribution of epitaxial Y203 pinning particles. Low vacuum deposition, high growth rates and easy composition control with great flexibility in the feeding method are very attractive process characteristics. In addition the process has a high efficiency of material utilization, and thick films can be produced with excellent crystallinity and high critical current densities. These features suggest that HLPE has the potential to be a robust high-rate low-cost process for coated conductor processing. [1] Hybrid liquid phase epitaxy processes for YBa2Cu3O7 films, A. Kurusmov et al., Supercond. Sci. Technol. 17 (2004) 1215-1223.
HF gas behavior in front of the growing YBCO during conversion of oxyfluoride precursor films is known to govern YBCO growth and, therefore, it is quite important to know the mechanism by which the decomposition of oxyfluorides occurs and its effect on the control. The partial pressure of HF gas (P(HF)) in equilibrium with oxyfluoride precursor films and YBCO is influenced by the reaction path and, therefore, the F/ Ba ratio trajectory of the film. The measurement of P(HF) and F/ Ba ratio trajectory are unique and effective macroscopic methods to analyze the mechanism of oxyfluoride decomposition during the conversion process, and they can be compared with results of microanalysis. In this study, the measurement of P(HF) and F/ Ba ratio trajectory are performed during ex situ processing to obtain information about the mechanism of oxyfluoride decomposition. Both MOD derived precursor films and e-beam derived films are analyzed to show the differences caused by the precursor films’ preparation method. The F/ Ba ratio of green MOD derived oxyfluoride precursor films is close to 3 and drops with temperature to ~1.5 below 700°C. On the other hand, green films of e-beam derived precursor show a F/ Ba ratio of about 2. The F/ Ba ratio decreases with temperature; however, the temperature dependence of F/ Ba ratio is quite small and the F/ Ba ratio is still ~1.8 at 700°C. The results of P(HF) measurements indicate oxyfluorides decomposed by e-beam source much slower than MOD derived oxyfluorides. P(HF) values of e-beam derived films are several times smaller than that of MOD derived films under the same conditions. A thermodynamic analysis of the data indicated that experimental free energy of formation values for YBCO matched literature values for the expected formation reaction for YBCO. However, the experimental results are not in agreement with literature values for predicted reactions to form intermediate compounds.

4:15 PM C7.8 Development of High-Ie ex situ YBCO Coated Conductors: Trends in Thickness Dependence, Grain Boundary Networks, and Vortex Pinning. Ron Feenstra1, 2, A. A. Gapud1, E. D. Specht1, C. Cantoni1, A. Ijaduola1, 2, J. R. Thompson1, 2, D. K. Christen1, T. G. Holesinger3, D. M. Felkman4, D. C. Labalet5, A. Palau1, T. Puig1 and X. Obradors1; 1Oak Ridge National Laboratory, Oak Ridge, Tennessee; 2University of Tennessee, Knoxville, Tennessee; 3Los Alamos National Laboratory, Los Alamos, New Mexico; 4Applied Superconductivity Center, University of Wisconsin, Madison, Wisconsin; 5Institut de Ciencia de Materials de Barcelona, CSIC, Bellaterra, Spain.

Ex situ processes based on the post-deposition conversion of precursor layers containing BaF2 are attracting attention worldwide for their possible deployment in YBCO coated conductor production processes. Interesting from a materials science perspective is the fact that, while there exist multiple ways to produce the precursor layer, basic thermodynamic and kinetic features of the ex situ conversion process are invariant of the precursor choice. The YBCO growth mechanism appears to be controlled by transient liquid phase formation, producing highly anisotropic, laminar grain structures with variable densities of pores and secondary phases. This paper presents recent progress in high Ic (77 K) critical current densities (Jc) of over 3 MA/cm² on 10 meter long tapes with an end-to-end critical current (Ic) of 270 A/cm-width have been achieved. Recently, maintaining high current densities at high magnetic fields using enhanced magnetic flux pinning has merited a lot of attention from the community. The most successful amongst the many approaches being studied is the addition of nanoparticles to the YBCO film. Significant enhancements in flux pinning have been reported for in situ YBCO films grown using pulsed laser deposition using this approach. Solution deposition for processing buffer layers and YBCO has the potential to reduce the process complexity and make the conductor fabrication more cost-effective. At Oak Ridge, when coated conductors are much closer to commercialization, an important goal for better performance and lower fabrication costs is to achieve enhanced flux pinning in a practical, cost-effective way in solution processed coated conductors. We have developed an innovative method to synthesize nanoparticles using a solution based approach. This route is compatible with MOD-YBCO synthesis and hence can be used to incorporate pinning centers in MOD-YBCO. Using this approach, we have successfully produced nanoparticles of various rare earth oxides, barium cerium oxide, and barium zirconate. Preliminary XRD and TEM analysis shows that the particle size is typically around 4 nm for the rare earth oxides and barium cerium oxide, and about 10 nm for barium zirconate. Pinning enhancements obtained by using these particles in MOD-YBCO are currently being studied, and the results from these studies will be reported.

Research supported by the Department of Energy, Office of Electric Transmission and Distribution. This research was performed at the Oak Ridge National Laboratory, managed by UT-Battelle, LLC for the USDOE under contract DE-AC05-00OR22725.

SESSION C8: Poster Session

C8.1 In Situ Studies of Phase Evolution in Ba2YCu3Ox Films During the BaF2 Process. Igor Levin1, Winnie Wong-Ng2, Mark Vaudin1, Lawrence Cook1, Ron Feenstra2 and Amit Goyal2; 1NIST, Gaithersburg, Maryland; 2Solid State Division, ONR, Oak Ridge, Tennessee.

The “BaF2 ex situ process” has demonstrated the potential for producing high quality long Ba2YCu3Ox (Y-213) superconductors. This process involves post-annealing in the vapor phase of either e-beam co-evaporated or open-air solution processed BaF2-Y-Cu precursor films on rolling-assisted biaxially textured metal substrates (RABITS). Despite the commercial potential of the “BaF2 ex situ process”, the phase evolution upon formation of the Y-213 phase in the multi-component Ba-Y-Cu-O-F-OH system is not completely understood. In this work, we used high temperature X-ray diffraction (HTXRD) to follow the phase formation during the BaF2-precursor process in situ. The studies were conducted using the amorphous precursor BaF2-Y-Cu films as well as the films representing the subsistems. The films were prepared using either the three-source e-beam evaporation or the TFA solution process. The HTXRD experiments were complemented by transmission electron microscopy studies of the samples quenched from the different stages of the process to further analyze the nature of the intermediate phases. The current understanding of the phase evolution process upon formation...
of the Y-213 phase from amorphous precursor films will be discussed.

C8.2 Structural Properties of YBa2Cu3O7·5 nm Films on SrTiO3 Single Crystal and Bi-crystal Substrates.
Maria Angeles Navacerrada1,3, Mehta Apurva1, Hizamu Sahibudeen2 and Juana A. Vivo Arruebo1, Applied Physics, Complutense University, Madrid, Spain; 2Center for Materials Science and Engineering, San Jose State University, San Jose, California; 3Stanford Synchrotron Radiation Laboratory, Stanford University, Stanford, California.

Since discovery of superconductivity in the oxide system YBa2Cu3O7·5 (YBCO) there has been a surge of interest in the growth of thin films of this material on different kind of substrates. We present a comparison of some properties of structures fabricated on X-ray diffraction diagrams between YBCO thin films fabricated on SrTiO3 (STO) single crystal substrates and bicrystalline substrates with a symmetrical tilt angle of 24 degrees. YBCO thin films were epitaxially grown by high pressure hot pressing and by PLD method. Critical temperatures (TC) are in the range of 89.5 - 91 K. The experiments have been carried out at room temperature at the station 7.2 of Stanford Synchrotron Radiation Laboratory (SSRL). Periodic Lattice Distortions (PLD) have been found around several Bragg peaks in YBCO thin films deposited on STO bicrystals while only diffraction peaks appear in the diagrams corresponding to the YBCO thin films deposited on STO single crystal substrates. The PLD may be associated with the 2° lattice mismatch between the YBCO and the STO substrate, but since the PLD are not observed in the YBCO thin films deposited on STO single crystal substrates they may be associated with the distortion induced by the GB of the YBCO thin film deposited on the bicrystal. Transmission electron microscopy measurements show that interatomic distances and relative positions of atoms, are changed by strain in the vicinity of the GB. This results in a change of the bond lengths, valence atoms and the number of charge carrier present in the grain boundary. Oxygen atoms have especially large displacements and a non-superconducting region enveloping the crystallographic GB is generated. The maximal displacements are in the atomic plane next to the geometric plane of the GB and it is not clear how this changes away from this plane. A small amount of twinning could be necessary to reduce the elastic energy associated to the GB. In this sense, qPLD would be associated to a long-range modulation induced in the YBCO thin film by the GB. Typical twinning directions in this material are in the (110) and (11-1) directions to accommodate the strain energy (of tetragonal, probably present in the GB region of YBCO thin film to orthorhombic phase). The small value of qPLD suggests it may not be detectable in TEM experiments. Thus XAS and XRD measurements in films showing this qPLD versus distance from the grain boundary is necessary for better understanding the PLD and their effect on transport applications.

C8.3 Transport Properties of Ca2ZrO3-Doped YBa2Cu3Oy Films.
Noel Rutter, John Durrell, Mark Hamline and Judith MacManus-Driscoll, Dept. of Materials Science, University of Cambridge, Cambridge, United Kingdom.

We have doped YBCO films with CaZrO3 in order to study the effects on the inter-granular and intra-granular critical current densities. Films deposited by PLD from a doped target have a significantly reduced critical temperature. In an attempt to improve the properties, we have varied the oxygen partial pressure during initial oxygenation in order to lower the oxygen content. Additionally, we have post-annealed the films in a low oxygen atmosphere. We report the transport properties of these films as a function of temperature, magnetic field and field orientation. We do not observe the effects obtained when the CaZrO3 is diffused in from an overlay rather than being dispersed throughout the bulk.

C8.4 Characterizing Superconducting Thin Films in Terms of the Microwave Surface Resistance. Pelling Wu, University of Nanjing, Research Institute of Superconductor Electronics, Nanjing, China.

High temperature superconducting thin films are excellent materials based on which many passive microwave devices (such as filters, resonators, etc.) of outstanding performance can be made. For such applications it is crucial for the thin films to have surface resistance as low as possible. Experimentally many schemes have been devised to measure the surface resistance, while theoretically we can calculate the resistance at the surface of the thin film, the resistance at the interface between the thin film and the substrate, and the resistance of a bulk superconductor sample. Taking YBaCuO high temperature superconductor as an example, we can carry out studies on the relationship between the measured surface resistance and other resistances mentioned above. For various values of the film thickness, the operating frequencies and the substrate parameters, we show that the relationship is nonlinear. These effects should be taken into consideration in characterizing superconducting thin films as well as in designing passive microwave devices based on them.

C8.5 Thickness Dependence of Critical Current, Ic, in PLD-YBCO Coated Conductor on PLD-CeO2/IBAD-GZO Buffered Substrate.
Ajata Liu1, Kenjiro Falakzadeh2, Masaya Komatsu3, Takemi Muroga3, Seiki Miyata4, Torenori Watanabe4, Yutaka Yamada5 and Yuh Shiookara2, 1ISTEC-SRL, Nagoya Coated Conductor Center, Nagoya, 2ISTEC-SRL Division of Superconducting Tapes & Wires, Tokyo.

Critical current, Ic, of YBa2Cu3O7·5(YBCO) coated conductor by ion-beam assisted deposition (IBAD) substrates and pulsed laser deposition (PLD) method has been improved in several institutes. Nevertheless, further high Ic is required for the industrialization. To obtain high Ic, it is necessary to increase the YBCO thickness. However, Ic saturates at a certain YBCO thickness, which is called critical thickness. It is important to investigate the cause of critical thickness for the fabrication of YBCO coated conductor with high Ic. Moreover, we found a new epitaxy phenomenon of PLD-CeO2, called the self-epitaxy which is effective to obtain a good in-plane texturing. The so-called microstructural epitaxy can be used to reveal the properties of YBCO coated conductor on the self-epitaxial PLD-CeO2 / IBAD-GZO buffered substrates is not yet investigated in detail. Therefore, we have investigated the delta phi, Ra value, the amount of exact (a,b)-axis oriented crystals, and Ic value of YBCO coated conductor on this buffered substrate by PLD method. For the sample with the in-plane alignment of 18° of delta phi of CeO2 cap layer, the Ic is 67.1 A/cm-width at about 2.0μm and the critical thickness is about 1.0μm. The other hand, for the sample with the in-plane alignment of 4° of delta phi of CeO2 cap layer, the Ic is 177.2 A/cm-width at about 2.0μm and the critical thickness is about 2.0μm. Namely, a high degree of in-plane texturing enhanced a critical thickness and thus a good in-plane texturing of substrate is required to obtain thick YBCO coated conductor with high Ic. However, Ic saturated over the critical thickness of YBCO. Ra value of YBCO increased with increasing YBCO thickness, and the ratio of a-axis oriented crystals was increased drastically over the critical thickness. From these results, the YBCO thickness increased, the surface morphology became much rougher. This was considered to be attributed to the surface temperature decrease of the YBCO with increasing the thickness and then the amount of the a-axis oriented crystals in the YBCO was increased. To solve this problem, we fabricated YBCO by multi-layer deposition, which was carried out at differentTexts calculations temperatures and kept YBCO surface temperature constant with the increase in YBCO thickness. The YBCO 0.1μm in thickness was deposited in each deposition using Reel to Reel system. The first to third YBCO layer was deposited at a same setting temperature (840°C), then setting temperature was increased to a higher temperature of 840°C for 4 and 5th deposition. This process increased Ic from 27.2 to 44.6 A/cm-width. Thus, for the fabrication of thick YBCO coated conductor with high Ic, it was proved that multi-layer deposition was effective. This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) as the Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications. 


An increasing number of applications of the 123-type high-Tc superconductors use materials other than Y. For example, in many bulk forms and multilayer applications, Y is replaced by Nd, Sm, or other rare-earth elements (RE). Although a nice trend of Tc, in RE-123 superconductors has been revealed by Lin et al in 1995, the detailed studies at microscopic scale is missing due to complexity in both geometry and electronic structures. In addition, the variation of Tc, in RE-123 is fairly small (between 87K and 95K). This motivates us to perform systematic studies on the trend of the critical temperature Tc, due to both Madelung site potential differences and other resistances mentioned above. For various values of the film thickness, the operating frequencies and the substrate parameters, we show that the relationship is nonlinear. These effects should be taken into consideration in characterizing superconducting thin films as well as in designing passive microwave devices based on them.
The coherent interlayer single particle tunneling parameter $t_x$ has more profound effect than $t_y$ on the overall AMR behavior as a function of rare-earth ionic radius. These results reveal the importance of electronic origin of the rare-earth ionic size effect on $t_x$ in this family of bilayer cuprates.

C8.7
Discrete Fluxoid Dynamics Model. Masato Hiratani and Vasily V. Bulatov: CMS/MSTD, Lawrence Livermore National Laboratory, Livermore, California.

The study of stability of the fluxoid system is essential to predict and control the critical current of type II superconductors. In this work, a discrete computational model is developed to investigate 2D and 3D fluxoid dynamics. While physical properties of individual fluxoids are relatively clear, collective behaviors of fluxoids are so complex due to random thermal noise, interactions with local quenched disorders and other fluxoids, the AC/DC applied forces, and dissipations. Fluxoids are discretized as nodes and interconnected as edges. Interactive forces between links are evaluated in pair manner (N-square terms) assuming the superposition of interactive forces. Draped by this model is a question of density of quasi-electrons. Preliminary results indicate that there is a cross-over of fluxoid behavior from avalanche-like motion to smooth viscous motion as the applied force increases. Simulation results of a single and many fluxoid systems in low superconductors at different temperatures, magnetic fields, and pinning strengths will be presented. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

C8.8
Critical Current Anisotropy in Nano-Structured Superconductors. Heo Durlen1, Noel A. Rutter1, Boris Maiorov2, Haiyan Wang3, Steve Foltyn4, Leonardo Civale5, Jia E. Evett1, Mark G. Blamire1 and Judith Driscoll1; 1 Materials Science and Metallurgy, University of Cambridge, Cambridge, United Kingdom; 2 Superconductivity Technology Centre, Los Alamos National Laboratory, Los Alamos, New Mexico.

In order to properly characterise the magnetic field dependence of the critical current in a superconductor measurements of the critical current need to be carried out over the whole angular range of field. Such an approach, which requires a two-axis goniometer, allows effects which are otherwise obscured by the symmetry of the measurement system to be observed. Examples of this include intrinsic flux channelling in off-axis superconductors and the grain boundary in-grain critical current transition at grain boundaries in YBa2Cu3O7-δ. We present measurements on examples of the new generation of high- Tc superconductors at different temperatures, magnetic fields, and pinning strengths will be presented. This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

C8.9
Matching Field Effect in the Critical Current of YBa2Cu3O7 Films due to Periodic Y2BaCuO5 Inclusions. Boris A. Maiorov1, Timothy Haugan2, Terry G. Holiesinger1, Paul N. Barnes3 and Leonardo Civale1; 1 Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, New Mexico; 2 Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio.

The introduction of artificially engineered extended defects is one of the most promising ways of increasing the critical current density ($J_c$) in YBa2Cu3O7 (YBCO) films. We present measurements as a function of magnetic field ($H$) and orientation for YBCO films grown on single crystal LaAlO3 with periodic Y2BaCuO5 (211) inclusions, that have been introduced into the YBCO in a layered fashion. The 211 inclusions induce a systematic increase of $J_c$ for almost the whole angular and magnetic field range. In particular, for what concerns broad-band photon detection, the 211 films have been fabricated on top of the in – field power-law-decay exponent $\alpha$, with values as low as $\alpha=0.30$ as compared to $\alpha = 0.55$ for YBCO films without 211 particles. For $H$ orientations near the ab-planes, the 211 inclusions induce a monotonic effect on $J_c$. For low particle density, the ab-peak decreases, but further increase in the 211 density results in a continuous enhancement of the ab-peak. The periodic distribution of the 211 inclusions give an additional increase in $J_c$ for $H \parallel ab$ when $H \parallel a$. On the other hand, $B* (\parallel ab)$ is equal to the matching field for 211 films. This situation when the separation between vortex rows coincide with the distance (5-6) between the equidistant planes that contain the 211 inclusions. Measurements performed in samples with different 211 content and the spread in the contact dependence for $B* (\parallel ab)$, also, the values found for $B* (\parallel ab)$ are temperature independent. These two finding are fingerprints of a geometrical matching. This creates the possibility to increase $J_c$ at a particular desired field by tuning a particular $B*$ through controlling the 211 density.

C8.10
Magnetic Field Dependence of Critical Current Density of PLD RE-Ba-Cu-O(RE=Er,Dy,Gd,Y) Film on CeO2 Capped IBAD-GZO Layers. Karuhiro Takahashi1, Masaya Konishi2, Tomonori Watanabe3, Akira Ibi1, Takumi Muroga1, Seiki Miyata2, Yutaka Yamada1 and Yuh Shiohara2; 1 Nagoya Coated Conductor Center, ISTEC-Superconductivity Research Laboratory, Nagoya, Japan; 2Division Of Superconducting Tape and Wire, ISTEC-Superconductivity Research Laboratory, Tokyo, Japan.

Magnetic field dependence of critical current density is very important for both practical applications and understandings of the current limitation mechanism of high-$T_c$ oxide superconducting materials. In order to investigate the magnetic field dependence of critical current density, we prepared samples of RE-Ba-Cu-O (RE=Eu, Dy, Gd, Y) films with various thicknesses using pulsed laser deposition (PLD) method on CeO2/Ion-Beam Assisted Deposition (IBAD)-Gd-Zr-oxide(GZO) layer deposited on Hastelloy substrates. The RE-Ba-Cu-O(RE=Er,Dy,Gd) films were deposited for fixed substrates. The thickness of the films was estimated from the laser repetition rate and the deposition time. Y-Ba-Cu-O films were grown using multi-plume continuous PLD. The thickness was changed by the number of the deposition time. We measured the magnetic field B dependence of the critical current $J_c$ measured by the conventional four-probe method in the magnetic fields up to 8T and compared those characteristics. In the GD-Ba-Cu-O films, $J_c$ less decreased with increasing the magnetic fields than Y-Ba-Cu-O films. This tendency was particularly clear over 5T magnetic field perpendicular to the film surface. For example, the $J_c$ value of GD-Ba-Cu-O film was 28000A/cm2 at 7K in 6T magnetic field. This value of GD-Ba-Cu-O film showed about 10 times as large as the $J_c$ value of Y-Ba-Cu-O film. This result indicates that GD-Ba-Cu-O film on a CeO2/IBAD-GZO layer buffered Hastelloy substrate has an applicability for the use in high magnetic fields. This work is supported by New Energy and Industrial Technology Development Organization (NEDO) as Collaborative Research and Development of Fundamental Technologies for Superconductor Applications.

C8.11
Growth and Characterization of Si/YSZ/CoO/YBCO for Broad-Band Photon Detection. Bruno Minetti1,2,3, Angelica Chiodone1,2,3, Carlo Camerlingo1,2, Fabio Fabbrini2, Laura Gazzello1,2, Francesco Lucignano1,2,3, Candido F. Piria1,2, Giuseppe Rombola1,2,3, Grazia Tallarida2, Elena Tresso1,2 and Enrico Mezzetti1,2,3; 1 Dept. of Physics, Politecnico di Torino, Torino, Italy; 2 I.N.F.M. UdR Torino Politecnico, Torino, Italy; 3 I.N.F.P. Sez. Torino, Torino, Italy; 4C.N.R. Istituto di Geofisica, Pisa (NA), Italy; 5I.N.F.M.-Laboratorio MDM, Agraete Branzola (MI), Italy; 6ENEA, Frascati (Roma), Italy.

The possibility to take advantage of different materials features to implement hybrid devices for different applications was up to now an important goal. The integration between superconducting films and silicon is challenging because in such hybrid devices the unique properties of superconducting electronics would be exploited at best. In particular, for what concerns broad-band photon detection, the YBa2Cu3O7-δ (YBCO) is very appealing due to the wide superconducting gap. Furthermore, the characteristic features of the R vs. T curves, the quasi-particles created at low temperature and dc the transport measurements, in particular R vs. T curves at different bias currents, and E vs. J characteristics at different temperatures. We investigated also the behaviour of pinning energy as...
a function of current density at different temperatures. The structural characteristics (not optimised yet) explain the quite wide R vs. T transitions. However, it turns out that in the low temperature regime, the E-J characteristics exhibits transitions from under-critical state to over-critical state sharp enough to be considered in the framework of applications centred on photon detection. Further optimisations are in progress. The issue of the read-out of the voltage signals is also addressed and some new solutions are proposed.


C8.12 Transport Properties of YBa2Cu3O7-O Coated Conductors: Grain Boundary and Grain Vortices Behaviour.

Joffre Gutierrez Royo1, Anna Palau1, Teresa Puig2, Xavier Obradors1, Laura Fernandez3, Bernardo Holzapfel4, Alexander Usakina5 and Herbert Freyhardt5; 1Materials Magneticos y Superconductores, ICAMAB-CSIC, Barcelona, Barcelona, Spain; 2HFW, Dresden, Germany; 2Zentrum fuer Funktional Kristalle, Goettingen, Germany.

Nowadays YBa2Cu3O7-O coated conductors are the most promising superconducting materials for power applications (cables, fault current limiters, motor etc.) and their performances are reaching their expected limits. However, Magneto-optic flux imaging and critical transport measurements have demonstrated the percolative nature of the supercurrent flow through their low angle grain boundaries (LAGBs). The effects derived from the granular character of these materials has become crucial for the understanding of the transport mechanisms. In this work we present an study of the transport properties of RABIT and IBAD YBa2Cu3O7-O coated conductors compared with results obtained on YBa2Cu3O7-O single crystals grown by standard techniques. Recent calculations show a dependence of Jc (11 T) and high fields (9T), Jc angular dependence and irreversibility line will be presented. The differences found between the systems are interpreted in terms of the different vortex pinning mechanisms with the LAGBs. The magnetic hysteresis found at low magnetic fields in transport measurements is compared with those previously observed by dc-magnetization measurements[1]. The analysis is envisaged to sort out granularity effects from vortex pinning effects on coated conductors. [1]: A.Palau et al, Appl. Phys. Lett. 80, 84, (2004)

C8.13 AC Losses in High-Tc Superconductors with Finite Thickness. Masaaki Kenjiro and M. Mustafa; Physics, UAE University, Al-Ain, United Arab Emirates.

The structure and dynamics of magnetic vortices in high-Tc superconductors are studied. The model we use is applicable to highly anisotropic high-Tc superconductors, such as Bi and Th compounds, where the Josephson coupling is between the superconducting layers. The motion of the vortex lattice under the effect of an applied current causes dissipation. In this paper, we studied the AC losses occurring in a finite number of superconducting layers due to an applied AC current. It is found that the AC losses increase with the frequency and the amplitude of the applied current. To see the effect of pinning on the ac losses, we introduce randomly pinning centers in the layers. The effect of pinning on the ac losses is clear from the calculations.

C8.14 Progress on Control of Y2O3 Nano-Isoins Density in Order to Induce Artificial Grain Formation in YBCO Thin Films. Paolo Male1,2,3, Kunsan Matsumoto1,2, Tomoya Horibe1,2, Osuke Miura2,3, Aituru Ichinose1,2, Masakazu Mukaida4,5, Yukata Yoshida1,5 and Shigeru Horii1,5; 1Material Science and Engineering, Kyoto University, Kyoto, Japan; 2Electrical Engineering, Tokyo Metropolitan University, Tokyo, Japan; 3CREJEP, Nagasaki, Japan; 4Yamagata University, Yamagata, Japan; 5Nagoya University, Nagoya, Japan; 6University of Tokyo, Tokyo, Japan; 7DCCL, University of Genova and INFN, Genova, Italy; 8CREST-JST, Saitama, Japan.

For wide applications of YBa2Cu3O7-0 (YBCO) high-temperature superconductors, effective devices it is necessary to obtain high high-current critical density Jc at the liquid nitrogen temperature and under magnetic fields. With this purpose, we introduced high-density columnar defects as artificial pinning centers (APCs) of the quantized vortices into YBCO films, during the film deposition procedure. APCs were introduced perpendicular to the film surface by using the distributed nano-sized Y2O3 islands prepared on SrTiO3(100) substrates. Varying the deposition and annealing conditions it is possible to control the density of the Y2O3 islands. The highest Y2O3 islands density (228 mm-2) was obtained with fifteen laser pulses heating the SrTiO3 substrate at 800 °C, then annealing in flowing oxygen at the same temperature. With a lower number of pulses the formation of nano-islands was not observed, while after a larger number the nano-islands tend to coalesce and their density decreases (45 mm-2 with thirty pulses). Keeping fifteen laser pulses and lowering the deposition temperature the density of the nano-islands becomes lower (13 mm-2 at 500 °C, 28 mm-2 at 700 °C, both annealed at 800 °C). If the annealing temperature of samples prepared with fifteen pulses at 800 °C changes, the islands density becomes lower even lower with temperature (700 °C) and higher (50 mm-2 with 900 °C) than 800 °C. After the island formation, PLD YBCO films are grown on the Y2O3/SrTiO3 substrates. In order to clarify the correlation between the densities of islands and of the APCs, the as-grown YBCO films were studied by wet-chemical technique. The etch pits demonstrate the presence of screw dislocations inside the YBCO grains. A first comparison reveals that the density of dislocations is only 1/3 of the density of islands. It seems reasonable that controlling the island size it will be possible to increase the fraction of islands with an effective size to induce APCs.

C8.15 Ca Doped YBa2Cu3O7-Thin Films. Sripravate Sathirapongsasuti1,2, Andrew D. Chaney1 and Paul N. Barnes1; 1National Research Council, PRPG, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio; 2Propulsion Research and Power Management, Air Force Research Laboratory, Wright Patterson Air Force Base, Ohio; 3Propulsion Research and Power Management, Air Force Research Laboratory, Wright Patterson Air Force Base, Ohio.

Recently our group has reported a new process for achieving a controlled dispersion of nanoparticles of YBa2Cu3O7 (211) in YBa2Cu3O7-δ (YBCO) thin films with the necessary particulate nanosize and high density [1]. In this paper we report the studies on Ca doped 211 nanoparticles. Y2-xCaxBaCuO4 (where x = 0, 0.1 and 0.2) targets were prepared using standard solid state route. Magnetisation studies have shown that x = 0 has relatively better pinning properties than Ca doped 211 particulates when prepared under some deposition conditions although studies are needed for improvement of intergranular current densities was inconclusive. To better understand the nature Ca doped 211 nanoparticles, we have deposited Ca doped 211 thin films on LAO and SrTiO3 single crystal substrates and noticed that when x = 0.2, the films are superconducting below 77K. X-ray pattern show 211 peaks as well as peaks similar to c-axis oriented YBCO indicating the potential of minor phase separation in the processed material. The structural and microstructural properties of Y1-xCaOxCa2Cu3O7 films will be presented and discussed. [1] T. Haugan, P.N. Barnes, R. Wheeler, F. Meisenkothen, and M. Sumpton, Nature 430,867 (2004).

C8.16 Enhancement of Flux Pinning in YBCO Coated Conductors via Processing-Induced Nanostructures. Albert A. Gapud1, Roeland Feenstra1, Amit Goyal1, Claudia Cantoni1, Tolga Aytag2, Mariappan Paras Paranthaman3, Sukil Kang4, Keith J. Leonard5, Terry C. Holesinger5, Mariappan Paranthan1an1, Sukil Kang1, Keith J. Leonard1, David K. Christen1, Mariappan Paranthan1an1, Sukil Kang1, Keith J. Leonard1, Dhananjay Kumar2 and James R. Thompson3,1; 1Oak Ridge National Laboratory, Oak Ridge, Tennessee; 2North Carolina A & T State University, Greensboro, North Carolina; 3Los Alamos National Laboratory, Los Alamos, New Mexico; 4University of Tennessee, Knoxville, Tennessee.

In developing high-temperature-superconductor(HTS)-coated conductors for motor applications, there is great interest in improving the critical current density Jc at temperatures ~ 30 K, in fields ~ 2 T, and at different orientations of field relative to the c axis. Several groups have pursued this by modifying the HTS-film processing to induce nanostructures into the superconducting layer with the purpose of improving flux pinning (via the nanostructures themselves or strains and/or defects that they may induce). In this work we examine the structures that promote flux pinning in various films on RABITECH: (1) exist free-standing films with Y211 nanoparticles which show an improvement in the uniformity of the angular dependence of Jc; (2) films processed by pulsed-laser deposition (PLD) with self-organized nano-inclusions of BaZrO3 which show a strong Jc enhancement, (c direction); and (2) as "frosted" with nano-islands of various compositions. For each case we report significant improvement of Jc, at target conditions, in terms of (1) in-field enhancement, (2) improvement in self-field, and (3) more uniform Jc, with respect to 0. With careful scaling analysis, that the pinning is highly correlated. There is also an interesting scaling relation that is common to these films between Jc(2 T, 30 K) and self-field Jc at 77 K, which may prove useful as
benchmark for suitability in motor applications, as will be discussed.

Introducing; means of calculating total AC loss. The calculated values by several models are compared with the demonstrated in pulsed laser deposited YBCO films with insulating characteristics. A challenge to reduce the AC loss in a perpendicular orientation is demonstrated using non-twisted multifilamentary YBCO coated conductors that act as flux pinning centers. Significant improvements were observed in the films which are not deposited in a layered fashion may be desired to avoid any preference for a given magnetic field orientation. This is especially relevant since in superconducting coil applications, the magnetic field will be present at a variety of angles to the coils. To determine the differences between the layered-inclusion of particulates and controlled random inclusion of particulates, a special pulsed laser ablation YBCO target with a Y2BaCu1O5 (Y211) sector was made and used to form YBCO films with Y211 particulates. By selecting a proper laser scanning sequence, desired amounts of Y211 particles were introduced randomly in the growing YBCO films. This technique allows separation of the respective constituents for a more controlled introduction of random non-layered particulates. Initial results show that YBCO films without particulates can be grown with critical current density > 3MA/cm² at 77K in self-field using this kind of target. Other results such as microstructure, magnetization Jc, etc. will be presented and comparison to the layered structure will be given.

SESSION C9. Multiscale Characterization of YBCO Films
Chairs: Leonardo Civale and Kansame Matsumoto
Friday Morning, April 1, 2005
Room 2000 (Moscone West)

Chakrapani Varanasi1,2, Barnes N. Paul1, Timothy J. Hoggan1 and Srinivas Sathiraju2,3; Metals and Ceramics, University of Dayton Research Institute, Dayton, Ohio; 1PPC, Wright-Patterson AFB, Ohio; 2National Research Council, AFRF, Wright-Patterson, AFB, Ohio.

Introduction of flux pinning centers into bulk YBa2Cu3O7–δ (YBCO) is widely known to improve the critical current density (Jc) significantly. Approaches to obtain similar enhancements in YBCO films that are used in coated conductor applications are presently looked at by several research groups in incorporating particulates that act as flux pinning centers. Significant improvements were demonstrated in pulsed laser deposited YBCO films with insulating particulate pseudo-layers by our group. The films, processed in this manner with pinning centers arranged in a laminar fashion, allow structured pinning centers with directional dependence of critical current density, controlled by the separation of the particulate pseudo-layers. However, a random distribution of pinning centers in the films which are not deposited in a layered fashion may be desired to avoid any preference for a given magnetic field orientation. This is especially relevant since in superconducting coil applications, the magnetic field will be present at a variety of angles to the coils. To determine the differences between the layered-inclusion of particulates and controlled random inclusion of particulates, a special pulsed laser ablation YBCO target with a Y2BaCu1O5 (Y211) sector was made and used to form YBCO films with Y211 particulates. By selecting a proper laser scanning sequence, desired amounts of Y211 particles were introduced randomly in the growing YBCO films. This technique allows separation of the respective constituents for a more controlled introduction of random non-layered particulates. Initial results show that YBCO films without particulates can be grown with critical current density > 3MA/cm² at 77K in self-field using this kind of target. Other results such as microstructure, magnetization Jc, etc. will be presented and comparison to the layered structure will be given.

SESSION C9. Multiscale Characterization of YBCO Films
Chairs: Leonardo Civale and Kansame Matsumoto
Friday Morning, April 1, 2005
Room 2000 (Moscone West)

Chakrapani Varanasi1,2, Barnes N. Paul1, Timothy J. Hoggan1 and Srinivas Sathiraju2,3; Metals and Ceramics, University of Dayton Research Institute, Dayton, Ohio; 1PPC, Wright-Patterson AFB, Ohio; 2National Research Council, AFRF, Wright-Patterson, AFB, Ohio.

Introduction of flux pinning centers into bulk YBa2Cu3O7–δ (YBCO) is widely known to improve the critical current density (Jc) significantly. Approaches to obtain similar enhancements in YBCO films that are used in coated conductor applications are presently looked at by several research groups in incorporating particulates that act as flux pinning centers. Significant improvements were demonstrated in pulsed laser deposited YBCO films with insulating particulate pseudo-layers by our group. The films, processed in this manner with pinning centers arranged in a laminar fashion, allow structured pinning centers with directional dependence of critical current density, controlled by the separation of the particulate pseudo-layers. However, a random distribution of pinning centers in the films which are not deposited in a layered fashion may be desired to avoid any preference for a given magnetic field orientation. This is especially relevant since in superconducting coil applications, the magnetic field will be present at a variety of angles to the coils. To determine the differences between the layered-inclusion of particulates and controlled random inclusion of particulates, a special pulsed laser ablation YBCO target with a Y2BaCu1O5 (Y211) sector was made and used to form YBCO films with Y211 particulates. By selecting a proper laser scanning sequence, desired amounts of Y211 particles were introduced randomly in the growing YBCO films. This technique allows separation of the respective constituents for a more controlled introduction of random non-layered particulates. Initial results show that YBCO films without particulates can be grown with critical current density > 3MA/cm² at 77K in self-field using this kind of target. Other results such as microstructure, magnetization Jc, etc. will be presented and comparison to the layered structure will be given.

SESSION C9. Multiscale Characterization of YBCO Films
Chairs: Leonardo Civale and Kansame Matsumoto
Friday Morning, April 1, 2005
Room 2000 (Moscone West)

8:30 AM *C9.1
AC Loss Characteristics of YBCO Coated Conductors.
Naoyuki Amemiya, Department of Electrical and Computer Engineering, Yokohama National University, Yokohama, Japan.

YBCO coated conductors are being considered the next generation high Tc superconductors. Since many electrical devices are operated with alternating current, AC loss reduction and its estimation are important issues for achieving practical electrical devices using high Tc superconductors. They are particularly crucial for YBCO coated conductors, because a large AC loss is generated in wide YBCO coated conductors carrying normal or superconducting current. The author has been studying the AC loss characteristics of YBCO coated conductors experimentally and numerically: the AC loss of YBCO coated conductors has been measured using an AC loss measurement system, and the temporal evolution of electromagnetic field in YBCO coated conductors has been calculated numerically to evaluate the AC loss using several in-house codes based on the finite element method. In this presentation, the AC loss characteristics of YBCO coated conductors are reviewed. First, the author presents the AC loss characteristics of single YBCO coated conductors with conventional monolayer of YBCO on metal substrate. The presented data include the measured and calculated total AC loss in YBCO coated conductors carrying normal and superconducting current in an AC external magnetic field. The calculated values by several models are compared with the measured values to validate the numerical modelings. Conductor width, critical current, critical current density profile across the width of conductors, etc. are varied to study their influences on AC loss characteristics. A challenge to reduce the AC loss in a perpendicular magnetic field is the application of multifilamentary structure to YBCO layer. Actually, a substantial AC loss reduction was demonstrated in twisted multifilamentary YBCO coated conductor samples with finite-length L. They simulated the twisted multifilamentary YBCO coated conductors with pitch 2L. These samples were prepared by striating Ag and YBCO layers using a laser ablation technique at the next step. The calculation of AC loss reduction in twisted multifilamentary YBCO coated conductors is expected. A numerical model to simulate the electromagnetic phenomena in a multifilamentary YBCO coated conductor has been developed. Using this model, we found that coupling time constants of very thin multifilamentary YBCO coated conductors are rather small. Calculated AC losses in various multifilamentary YBCO coated conductors are presented to scale the AC loss with various conductor parameters. The whole AC loss of a winding or a cable composed of YBCO coated conductors can be estimated by integrating the AC loss of single conductors. With this approach, a method to evaluate the whole AC loss of a winding or a cable is presented finally. This presentation reviews in part the work supported by METI & NEDO and in part the work supported by AFSOR.

9:00 AM C9.2
1Naval Surface Warfare Center, Bethesda, Maryland; 2MIT Lincoln Laboratory, Lexington, Massachusetts.

The nonlinear Meissner effect (NLME) describes the dependence of the magnetic field. Although on magnetic field orientation. An important question is whether the NLME is a source of nonlinearities such as intermodulation distortion (IMD), which can be detrimental in microwave devices such as bandpass filters. Although the d-wave symmetry of the order parameter in the cuprates leads at low temperatures, and 3) a nonmonotonic slope of the dependence of intermodulation power on the circulating current. We compare the calculations with our recently reported measurements of the temperature and power dependence of the NLME in high-quality YBCO films. We use measurements of the IMD power to extract the nonlinear penetration depth. These predictions, which involve only measurable parameters such as the London (linear) penetration length and lattice constant, agree very well with existing data. This agreement lends credence to the assertion that the observed nonlinearity in high-quality YBCO films is of intrinsic origin and is important implications for practical HTS passive microwave devices.

9:15 AM C9.3
1Code 6361, Naval Research Laboratory, Washington, District of Columbia; 2University of South Florida, Tampa, Florida; 3Geocenters, Lanham, Maryland.

The successful application of superconductivity to motors and power system components depends on several factors. One of these involves characterization and minimization of the AC loss in the superconductor used for fabrication of the component. The sensitivity of these measurements of AC loss has been able to measure AC loss with much improved sensitivity. We report on measurements of AC loss of several YBaCuO tape-shaped coated conductor HTS wires immersed in liquid nitrogen.

9:30 AM C9.4
Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, New Mexico.

The successful application of a high temperature superconductor is dependent on both its ability to carry large critical current, Ic, and to remain undamaged if the critical current is exceeded, e.g. under fault conditions. Coated conductors fabricated in Los Alamos consist of a polycrystalline nickel alloy substrate 1 cm wide, a template layer of MgO produced by ion beam assisted deposition (IBAD), one or more buffer layers, a Yttrium Barium Copper Oxide layer produced by pulsed laser deposition, and a silver overcoat. To protect the coated conductor in the event of currents in excess of Ic being carried we have developed copper with current carrying capabilities as a current stabilizing layer on the silver overcoat. Ics of the coated conductor samples were characterized as a function of position and magnetic field before and after the electropolishing process. Results show a slight (few percent) decrease in Ic after the electropolishing.
process. The self-field \( I_c \) values of the samples using a microtome criterion were greater than 200 amperes and the samples had critical current densities greater than 1 MA/cm² at 77 K. In an experiment during which the current in a stabilized conductor was ramped past \( I_c \) to the point of sample destruction, good power law behavior was observed for low voltage levels (\( V<150 \) microvolts), with fitted power law exponents that varied near 30. At higher voltages, the in value decreased to a near linear voltage response as an increasingly larger fraction of current was being carried by the copper stabilizer layer. Eventually the current was increased to the point where heating became large enough for the conductor temperature to increase. The cooling ability of the liquid nitrogen bath and the sample was destroyed at a current of 550 amperes and 2-5 times \( I_c \). We present these results and discuss stabilized conductor performance and applications. As a function of current stabilizer thickness, one or two sided coatings, and as a function of magnetic field.

10:15 AM *C9.5 Phase Separation and Lattice Disorder in YBCO Films on Coated Conductor Substrates. Victor A. Maroni1, Beihai Ma1, Quanxi Jia2 and Jodi Reeves2; 1Argonne National Laboratory, Argonne, Illinois; 2Los Alamos National Laboratory, Los Alamos, New Mexico; 2SuperPower, Inc., Schenectady, New York.

The occurrence of phase separation and lattice atom reordering in YBa$_2$Cu$_3$O$_{7-\delta}$ (YBCO) materials (thin films, thick films, textured bulk structures, and polycrystalline solids) has been known for well over a decade. At least four crystalline morphologies, Ortho-I (O-I), Ortho-II (O-II), tetragonal (T), and tetragonal-prime (T'), have been identified and have been found to coexist in a variety of embodiments. Lattice atom ordering effects occur in numerous ways, including vacancies, site exchanges, or intrusion by impurity atoms. Raman spectroscopy measurements have provided the most direct evidence of these phenomena, but some enlightening findings have come from x-ray diffraction and electron microscopy examinations. There is ample evidence in recent work on YBCO thick films to make a case that phase separation and cation disorder are two of the factors limiting the performance of the YBCO coated conductor. In this presentation we illustrate the manifestations of phase separation and lattice atom disorder in spectroscopic and diffraction data and will show how these deviate structures correlate with the transport of current in the YBCO film. [*Work sponsored in part by the U. S. Department of Energy, Office of Electric Transmission and Distribution, and as a DOE program to develop electric power technology, under Contract W-31-109-ENG-38.]

10:45 AM *C9.6 Imaging and Characterization of Nonuniform Current Transport in YBCO Coated Tapes. Takanobu Kiss1, 2, Masayoshi Iino1, Hidekazu Tokutomi1, Yoshihiro Shounuma1, Satoshi Koyanagi1, Kazutaka Inamura1, Akira Ibi1, Junko Matsuda1, Teruo Imazu1, Yutaaka Yamada2 and Yuh Shiohara3,4,5; 1Electrical and Electronic Systems Engineering, Kyushu University, Fukuoka, Japan; 2Research Institute of Superconductor Science and Systems, Kyushu University, Fukuoka, Japan; 3Japan Atomic Research Center, Superconductivity Research Laboratory, Nagoya, Japan; 4Division of Superconducting Tape and Wire, Superconductivity Research Laboratory, Tokyo, Japan.

Local current transport properties in YBCO coated tapes have been investigated by the combination of spatially resolved electric- and magnetic-imaging techniques. Moreover, relationship to the microcrystal structure has been studied by site-speciﬁed measurements of SEM and TEM. Local electric dissipation in YBCO coated tapes has been visualized in micro-meter length scale by use of low temperature scanning laser microscopy (LTSLM) at various conditions of bias current, temperature and magnetic field. As a complementary measurement, magnetic imaging has also been carried out for the same sample by using scanning SQUID microscopy (SSM). SSM allows us to observe the magnetic image difference in the YBCO tapes. Correlation between the LTSLM image and the SSM image has been studied in detail. Furthermore, based on the insights of LTSLM and SSM, local crystallographic structure has been investigated at the site-speciﬁed position by SEM and TEM. Based on the combination of these measurements, we succeeded to clarify inhomogeneous current ﬂow and the inﬂuence of current limiting obstacles in the tapes. This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) as Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications.

11:15 AM C9.7 Current Flow Characteristics in Striated Coated Conductors. Chihwei Kwong1, L. B. Wang1, P. Shelby1, C. Khalili1, J. L. Young1, G. You1, K. R. Barraza1, George A. Levin2, Timothy J. Haugan2 and Paul N. Barnes3, 1Physics and Astronomy, California State University Long Beach, Long Beach, California; 2Air Force Research Laboratory, WPAFB, Ohio.

YBCO coated conductors with various striation patterns are investigated by scanning laser microscopy (SLM). The samples with long filamentary strips created by striation have shown to reduce the \( \sigma \) loss. Since the filamentary geometry without current sharing is susceptible to a single defect, discharging a filament, various striation patterns are proposed to create the current sharing between filaments. In the superconducting transition region, we have studied the current distribution and \( T_e \) distribution using variable temperature scanning laser microscopy (VTSLM). In \( T<T_c \), we have measured the local dissipation in order to locate the lower \( T_c \) area in low temperature scanning laser microscopy (LTSLM). Striations are clearly visible in VTSLM images. The inside of striations has weaker signal to the point of sample destruction, good power law behavior was observed for low voltage levels as an increasingly larger fraction of current is being carried by the copper stabilizer layer. Eventually the current was increased to the point where heating became large enough for the conductor temperature to increase. The cooling ability of the liquid nitrogen bath and the sample was destroyed at a current of 550 amperes and 2-5 times \( I_c \). We present these results and discuss stabilized conductor performance and applications as a function of current stabilizer thickness, one or two sided coatings, and as a function of magnetic field.

11:30 AM C9.8 Effects of Space Charge, Dopants, and Strain Fields on Surfaces and Grain Boundaries in YBCO Compounds. Ruiheng He1 and David O. Welch2,1; Caltech, Pasadena, California; 2Brookhaven National Laboratory, Upton, New York.

Statistical thermodynamical and kinetically-limited models are applied to study the origin and evolution of space charges and self-field effects at high field [001] tilt grain boundaries in YBa$_2$Cu$_3$O$_{7-\delta}$ and the effects of Ca doping upon them. At one limit, \( O_6 \), the system is an insulator, while at \( O_7 \), a metal. This is analogous to the intrinsic and doping cases of semiconductors. The site selections for doping calcium and creating holes are also investigated by calculating the heat of solution. In a continuous treatment, the volume of formation of doping calcium at Y-sites is computed. It is then applied to study the segregation of calcium ions to grain boundaries in the Y-123 compound. The influences of the segregation of calcium ions on space charge profiles are finally studied to provide one guide for understanding the improvement of transport properties by doping calcium at grain boundaries in Y-123 compound.
Recent progress in the development of coated conductors (CC) has been remarkable, mainly in terms of eliminating the current carrying limitations due to large-angle grain boundaries, and in producing long lengths of tapes with good superconducting properties. As a result, a large fraction of the effort has now shifted towards the development of methods to enhance flux pinning. In order to evaluate the pinning density efficiently, recent results on critical current density $J_c$, particularly at high fields. Of special interest are the different methods on either single crystal or metallic substrates. These studies allow us to identify several pinning sources and mechanisms, and ultimately to determine the $H$-$T$-$J_c$ plane. We observe systematic differences in $J_c(H,\Theta,T)$ for different fabrication methods, and in most cases clear correlations with the architecture and structure can be established. Particularly useful in this regard are scaling laws, which permit to characterize the pinning by a few fundamental parameters. This knowledge can be used as a guide to explore practical methods for process optimization and nano-engineering of pinning defects. We will show several examples of successful approaches to pinning enhancement, including introduction of nanoparticles, rare earth combinations, and modifications of the interface between the buffer layer and the RE-123 film. One of the most surprising conclusions of these studies is that several different approaches, such as GB's and GB/Z interfaces, are indeed very successful at increasing $J_c$. This indicates that there are still many possibilities that remained to be explored, particularly if combinations of pinning enhancement methods are considered, and suggests that pinning in CC can be "tuned" depending on the application.

Performance improvement of coated conductors (CC) is rapid, and there is a strong need for better evaluation of conductor performance. We recently measured $J_c(H,T)$ and flux pinning plots for different conductors with different textures, including a single crystal film, possessing $J_c(0T,77K)$ values of 0.9 - 5 MA/cm². Here we present these data, which show how scaling of $J_c(H,T)$ and flux pinning plots can ultimately determine the domain in which grain boundary flux flow is limited by the GB properties. Scaling of $J_c(H,T)$ over a wide range of the single crystal sample based on a simple second order polynomial fits of $J_c(0T)$ allows us to estimate $J_c(0T,12T)$ at any temperature. We found that $J_c(0T)$ and the irreversibility field change by $\sim 6\%$ $(0.3$ MA/cm²) and by 0.8 - 0.9 $T$ per Kelvin near 77 K, respectively, making performance of CC near 77 K very sensitive to small differences in superconducting transition temperature (Tc).

In the past decade, it has been stated in probably hundreds of papers that the optimum pinning centers are provided by continuous tracks created by ionic damage (known as columnar defects). The conventional wisdom, that the best pins come from tracks produced by various methods, has been repeatedly questioned, nor experimentally tested. Although irradiation of HTS materials has been broadly studied, and GB's have been repeatedly observed that above certain columnar defect density thresholds irradiation of GB's has not been investigated in depth. Columnar defects provide the maximum pinning potential. However, because of their large size they also severely reduce the percolating area, reducing $J_c$ and the maximum pinnable field in the HTS material. Following this analysis, we proposed a new effective type of pinning center. We proposed to create discontinuous ionic damage with a lower damaged cross section. Both characteristics reduce the loss in the percolating area, hence we argued increasing $J_c$, despite reducing the pinning potential. By the question of which effect will be larger - the increase of $J_c$ due to the improved percolation or the decrease in pinning potential - we experimentally compared pinning morphologies, varying from continuous columnar defects to broken columns to aligned string-of-beads. The different pinning morphologies were formed by varying, in a controlled manner, the energy of the irradiations. The experiment was conducted at the GSI (Germany) heavy ion accelerator using a 70 GeV ion beam. This experiment allows us to directly compare which pinning center type results in the highest $J_c$. Our results presents a unique opportunity to better understand the physics of pinning centers. For the first time in a controlled experiment the energy loss per unit length, $dE/dx$, was a controlled variable, and tuned so as to produce pinning centers of various sizes and geometries. $dE/dx$ varying between 14 KeV/μm to 40 KeV/μm were investigated. In our latest paper (Physics Letter A, Vol. 331/3-4 pp 276-280, 2004), the data clearly show that discontinuous defects, formed at values of $dE/dx = 150$ keV/μm, improve $J_c$ more than columnar defects, which are formed at values of $dE/dx > 35$ KeV/μm, by factors of three to
sixty. This experimental finding is in clear contrast with the conventional, but experimentally tested, belief. This work stands as the first experimental test of the postulate that continuous columnar pinning centers produce the highest Jc, and shows that the postulate is incorrect.

3:15 PM *C10.5
Effects of Artificial Pinning Centers on Vortex Pinning in High-Temperature Superconducting Films. Kaname Matsumoto1, 2, T. Horibe1, 2, P. Melen2, F. Y. Yoshiida2, 6, M. Mulas1, 2, and S. Horii3, 2, 6. 1Department of Materials Science and Engineering, Kyoto University, Kyoto, Japan; 2Nagoya University, Nagoya, Japan; 3Yamagata University, Yamagata, Japan; 4CRIEPI, Yokosuka, Japan; 5University of Tokyo, Tokyo, Japan; 6CREST-JST, Saitama, Japan.

For drastic improvement of Jc, we are investigating a novel technology by means of a nano structure engineering to introduce artificial pinning centers (APCs) into HTS films by the thin film technology with low cost. We have successfully introduced high-density extended crystalline defects, which resulted in one-dimensional APCs of the quantized vortices, into c-axis oriented YBa2Cu3O7-x (YBCO) films. The crystalline defects, created perpendicular to the film surface, were derived from the film deposition process by the distributed nano-sized Y2O3 islands prepared on SrTiO3 (100) substrates. The Y2O3 nano-islands were approximately 3 nm in height and 35 nm in diameter and the density was controlled from 100 µm−2 to 300 µm−2 by choosing the Y2O3 deposition condition. In-field Jc of the films was remarkably enhanced by this method and reached to 0.12 MA/cm² (77K, B//c, 5T), which was 2-2.5 times higher than that of a pure YBCO film. The present films had a large Jc peak when the field was applied close to the c-axis. The results indicate that the strong APCs were introduced into the YBCO films. The vortex pinning by the present APCs is discussed based on the accommodation angle of the vortices.

3:45 PM *C10.6
Columnar Defects Comprised of Self-Aligned Nanodots and Nanorods in YBa2CuO on RABiTS. Sukil Kang1, 2, Amit Goyal1, 2, Keith .T. Leonard1, 2, Leonidas A. Gavalas1, 2, Mariappan Paras Paranatham1, Patrick M. Martin1, Amota O. Ij合成2 and James R. Thompson1, 2, 1Oak Ridge National Laboratory, Oak Ridge, Tennessee; 2University of Tennessee, Knoxville, Tennessee.

For over a decade, scientists world-wide have sought means to produce columnar defects in superconductors similar to those produced by ion irradiation without the expense and complexity of ionizing radiation. We have succeeded in producing long, nearly continuous vortex pins along the c-axis in YBCO, in the form of self-assembled stacks of BaZrO3 nanodots and nanorods using simple and practically scalable techniques. The nanodots and nanorods have a diameter of ~2-3 nm and an areal density ("matching field") of 8-10 tesla for 2vol% incorporation of BaZrO3. In addition, four misfit dislocations around each nanodot or nanorod are aligned and act as extended columnar defects. YBCO deposited by laser ablation on standard "RABiTS" substrates for potential coated conductor applications exhibits enhanced pinning and a weak falloff in large magnetic fields H. In particular, the current density varies as Jc ∝ H−α, with α = 0.3 rather than the usual values 0.5 - 0.65. Similar results were also obtained for BaZrO3 and YSZ as well as other materials. Details of the defect structure and transport and magnetic characterization of the samples as a function of volume percent of incorporated nanodots and nanorods will be presented. Research was sponsored by the U.S. Department of Energy under contract DE-AC05-00OR22725 with the Oak Ridge National Laboratory, managed by UT-Battelle, LLC. S. Kang would like to acknowledge the support of OHIOSE.

4:15 PM C10.7
Chemical Routes to Nano-Scale Pinning in Coated Conductors. Judith MacManus-Driscoll1, 2, 3, Steve Pattryn1, Quanxi Jin1, Haiyuan Wang2, Adriana Sorquis3, Leonardo Cevalle3, Boris Maiorov4 and Dean Peterson4, 5. 1Los Alamos National Lab, Los Alamos, New Mexico; 2Department of Materials Science, University of Cambridge, Cambridge, Cambridge, United Kingdom; 3Centro Atomico Bariloche, San Carlos de Bariloche, Rio Negro, Argentina.

We have previously reported on systematic studies to increase pinning in REBa2Cu3O7-x (YBCO) coated conductors grown by pulsed-laser deposition. Different chemical modifications (including BaZrO3 nano-particle additions, changing RE ion size variance (for constant RE ion size), and RE ion size (for constant RE ion size variance) have led to these improvements. In this work, we report on our efforts to combine these different pinning routes.

4:30 PM C10.8
Enhancement of the Superconductivity in High Fields of Y-Ba-Cu-O Materials. Shih-Yen Chen1, Chun-Chih Wang2, In-Gann Chen3 and Maw-Kuen Wu1, 1Institute of Physics, Academia Sinica, Taipei, Taiwan; 2Department of Materials Science and Engineering, National Cheng-Kung University, Tainan, Taiwan.

It is known that the critical current density (Jc) of superconductors can be enhanced by incorporating of extended defects to act as different pinning routes. Pinning is optimized when the size of the defects approaches the superconducting coherence length (ex. 2-4nm for YBCO at 77K). On the other hand, field pinning centers (ex. compositional fluctuation) were proven to enhance Jc in high field regions. In this study, nano-scale non-superconducting-particles, includes RE2BaCuO5 (RE211) and RE2O3 (RE: rare earth elements, includes Sm, Nd, and Gd), which were expected to act as artificial pinning centers, has been introduced into large, single-grain Y-Ba-Cu-O superconductors. The results indicate that the Jc-H curves varying with the type of addition. Two types of action of the additions were observed: one act as non-superconducting particle and nuclei site, and the other produce regions with oxygen deficiency and variation of Tc. By controlling the type and amount of additions, a pronounced peak extend till high fields was obtained. The method provides a possibility for the fabrication of Y-Ba-Cu-O superconductors, includes films, with enhanced flux pinning in high field regions.

4:45 PM C10.9
Studies on Nanolayered Flux Pinning Structures in YBa2Cu3O7-x Films. Paul N. Barnes1, Timothy J. Haagan1, Srinivas Sathiraju1, Timothy A. Campbell2 and Chakrapani V. Varanasi3, 1Air Force Research Laboratory, WPAFB, Ohio; 2University of Dayton Research Institute, Dayton, Ohio.

Fundamental studies directed toward higher critical current densities by improved magnetic flux pinning in YBa2Cu3O7-x (YBCO) is critical to coated conductor applications. Pinning is optimized as the size of the defects approaches the superconducting coherence length ~2-4 nm for YBCO 77K, and when the number of defects per unit area is sufficiently large, (~ H//2x1011 #/cm2 where H is in Tesla. A new process has been recently developed for achieving a controlled dispersion of nanoparticles in YBCO thin films with the necessary particulate nanosize and high density [1]. The deposition process incorporates insulating nanoparticles into the YBCO films by multiple alternating, consecutive depositions of YBCO and the insulating material, such as Y2O3 and Y211. Particular formation is caused by lattice mismatching with the YBCO, with a greater mismatch producing finer sized nanoparticles for similar layer coverage. However, based on initial magnetization results, lattice matched insulating material such as CeO2 provides alternate effects although the composite films are prepared in a similar manner. Flux pinning was found to be in some cases either slightly improved at either low fields < 0.5 T or in other cases at high fields > 8 T although degraded, sometimes severely, at intermic magnetic fields. Most unexpectedly, the pinning performance of the various samples rapidly converges as the temperature is reduced from 77 K to 65 K, causing all films to have similar Jc(H) behavior at 65 K even though dramatically different at 77 K. Differences resulting from the above approach and a technique to remove the layered structure as well as the addition of Ca and Ag doping will be discussed. [1] T. Haagan, P.N. Barnes, R. Wheeler, F. Meinlenothen, and M. Sumption, Nature, vol. 430, 867 (2004).