SYMPOSIUM EE

EE: Frontiers in Superconducting Materials-New Materials and Applications

December 1 - 4, 2003

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*Invited paper
SESSION E11: Coated Conductors—Fabrication
Chairs: Ron Feenstra and Vladimir Matin
Morning Meeting, December 1, 2003
Constitution B (Sheraton)

8:30 AM *E11.1
Development of IBAD/PLD Process for 100-mm Length Y-123 Coated Conductors. Yasuhiro Iijima, Kenichi Kubono, Masanori Sato, Shoji Ajimura and Tatsuki Sato; Fujikura Ltd., Tokyo, Japan.

In recent years remarkable progress has been made on processing technology for Y-123 coated conductors. Ion-Beam-Induced Deposition (IBAD) and Pulsed-Beam-Deposition (PLD) have developed to be viable methods with the aid of recent improvement for vacuum technology and large inner diameter industrial evacuator liner, etc. We have performed 100-mm length formation of Y-123 tapes by using independent reel-to-reel vacuum systems of IBAD and PLD. Basically textured Gd$_2$Zr$_2$O$_7$ buffer layers were routinely fabricated with $\Delta a$ of 0.1 degrees by IBAD with production speed of 0.5 m/hr. In order to search for missing growth parameters during long time reel-to-reel operation, an ion beam divergence measurement system was developed which has Faraday cup scanning behind arranged apertures. The dependence of basically textured growth on assisting beam divergence was investigated, considering the dependence on ion energy, and ion current density. In-plane texture improvement was discussed using ion/farad flux ratio and beam divergence. For further improvement of interaction with the substrate, CeO$_2$ powder buffer layers were deposited by PLD on IBAD Gd$_2$Zr$_2$O$_7$-films of $\Delta a$ of 0.1 degrees. 1.5-2.0 \mu m thick CeO$_2$ and Gd$_2$Zr$_2$O$_7$ films were deposited with both $\Delta a$ of 0.1 degrees. Those secondary buffer layers had very large grain sizes over 1 \mu m and the IBAD PLD films. A stress contrast was observed by TEM cross-sectional images near the interfaces between PLD and IBAD buffer layers. Y-123 films were formed on them by PLD with $\Delta a$ of 0.1 degrees. Y-123 films with $\Delta a$ of 0.1 degrees and 57 nm thick IBAD tapes with $\Delta a$ of 0.1 degrees. The tape moving speed was 4.6 m/hr and cyclically deposited for several times in order to homogenize longitudinal Ic/Jc distributions. Ic of 40A and Jc of 0.88 MA/cm$^2$ (77K, self-field) was obtained in 100-mm length. Jc of 24A and Je of 0.84 MA/cm$^2$ (77K, self-field) was obtained in a 60-mm length. 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.

9:00 AM *E11.2
YBCO Coated Conductors with Extra-High Engineering Current Density and Their Implementation in Power Engineering. Alexander Iloskin, Herbert C. Freyhardt, Alexander Isserov and Jurgen Knolle; Forschungswerke gGmbH, Gottingen, Germany; Institut fuer Materialphysik, Universitet Gottingen, Gottingen, Germany.

Newest state of the art in developing coated conductors with extra-high engineering current densities, up to almost 400A/mm$^2$, is reported. Features of cost-efficient technological route based on employment stainless steel substrate tapes, IBAD and high-rate pulsed-laser-deposition are discussed and compared with alternative routes. It is clearly shown that an optimization of CuO$_2$ layer in IBAD-YSZ and Co$_2$O$_3$ double-layered buffers can lead to a significant enhancement of the in-plane texture of YBCO film accompanied by a considerable increase of their critical current densities. Employing a modified IBAD technique the IBAD-YSZ-buffered stainless steel tapes up to 25mm long, 4mm wide, have been fabricated. Typical FWHM values of 1.1-1.5$\mu $m of the in-plane texture were achieved for 1.1-1.5$\mu $m thick buffer layers. Co$_2$O$_3$ buffer layers were deposited using either an e-beam evaporation or a high-rate pulsed-laser-deposition (HRLD) methods. Exploiting the HRLD for the subsequent processing of thin [0.02-0.1$\mu $m] Co$_2$O$_3$ layer and YBCO film, coated tapes with a length up to 1m have been manufactured. At YBCO in-plane texture with FWHM=1.5$\mu $m critical currents of 85-105A/mm$^2$ in an applied magnetic field of 17K & SF have been achieved in [5.5mm wide long coated conductors. With thickening the Co$_2$O$_3$ layer up to 2.5$\mu $m, the FWHM value of 6.0$\mu $m in the in-plane alignment have been measured in an applied magnetic field of thick [35um] YBCO films, which can exhibit an FWHM of only 3.5$.\mu $m. With high purity buffer layer systems, an effect of self-improvement of YBCO in-plane texture with increasing YBCO film thickness is observed and discussed. In long coated conductors (6-10$\mu $m) and very high Ic's of 85-125A/mm$^2$ were observed. These Ic-values correspond to critical currents per cm-width of 217-224A/cm. In shorter conductors with a length of 0.2m, the critical currents of 317-391A/cm per cm-width of the tape could be measured. With a 0.1mm-thick substrate-tape employed, the engineering critical current density of the coated conductors exceeds presently 290A/mm$^2$ for the tapes in 18mm-lengths and 350A/mm$^2$ for the tapes in 1mm-lengths. We consider a realistic possibility for further improvement of the current density to $\geq$ 500 A/mm$^2$. These extra-high engineering current densities reveal new functionalities of the coated conductors in the power engineering, especially in the power transmission and conversion. Various application fields are considered with this respect. This work was supported in part by the E11 within the "Growth" Project No. GR10(R) 00025267, and the German BMBF within the Project No.13N0787.

9:30 AM *E11.3
Continuous Preparation of Pulsed Laser Deposited Oxide Buffer Layers and YBCO for Coated Conductor Applications. Brady J. Gibson, Sascha Kreisikott, Chris Sheehan and Vladimir Matin; MSSTC, 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 electroplating of Hastelloy C276 substrate tape (1 cm x 0.1 mm), continuous ion-beam assisted deposition (IBAD) of an MgO template layer, and continuous pulsed laser deposition (PLD) of oxide buffer layers and the superconductor (YBa$_2$Cu$_3$O$_y$). We are currently producing YBCO-coated conductors using a 100 mm thick Li$_2$MgO$_3$ (LMO) buffer layer. The in-plane texture improves from 6$\sim$8$\mu $m in the MgO to less than 3$\mu $m in YBCO. We have attained YBCO performance of over 170 A/mm in short lengths in our system and can be increased as a rate of up to 21 m/hr. Continuous YBCO over the LMO layer is produced currently at ~1 m/hr. We will present results of studies to increase the throughput of the YBCO layer. The effects of high rate deposition on the electrical and mechanical properties will be discussed. This work is funded by the Department of Energy, Office of Power Technologies.

9:45 AM *E11.4

Rare earth (RE)-Ba$_2$Cu$_3$O$_y$ superconducting materials have been investigated as a next generation superconducting wire with the high Jc and Ic under the high magnetic field. We have investigated HoBa$_2$Cu$_3$O$_y$ (HoBCO) material and have also tried to fabricate a coated conductor and a thin film on a single crystal substrate. Through these accumulations, we confirmed that the HoBCO had the excellent superconducting properties as well as the YBCO has. HoBCO coated conductors have been developed by using physical vapor deposition such as a pulsed laser deposition (PLD). HoBCO layers have been deposited on flexible metal substrates with high-nickel buffer layers. We have also developed a new HoBCO coated conductor experimentally and have kept to improve the electrical properties and the long length deposition technique. The latest results about our trial production will be reported.

10:30 AM *E11.5

Coated conductors will play a crucial role for the generation and distribution of electrical energy in the future. Production of meters of flexible steel tape coated with the complex high temperature superconductor oxides TlBxOy is exploring and trending entirely new paths. In search of a scalable and economic production technique we have focussed on proprietary technologies which combine buffer layer alignment by inclined substrate deposition (ISD) and the fabrication of coated conductor tape based on vacuum evaporation. In the course of this year several crucial breakthroughs have been achieved which render this route a viable industrial process, offering the advantages of high volume deposition rates, uniformity and little maintenance. Since all fabrication steps are a reel to reel processes they allow straightforward upscaling from the pilot plant handling hundred meters to the production of kilometers of tape. The basic corner stones of the technology, deposition of several micro thick films, high speed growth and continuous long lengths coating have been successfully demonstrated. A consistent pilot product production covering all steps from electropolishing the steel tape, oriented buffer layer deposition to the superconductor growth.
Investigation on Microstructures and Growth Mechanism of YBCO Films Deposited by Modified TFA-MOD Method. Hikaru Yamasaki, Jin Kim, Isamu Tokanai, Hiroshi Fujii, Atsushi Kuroda, Shigenobu And no, Tetsuo Horji, Yoohiro Iijima, Tsukisu Sata, Teruo Izumi, and Yu Shichida

11:45 AM EEL9

All-solution coated conductor fabrication. Swaminathan Subramanian, Margaret R. Cahanman, Hong Ying Zhu, Sukil Kang, Amit Goyal, Shafiq M. Bhatiyan, and Kamal Salama

11:50 AM EEL8


SESSION E2: Coated Conductor-Properties

Chairs: Brady Gibbons and Werner Prinzett

Monday, December 1, 2003

1:30 PM EEE2.1


The role of thickness dependent microstructures in controlling the critical current density Jc is examined for YBCO epitaxial films produced by a BaF2 ex situ process. A fundamental question, which has remained unanswered to date, relates to the nature of defects enabling strong flux pinning in these films and the observed large Jc. Theoretical models taking into account the size, distribution, and geometry of the flux pinning defects lead to distinct predictions for the thickness dependence of Jc, depending on which defect type dominates. Identification of the relevant intrinsic behavior, thus, is essential for understanding thickness dependent trends in Jc, and formulating pathways to increase Jc, the total current critical. In this presentation, data of Jc, as a function of YBCO layer thickness d for films of variable thickness (0.3-3 μm) are examined, alongside through-thickness data obtained by successive thinning of thick-film samples. Substrates include RABITS, IBAD, and single crystals. The microstructure was determined by XRD, SEM, and TEM at various magnifications, both in plan-view and cross-sectional imaging. Early indications are that besides obvious current-blocking defects (e.g. non-α YBCO grains), the presence of pinning defects with a length scale of a few 1 μm is at least partially responsible for the observed thickness dependence of Jc.
2:00 PM EE2.2
Identification of pinning mechanisms in YBa2Cu3O7
cast conductors. L. Guo1, J. Y. Coulter1, J. O. Willis1, A. Serquis1, B. Maihow1, Q. X. Jin1, H. Wang2, S. R. Folkins1, J. L. MacManus-Driscoll1,2, P. N. Arendt2 and M. P. Maley2.
Los Alamos National Laboratory, Los Alamos, New Mexico; Dept. of Materials Science and Engineering, University of Cambridge, Cambridge, United Kingdom.

The objective of this work is to explore the mechanisms that limit the supercurrent density (Jc) in YBa2Cu3O7
cast conductors on IBAD MgO with improved texture, which exhibit Jc at 75K and self field as good as that of films on single-crystal substrates. To that end we characterized the transport Jc of the COs as a function of temperature and magnetic field in fixed- and variable orientation, and we investigated their microstructural properties using X-ray diffraction, transmission electron microscopy, scanning tunneling microscopy, and scanning electron microscopy, looking for correlations with the transport results. We then compare these results with those of YBCO films on single-crystal substrates. We have used the angular dependence of Jc for identifying several pinning sources that are dominant at different field orientations. In particular, we have investigated in detail the peaks in Jc, which arise from different types of correlated disorder for applied magnetic field parallel to the c axis and the a-b planes. We found that the relevant sources of pinning are similar in CC and films on single-crystal substrates, although the relative importance of each mechanism is different, resulting in slightly different angular and field dependences of Jc. An important conclusion of this study is that over large field and orientation ranges, the Jc in the CC is higher than in films on single-crystal substrates. This demonstrates that the Jc in films on single-crystal substrates does not constitute an upper boundary for the performance of CCs, and that pinning in the latter materials can be further improved by appropriate engineering of the microstructure.

2:30 PM EE2.3
Through-thickness superconducting and normal states transport properties revealed by thinning of thick film ex-situ YBa2Cu3O7-x cast conductors. Tae-Woo Kim1, David Larbalestier2, Ron Fentner3, A. Gopud4, Terry Holejsinger5 and P. Arendt6. University of Wisconsin, Madison, Wisconsin; 2ORNL, Oak Ridge; 3LANL, Los Alamos, New Mexico.

It is generally observed that the critical current density of YBCO films decreases rapidly as their thickness increases. While such behavior is predicted from 2D collective pinning models, empirical observations of the thickness dependence of Jc are believed to be largely processing dependent at present. To investigate this behavior in ex-situ YBCO casted conductors, samples with YBCO layer thickness of 0.82 to 29 um on buffered metal tapes were repetitively thinned by ion milling and measured for rho(T) and Jc(II). Films of YBCO thickness 2.0 and 2.9 um were deposited on IBAD YSZ substrates, and had Jc values of 0.73 and 0.97 MA/cm2 respectively. These films exhibited very linear Ic(T) dependences as they were thinned, with little or no evidence of dead layers in the YBCO, suggesting that further increases in Jc can be obtained by further YBCO film growth. They also exhibited an increase in Jc at small thickness (< 0.5 um), the 2.0 and 2.9 um films had lower Jc values than those found for films reacted from thin (< 0.5 um) precursors on identical substrates. This result may be explained by a variable microstructure through thickness as revealed by cross sectional SEM and TEM.

2:45 PM EE2.4

For the development of YBa2Cu3O7
cast conductors, it is desirable to electrically and thermally stabilize the high temperature superconducting (HTS) coating. In addition, non-magnetic tape substrates are an important factor in order to reduce the ferromagnetic (FM) hysteresis energy loss in ac applications. Here, we demonstrate electrically connected high-Jc (> 2x10^6 A/cm2 at 77 K) YBCO coatings on bi-layer textured non-magnetic Cu tapes having a conductive metal coating (Cu or Ti/Cu) and a superconductor (YBa2Cu3O7-x). The current-voltage (LV) and power handling characteristics of a model, ideally coupled conductor architecture (HTS + conductive buffer + Cu-substrate) were analyzed and compared with the experimental results. In addition, FM Ti/Cu or Ni seed layer was also investigated and compared to the projected loss for an achievable conduct conductor tape. Fundamental issues and measures that are imperative for electrical stability of a coated conductor are also addressed.

3:30 PM EE2.5
Chemical Routes to Increasing Low Field and High Field Pinning in Epitaxial REBa2Cu3O7 films. Judith Louise MacManus-Driscoll1,2, Stephen Folkins1, Qianxi Jin1,2, Hayan Wang1, Adriana Serquis1, Leonardo Cavale1, Boris Maihow1 and John Petersen2. 1Materials Science and Metallurgy, Univ. of Cambridge, Cambridge, United Kingdom; 2MST-STC, Los Alamos National Lab, Los Alamos, New Mexico.

Over the past 15 years, many studies have focused on understanding the naturally strong pinning in REBa2Cu3O7 films. It is clear that line defects associated with the mode of epitaxial growth from the vapor phase play a strong role. Despite the wealth of information about the nanostructures and pinning mechanisms, so far there has been no success in increasing pinning in already high-quality films by a simple, practical route. It is important to do this in order to decrease the cost of conductors as measured by the $/Km figure. In this talk, we report our systematic studies of REBa2Cu3O7 films deposited by pulsed laser deposition. By using different chemical modifications, we show that it is possible to separately enhance Jc in both the low field and high field pinning regimes.

4:00 PM EE2.6
Microstructural Development of Ex-Situ YBa2Cu3O7 Films on RABITS and IBAD MgO Templates. Terry George Holejsinger1, Paul Arendt2, Vladimir Mazin1, Brady Gibbons1, Roland Ferrar2, Amit Gopud1, Elliott Speck1, Matthew Feldmann2, J. Kim3, David Larbalestier4, Darren Verheghe5, Wei Zhang5, Xi Li6 and Martin Rapid7. 1Los Alamos National Laboratory, Los Alamos, New Mexico; 2Oak Ridge National Laboratory, Oak Ridge, Tennessee; 3University of Wisconsin, Madison, Wisconsin; 4American Superconductor Corporation, Westborough, Massachusetts.

Ex-situ conversion of E-containing YBa2Cu3O7 precursors is an economically attractive process for adding the superconducting layer to a coated conductor substrate. Understanding the phase conversion process and final microstructure is crucial to maximizing the superconducting properties. Each process used to build a YBa2Cu3O7 (Y-123) coated conductor creates an interface along which defects or interfacial reactions may occur. These defects can adiabatically propagate through the entire film structure to affect the growth and properties of the superconducting film. The effects of substrate features, buffer layers, and conversion processes of the ex-situ Y-123 films on the resulting microstructures are discussed. Interfacial reactions between the substrate, buffer layers, and Y-123 films are examined. Y-123 films produced from BaF3-based precursors deposited by e-beam evaporation or metal organic deposition (MOD) of trifluoroacetates are compared in terms of their final microstructures, phase assemblage, and superconducting properties. The initial stages of processing during which phase segregation can occur, Y-123 and secondary phase development, and the degree of conversion completion in fully processed coated conductors are also examined. Implications for increasing Jc via (t > 1 micron) development and structural refinements are discussed.

4:15 PM EE2.7

Recoated-Ribbon (RRR) ribbon microscopy investigations have been performed on YBCO coated conductor tapes ranging in length from one to twelve meters. Tapes formed using a variety of YBCO precursor approaches (i.e., trifluoroacetate, MOCD, and ex situ BaF3) were examined. Several of the investigation tapes were processed using a quenched tape methodology wherein the tape is slowly rolled into a preheated furnace and then rapidly reeled back out of the furnace to create a graded Y-Ba-Cu-O phase assemblage along the length of the tape. The RRR results for these quenched tapes track YBCO phase evolution from the amorpherous precursor state, through early YBCO phase formation, through optimum YBCO development, and on into the over-heated-treated state. RRR ribbon measurements/electrical-transport properties provided informative insights about the correlation between local phase composition/tecture and relative critical current. The ability of RRR microscopy to (1) track YBCO a-axis texture, (2) detect inclusions and impurities (such as CuO, for the Ba-Cu-O compounds, and BaCoO3), (3) provide information about their location and morphology, and (4) function effectively on moving tapes suggests that RRR-based methods may be useful for in-line conductor process monitoring. [Work at Argonne National
Laboratory and Oak Ridge National Laboratory was sponsored by the U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy, Office of Fossil Energy, as part of a DOE program to develop electric power technology.

4:30 PM EE2.8 Microstructure-Property Relationships in Thick MOCVD and PLD YBCO Coated Conductors. Michael Hutzinger,1, Harry Ettleman,2, Cedric H. Omlin,3 Jodi Reeves2, V. Schumann,3,4,5, Eric Lihin1 and Pradeep Haldar1. 1University of Southern California, NANO Engineering. 2School of NanoSciences and NanoEngineering, University at Albany - SUNY, Albany, New York, 3SuperPower Inc., Schenectady, New York.

YBa2Cu3O7−δ (YBCO) high temperature superconducting films were grown 0.4 μm to 4.2 μm thick on buffered substrates by pulsed laser deposition (PLD) and metalorganic chemical vapor deposition (MOCVD). The microstructural and electrical characterization of the films was performed by focused ion beam microscopy, scanning electron microscopy, x-ray diffraction, x-ray reflectivity, and microbending measurements at 277 K in self-field. As commonly reported in the literature, a decrease in the critical current density (Jc) in some MOCVD and PLD YBCO films was observed with increasing film thickness. For MOCVD films increasing in thickness from 0.5 μm to 4.2 μm, the Jc dropped from 2.9 MA/cm² to 0.1 MA/cm². Similarly, as PLD films increased from 0.4 μm to 2.0 μm, the Jc dropped from 2.5 MA/cm² to 0.6 MA/cm². The Jc decrease in the thick films was found to be related to compositional and structural defects that were directly observed using cross-sectional focused ion beam imaging, which revealed defects such as pores, misaligned grains and second phase particles that were confirmed by x-ray diffraction and scanning electron microscopy. In the above observations, and in contrast to many reports in the literature, one set of PLD YBCO films did not suffer a substantial decrease in Jc with increasing thickness. In these films, the Jc of 1.0 μm, 2.0 μm, 3.0 μm, and 4.0 μm thick PLD YBCO films was 1.2 MA/cm², 1.1 MA/cm², and 0.8 MA/cm² respectively. In this work we will compare and contrast the microstructural variations that caused the very different Jc dependence within and among these PLD and MOCVD YBCO films.

4:45 PM EE2.9 Coated Conductors: Phase Relations in the Ba-Y-Cu-O-F-H System. Wei-Chi Wang,1,2,3 Laurence P. Cook,2,3,1

We have characterized the equilibrium phase diagram of the Ba-Y-Cu-O-F-H system using x-ray diffraction and chemical microanalysis. The results have implications for the design of high temperature superconducting tapes.

SESSION EE3: Coated Conductors Scale Up Chairs: Judith Driscoll and Alexander Ooskin Tuesday Morning, December 2, 2003 Constitution B (Sponsor)

8:30 AM EE3.1 Progress in Coated Conductor Technology Scale Up at SuperPower. Yen-Chun Shen,1,2 Chen-Hao Chang,3,1 Hsueh-Chao Tsai,1,3 Yi-Ling Li,1,2 Xuming Xiong,1,2 Yunhe Qiao,1,2 Yi-Yuan Xie,1 Jodi Reeves2, Allan Knoll,3 Tom Sajnaj2 and Ken Lementh,3 SuperPower, Schenectady, New York.

Coated conductor technology is being scaled up to manufacturing in the pilot-scale facilities at SuperPower. SuperPower is developing High Temperature Superconductor (HTS) deposition technologies that have been used to achieve high deposition rates. These deposition techniques are Metal Organic Chemical Vapor Deposition (MOCVD) and Pulsed Laser Deposition (PLD). An additional advantage of large deposition zone area provided by MOCVD the potential for high throughput ashing MOCVD deposition processes for coated conductors. Ion Beam Assisted Deposition (IBAD) is used for buffer deposition. IBAD provides the advantages of room temperature deposition and high deposition rates. Several unique processing steps were developed to produce IBAD layers with high performance, such as in high magnetic fields and at high levels of mechanical strain. These properties are important for practical use of coated conductors in several device applications.

9:00 AM EE3.2 Commercial YBCO Coated Conductor Wire Development. Xiaoping Li,1,2 Fangzhou Kong,K, Wei Wang,1,2 Ura Shouma,3,4,5, Cees Thieme,2,3,4,5 Murtis Ruzicka, Ed Sigiel, Nguyen-Nguyen and Joe Lynch,1,2 American Superconductor Corp., Westborough, Massachusetts.

The development of the Second Generation (2G) high temperature superconducting wire has progressed past the initial stage of laboratory demonstrations and is now focused on developing and testing high current critical conductors. Designs are now required for 10 meter lengths for commercial applications. YBCO wires are now being produced by AMSC in 10 meter lengths with critical currents of up to 1840 A/cm² (77K, self-field) and in short length with significantly higher critical currents. However, the operational demands of commercial HTS applications require that, in addition to a high critical current, the superconducting wire also meets stringent mechanical and electrical stability requirements which vary by application. These mechanical and electrical stability requirements can be achieved by laminating a copper foil to the YBCO tape. This architecture can provide mechanical and electrical stability properties meeting the commercial wire requirements. Results will be presented on [1] improvements in the performance of 10 meter lengths of continuously processed 2G wires [2] the fabrication and characterization of the laminated wire architecture [3] the performance of prototype devices fabricated from the 2G wires.

9:30 AM EE3.3 Development of Long YBCO Coated Conductor using Self-Epitaxial CeO2 Buffer IBAD in SRL Nagoya Coated Conductor System. Yoshio Yamada1, Takanori Muragaki1, Tomonari Watanabe1, Hirokazu Iwai2, Seki Miyas1 and Yuh Ishihara3,4,5,1 Nagoya Coated Conductor Center, ISTECL-SRL, Nagoya, Japan; 2Division of Superconducting Tapes and Wires, ISTECL-SRL, Tokyo, Japan.

SRL Nagoya Coated Conductor Center (NCCC) is now studying intensively long Y123 coated conductor with newly installed continuous Roll-to-Roll machines of IBAD and PLD. In this presentation, I will introduce our recent results using these machines and a new buffer layer deposition technique. 1) New buffer method to a long conductor fabrication Recently we found a new phenomenon, Self-Epitaxy of PLD-CeO2 buffer, meaning that a CeO2 layer on an IBAD coated layer develops the degree of the bi-axial alignment without any help of assisting Ar ion. With this method, the deposition rate was more than 10 times faster than the conventional IBAD process. Thus, the whole wire production speed will be improved much. Up to now we obtained the highest degree around 9 degrees of CeO2 buffer on the IBAD tape substrate. This resulted in also high Jc of 4.4 MA/cm² for PLD-YBCO coated conductors. 2) Long wire fabrication Using the above Roll-to-Roll machines, we are now fabricating long IBAD tapes. Now the length reaches up to 500 m and the bi-axial alignment up to 15-20 degrees. In the following process using PLD, the edge for the long wire is also being carried out. PLD-CeO2 self-epitaxial layer exhibited the high production speed more than 1 cm/hr in this PLD Roll-to-Roll system. Our results show that, including high Jc of 2MA/cm² and Jc of 1000 MA/cm² for self-epitaxial IBAD methods is considered to be promising for the industrialization of YBCO coated conductor. For the future purpose, we might also be able to see also the possibility of the enhancement of the production rate of the
whole YBCO coated conductor. This work was supported by NEDO as collaborative Research and Development Fundamental Technologies for Superconductivity Applications.

10:30 AM EE3.4 Continuous Preparation of IBAD-MgO Templates for YBCO Coated Conductor Applications, Sacha Kreukelt, Brady J Gibbons, Chris J. Sheehan and Vladimir Mata, Superconductivity Technology Center, LANL, Los Alamos, New Mexico.

A reel-to-reel deposition system at the Los Alamos Research Park has been used extensively for the ion-beam assisted deposition of MgO (IBAD-MgO). Subjects of our work have been both the production of longer length substrates (~10 meters) and combinatorial research on the IBAD-MgO process. The quality of the IBAD-MgO layers was analyzed by x-ray diffraction. X-ray data was obtained for 100-200 nm thick MgO layers on top of YBCO. Electropolished Hastelloy C276 targets (1 cm width) with an RMS surface roughness values below 1 nm (measured by AFM on 5 x 5 μm²) were used as substrate. Several factors have been found to have an important influence on the resulting in-plane MgO texture. Most importantly, the texture is determined by the flux-ratio of the incoming MgO vapor and the Ar ions. The higher the ion to MgO flux ratio, the sharper is the achieved in-plane texture. Another very important influence comes from the amorphous Al₂O₃ and Y₂O₃ buffer and seed layers for the IBAD-MgO growth. A seed layer, such as Y₄Fe₅O₁₁ is required for the IBAD-MgO process. An additional buffer between the substrate and the seed layer increases the stability of the template during sequential coating processes by preventing previous diffusion and reaction. In dependence of surface roughness, microstructure, and architecture of the amoraphous layer stack, different growth behavior and resulting in-plane texture for fixed IBAD-MgO growth conditions could be found. With optimized deposition conditions IBAD-MgO/epi-MgO layers with in-plane texture FWHM values as low as 3° could be deposited in a continuous way on a single 6 mm thick Y₄Fe₅O₁₁ seed layer. Because a thin single seed layer provides only limited protection against oxidation diffusion from the substrate, a thicker amorphous Al₂O₃ buffer layer of approximately 80 nm thickness is added between substrate tape and Y₄Fe₅O₁₁ seed layer. On this stack IBAD-MgO/epi-MgO layers of several meters length with in-plane orientation FWHM values below 5° have been achieved. On the MgO templates LaMnO₃ buffers and YBCO were deposited using PLD. On both thin and thick buffer/seed layer architectures high Jc (>10^6 MA/cm², 75 K, self field) YBCO films of more than 1 μm thickness could be obtained. However, deposition conditions for YBCO were less restrictive for the use of the thicker buffer architecture. This work is funded by the Department of Energy Office of Power Technologies.


The original Stanford process for ion-beam assisted deposition (IBAD) of bimorph-textured (001) MgO buffer layers for superconductor coated conductors has now been widely explored and further developed by Los Alamos National Laboratory and others. As this method approaches potential use in manufacturing, it is becoming very important to understand the way the process behaves in different environments. To date, most of the research on IBAD MgO has been done using electron-beam and, to a lesser extent, ion-sputtering vapor sources. We have been running experiments using pulsed-laser deposition (PLD) as the vapor generation method, and will present the results of these studies. In particular, we will point out the similarities and differences between the results by PLD and the other methods, and thereby further define the "process window" for successful (001) MgO growth.

11:00 AM EE3.6 Influence of Assisting and Spattering Ion Beams on Films in IBAD Process, Seiki Miyata, Tomonori Watanabe, Takemi Muragaki, Hiroaki Inami, Yuuki Yamada and Yuk Shiohara, 1Nagoya Coated Conductor Center, ISTE-SRL, Nagoya, Japan; 2Division of Superconducting Tapes and Wires, ISTE-SRL, Tokyo, Japan.

Since a long length and high degree of an in-plane alignment can be attained, ion beam assisted deposition (IBAD) is a promising method to fabricate a large scale film for YBCO coated conductors. We fabricated a film long IBAD tape using reel-to-reel system and obtained 4.5 MA/cm² of Jc for a short YBCO sample. Despite of the excellent results, however, the mechanism of the basically alignment of IBAD in still not clear. The IBAD method employs ion beam system, where one is for sputtering a target material and the other is for assisting an alignment of a film. Off-normal incident angle of assisting beam provides an in-plane alignment in addition to an out-of-plane alignment of the film. To clarify effects of these ion beams in detail, we investigated influence of changes in the ion beam currents and voltages on film properties. Decreasing current of an assisting ion beam induced a tilting of out-of-plane axis of <100>, indicating underlying crystal orientation. No such assisting ion beam, <100> axis no longer appeared as an out-of-plane axis, but <111> axis did. Roles of ion beams for an in-plane alignment and crystallization energy of the material will be also discussed. This work is 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 EE3.7 Recent Advancements in the Chemical Solution Deposition of YBa₂Cu₃O₇₋ₓ Coated Conductors, Jeff Davley 1, Paul Clem 2, Michael P. Segal 1, Todd L. Tollefson 1, and Fred Liu 2, 1Sandia National Laboratories, Albuquerque, New Mexico; 2Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Chemical solution deposition (CSD) has the potential to be an economical approach for fabricating films of oxides YBa₂Cu₃O₇₋ₓ (YBCO) and buffer materials, such as ABO₃ perovskites, for coated conductor applications. However, in order for CSD to be a viable commercial process, the time required to deposit, sinter, and crystallize the YBCO needs to be as short as possible while maintaining high quality. We previously demonstrated that a novel fluorinated solution synthesis approach, using diethanolamine (DEA) to control the organics, could dramatically reduce the pyrolysis time for CSD-YBCO films. In this presentation results of integrating the SnDEA precursor onto buffered metal tapes will be discussed. Growth rate experiments show that the SnDEA precursor can be crystallized in CSD-YBCO at rates up to ~35 Å/sec. Jc (77K) values > 1 MA/cm² have been measured for ~0.25 micron thick films fabricated on Oak Ridge’s CeO₂/YSZ/Y₂O₃/Ni/NS-W(5%) substrates. Integration of the SnDEA precursor onto solution deposited SrTiO₃ buffered metal tapes, and results for 0.75 micron thick, single coating YBCO films will also be discussed. Sandia is a multiprogram laboratory operated by Sandia Corp., a Lockheed Martin Company, for the US Dept. of Energy under contract DE-AC37-99SR20679. Oak Ridge National Laboratory is managed by UT-Battelle, LLC for the United States Department of Energy under contract No. DE-AC05-84OR22225.

11:30 AM EE3.8 All-solution deposited coated conductors: defects and current limiting mechanisms, Paul Clem 1, Jeff Davley 1, Michael P. Segal 1, Donald L. Overmyer 1, Jacob Richardson 1, James A. Voigt 1 and Terry Holesinger 1, 1Sandia National Laboratories, Albuquerque, New Mexico; 2Los Alamos National Laboratory, Los Alamos, New Mexico.

A recently developed solution-deposition method has enabled all-solution deposition of YBCO/SrTiO₃/Ni/NS-W coated conductor composites with MA/cm² critical current densities. This talk will summarize some of the current features of this process, including a cataloging of defects within the YBCO and SrTiO₃ buffer layers that can limit current density. In particular, we will discuss high resolution transmission electron microscopy (HRTEM) and scanning electron microscopy (SEM) to samples and found grain misorientations, film porosity and high surface roughness of the SrTiO₃ buffer layer to be deleterious to Jc values and YBCO microstructure. Additionally, defects within the YBCO film have been found to limit coated conductor Jc. This talk will discuss efforts to eliminate these YBCO and buffer defects in pursuit of higher critical current densities for all-solution deposited coated conductors. Sandia is a multiprogram laboratory operated by Sandia Corp., a Lockheed Martin Company, for the US Dept. of Energy under contract DE-AC04-94AL85000.

11:45 AM EE3.9 Microstructures of YBa₂Cu₃O₇₋ₓ Thick Films by Metal-Organic Chemical Vapor Deposition, Jinning Zeng 1, Pengchu Chao 1, Alex Ignatiev 1, Jie Liu 1 and Luming Wang 2, 1University of Houston, Houston, Texas; 2University of Michigan, Ann Arbor, Michigan.

High quality superconducting YBa₂Cu₃O₇₋ₓ (YBCO) thick films were grown on LaAlO₃ (LAO) substrates by a photo-assisted metalorganic chemical vapor deposition (PhA-MOCVD) technique with a single liquid precursor delivery system. Employement of single liquid precursor delivery process is found to be much effective for PhA-MOCVD-YBCO thick film growth since the reproducibility of high quality YBCO thick films is drastically improved compared to the case of usually used separate solid precursor delivery. This strongly suggests that PhA-MOCVD with a single liquid precursor
SESSION EE4: Coated Conductors - Buffers, HTS Layers

Chair: Tore Holinges and Venkiselvamickam
Tuesday, December 2, 2003
Constitution B (Sheraton)

1:30 PM EE4.1

The main goal of our work is to research and develop faster, potentially lower cost, and simpler RABiTS buffer-layer architectures that are compatible with c-axis BtF2 or TFA processes. Alternative to the standard RABiTS four-layer architecture of G-O2/N2/Y2/203/Ni/Ni-W, we have developed several architectures based on two effective potential Ni diffusion barrier layers, LnMnO3 (LMO) and Ln2Fe2O5 (L2O). These buffers were grown epitaxially on biaxially textured and strengthened Ni-W metal tapes by e-beam vapor and/or solution techniques. We have also successfully eliminated the need for Ni over-layers using either LZO or MgO seed layers. Using the met-allographic decomposition (MOD) approach, we have developed a new structure to grow epitaxial G-O2 buffer layers. Thick YBCO films with c-axis approaching 190 A/cm-width have been obtained on these alternative architectures and the results will be presented in detail. Research sponsored by the U.S. DOE, Division of Materials Sciences, Office of Science, Office of Energy Efficiency and Renewable Energy, Office of Distributed Energy and Electric Reliability, Superconductivity Program, Oak Ridge National Laboratory and managed by UT-Battelle, LLC for the U.S. Department of Energy under contract No. DE-AC05-00OR22725.

1:45 PM EE4.2

A thin layer of SrTiO3 has been successfully used as buffer layer to grow high quality superconducting YBa2Cu3O7 ± δ films on non-textured substrates. In order to grow SrTiO3 films, we used a co-sputtering technique and a MgO template produced by ion-beam-assisted deposition (IBAD). Using this architecture, 15 μm-thick-YBCO films with an in-plane mosaic spread in the range of 2.5° ~ 4° in full width at half maximum have been grown. In addition, the current density over 2 x 10^6 A/cm^2 at 78 K has been achieved routinely. It is interesting to note that the pulse laser deposition growth conditions of SrTiO3 buffer layers, such as growth temperature and oxygen pressure, have strong effects on the superconducting properties of YBCO. For example, the critical current density of YBCO films increases by a factor of two when the deposition temperature of SrTiO3 buffer layer increases 100°C systemically. Detailed microstructure studies including transmission electron microscopy (TEM), scanning electron microscopy (SEM) and atomic force microscopy (AFM) were used to explore the microstructure and growth mechanisms of SrTiO3 thin films deposited under different conditions and further understand their effects on the growth and superconducting properties of YBCO films. Our cross-sectional TEM studies reveal that SrTiO3 has a good lattice match and a clean and sharp interface with both MgO and YBCO, which further proves that SrTiO3 can be a promising candidate as the buffer layer for high performance superconductor coatings.

2:00 PM EE4.3
Electrodeposition of buffered layer for YBCO Superconductors: Oxide Films: Raghuv Nath Basak, Priscilla Spagnolo, Jun Chen, Togha Ayog, Chaudin Cao, David Christen and Dominic Lee; NREL, Golden, Colorado; ORNL, Oak Ridge, Tennessee.

In this presentation we will discuss the electrodeposition of biaxially textured seed metal buffer layer for YBCO superconductor oxide films. It is well established now that to obtain superior critical current densities for YBCO superconductors we need biaxially textured crystalline substrates. One way to accomplish biaxial texturing in a superconducting matrix is to grow epitaxial YBCO onto biaxially textured oxide substrates. Such superconductors interact with the substrate in a manner that degrades the superconductor material, especially during the high temperatures at which the superconductor materials are deposited or processed. To overcome these adverse interactions, a buffer layer of material is deposited to form a chemical barrier between the metal substrate and the superconductor. At present we are developing biaxially textured seed metal buffer layer materials inexpensively by electrodeposition method. We are testing electroplated biaxially textured Au and Ni on textured metal tapes of NiW and Cu, and on epitaxial CuO layers on single crystal MgO and LAO. In this meeting we will discuss the epitaxial growth of electroplated Ni and Au on single crystal MgO/Cu and LAO/Cu and also the properties of the superconducting YBCO material prepared on these substrates.

2:15 PM EE4.4

We have investigated the surface structural properties of the epitaxial Ni(001) films on Ni(001) SrTiO3 substrates as a function of gas ambient conditions (O2, forming gas, and H2O) and their effects on the epitaxial growth of oxide materials by reflection high energy electron diffraction (RHEED). Depending on the gas environment and the substrate temperature, the oxide films show three different superstructures: clean (001) Ni, c(2x2)-O superstructure, and textured NiO. The metastable oxygen c(2x2) superstructure on the Ni(001) was always be formed by water vapor dissociation in a forming gas environment which significantly increases the growth temperature to a growth temperature of 600°C. As a consequence of the c(2x2)-O superstructure, we have successfully achieved epitaxial growth of various oxide materials (SrTiO3, CeO2, TiO2, NiO, etc.,) by pulsed laser deposition (PLD). In contrast, growth on textured NiO surfaces or clean Ni surfaces produces multi-oriented films. This result is similar to the epitaxial oxide buffer layer growth on a c(2x2) reconstructed NiO surface by Cao et al. Details of nucleation mechanism of epitaxial oxide thin films on Ni and the thermodynamic and kinetic limitations of the c(2x2)-O surface for the epitaxial growth of various oxide buffer layers will be discussed.

2:30 PM EE4.5

We have grown epitaxial CeO2 buffer layers on biaxially textured Ni-W substrates for YBCO coated conductors. Using a novel MOD approach. Pre-cursor solution of 0.25M concentration was spin coated on short samples of Ni-35W substrates and heat treated at 1100°C in a gas mixture of 4:1H2 for 15 minutes. Detailed X-ray studies in situ show that the CeO2 film has a good out-of-plane and in-plane texture with a full-width-half maximum of 5.8° and 7.5°, respectively. High temperature XRD studies show that the nucleation of CeO2 starts at 600°C in c-axis and reaches the complete crystallization at 1100°C in c-axis. Results on the properties of the YBCO films grown on RABiTS architecture with CeO2 seed layer will be presented.

2:45 PM EE4.6

We present an experimental study of nucleation of 1.5 microns thick YBCO layers on flexible metallic substrates. YBCO precursor was deposited by vacuum co-evaporation of BaF2, Y and Ce. Initial state of the precursor is proven to be important for stable c-axis growth of thick YBCO films. We believe that the way the precursor is oxidized after the vacuum deposition determines the film permeability for H. High permeability is needed for thick films to allow by out-diffusion of H, which has a significant effect on YBCO nucleation. Oxidation of yttrium metal in the precursor is important in this respect. High-temperature oxidation results in formation of dinitrium oxide. Such a precursor has low permeability for H and is unsuitable for the thick film growth due to extensive random grain nucleation. Low-temperature oxidation in water vapor converts yttrium metal to low-density oxy-hydroxides. This forms highly permeable precursor, which can be converted to c-axis oriented
YBCO. We report about results of controlled oxidation of the precursor and demonstrate correlation between the oxidation state and the YBCO phase. This work was performed under the auspices of US Department of Energy under contract No DE-AC-02-88CH10886.

3:30 PM EE4.7

Low-angle grain boundaries are commonly considered as the limiting factor determining the critical current of coated conductors. Precisely we show that for grain boundaries in YBa2Cu3O7-δ the critical current density, \( J_c \), exhibits a magnetic field angle dependent crossover from grain boundary (GB) to in-grain (IG) behavior. This behavior has been modeled by treating the grain boundary as a weak pinning plane intersected by vortices that strongly pin at the GB and are then scattered to and from the grain interior. Within the simplest picture the current crossing the grain boundary exerts a Lorentz force on the vortex which is balanced by weak pinning in the GB and by vortex deceleration due to scattering at its ends. When in-grain pinning is high, \( J_c \), is determined by the force to cut a vortex line at the boundary. A crossover occurs for low in-grain pinning or when insufficient vortices cross the grain boundary. As would be expected from such a single vortex model, the form of \( J_c(\phi) \) is independent of \( B \) but dependent on \( T \). From model the force required to cut a vortex line has been determined as a function of \( T \). Transport critical current measurements have been performed on YBa2Cu3O7-δ single grain boundaries with various GB angles, and the magnetic field applied both in and away from the plane of the film. The variation of \( J_c \) has also been determined as a function of the angle between the magnetic field and the grain boundary for grain boundaries which are not perpendicular to the direction of current flow. As in the case of perpendicular grain boundaries \( J_c \), is found to be strongly suppressed only when the applied magnetic field is within an angle \( \phi_g \) of the grain boundary. This angle is as small as 1° at 8 T and 75 K. The minima in the observed \( J_c(\phi) \) behavior is always symmetrical. This means that in the grain boundaries studied the current flow is perpendicular to the grain boundary in the angular range for which the GB properties dominate. This observation implies that the \( J_c(\phi) \) behavior that would be observed for in-plane fields in coated conductors will differ depending on whether current flow is IG or GB limited.

3:45 PM EE4.8

Our coated conductor development effort utilizes research, development and characterization of small samples to provide directions for our 1 cm wide by 1 meter plus long sample fabrication efforts. Small coated conductor bridges (~1 cm long by ~0.02 cm wide) are fabricated, and their critical currents, \( I_c \), are measured as a function of temperature, applied magnetic field, and field angle \( \beta \). The \( V-I \) curves are fitted by a power law, \( I_c \propto B^n \), to determine the exponent, \( n \). Meter long coated conductor samples are also manufactured for self-field \( I_c \) and then for \( I_c \) homogeneity as a function of position. On these long samples, we find that the \( n \) is an increasing function of the critical current. While there is a good correlation between \( n \) values derived from analysis of \( V-I \) curves measured on small bridges and on the larger coated conductor tapes, \( I_c \) (B, F) measurements demonstrate that \( n \) values calculated from \( V-I \) curves taken as a function of applied field angle \( \beta \), are not simply a unique function of the critical current. When \( V \) is \( V_{0}/T \), \( T = 25K, B_0 = (0.7T) \) is plotted, two distinct functions emerge, one for \( N = 1 \) and \( \beta = \pi \), the other \( N = 2 \) and \( \beta = 0 \), with \( n \) a consistent difference between the curves. These results suggest a transition between dissipation mechanisms occurring when \( B \) is parallel to the c-axis and \( B \) is parallel to the ab plane and is consistent with the existence of an angular-dependent irreversibility line, which is highest for \( \beta = 0 \) and \( \beta = \pi \), for both \( I_c \) and \( N \) values for small bridges on metal and single crystal substrates and on large 1 cm wide tape coated conductors. From the comparison of these results we obtain information on the relevant pinning mechanisms in these different types of samples.

4:00 PM EE4.9
Comparative Study of the Through-Thickness \( J_c \) in Two or more YBa2Cu3O7-δ Coated Conductors with Exceptional Performance. Sng Il Kim1, David M. Feldmann1, David C. Lambrecht1, Darren T. Vetrivel2, Wei Zhuang2 and Terry G. Holesinger1, 1Applied Superconductivity Center, University of Wisconsin - Madison, Madison, Wisconsin, Wisconsin, 2American Superconductor Corporation, Westborough, Massachusetts, 3Los Alamos National Laboratory, Los Alamos, New Mexico.

Recently, recent metal-organic deposition (MOD) processed YBCO filmation RABITS (NiW) have developed exceptional properties with critical currents per unit width reaching a value of 270 A/cm. We have used initial matrixing to compare the thickness performance of this conductor to an earlier 120 A/cm conductor. We find that both conductors show a rising \( J_c \) with decreasing thickness and that the higher \( I_c \) conductor attains a \( J_c \) of 4 MA/cm² below 0.3 mm thickness. The \( J_c \) values of the lower \( I_c \) conductor are about half the higher \( I_c \) conductor, but the normal state resistivities are equal. The data will be discussed in terms of their through-thickness microstructure and properties. It is clear that this performance is extremely promising for commercial coated conductor performance.

4:15 PM EE4.10

RABITS based coated conductor samples were used to investigate the influence of the low angle grain boundary network on the temperature and magnetic field dependence of the critical current density and IV-characteristics. YBCO layers with critical current densities \( > 1 \) MA/cm² were fabricated on the same template via chemical solution deposition and by the standard pulsed laser deposition (PLD) process. The transport properties show clear crossover behaviour between inter- and intragranular Jc limitation. The underlying grain boundary network of the samples was qualitatively characterized by Electron Backscattering Diffraction (EBSD) mappings. Jc simulations using a fast and simple limiting-path algorithm were used to investigate the influence of the grain boundary misorientation statistics and its impact on Jc in these samples. Due to the limitation of the critical current density Jc by grain boundaries and the percolative flow through a statistical network of grain boundaries, Jc depends strongly on length and width of the sample area under consideration. This effect is investigated using large EBSD maps and will be compared to existing pure statistical approaches.

4:30 PM EE4.11

We present measurements of the angular dependence of the critical current density \( J_c \) in DyBa2Cu3O7-δ films as a function of magnetic field and temperature. We found evidence of the presence of two types of naturally grown correlated disorder, one parallel to the c-axis and one inclined by a few degrees with respect to it. Each type of defect produces a peak in the angular dependence of \( J_c \), with its own characteristic field and temperature dependence. The peak is more prominent at lower temperatures and higher fields, while the inclined defects are stronger at higher temperatures. The maximum of the inclined peak shifts away from the c-axis as the field is lowered due to the alignment between the internal and applied magnetic fields. We studied films of different thicknesses and compared their properties with those of typical YBa2Cu3O7-δ films.

4:45 PM EE4.12
Magnetooptical Imaging of Flux Pinning Characteristics in YBCO Thick Films Grown by PLD and BaF2 ex-situ Processes. Qing Li1, Zuxin Ye1, Masaki Sunaga2, Yimei Zhu1, Zhenzhen Shilov2, Weidong Si1, and Stephen R. Foltyn1, 1Brookhaven National Lab, Upton, New York, 2Los Alamos National Lab, Los Alamos, New Mexico.

Magnetooptical imaging (MOI) techniques were used to investigate the flux pinning characteristics in the YBCO thick films grown by either BaF2 ex-situ post-reaction process on SrTiO3 (STO) substrates or by pulsed laser deposition (PLD) on LaAlO3 (LAO) or STO substrates. A uniform pattern of flux penetration and trapping was observed in the PLD films on either LAO or STO substrates. A tree branch pattern of flux penetration and trapping was observed in BaF2 ex-situ processed films. The branching scale is in the order of tens of microns. Despite this remarkable difference, the averaged value of critical current density for all these films obtained by both the MOI and bulk magnetization measurements is similar. The MOI results suggest that the addition of disorder unique to BaF2 films affects the low field current distribution in such a way that the coherence length of YBCO, which does not change the intrinsic pinning of YBCO. This work was supported by the US Department of Energy, Division of Materials Sciences, Office of Basic Energy Sciences under contract No. DE-AC02-88CH10886.
EE5.1
Pulsed electron beam deposition of YBa$_2$Cu$_3$O$_{y-2}$ thin films.
Ram Jay Choudhary$^1$, R. S. Shinde$^1$, S. B. Ogale$^1$, V. N. Kulkarni$^1$, T. Venkatesan$^1$, K. S. Harikrishna$^2$ and Mikhail Strikovski$^2$.

Thin films of YBa$_2$Cu$_3$O$_{y-2}$ (YBCO) are grown on [001] LaAlO$_3$ substrates by pulsed electron deposition (PED). This technique is based on charged discharge system with magnetically self-focused electron beam. Parameters such as discharge voltage and background pressure have been optimized for the growth of high quality YBCO films. The films grown under optimized conditions are found to be highly c-axis oriented and exhibit good in-plane alignment as observed in the x-ray diffraction (XRD) $\phi$-scan. The rocking curve full width at half maximum for the (005) peak is 0.4 degree compared to that of the substrate of 0.3 degree. The surface of the films is smooth, with the RMS roughness of $\sim$5 nm. For a 100 nm thick films, the measured critical current density ($J_c$) is about 14.8 and 0.9 MA/cm$^2$ at 4K and 77K respectively. Various issues such as the angular distribution of the composition profile, surface morphology of the film, variation in $J_c$ with thickness of YBCO, variation in composition of the film with changes in the growth conditions will be discussed. The results are compared with those for films grown by other deposition techniques. This work is supported by Maryland Industrial Partnership (MIPs) program.

EE5.2
Using High Speed Imagery During The Pulsed Laser Deposition Of YBa$_2$Cu$_3$O$_{7-x}$ To Identify Key Process Control Parameters. Carl J Draffan and Glen P. Perram, Department of Engineering Physics, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

Optical signatures from the pulsed laser deposition (PLD) of YBa$_2$Cu$_3$O$_{7-x}$ (YBCO) superconducting films may be used for the process control required to produce long lengths of coated conductors. An intensified, gated CCD camera has been used to observe the PLD plume propagation dynamics with high spatial (200 micron) and temporal (50 ns) resolution. Plume imagery, with 100s of video frames per plume movie, have been obtained with several band pass filters to restrict the emission to various components of the plume, including Ba, Cu, O, and Y. The plumes are highly forward peaked, with a cos$^\alpha(\theta)$ angular distribution where $\alpha$ = 50-1000, depending on the propagation distance and time. The dependence of the forward peaking on laser fluence, oxygen pressure, plume expansion time, and emitting species has been characterized. Most significantly, a strong correlation has been identified between the difference in copper and barium angular distributions and the critical currents of the deposited films. Plume images may also be analyzed to characterize the times-of-flight speed distributions. The width of the speed distributions exhibits a minimum for a specific ratio of oxygen pressure for conditions where the best films are typically achieved.

EE5.3
Partitioning of energy among translational, electronic, and vibrational states during the pulsed laser deposition of YBa$_2$Cu$_3$O$_{7-x}$. Patrick D Kee and Glen P. Perram, Department of Engineering Physics, Air Force Institute of Technology, Wright-Patterson AFB, Ohio.

Extremely fast laser ablation of YBa$_2$Cu$_3$O$_{7-x}$ targets at 1-2 J/cm$^2$ yields highly excited atoms, with less than 1% of the laser beam energy required for vaporization. Emission times-of-flight spectra establish kinetic energies of 1.15-5.0 eV and emission spectra indicate electronic state distributions of 1.000-10,000. The plumes remain collisionally dynamic even at high background pressures and low laser beam energy. For plume expansion temperatures in the ambient chamber (30°C), the temperatures derived from Y I (D$^0$, F$^0$) are much higher, 8000 ± 1000 K. The plume components retain high electronic temperatures and significant ionization, even at laser beam energies near threshold for plume emission. The times-of-flight spectra exhibit plume splitting as oxygen background pressure above 1 Torr, with the fast component increasingly intense at higher pressures. A systematic characterization of the times-of-flight and emission spectra has been conducted to aid process control in the manufacture of long lengths of superconducting YBCO wires.

EE5.4
Measurement of HF Partial Pressure during the BaF$_2$ Process. Masami Yoshimura and Michael J. Glenn, Massachusetts Institute of Technology, Cambridge, Massachusetts.

The BaF$_2$ process is one of the commonly used processes for deposition and growth of highly oriented YBCO films since they are highly textured and achieve high values of Jc. Recently, it has been clarified that the removal of HF gas from the film surface controls YBCO growth. The partial pressure of HF gas ($P_{HF}$) is quite important either to improve the process or to understand the thermodynamics of the process. There is no experimental determination of this partial pressure and the thermodynamic stability of the solid phases is not sufficiently accurate for its estimate. A new method was developed for the $P_{HF}$ measurement in equilibrium with MOI-derived YBCO films during processing. A Knudsen cell is used to measure the vapor pressure. The method can accommodate the small $P_{HF}$ by quenching specimens and measuring fluoride content by a selected electrode. This approach offers greater precision than the traditional mass measurement. YBCO precursor films on LAO single crystals were placed in a small ceramic cell covered with a plate. A precision hole has been fabricated in the plate. The cell assembly heated for a specified time in a furnace under appropriate atmosphere. Quenching the cell is followed by residual fluoride measurement. The $P_{HF}$ in the cell can be obtained by difference between samples from different cell times. The results have been used to determine the free energies of relevant reactions.

EE5.5

To achieve high critical currents in second generation superconductors deposited on metallic substrates, substrate surface roughness and texture of the buffer layer are key factors. Especially when depositing buffer layers using ion beam assisted deposition (IBAD), the substrate smoothness is key for obtaining good texture of the buffer layers. However, there are no systematic studies reported on the substrate planarization to the best of our knowledge except for a limited study by Los Alamos National Lab. In this paper, planarization of ion beam assisted deposition (IBAD) substrate and deformation textured substrate (RADIBS) is presented using an inductively coupled radio frequency (RF) discharge operated at 13.56 MHz. The inductively coupled discharge system was constructed using a pancake coil antenna. Linearized substrates were created by exposure to an Ar discharge for varying time periods. Instead of polishing, and textured Ni foils have been studied under varying RF power conditions, such as pressure, RF power and etch time to determine the effects on substrate roughness. Results will be presented on the planarization effects on the substrate and subsequent buffer/YBCO layers using both process. Plasma planarization conditions will be presented with respect to surface roughness also.

EE5.6

High current densities are now routinely obtained in coated YBCO conductors deposited on textured nickel and nickel alloy substrates. An alternate substrate that is non magnetic (for low AC losses) and highly conductive (for thermal and electrical quench protection) is preferable for many practical applications. Textured metallic substrates based on copper may provide such an alternative that meets these requirements. In our work, highly textured metallic copper substrate tapes were produced using the rolling-assisted initially textured substrate (RAITS) process. This process incorporates cold rolling and subsequent recrystallization resulting in excellent in-plane as well as out-of-plane alignment. Results will be presented on the texture development behavior of copper subjected to various deformation levels and recrystallization heat treatments. X-ray diffraction was performed to gauge the quality of in-plane and out-of-plane texture in copper and the Phi Scan FWIMB indicated in-plane macroscale texture orientations as low as 5°. Orientation Imaging Microscopy analysis will be included in addition to preliminary results.
on depositing buffers layers and the subsequent YBCO film.

EES.7
Fabrication of YBCO Film on CeO₂-Capped IBAD Layer
Tomihiro Watanabe, Hiroki Iwami, Takahiro Murog, Seiki Miyama, Yutaka Yamada and Yuh-Shih Hara;
Nagoya Coated Conducting Center, ISTEIC-JRIL, Nagoya, Japan; Division of Superconducting Tapes and Wires, ISTEIC-JRIL, Tokyo, Japan.

YBa₂Cu₃O₇-δ (YBCO) deposition on CeO₂ capped Ion-Beam Annealed Deposition (IBAD) substrate has been studied for the fabrication of coated conductors. The CeO₂ cap layer, which was deposited on the IBAD Gel-Zr-oxide (GZO) layer using pulsed laser deposition (PLD), showed high grain alignment with a full width at half maximum (FWHM) of 1.8°. YBCO layer was deposited by PLD. In a short samples, we obtained the highest critical current density (Jc) of 4.14 MA/cm² for 0.4μm thick YBCO film and high critical current (Ic) of 276 A/cm² for 1.2μm thick one. The continuous deposition (IBAD) substrate has been studied for the fabrication of long coated conductors. We obtained high Jc of 0.96 MA/cm² at 77K in the continuously deposited YBCO films on the CeO₂ capped IBAD-GZO layers as well as in those in short samples. In order to improve Jc and Ic coated conductors, we have been investigating the influence of YBCO film deposition rate and thickness on Jc and Ic. These influences and our progress in several/meter-length coated conductor preparation will be reported. This work was supported by New Energy and Industrial Technology Development Organization (NEDO) in Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications.

EES.8
Development of Y-Ba-Cu-O Coated Conductor Using Aerosol Assisted Chemical Vapor Deposition Approach
Daniel Fisher, Manisha Rane, Harry Efstathiou and Pradeep Holdi; School of NanoSciences and NanoEngineering, University at Albany - SUNY, Albany, New York.

A non-vacuum method of producing high temperature superconducting YBa₂Cu₃O₇-δ films on SrTiO₃ (STO) substrates using an Aerosol Assisted Chemical Vapor Deposition (AACVD) process is being implemented. Efficient AACVD is desirable in YBCO superconductor development due to its high film growth rate and low cost. Two different aerosol generation processes have been investigated. Scicosiometric solutions of Y, Ba, and Cu nitrate were used as the aerosol source delivered by a controlled flow rate. Film deposition was performed at the substrate temperature range of 800°C to 1000°C in atmospheric pressure for a variable duration of time depending on the desired film thickness. Microstructural, chemical, and electrical characterization of the films was performed by x-ray diffraction (XRD) spectroscopy, plm view scanning electron microscopy (SEM), energy dispersion spectroscopy (EDS), focused ion beam (FIB) microscopy, and current-voltage (I-V) measurements performed in a self-field at 77K. Film composition depth profiling was performed by Auger electron spectroscopy (AES). Film thickness and composition uniformity have been found to change with varied substrate temperature and inert gas delivery flow rate.

EES.9
Growth of YBCO Films on NbN RABITS in the partial pressure using the Ba₆F, ex-situ process
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YBCO films are grown on NbN RABITS in the range of total pressure 55-80 Torr using Ba₆F ex-situ process. We investigate effects of post-annealing parameters on transport properties of YBCO films using 0.5 -1 μm precursor films. For 0.5 μm films, the highest Jc values of 2.6 MA/cm² was obtained under the conditions of P_{c+} = 35 Torr, T_{s+} = 740°C. For 1 μm precursor, mainly, when vapor pressure is modified in order to achieve high Jc value. For 0.8 μm films, Jc values of 1.4 MA/cm² was obtained.

EES.10
Growth of high quality, epitaxial TIN seed layers on RA-BITS
Jason Yoo 1, Amit Goyal 1, Sukil Kang 2, and Joel Rutter 2, 1Materials Science & Technology, University of Cambridge, Cambridge, Pembroke, United Kingdom.

We investigate the experimental parameters for growth of high quality, epitaxial TIN seed layers directly on NbN RABITS using RF sputtering as a function of RF sputtering power, substrate temperature and the N₂/Ar ratio used. RF sputtering power P_{RF} was varied between 25 and 200 W, the substrate temperature T_s was varied between 350 and 750°C, and the N₂/Ar ratio was varied between 1 and 10. The crossover from [111]-oriented grains to [001]-oriented grains of TIN thin films occurred as T_s increased for NbN substrate while for Cu substrate, crystalline orientation changed from [010] to [111] with increase in deposition temperature. The in-plane texture, 0°- and 90°-rotated grains are competing according to growth condition due to large lattice mismatch (lattice constant 11 for TIN 2.42 Å, for Ni 3.52 Å, for Cu 3.61 Å). TIN thin films on NbN are grown in low textured condition with an in-plane texture of [010] (90°-rotated) and high T_s (>> 600°C) with certain ratios of N₂/Ar gas. We demonstrate YBCO films with high Jc values using the buffer structure of TIN/MgO/LaMnO₃.

EES.11
YBa₂Cu₃O₇-δ Thin Film Growth by Post-deposition Processing of Precursors at Very Low Oxygen and Water Pressures
Yifei Zhang 1, 2, Ren Hanifman 3, and Thomas M. Reinecke 1, 4
1Albert A. Gossedt, 2Teck J. Ayut 5, and David K. Christen 6, 7, Oak Ridge National Laboratory, Oak Ridge, Tennessee; 2The University of Tennessee, Knoxville, Tennessee.

YBa₂Cu₃O₇-δ (YBCO) epitaxial films of thickness 0.1-1μm were grown on single crystal substrates using ex-situ post-deposition processing in which co-evaporated Ba₂Cu₂ precursors and TFA precursors were annealed in a low-pressure gas mixture of oxygen and water vapor. The partial pressures of oxygen (PO₂) and water vapor (PH₂O) are as low as 10mTorr and 0.1mTorr, respectively. X-ray diffraction and SEM inspection were conducted for structure characterization of the films. The effects of water vapor pressure as well as other processing parameters on film microstructure and properties were investigated. High critical current densities (Jc) of ~3.6 MA/cm² at 77K in self-field were achieved, yielding properties comparable to those of the best ex-situ-coated ex-situ films from similar precursors processed under normal atmospheric pressure condition. This research is supported by United States Department of Energy under contract DE-AC05-00OR22725 with the Oak Ridge National Laboratory, managed by UT-Battelle, LLC.

EES.12
Monofilamentary dysprosium-doped Bi-2212 superconducting tapes produced by a melt-textured growth process under an external 1T magnetic induction from a gel-like precursor on nickel substrate
Marcel Asseln 8, Schieben Rahber 8, Nicole Fonder 8, Jean-Francois Fagnard 8, Philippe Vandenbend 8, and radi G. Cloots 8
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Dysprosium doped Bi-2212 superconducting tapes have been produced by a melt-textured growth process under an external 1T magnetic induction. Nickel substrates have been preferred due to the chemical compatibility between NiO and the Bi-2212 liquid phase at high temperature. 2201 secondary phases are produced during the melt-textured growth process following the peritectic decomposition of the Bi-2212 phase. Annealing under different atmospheres has been tested in order to favour the peritectic recrystallization of 2201 and the residual liquid phase. Superconducting properties have been measured to determine the best conditions for producing the optimized material. Mechanism for recrystallization through the peritectic temperature by annealing has been studied on bulk specimen. Microstructural data confirmed the complex chemistry of this material.

EES.13
Abstract Withdrawn

EES.14
Measuring the Hole State Anisotropy in MgB₂ by Electron Energy-Loss Spectroscopy
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We have examined polycrystalline MgB₂ by high-resolution electron energy-loss spectroscopy (EELS) on a multiple-acquisition electron energy-loss spectroscopy (M-AELS) to study the strong anisotropy of the hole state in MgB₂. In particular, we have studied two different crystal orientations, [110] and [100] with respect to the incident electron beam direction, and found significant changes in the near-edge fine structure of the B-1d core level binding energy, indicating that the pre-peak of the B-1d core level is composed of a mixture of pxy and pz hole states. The EELS results were obtained using the JEOI, 3300® and the JEOI, 2010® operated at 300kV and 200kV, respectively, and a VG HB01 operated at 100 kV, equipped with a...
spherical aberration corrector. We will show that the individual contributions in the K-edge pre-peak can be distinguished only in the VG HB501 with an experimental energy resolution better than 0.5 eV. For conventional TEM/STEM instruments with an energy resolution of ~1.0 eV the pre-peak still contains valuable information about the local charge carrier concentration that can be probed by core-loss EELS. By considering the scattering momentum transfer for different crystal orientations, it is possible to analytically separate pty and py components from of the experimental spectra. Direct measurements of the pty-carrier concentration with a sub-nanometer scale. This work is supported by the U.S. Department of Energy, Division of Materials Sciences, Office of Basic Energy Science, under Contract No. DE-AC02-8CH10886.

EELS 15
Fabrication of MgB2 Conductors by Hot Rolling.

Steel sheathed MgB2 rods having a dense, well-connected, core have been fabricated using a hot rolling technique. The starting materials consist of powdered boron and magnesium granules which are packed inside a steel sheath wall. The whole mixture is then hot rolled with a diamond grooved rolling mill through several passes and reductions until a 90% reduction in area is achieved. The hot rolled rod is then allowed to cool slowly from 900°C in a furnace. The resulting 2 mm diameter MgB2 core appears, on a metallographic basis, to be dense and well-connected. Resistivity and transition temperature measurements on a sample of the MgB2 core extracted from the sheath indicate a low resistivity with a sharp transition. This experiment demonstrates that a useful MgB2 superconductor, with a simple geometry can be produced using the combination of an in situ synthesis reaction coupled with simultaneous hot deformation.

EELS 16
Intergranular Nanostructure and Possible Spinodal Decomposition in Low Resistivity Bulk MgB2 with Varying Critical Fields.
Xueyao Song, Vlastimil Brada and David Labudovic, Applied Superconductivity Center, University of Wisconsin-Madison, Madison, Wisconsin.

Three electromagnetically well-characterized bulk samples with resistivities at 40 K varying from 1 to 18 µΩ cm were investigated by conventional electrical resistivity, electron-probe microanalysis, X-ray diffraction, and transmission electron microscopy. Clean, coherent or semi-coherent grain boundaries and dirty grain boundaries wetted by amorphous phases were found in all three samples, even though the starting sample A had the very low resistivity characteristic of clean-limit samples of 1 µΩ cm at 40 K. Taking account both of porosity and the wetted grain boundary density reduces π/4(K) to ~0.5 µΩ cm. Additional samples B and C generated by exposing samples A and Mg vapor had π/4(K) of 14 and 18 µΩ cm. Intragranular nanocrystals indexed from the electron diffraction rings as MgB7 with a size of 1-5 nm were observed in local areas of the 1 and 18 µΩ cm samples. Because the starting samples were found to be Mg-deficient by 2 western measurements, we propose that nanocrystals form by reaction such as Mg0.68B going to MgB2 4y MgB7. The possibility of this being a spinodal reaction is discussed.

EELS 17
Artificial Pinning Technology and Nano Structure Engineering for High Jc Superconducting Films.
Kazumasa Mano, Masahiro Marui, and Yutaka Yoshida,3,4

EELS 18
Route Into Room-Tc Superconductivity on Base of Resonant Coupling Effect In 2D Crystals If MgB2-Type Nanotubes. V. Vladimir Popkovny, IHEOR.MAT.SCI, Inst Problems Materials Science of NAm, Kiev, Ukraine.

Superconducting properties of nanotubes (NTs) are reviewed. Theoretical ideas for ideal room-Tc superconductor (RTSC) are put forward on two-dimensional (2D) crystals built from nonconventional NTs of superconducting bulk material as the ideal medium. Combining Little's and Ginzburg's ideas with recent progress in NTs research, this review attempts to compare the state of superconducting nanotubes (NTs) shined to be as unique quantum macroscopic effect of superconducting bulk material and the ideal RTSC1,2. Coherence low-temperature propagation in these nanotubes provides a unique opportunity for Cooper pairing and Bose-Einstein condensation. However, a fabrication of such crystals is a very difficult technological procedure. The need of composition of YBaCuO, etc. Superconductivity in new simple MgB2 compound with Tc 39 K is a puzzle. The ability of double-phonon mechanism on base of E2g-mode. Novel joint research on superconducting nanotubes with complex multiple gap room-Tc superconductivity is suggested in base of whispering gallery of circular zero-points phonon modes (twistons, rotation), in particular E2g-mode, resulting to resonant electron-phonon coupling. It is in accordance with some recent experimental data confirming the effect of nanotubular superconductivity and indicating on possible RTSC with Tc 100 K in 2D bundles of C-NTs. Novel route is advanced to fabricate such RTSC on base of 2D crystals built from single MgB2, NbSe2, Si, Sn or other superconducting nanotubes. 1. V. V. Popkovny, J Superconductivity 13, 607 (2000). 2. V. V. Popkovny. Physica C351, 71 (2001).

EELS 19
Correlation of Local Magneto-Optical Measurements of Critical Current Density to Microstructure in Polycrystalline Superconductors. Sagyn Lin,1,2 Eric H K PSTL, and David C Labudovic1, Applied Superconductivity Center, University of Wisconsin-Madison, Madison, Wisconsin, Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, Wisconsin.

Crucial to significant application of large-scale superconducting electric devices for power industry is the development of wires with high critical current densities (Jc) at temperature where cryogenic losses are tolerable. In a state-of-art overpressure processed Ag-sheathed (Bi2212)2Sr2CaCu2O8+4 nanowires conductor with selffield bulk transport Jc ~ 48 kA/cm2 at 77 K, large variations of local Jc were observed and the local Jc can be as high as 5 times the bulk transport Jc, indicating that current percolates through polycrystalline conductors and a clear fraction of current-carrying cross-section is significantly less than unity. Therefore, fully exploring the fundamental current-carrying capability of polycrystalline superconductors requires an understanding of the correlation of local Jc and microstructure. In our present work, we have a novel critical current Jc distribution on a polished cross section of a superconductor in shot geometry by quantitative magneto-optical imaging (MOI) of flux distribution together with a model-independent determination of the corresponding current distribution and use backscattered-SEM imaging and EDS mapping to define the microstructure and phase balance. The spatial correlation between the images is established by using the registration marks cut by focused ion beam (FIB). In this work, we will evaluate the spatial resolution of each technique and justify the correlation precision between local magneto-optical measurements of Jc and microstructure in polycrystalline superconductors.
EES 20

Interaction of MgB$_2$ with Atmospheric Contaminants, and Its Effect on Properties. Lawrence F. Cook$^{1}$, Ralph Klein$^{2}$, Winnie Wong$^{3}$, Edge S. Ezr$^{4}$, Roque A. Ribeiro$^{5}$ and Paul C. Canfield$^{6}$.

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Vapor pressure and enthalpy of solution measurements have been completed on several different samples of MgB$_2$ from different sources. One explanation of the differences in results among the samples has to do with their preparation, handling, and storage. We have observed that materials handled only under glovebox conditions with others exposed to air. To investigate the effect of interaction of MgB$_2$ with water vapor, samples have been exposed to high humidity and characterized calorimetrically, thermogravimetrically, and by x-ray powder diffraction. The results indicate that the atmospheric CO$_2$ and O$_2$ are also being investigated. Results of measurement before and after exposure will be presented and compared, and discussed with regard to equilibria in the system MgO-B$_2$O$_3$.

EES 21


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The mechanism behind supercurrent flow through grain-boundary networks in superconductors is a topic of great interest, especially for potential industrial applications of materials such as coated conductors (CC). It is well-known that the critical current density, $J_c$, in such systems can be hysteretic relative to increasing or decreasing applied field. Of particular interest is the observation of a "peak" in $J_c$ at low fields as $J_c$ is decreased from high fields, due to the cancellation of applied field by the return field within grain boundaries produced by trapped flux inside the grains. In the case of CC the presence of this phenomenon in the magnetization has been analyzed recently by Palus et al. However, because of the percolative nature of current flow in these materials, until now the hysteretic behavior of transport critical current has not been observed. Films grown on RABIT and HABIT-YSZ substrates were patterned to contain a single parallel array of 100 wirewide parallel arrays, eliminating the case of RABIT most percolative flow around grain boundaries — then transport measurements were made in a standard four-contact configuration. Hysteresis and the flux-trapping peaks in $J_c$ are clearly seen for the first time for these materials. Control studies were conducted using YCO films deposited on SiO$_2$ interlayer substrates containing a single [001] grain boundary, with angles of 2 to 7 degrees. Using both line- and ring-patterned samples, transport critical currents and magnetic moments were measured in applied magnetic fields, revealing hysteretic with a greatly pronounced flux-trapping peak in $J_c$ for decreasing field. The results can be modeled to yield non-quantitative agreement with the observed interwire and intrawire grain-boundary effects, lending new opportunities for granular studies, especially on the nature of percolative current flow in CC, as will be discussed. Research sponsored by the U.S. Department of Energy under contract DE-AC05-00OR22725 with the Oak Ridge National Laboratory, managed by UT-Battelle, LLC.

EES 22

Effects of Oxygen on the Superconductivity Properties of MgB$_2$ studied by EELS and DPT. Juan Carlos Iribarne$^{1}$, Nigel Browning$^{2,3}$ and Senthur Govt$^{4}$.

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Since the discovery of MgB$_2$ a range of different values for the critical temperature, critical current density, and resistivity have been reported, indicating that transport properties in MgB$_2$ depend strongly on sample preparation conditions. Two main causes have been considered for the property variations: Mg vacancies and O impurities. Superconductivity in MgB$_2$ is driven by hole transport through the boron orbitals. The presence of oxygen as segregates into the grain boundaries is a prerequisite for the onset of superconductivity in MgB$_2$. Therefore, MgB$_2$ materials could have a large effect on the hole carrier concentration, thereby changing the superconducting properties and explaining the variation measured in the transport properties of MgB$_2$. In this work we present measurements of oxygen segregation in MgB$_2$ using transmission electron microscopy (STEM) using atomic resolution Z-contrast imaging and electron energy loss spectroscopy (EELS). We have studied in detail the segregation of oxygen into the grain boundaries as well as precipitates into the bulk. We have found experimentally and using first principles calculations that some precipitates present changes in the electronic fine structure of the boron orbitals, i.e. sharp peaks associated in a change in density of states close to the Fermi level. This peak has been the focus of diverse studies, and an increase in its intensity is associated with a better performance of MgB$_2$ as a superconductor with a higher critical temperature. Work is underway to understand the origin of the change in the peak’s shape and its effect on superconducting properties.

EES 23

High $Jc$ MgB$_2$ Powder-in-Tube samples using mechanically alloyed nanocrystalline precursor powder. Bernhard Holzapfel, Wolfgang Hessler, Claus Fischer, Olaf Ponter, Jürgen Ecker, Konstantin Nenkov, Guenter Buda and Ludwig Schrader, Institute of Metallic Materials, IFW Dresden, Dresden, Germany.

Since the discovery of superconductivity at 35 K in intermetallic magnesium diboride intensive research has been carried out to develop a low-cost MgB$_2$ conductor that can be used for magnet applications at intermediate temperatures using the "powder-in-tube" (PIT) technique. It was demonstrated that nanocrystalline MgB$_2$ powders obtained by mechanical alloying showed improved superconducting properties. In this contribution we report on our recent results on Fe-doped MgB$_2$ powders that have been prepared by the PIT method using mechanically alloyed nanocrystalline Mg$_2$B$_4$O powder mixtures as precursor consisting of the constituents Mg, B and MgO. Despite reduced Tc values of about 31 K, maximum critical current densities (Jc) of 22 MA/cm$^2$ and 7 kA/cm$^2$ in external magnetic fields of 7.5 and 10 T, respectively, are achieved at 4.2 K. These values exceed those of all other so far reported undoped MgB$_2$ deposits, which can be attributed to the very fine-grained microstructure of the superconducting phase. The irreversibility fields Hir of these tapes are 9.5 T and 4.2 T at 10 K and 20 K, respectively.

EES 24

Critical Current Modeling for Coated Conductor Applications. Neil Antony-green$^{1}$, the late Andrew Nagy$^{2}$ and Antal Nagy$^{3}$.

1Materials & Ceramics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee; 2Department of Materials Science & Metallurgy, University of Cambridge, Cambridge, United Kingdom.

In multi-granular superconducting tapes, as those fabricated by the RABITS method, the overall critical current density will usually be limited by dissipation at grain boundaries. A Monte Carlo grain growth simulation has been incorporated into existing percolation models in order to calculate critical currents of grain networks. Intragranular dissipation is also included in the model in order to investigate the conditions for which grain boundaries cease to be the limiting factor. Using the model, the effects of the overall conductor dimensions and the average grain size have been investigated in detail. For standard conductor shapes, it is most favorable to have a small average grain size, a factor which will be most important for applications in which reduction of AC loss is important. The effect of grain boundaries will be reduced by having very large grain shapes, such that they are intersected along the tape length direction. The grain shape will also determine the effect of magnetic fields on the boundary network, with implications for high-field applications.

EES 25

The Reaction Sequence and Growth Kinetics of MgB$_2$ Layer during ex situ Annealing of Amorphous Boron Film. Hyun-Mi Kim$^{1}$, Sung-Soo Yim$^{1}$, Ki-Bum Kim$^{1}$, Do-Hwan Kang$^{1}$, Seung-Hyun Moon$^{2}$, Young-Woo Kim$^{3}$ and Ho-Nyun Lee$^{2}$.

1School of Materials Science and Engineering, Seoul National University, Seoul, Seoul, South Korea; 2LG Electronics Institute of Technology, Seoul, South Korea.

The discovery of superconductivity in MgB$_2$ with a relatively high transition temperature ($T_c = 39$ K) in MgB$_2$ by Nagamatsu and motivated worldwide intensive research efforts on this material. Right after the introduction of the superconducting property in this material, many researchers have become interested in growing thin films of MgB$_2$ in order to fabricate Josephson junction devices. Among the various methods employed so far, the two-step method of $\alpha$-B deposition and post annealing at a temperature above 800°C under Mg vapor pressure has produced the best quality films. Unfortunately, however, the films made by this two-step process usually displayed critical current densities far below the theoretical predictions of the operation of thin film devices. It has been reported that the reaction sequence and microstructure evolution of an MgB$_2$ layer during the two-step process. The reaction sequence and microstructure evolution of MgB$_2$ layer is examined during post annealing of the evaporated amorphous boron ($\alpha$-B) with the Mg vapor. Mg is found to diffuse rapidly into the $\alpha$-B layer in the initial stage of reaction with uniform concentration of about 1 to 2 at%. The layer of crystalline MgO layer is observed at the interface.
between α-B and Al2O3 substrate. It is identified that an MgB2 layer starts to form at the surface by the nucleation and growth process in polycrystalline MgB2 tapes that are made by a two distinct growth fronts in MgB2 layer, one lies at the surface and the other lies at the interface between the MgB2 layer and the α-B. The microstructural evolution of this layer shows significant difference depending on the location of these two growth fronts, unlikely conventional gas-solid reaction in thin film process. Thus, the fully crystallized MgB2 layer is composed of the two layers differently grown. However, the overall growth kinetics of MgB2 layer obeys the conventional continuous layered growth model of the thin film by a diffusion couple. The growth kinetics of each layer also followed the model.

EES. 26
Superconducting MgB2 thin film deposited by laser ablation through an in situ heating process. Seung Ho Shin1, Jong-Woo Yoon2, Kenji Kawaguchi3, Noto Koshizaki4 and Kwang Bo Shim1; 1Hanyang University, Seoul, South Korea; 2AIST, Tsukuba, Japan.

The discovery of superconductivity at 39 K in binary compound MgB2, including the particular properties such as relatively higher critical current density and negligible effect of grain boundary on the current density, compared to high Tc superconductors, has created excitement about the possibility of this material in electronic application (e.g., microwave filter and SQUIDs). In this work, nanostructured MgB2 thin films were deposited on various substrates (sapphire, MgO and Si) by in situ one-step process of laser ablation with substrate heating. The fully densified MgB2 pellets prepared by spark plasma sintering was used as a target. The deposition process was carried out under various Ar background gas pressures. Laser energies varied from 50 to 200 mJ/pulse for fixed repetition rate of 20Hz. The microstructure and morphological measurements of stoichiometric MgB2 film, the film was deposited with multilayer structure, i.e., Mg-rich layer interspersed between near stoichiometric MgB2 layer. Because the Mg is easily evaporated during the high temperature process, a further confirmation of film structure was done from PEEM-SEM analysis, the surface morphology of the as-deposited thin films showed uniformity without debris. The Ar pressure dependence on film composition was investigated using XPS. At low pressure range below 50 Pa, boron deficiency was observed. Over 100 Pa, boron concentration of all constituent elements was almost constant, especially with the [Mg]/[B] ratio to be 1:2. From these results, we have succeeded in preparation of nanocrystalline MgB2 thin film in certain pressure range and investigated the effect of its microstructural features on the superconductivity by measuring the dc magnetic susceptibility and magnetization hysteresis using a SQUID magnetometer.

EES. 27
Electrodeposition of Bi-2212 Superconductor Oxide Films. Priscila Delega Spagnol1, Raghu N Bhattacharya2, Jun Chen3 and Allen M Hermann4; 1NREL, Golden, Colorado; 2Physics, University of Colorado, Boulder, Colorado.

Biaxially textured Bi2Sr2CaCu2O8 (Bi-2212) films with thickness around 1-2 µm have been prepared by electrodeposited precursors by a modulated growth process. A modified method of electroplating was explored for the electrodeposited, Bi-2212 superconductor films show current density values greater than 5 x 10^4 A/cm^2 at 4 K in zero field. The electrodeposition technique is a potentially low-cost non-vacuum technology. The present results of the Bi2212 film were codoped at a concentration of 0.1% to 0.4% of composition of 

EES. 28
Reduced AC Transport Losses for Ag-Shunted Bi2223 Tapes by Controlling Filament Arrangements. Ryoji Inuki1, Yuichi Nakamura2, Akio Oota3, Tetsuya Rikunaga4 and Pingxing Zhang5; 1Toyoohashi University of Technology, Toyoohashi, Aichi, Japan; 2Gifu National College of Technology, Motokun-gun, Gifu, Japan; 3Northwest Institute for Nonferrous Metal Research, Xian, Shaanxi, China.

We succeeded in reducing the AC transport selffield losses at 77 K for Ag-shunted (Bi,Pb)-2223 tapes by controlling the filament arrangements in their cross section. The multifilamentary tapes with sectioned filament arrangements along a width direction were prepared by rectangular deformation process, composed of screw rolling and standard one-axis flat rolling. The transport selffield losses at 77 K in the frequency range between 480 and 500 Hz were measured by standard AC four-probe method using a dural phase lock-in amplifier. Although the losses were mainly dominated by the hysteresis loss of the superconductor filaments, the loss values for the tapes with optimized filament arrangements are reduced by 54-65% compared with that for the tapes by standard PIT process, even in the higher current range near the critical current Ic. Numerical calculation shows that the loss reduction is mainly attributed to the suppression of magnetic flux due to self-field passing through between the current-free region and the filaments positioned near the tape edge. The effect of longitudinal magnetic field externally applied parallel to the tape surface on the transport losses for the tapes with various filament arrangements were also studied. This work is supported in part by the 21st century COE program "Intelligent Human Sensing", from the ministry of Education, Culture, Sports, Science and Technology of Japan, and Research Foundation for the Electrotechnology of Chubu.

EES. 29
Development of a MOVD Technology for Integrated Single Buffer Layer/YBCO Layer Fabrication for Coated Conductors. Alexander Medyk1, Xin Zhang2, Jin-Ming Zeng2, Jin-Shu Liu3, Pen-Chu Chou4, Alex Ignatiev5, Louis Castellano6, Les Frechette7 and Rene Kwant8; 1Texas Center for Superconductivity and Advanced Materials, University of Houston, Houston, Texas; 2Metal Oxide Technologies, Inc, Houston, Texas.

A MOVD technology to commercially fabricate YBCO coated conductors on biaxially aligned metal tapes at up to five kilometer lengths is under development. The conductor architecture is based on a single CeO2/(Sm2O3) buffer layer and a YBCO superconducting layer. Both the buffer and YBCO layers are deposited by the photo-assisted MOVD technique that allows achieving high deposition rates on the large areas necessary for industrial scale applications. The prototype fabrication system implements a continuous single roll-based process with in-line structure where the buffer and YBCO layers are deposited successively without breaking vacuum. The substrate tape is inserted from air, pre-treated prior to deposition. The finished multi-layer tape undergoes an oxygen anneal before the conductor is received in air at the take-up reel. Thus, the in situ process starts with a bare metal tape yielding finished product at the other end of the system. Excellent superconducting properties (over 1 MA/cm^2; 77 K, in self-field) have been achieved in the system on small, buffered metal samples. Continuous deposition of 15 mm long, modern-equipment quality YBCO tape has been performed demonstrating good system stability. The deposition of 1 mm height quality YBCO tape is ongoing. The results of XRD, SEM studies, and electrical measurements of small samples and long tapes will be presented.

EES. 30
Processing for Coated Conductors Modified TFA-MOD Method. Hiroshi Fugi1, Tetsuji Hongo2, Ryo Iwashita1, Yoshihisa Tokunaga1, Junzo Shibata3, Shigenobu Asada1, Yukim Yamada1, Teruo Inumi1, Yuh Shiochiro, Yamashiro Ijima2 and Takashi Suzuki3; 1ISTEC-SRL, Tokyo, Japan; 2Fujikura Ltd., Tokyo, Japan.

Metallographic deposition using TFAfellow centers (TFA-MOD) processing has been expected as a strong candidate for the fabrication processes of coated conductors because of its low cost and high superconducting performance. In order to realize the applications, the development of higher Ic, the longer tape and the higher production rate etc. is required. In order to realize higher Ic, the following two approaches were considered. One is to make Je increase and the other is to increase thickness of the superconducting layer with unit mass. As the next high approach, a high textured CeO2 buffer layer by PLD deposition on a GZO/IBAD buffered tape was used. Concerning the latter approach, the multi-coating process has been investigated. On the other hand, the new starting materials were developed in order to shorten the calcinations time for increasing overall production rate. Consequently, the high superconducting performance was obtained as to be 2.0 MA/cm^2 and 292 A% in self-field on a highly textured CeO2/GZO/IBAD buffer tape by the multicoating method using newly developed starting materials. Furthermore, a large scale equipment for the continuous tape process by Roll-to-Roll system was applied. As a result, the uniformity of Ic and texture by XRD analysis and the superconducting characteristics will be reported. This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) in Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications.

EES. 31
Study on Bi(2223)/Ag Tapes of Inscribed Rolling Process. GuanSen Yuan1 and Rihong Feng; Coated Conductors Materials Research Center, General Research Institute for Nonferrous Metals, Beijing, China.

An inscribed rolling (IR) technique was designed for deforming the high temperature superconducting Bi(2223) tape in PIT method. The elasto-plastic finite element method (FEM) was applied for simulating the IR process. By the analysis of stress field, strain field and
pressure field etc., some advantageous characteristics in IR process are investigated for applying to manufacture the Bi2212 tape. Meanwhile the effects of various improvements on the properties of the tapes were studied by the contrast experiments with traditional rolling (TR) and cold pressing (CP). Because of the homogeneous stress distribution and obvious widening in the tape during the IR process, it is in favor of decreasing the cracks along the transverse direction. The experimental results show that the volume and texture of Bi2223 are improved and much more density of the superconducting filaments is taken by multiple IR process. The widening of the tape obtained by IR process is closer to the ideal one and is less easy to cause cracks. The TR process was obviously. So that IR is a typical deformation of two-axis extendedness and will impinge on the distribution and type of crack generated in the tape. The critical current (Ic) measurements of the tapes made by different deformation process are also discussed in this paper. This work is supported by National Natural Science Foundation of China.

EES.32  Optimization Studies on Thermal and Mechanical Manufacturing Processes for Multifilament Superconducting Tape and Wire
Baruk Bawer, Bengt Engquist, and Kjell Andervall
MECHANICAL ENG., TEXAS A&M, COLLEGE STATION, Tex.

There are many parameters profoundly effective on the electrical performance of ceramic core superconductor composite wire and tapes, which remain ambiguous and require more labor on their optimization. BSCCO-2212 has not been paid the attention and investment it deserved in this regard, all optimization efforts were made for BSCCO-2223. In our work, a practical and independent manufacturing method thermally and mechanically optimized for Pb doped Bi2Sr2CaCu2O8+δ 2212 superconducting multifilament (38 filaments) wires and tapes was successfully employed by utilizing standard and easy to obtain materials available on the market. Optimized parameters can be classified under material, mechanical (deformation) and heat treatment (thermal) subgroups. Parameters involved with materials included investigation of deformation behavior of two different silver sheets, pure silver and 0.025% magnesium dispersion reinforced silver alloy. Pb doped Bi2Sr2CaCu2O8+δ 2212 ceramic superconductor powder, the other source of material related parameters, was synthesized following Thermal co-deposition method. Fabrication of mono- and multifilament wires with Oxide Powder in Tube (OPT) method followed next. Optimization of drawing deformation was practiced to achieve the best ceramic grain alignment and smoother ceramic powder core/metal sheath interface in order to reveal 'messaging' in wires. Rolling of the wire products into tapes by following different deformation regimes was the other manufacturing stage of the project. Variable and constant reduction-per-pass deformation paths were employed to reveal their effects on our composites with distinct sheath material and filament formation. In search of best (optimum) heat treatment schedule for our Bi2212 superconductor composites, a modified version of 'step solidification partial melting' was employed successfully. A solution through tried and tested the bubbling process that occurred when our tapes were also addressed. Electrical performance tests of fully reacted wires were carried out in our laboratory and very promising results were attained.

EES.33  Transport properties of Ni-allyl sheathed MgB2 superconducting tapes
Giovanni Grassi, Andrea Mahgoli, Andrea Tininio, Carlo Fanciulli, Paolo Tatarelli, Carlo Perreghelli and Antonio Sergio Siri; LAMIA, INFM, Genova, Italy

Nickel and nickel-allyl sheathed MgB2 tapes were manufactured by the Powder-In-Tube method with mono- and multifilamentary configuration. Their transport properties were measured in liquid helium bath in an external magnetic field up to 20 Tesla, as well as a function of the temperature. The critical-current density up to 1 MA/cm² has been reported over short sections of conductors fabricated in unit length up to 100 meters. The magnetic field dependence of the critical current resulted to be very sensitive to the thermomechanical condition that the conductor experienced during the fabrication procedure. Improved field behavior is observed for conductors treated at lower temperatures, or that have experienced a higher degree of cold working.

EES.34  Atomically Smooth MgO/MgB2 Interface in Epitaxial MgO/MgB2/SiC Multilayer
Sheng-Yong Xu1, Jin-Guo Wang2, Guo-Da Lim3, Alexei V. Pogrebnjakov1, Qi Li1 and Xiao-Xing Xi1
1Physics, Penn State University, University Park, Pennsylvania, 2MRI, Penn State University, University Park, Pennsylvania
3Materials Research Institute, University of Pennsylvania, Pennsylvania, USA

For superconductor-insulator-superconductor (SIS) Josephson junctions, the superconducting and insulating layers should have thickness less than, or comparable to, the coherence lengths of the superconducting layers, thus it is always challenging to create a uniform and ultrathin insulating barrier layer for the system of conductors with short coherence lengths. We synthesized epitaxial MgO/MgB2 multilayers on [0001] SiC single-crystal substrates with the technique of hybrid physical-chemical vapor deposition (HPCVD). We directly observed atomically sharp interfaces MgO/MgB2 by means of high-resolution transmission electron microscopy (HRTEM) and electron energy loss spectroscopy (EELS). It shows that [111] MgO can be epitaxially grown on [0001] MgB2 and vice versa, with coherency interfaces MgO/MgB2. MgO/SiC multilayers, thick embedded in the single-crystal like body of the MgB2 film, are observed. These ultrathin MgO layers show sharp interfaces on both top and bottom surfaces to the MgB2 phases, and are structurally stable at room temperature under irradiation of electron beams by sharp and stable electron diffraction patterns. The thickness of the ultrathin crystalline MgO layers observed, 1-2 nm, is less than the coherence length of MgB2, which is around 3 nanometers along its c-axis. The results have direct impacts on the technical approaches for applications of MgB2 materials in SIS JJs and JJ-based electronics.

EES.35  Strain-Induced Changes of the Superconducting and Normal-State Properties of Epitaxial MgB2 Films Grown by HPCVD
M. Redwing1,2,3, James E. Jones1, Xiongxi Xi1,3, Sheng-Yong Xu1, Qi Li1,3, Venu Vaiyahatanh1,2,3 and Darrell G. Schrom1,2,3
1Department of Physics, The Pennsylvania State University, University Park, Pennsylvania; 2Department of Materials Science and Engineering, The Pennsylvania State University, University Park, Pennsylvania; 3Materials Research Institute, The Pennsylvania State University, University Park, Pennsylvania

An increase of the transition temperature, Tc, and a decrease of the residual resistivity, ρ0, with increasing film thickness was observed for epitaxial MgB2 thin films grown by hybrid physical-chemical vapor deposition (HPCVD) on 4H-SiC and sapphire substrates. In previous studies, the MgB2 film deposition rate depends linearly on the concentration of B2H6 in the inlet gas mixture. The superconducting and normal-state properties of the MgB2 films were found to be relatively independent of the deposition rate over the range investigated in this study. The calculated density for the films on 4H-SiC and sapphire substrates were similar, exhibiting an initial increase (decrease) of Tc (ρ0) with thickness accompanied by a leveling off at high thickness values (above about 300 nm for films on 4H-SiC and 150 nm for films on sapphire). Thick films on 4H-SiC substrates have Tc values of around 41.7 - 41.8 K, while Tc values of the films on sapphire substrates level off at around 40 K. This difference is attributed to residual stress in the MgB2 films due to a dismisalignment of the thermal expansion coefficients of SiC and graphite. The thickness dependence of Tc is believed to be related to strain in the films — an increase in tensile strain was measured with increasing layer stack thickness. The best parameters obtained were a Tc of 41.8 K, a ρ0 of 0.26 µΩcm, and a residual resistance ratio (RRR) of 32 for the films on 4H-SiC substrates and a Tc of 40.5 K, a ρ0 of 0.26 µΩcm, and RRR of 35.6 for the films on sapphire substrates.

SESSION E06: HTS Wires and Applications
Chair: Bernard Holzapfel and Yutaka Yamada
Wednesday Morning, December 3, 2003
Constitution B (Sherrington)

8:30 AM *E06.1  Evaluation of Current Limiting Mechanisms in Practical Superconductors
David C. Larbalestier, Applied Superconductivity Center, University of Wisconsin-Madison, Madison, Wisconsin; 2Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, Wisconsin; 3Department of Physics, University of Wisconsin-Madison, Madison, Wisconsin

An apparently simple goal of much conductor development is to raise the critical current density and thus the critical current of the whole conductor. In practice not only is that impossible, but the major factors controlling current density are, in fact, lower at higher temperatures, leading to the general situation that Jc and JL are limited not just by flux pinning but by other defects that control the active cross-section through which current flows. It is thus conceptually important to be able to separate that component of Jc that is controlled by flux pinning from the component controlled by defects. The characterization tools available to us for such a task are quite extensive, for example magneto optical imaging and low temperature scanning laser microscopy to reveal local Jc and Jn and all sorts of microstructural characterization tools to which we may correlate such measurements. I will survey some of the issues involved in understanding such current limiting mechanisms from our recent
studies of Nb$_3$Sn, Bi-2223 and YBCO coated conductors. In collaboration with many colleagues at UW-ASC and in the broader community.

9:00 AM *E06.2
Characterisation And Analysis Of Transport In HTS In Terms Of The Composite Vortex System, Bunnie ten Haken, Danko van der Laan, Marc Dhaille and Herman ten Kate, Univ of Twente, Enschede, Netherlands.

The transport properties of Bi based tapes are analysed in the frame of the phenomenological parallel path model. At high fields the current is only carried by a percolating “strong-linked” backbone, while in the low field “weak-linked” matrix also contributes to the overall current-carrying capacity. We illustrate this by showing how 1) the anisotropy of the critical current with respect to the direction of an applied magnetic field can only be fully understood when both paths are considered separately, 2) anomalous features in the shape of the current-voltage relation are easily explained within this framework and 3) the dependence of the critical current on stress strain gives indications as to the nature of the “weak links” in low magnetic fields. Even if the dissipation mechanisms limiting the critical current in both paths are different, their temperature dependence shows that they are not independent.

Based on results obtained on tapes whose oxygen content was cycled, we explain this coupling in terms of oxygen dependent transport properties. Furthermore, the parallel path analysis suggests that a similar picture might also hold for YBCO coated conductors.

9:30 AM *E06.3
Enhanced Residual Secondary Phase Dissolution by Atmospheric Control in Bi-2212 Superconductors, David Sager,1 Miraboi Koch,1 Lorenz Meier,2 Bengt Hallstedt3,4, Ludwig J Gauckler1, Michael Chen1, Markus Heid2 and Willy Paul,2 ETH Zurich, Zurich, Switzerland, ABB Corporate Research, Baden-Daettwil, Switzerland.

For power applications, where primarily high current carrying capabilities are required and therefore thick film and bulk material is processed, the Bi2Sr2CaCu2O8+δ (Bi-2212) compound has evolved as one of the most promising. The recrystallization from the partial melt state is incomplete, due to the stability of the 013δ24 plane and sterically hindered diffusion from recrystallized Bi-2212 platelets [1]. Therefore considerable amounts of residual 013δ24 and 4413, the mixed state of Bi-2212 and 2201, are present in the microstructures at 850°C. The subsequent annealing in oxygen leads to a limited dissolution of film phase and the curve of 4413 to Bi-2212 [2]. Hallstedt et al. [3] show that the stability range of 013δ24 depends on the oxygen partial pressure (pO2) in the Sr-Ca-O system. Calculation of BiO2.3/Sr2.9/3CaO3/3O4 cross-sections at 850°C is done by CalsymCalc. From these calculations the area of stability of 013δ24 is derived, showing that its stability range is substantially reduced with decreasing pO2. These results correlate well with the experiments. By annealing at low pO2 after recrystallization of small amount of 2201 the rate of recrystallization is reduced, increasing the critical current density of the fully processed material up to 65%. This increase is attributed to a gain in current carrying cross section as a consequence of recrystallization [1/3].

9:45 AM *E06.4
Correlation of AC Loss Data from Magnetic Susceptibility Measurements with YBCO Film Quality, Paul N Barnes1,2, Timothy J Higgins3, Srinivas Sridhara4, Inman Maertens4, Amanda L Westerfield5, Hana M Neklik6,7, Lyle B Brinkman8,9,10, Timothy L Peterson1, Juliana M Evans1 and Justin C Tollefson3,1, Propulsion Research Power Generation Group, Air Force Research Laboratories, Wright-Patterson AFB, Ohio, 3MLF, Air Force Research Laboratories, Wright-Patterson AFB, Ohio, 7US, Inc, 8EPAFB, Air Force Research Laboratories, Wright-Patterson AFB, Ohio.

For HTS films a sharp transition in resistivity vs. temperature at Tc, as well as a Tc, close to the maximum value, are typically desired for better quality films. Further, it has been previously observed that with spreading of the temperature-dependent ac susceptibility curves with increasing applied magnetic field, the quality of the YBCO film generally decreases. However, a documented study of this correlation to current transport properties using the lost component of ac susceptibility data has not been published, making it unclear how effective this transition is. A correlation of Tc to this level may prove useful as a preliminary screen of YBCO film quality, especially as good YBCO films can now be routinely made. A detailed study was performed using the available data on YBCO films produced by pulsed laser deposition on different substrates which included LAO, STO, and buffered metallic substrates. A few additional samples of YBCO coated conductor prepared by alternative methods were included in this study for comparison. The ΔT between the temperatures at which the maximum in the AC loss occurs for 0.155 and 2.2 Oe applied magnetic fields (peak to peak of χ”) was determined. In addition, the full-width at half maximum (FWHM) of the χ” vs. T width (ΔT) of the loss component of susceptibility data was determined for the 0.155 Oe applied magnetic field data. Both results were presented comparing analysis of the ac loss data from magnetic susceptibility measurements to the critical current density (Jc) as determined by current transport measurements. Jc is determined by M-H loops derived from vibrating sample magnetometry. [1] I. Maertens and A.K. Sirkar, J. Mater. Res., Vol. 8, 2177 (1993).

10:30 AM *E06.5
Comparison Between Bi-2223 and Y-123 Conductors for Moderate-Field HTS Devices, Marvin P. Oosen, Martino Leghissan, Bernd Utz and Heino-Werner Neumueller, CT P33, Siemens AG, Erlangen, Germany.

We investigate high-temperature superconducting materials for use in transformers, fault current limiters, motors / generators and MHD magnets. All these devices operate with moderate magnetic fields (up to a few T) and they require the production of coils comprising long lengths of HTS conductor. Materials manufacturers presently envisage two different length-scale conductor systems: Bi-2223 powder-in-tube multifilamentary tapes and Y-123 coated conductors. This presentation compares the presently known state-of-the-art in the two conductor systems. The current density that can be attained in a winding under operating conditions is similar for the Bi-2223 and Y-123 systems. The temperature dependence of the current density determines the optimum operating temperature for a given device. The AC loss in a Y-123 tape can be much lower than in a Bi-2223 tape; the loss in an operating coil depends on conductor and coil and current. The mechanical properties of Y-123 tapes appear to be made clearly better than for Bi-2223 tapes. However, for coil production we must also address practical issues like conductor homogeneity, stiction against quench, insulation, handling and thermal contraction during cooldown. For the Bi-2223 system these issues are well understood and have mostly been solved, due to the wide availability of the tapes. Y-123 tapes are presently available only in limited lengths. The material manufacturers have not yet agreed on the best tape production process and for finding such an agreement, all the practical coil-production issues for the Y-123 system are wide open and urgently need investigation. Therefore the planning and construction of prototype devices presently relies on the Bi-2223 conductor.

11:00 AM *E06.6
Enhanced Performance and Manufacturing of Bi-2223 Multifilamentary Composite Wire, Yihung Huang,1 M. Avin1, B. Carter1, K. Demoranville1, C. King1, S. Fleisher2, A. Otto1, R. Porrell3, E. Podstargt5, J. Schreiber1, A. P. Malozemoff,6 X. Y. Cui5, E. Hellsr,5 D. Liebal,5 M. Holsinger5 and V. A. Mihalas5, 1American Superconductors, Westborough, Massachusetts, 2Applied Superconductivity Center, University of Wisconsin-Madison, Madison, Wisconsin, 3Los Alamos National Laboratory, Los Alamos, New Mexico, 4Argonne National Laboratory, Argonne, Illinois.

Progress in the performance and large-scale production of multifilamentary composite Bi-2223 wire is reviewed. Critical current (Jc) of 185A and critical current density (Jc) of 62.4 kA/cm² at 77 K and self-field have been achieved in research samples with a new overpressure process, developed at the University of Wisconsin and applied to American Superconductor (AMS) production wires. The relative improvement over earlier wires is even greater when measured in 0.1 T field perpendicular to the tape plane because self-field suppression is no longer present. Microstructure and characterization by SQUID magnetometry, transmission XRD, SEM and TEM through the Wire Development Group, a nation-wide collaboration, shows a significant reduction of the residual 2212 intergrowth remaining in Bi-2223 grains on the higher 1c wires. Compared to its earlier pilot production facility, AMS is achieving even higher performance and longer piece length production wire in its Devens manufacturing plant.

11:30 AM *E06.7
Overpressure Processing and Characterization of Silver Sheathed (Bi, Pb) Sr$_2$Ca$_2$Cu$_3$O$_x$ Composite Conductors, Yongmei Yuan1,2, Jinping Zhang1,2, Ron Porrell3,3a,5, Dmytro Abruamov3,6, Sindy Lino1,1,2, David Liebaless6,2,4,2,5, Eric Hellsr,5 and Yihung Huang1,1,2,1,2,1,2, Applied Superconductivity Center, University of Wisconsin-Madison, Madison, Wisconsin, 2Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, Wisconsin, 3American Superconductor Corporation, Westborough, Massachusetts.
Silver sheathed [BiPb]$_2$Sr$_2$Ca$_n$Cu$_{2n+1}$O$_{2n+4}$ (2223) composite conductor is currently the only high temperature superconductor available in adequate lengths for industrial scale electrical applications. Porosity, deformation cracks, and low-Te 2212 are the most deleterious current limiting factors. We have developed a new (OP) process to densify the 2223. In the OP system, the 2223 conductor is heated in a high pressure isochronous flowing atmosphere at 1100°C for 24 hours in 2L Tesh. The optimized OP-2223 method was used to make 2212 OP samples. Electron microscopy observation and density measurement show that OP processing eliminates pores and cracks in 2223 conductors. The density and microstructure of the 2212 OP samples are improved compared to the conventionally processed 2212. Question: What is the main focus of this study?

The study investigated the structural characteristics and flux pinning in Bi$_2$Sr$_2$Ca$_n$Cu$_{2n+1}$O$_{2n+4}$ (Bi-2223) high temperature superconductors by selective doping. Flux pinning, change in critical temperature, as well as the change in lattice parameters and melting temperature were determined for post annealing at 1100°C for 24 hours. The effect of post annealing on the superconducting properties of the Bi-2223 samples was investigated. The results showed that the post annealing at 1100°C for 24 hours increased the critical temperature and reduced the residual resistivity. The oxygen content of the samples was also affected by the post annealing process, leading to an increase in the oxygen content and a decrease in the residual resistivity. The effect of the post annealing on the superconducting properties of the Bi-2223 samples was investigated. The results showed that the post annealing at 1100°C for 24 hours increased the critical temperature and reduced the residual resistivity. The oxygen content of the samples was also affected by the post annealing process, leading to an increase in the oxygen content and a decrease in the residual resistivity.

SESSION EEE7: MgB2
Chair: David Larkin and Xiao Xi
Wednesday Afternoon, December 3, 2003
Constitution B (Sheraton)

130 PM EEE7.1
The effect of intensity scattering on the enhancement of the resistivity by the upper critical field in MgB2 bulk and thin films. Valeria Braccini 1, A. Gurevich 1, S. Sergienko 2, A. K. Kim 1, and C. R. Niedermayer 1.

Gurevich has shown how one important consequence of the two-gapped superconductivity is that MgB2 is the first superconductor that experiences the upper critical field from the relatively low values found in the single crystals to a range of Hc2 values well above those of competing non-cuprate superconductors, like Nb3Sn and Nb-Ti, by tuning the intensity scattering through selective alloying on Mg and B sites. High magnetic field transport measurements have been performed at NIMHFL, Tallahassee (FL) in the 33 Tesla resistive magnet and at LANL, Los Alamos (NM) in the 50 Tesla pulsed-field facility on bulk samples and thin films of very different purity. Critical limit bulk MgB2 samples have been prepared by direct synthesis from isotopically pure 11B and Mg. They present sharp transitions at 39 K, high resistivity about 15 and low resistivity $\rho /\rho_{K}=10^{-4}$ $\mu$m cm. Hc2 (0) for these samples is about 2 T and the upper critical field of clean samples has been enhanced by alloying on both Mg and B sites. In particular, the effect of annealing in Mg vapor and C substitutions with different percentages have been studied. In particular, after annealing in Mg vapor, the samples showed an increase of the 40 K resistivity from 1 to 10 $\mu$m cm and a lowering of the resistivity ratio from 15 to 3, while the critical temperature decreased by only 1 K. By doping with carbon, the resistivity reached 40 $\mu$m cm at room temperature and 30 K in 5% C doping. Several thin films, grown by means of different techniques have been studied, with resistivities ranging from 7 to 200 $\mu$m cm and critical temperatures between 36 and 31 K. In all these cases, corresponding to an increase of the resistivity a significant enhancement of Hc2 has been achieved, passing from the low values reported for the single crystals Hc2 (0) $\approx$ 3.5 T perpendicular to the ab planes and Hc2 (0) $\approx$ 10 T parallel to the ab planes) to values of about 34 T and 49 T respectively in the two configurations for a high resistivity film and Hc2 (0) $\approx$ 27 T for one of the untextured bulk polycrystals.

1:45 PM EEE7.2
Superconducting Properties and Microstructure of MgB2 Thin Films Prepared by Post Annealing of Co-evaporated MgB2 Films. Sang-Soo Yim1, Ho-Nam Kim2, Do-Heon Kang3, Sung-Hyun Moon2, Young-Won Kim1 and Ho-Nyuan Lee1, 2School of Materials Science and Engineering, Seoul National University, Seoul, South Korea; 3LG Electronics Institute of Technology, Seoul, South Korea.

MgB2, due to its discovery of its superconductivity at 39 K, has been highlighted as one of the most promising materials for superconducting devices due to its high critical temperature $T_c$, critical current density $J_c$ and simple binary structure. Especially, there has been a large interest in MgB2 thin films for electronic devices applications. Among the methods to prepare MgB2 films is ion-beam deposition, with targets made from amorphous precursor films such as α-B and MgB2 via post-annealing at high temperature shows excellent superconducting properties including bulk like $T_c$, enhanced $J_c$ (> 1 MA/cm$^2$) and low resistivity. We report superconducting properties and surface morphology as a function of composition of precursor films and microstructure evolution during post-annealing of MgB2 films ($x = 2$) films as a function of annealing time. MgB2 films of about 500 nm were deposited in Al2O3 (001) substrates by e-beam evaporation at room temperature. As-deposited precursor films have composition of MgB2-x, MgB2 and MgB2, which were confirmed by Rutherford backscattering spectroscopy and oxygen content of all films was less than 5%. MgB2 films were annealed in a quartz tube under Mg vapor at 800°C for 30 min. The films made from the Mg-rich precursor films shows slightly better superconducting properties. The onset $T_c$ of MgB2 films after annealing of MgB2, MgB2 and MgB2 at 800°C was about 38 K. Corresponding superconducting transition widths ($\Delta T_c$) were 0.3, 0.6 and 0.9 respectively. The relative variation of composition of precursor films and resistivity can be found. The resistivities at room temperature of the films are 26, 28.15 and 25.8 $\mu$m cm and resistivity ratio (RRR) values are 2.0, 1.71 and 1.30 as a function of B increases. It is worth noting that the films made from the MgB2 precursor films have remarkably reduced surface roughness. Microstructure evolution during post-annealing of MgB2 precursor films, which shows best properties and surface morphology, are by using transmission electron microscopy and high resolution electron microscopy (TEM). The annealing times were varied from 10 to 30 min. The films annealed below 20 min have a nanocrystalline microstructure. It is observed, however, that there are large grains in the films annealed for 30 min. Therefore, the nanocrystalline MgB2 phase is formed in early stage of annealing and then grows. It is also noted that the nanocrystalline MgB2 films have cubic oriented microstructure which is confirmed by electron diffraction pattern in TEM.

2:00 PM EEE7.3
Epitaxial Growth Of Magnesium Diboride Thin Films By Hybrid Physical-Chemical Vapor Deposition. Jean M. Redwing1, A. Bogreznynyev2, S. Raghavan3, J. D. Acord4, J. L. Jones5, X. X. Xi5, B. S. Y. Xu6, Qi Li6, Z. K. Liu6, V. Vakulchyshan6 and D. G. Schlom7, 1Department of Materials Science and Engineering, Penn State University, University Park, Pennsylvania; 2Department of Physics, Pennsylvania State University, University Park, Pennsylvania; 3Materials Research Institute, Pennsylvania State University, University Park, Pennsylvania; 4Department of Physics, Pennsylvania State University, University Park, Pennsylvania; 5Materials Research Institute, Pennsylvania State University, University Park, Pennsylvania.

A hybrid physical-chemical technique was developed to deposit epitaxial thin films of superconducting MgB2. In this process, Mg evaporation is used in combination with the thermal decomposition of diborane gas in hydrogen to deposit MgB2 at growth temperatures between 720-730°C and pressures ranging from 10-70 Torr. The presence of hydrogen serves to inhibit the oxidation of MgO within the bulk of the film, as determined by x-ray diffraction measurements. Epitaxial growth of MgB2 on various substrates including sapphire, 4H and 6H SiC and MoCVD grown layers of AlN and GaN was investigated. The lattice constant and thermal expansion coefficient of the substrate as well as its chemical stability with Mg at elevated temperature are all important considerations when selecting a substrate for MgB2 deposition. Epitaxial layers of MgB2 were obtained on sapphire and SiC substrates as well as on the AlN epitaxial layer. Deposition of MgB2 on GaN, however, resulted in poor film morphology due to a reaction between Mg vapor and the GaN surface at the growth temperature. In the case of SiC and AlN, the hexagonal MgB2 grows directly on the hexagonal lattice of the substrate, due to the small lattice mismatch between these materials. On sapphire, MgB2 grows (1010) relative to the substrate lattice to accommodate the larger lattice mismatch. Lattice constant measurements of MgB2 films deposited on SiC and sapphire indicate
that the films are under tension and compression, respectively, due to differences in thermal expansion between the films and substrates. The difference in residual stress was found to impact the superconducting properties of the MgB₂ films.


The growth of completely in-situ MgB₂ thin films has been difficult primarily due to the high vapor pressure and oxygen affinity of Mg. To overcome these problems, we have developed a reactive coevaporation deposition technique that utilizes a localized source of Mg vapor. Using novel MgB₂ films on a variety of single-crystal substrates including MgO, LaAlO₃, SrTiO₃, c-, m-, and r-plane sapphire, LSAT, YSZ, and 4H-SiC. In all cases the films exhibit low resistivity values and Tc values over 37 K. We have also grown MgB₂ films on polycrystalline alumina and unpolished flexible stainless steel shim stock; these films display properties similar to those on single-crystal substrates. It thus appears that lattice matching is not required using our growth technique. We have thus far explored the growth temperature range of 400 to 600 °C with no in-situ annealing and equally good results. In addition to the relative ease with which we are able to obtain high quality MgB₂ thin films, this technique also allows us the ability to deposit films of up to 4" in diameter and to grow double-sided films. In this work, we will report on the morphology, current-carrying capacity, and microstructure of these films. This work was supported partially by ONR, Contract No. N00014-98-M-0005.

3:30 PM EE7.5 In-Situ Fabrication and Characterization of All-MgB₂ Josephson Junctions with Various Barriers and Their Electronic Characteristics. Jackomas, Raghuram, Geon, Kodama, Rakesh Singh, Brett Strawbridge, John Rowell and Nathan Newman: Chemical and Materials Engineering, Arizona State University, Tempe, Arizona.

We have optimized the synthesis of MgB₂ thin films by Molecular Beam Epitaxy using a novel thermochemical approach. The Mg sticking coefficient is found to strongly depend upon the B flux. By enhancing the incorporation rate of Mg on the surface using a high Mg flux and precise control of the B flux, we have been able to extend the process window to higher temperature. Transition temperatures of 37–38 K and surface roughness of ≤ 5 Å are obtained for films grown at 300°C. We have produced in-situ triple layers to explore the properties of MgB₂ tunneling and Josephson junctions. We have studied a variety of barrier layers including the MgB₂ thermal oxide, TaN, AlN, and GaN. MgB₂/AlN/MgB₂ and MgB₂/Ta:O thermal oxide/MgB₂ triple layers have been fabricated which exhibit RSJ (resistively shunted junction) characteristics. To date, no tunneling characteristics have been seen, indicating that the barriers that are insulating probably have pinholes. Results to date do indicate that the Ic/Rn product of the AlN and the MgB₂ thermal oxide barrier junctions are 6 mV and 0.35 mV, respectively. The temperature at which the critical current varies is about 30 K in MgB₂ thermal oxide barrier junctions and 20 K in AlN/buffer layers. Results for other barriers, including TaN and GaN, will also be presented.

3:45 PM EE7.6 Superconducting Properties of Electroplated MgB₂ Films. Hirotake Abe¹, Kenji Nishida¹, Motomasa Imai¹, Hideki Kitazawa¹ and Kenji Yoshih¹ ²: NIMS, Tsukuba, Japan; ²EAERI, MikiZuiki.

The superconducting boride MgB₂ is one of the most promising practical superconducting materials because of its high superconducting transition temperature of 39 K and high critical current density (Jc) under magnetic fields. A number of fabrication methods of superconducting MgB₂ films have been reported up to now. However, systematic research is not very clear and it has been reported so far. In recent, we have developed an electroplating technique of superconducting MgB₂ films with a transition temperature of 37 K by means of electrolysis on a fused mixture of MgC₂ and KCl, NaCl and MgB₂O₃. The superconducting MgB₂ film with tensmicrometer thickness were successfully electroplated on graphite substrates by optimizing the shapes and configuration of the electrodes. [5] We report the superconducting properties of electroplated MgB₂ films in this paper. Electrical transport measurements have revealed that the electroplated MgB₂ films show superconducting transition at 37 K and zero-resistivity below 33 K under the zero-field. IV characteristic measurements have shown that Jc of the electroplated MgB₂ films is about 10,000 A/cm² at 5 K at the highest. The magnetic field dependence of Jc of the electroplated MgB₂ films will be discussed at the conference. [6].

H. Abe, K. Nishida, K. Yoshih and M. Ima, Cond-mat/0211310

4:00 PM EE7.7 A Role for MgB₂ in Superconducting Electronics? John M. Hollway, Department of Chemical and Materials Engineering, Arizona State University, Tempe, Arizona.

The 39K transition temperature of MgB₂ makes this material of potential interest in a number of superconducting electronics applications. I do not expect MgB₂ to replace HTS materials in commercial wireless filter systems, which now operate at or near 77K. However, if an R&D digital technology could be developed operating at 20 to 25K, the cryocoolers required would be much smaller and more efficient than those now used with today's Nb technology at 5K. Tunnel junctions of MgB₂ would allow higher frequency operation of SiS detectors that junctions of Nb or NbN. I will review progress towards the development of such thin film and junction technologies. In the past year, novel deposition techniques have allowed the synthesis of very good films of MgB₂. Their resistivity is now as low as that of the best bulk samples. Also, uniform films on large area substrates have been made. Epitaxial growth is not necessary, so inexpensive substrates can be used. Progress towards a junction technology, of either the SNS or SS type, has not been as rapid. Weak link junctions have been reported, but, to date, MgB₂/substrate/MgB₂ junctions appear to have pinholes through the barriers. As good films and multilayers can be grown at temperatures as low as 300°C, I am hopeful that a junction technology at 20 to 25K will be made possible soon.

4:30 PM EE7.8 Tunneling Spectroscopy of Poly crystalline MgB₂ Micro-wires. Thomas W. Heinzmann¹, Paul C. Cardwell², Dougla Finney¹ and Mark S. Rudenow¹: ¹Physics Department, University of Wisconsin, Madison, Wisconsin; ²Department of Physics and Astronomy, Iowa State University, Ames, Iowa; ³Aerospace Laboratory, Ames, Iowa.

We report scanning tunneling microscopy of polycrystalline MgB₂ micro-wires using both normal metal-insulator-superconductor (N-I-S) and superconductor-insulator-superconductor (S-I-S) tunnel junctions. A segment of the micro-wire was affixed to a normal Pt-Ir STM tip and approached to a Au film in the first case and to another segment of the micro-wire in the latter case. In each configuration we observe both gaps, Δ₁ and Δ₂, and a third gap for the S-I-S junctions we observe a directionally dependent of the dI/dV on the relative orientation of the grains in each superconducting electrode. In particular, we found that for a certain orientation of the grains, which we infer to be perpendicular, tunneling between σ-bands and between σ-bands is strongly suppressed. This leaves only features in the dI/dV associated with tunneling from the σ-band in one electrode to the σ-band in the other.

4:45 PM EE7.9 Processing and Characterization of Powder in Tube MgB₂ Wires. Adriana C. Sengis¹, Leonardo Cimino¹, Xiaofeng Lu³, Dinesh M. Mookerjee¹, Duncan L. Haggstrom¹, Y. C. Ouhiøre¹, Vitali P. Nesterenko¹, Younan T. Zhu¹, Fred M. Miocinovic¹, Gordon D. N. Smith¹, Mark S. Rudenow¹: ¹MST-1, Los Alamos National Laboratory, Los Alamos, New Mexico; ²MST-2, Los Alamos National Laboratory, Los Alamos, New Mexico; ³Department of Structural Engineering, University of California, San Diego, La Jolla, California.

Since superconductivity in MgB₂ was reported, considerable progress has been made in the understanding of fundamental properties of this material and its possibilities for applications. However, to make practical devices, it is essential to enhance the pinning properties in order to increase the current carrying capability of MgB₂. We present a detailed analysis of the effect of heat treatments, including hot isostatic pressing (HIP), on the microstructure, magnetization and transport properties of MgB₂ wires and coils prepared by the powder in tube (PIT) method. We also present data of the bulk pinning force as a function of field derived from the magnetization data. We discuss the optimization of the annealing parameters that strongly improve the connectivity by eliminating most of the micro-cracks present in the un-annealed wires. The HIPed wires have a higher critical current density than the un-annealed wires, especially at high temperatures and magnetic fields, and higher irreversibility field (Hc2 ~ 17 T at 4 K). The Hc2 value is the largest reported in PIT MgB₂ wires or tapes. The improvement was attributed to a high density of structural defects, which are the likely source of vortex pinning.
EES 1
Al-Hf-Modified Memristive Switch Development.
Northrop Grumman Corporation, Baltimore, Maryland.

We are developing a technology for high-Q tunable filters from memristive capacitive switches using the high-temperature superconductor HTS YBa2Cu3O7-δ (YBCO) for both the static and movable capacitor electrodes. Northrop Grumman has demonstrated a low insertion loss tunable two-pole bandpass filter [1] which, when combined with a tunable biasing network (1-750 MHz) using room-temperature versions of such switches, [2] to move the bandpass tuning range. The capacitive switch is an electronically-driven memristive bridge. In our design, the electrical and mechanical functions of the bridge are decoupled so that an electrically floating bridge of YBCO can move up and down rigidly as the normal-metal supports, located away from radio frequency (RF) fields, are flexed. The bridge consists of the following epilayer layers: YBCO, a dielectric, a second dielectric serving as the sacrificial layer, YBCO, and non-sacrificial gold. The major critical part of process development is a differential etchant capable of removing the sacrificial layer without destroying the YBCO top electrode or the other dielectric layer. We are using SrTiO3 as the sacrificial layer. We will show results of our experiments to chem-mechanically polish the surface of the lower YBCO electrode to avoid having the switch stick when not in use. Supported in part by AFSOR Agreement F49620-03-1-0046. [3] M. Y. W. Yau et al., IEEE Trans. Microw. Theory Tech. 51, 1789-1794 (2003).

EES 2

Single crystals of the double perovskites Ba2PrRu1-xCuxO6 were grown from high temperature solutions of mixed PbO:Pr2O3 chosen from several solutions tried. Crystals were grown at different temperature in the range 1100 to 1200°C. The changes in the morphology and superconducting properties of the resulting crystals are presented. The crystals were found to grow with trigonal and hexagonal plate-like habit. The crystals exhibit a superconducting-like transition in the zero-field cooled state. This transition was found to depend both on the Cu concentration and temperature of growth. The transition temperature is found to vary from 7 to 11 K with either. Details of these investigations including X-ray, SEM and EDX analysis are presented. This is behavior similar to the Sr and Y based ruthenates of the same family produced in our laboratory and is interesting as the Pr2Ba3 is not known to be superconducting.

EES 3
Structure and EELS analysis of Na2Co2O4 yH2O superconducting system. Jiang Li and Y. G. Shi, Beijing Laboratory of Electron Microscopy, Beijing, China.

The structural properties and electron-energy-loss spectra (EELS) of Na2Co2O4 and Na2Co2O4 yH2O materials have been investigated. The Na2Co2O4 yH2O samples in general undergo superconducting transitions at around 3.5K. EDAX analysis suggest our samples have the average compositions of Na2Co2O4 for the parent compounds and Na2Co2O4 yH2O for the superconducting coherdorphides. TEM observation reveals a novel superstructure with wave vector q = {1,2,0,0} in the parent materials. This superstructure becomes weak in the superconducting samples. EELS analysis show that the Co ions have the valence states of around +3.8 in the Na2Co2O4 materials and around +3.7 in the superconducting materials.

EES 4
Phase Equilibria in the Sr0.5-CuO-TiO2 System: Application to High-Temperature Superconductors (HTS) via Chemical Solution Deposition (CSD). A. Ayala and T. G. Holesinger, Superconductivity Technology Center, Materials Science and Technology Laboratory, Los Alamos National Laboratory, Los Alamos, NM 87545. Alicia Ayala and Terry G. Holesinger, Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, New Mexico.

SrTiO3 (STO) is a candidate buffer layer for use in YBa2Cu3Oy (YBCO) coated conductors based on the ion-beam-assisted deposition (IBAD) MgO process. Deposition methods such as sputtering, reactive coevaporation, pulsed laser deposition, and metal-organic deposition have been used to prepare STO thin films. Chemical solution deposition (CSD) is an alternate means of thin film fabrication at a lower cost compared to sputtering. However, some aspects of the interfacial interactions between YBCO and the proposed buffer layer are still unclear. In order to identify optimum STO thin film compositions and deposition conditions, a portion of the phase diagram of Sr0.5-CuO-TiO2 system along the STO/SrCuO2 tie line was determined. Initial compositions ranged from x = 0 to x = 1 for Cu in Sr1-xCuTi1-xOy. Solubility studies show that a small amount of copper substitutes into the STO crystal structure, where the Sr site in STO does not incorporate into its structure. For sufficiently high Cu concentrations, partial melting can form in the temperature range of interest for CSD. These aspects of the phase diagram and CSD were combined to determine deposition conditions for high-quality CSD-deposited STO films on single crystal MgO and IBAD MgO substrates.

EES 5
Photocarrier injection into YBa2Cu3O7-δ thin films. Yuri Murakawa, Takaki Muramatsu, Torki Yamazaki, Jun-ichi Yamaura and Zenji Hiroi, ISSP. Univ. of Tokyo, Chiba, Japan.

It is well known that superconducting properties in high-Tc cuprates change as a function of hole carrier concentration. The common method to dope them with hole carriers is the chemical substitution of constituent elements, as in [La, Sr]2CuO4. However, randomness accompanied by the atomic substitution is introduced inevitably into a crystal, which has often obscured the physical interpretation of phenomena. It would be of great advantage if one could establish an efficient and reliable method to control hole density by applying certain external fields. Recently we presented a high and tunable photocarrier injection (PCI) method by using transition metal oxide (TMO) heterostructures [1, 2]. We prepared insulating and semiconducting thin films such as V2O5 and LaSr2CuO4 on n-type transition metal oxides substrates doped with Nb, and found that the hole concentration decreases under ultraviolet (UV) light irradiation. We also observed a positive photocurrent to the films, which evidences a hole carrier injection to the films. To explain this observation, we have proposed a simple picture where only hole carriers created by absorbing the light in the substrates are injected into the films through the interface, resulting in the large change in resistance. Here we apply the PCI method to a YBa2Cu3O7-δ/n-type SrTiO3/Nb heterostructure. We fabricated YBa2Cu3O7-δ films on n-type SrTiO3/Nb (100) (Nb: 0.05 wt% Nb) substrates. The film thickness was 400 Å. The film deposition was carried out in a vacuum chamber by using an ion beam deposition technique with a KLA Tencor Xerograph scanner (A = 248 Å). We measured the temperature dependence of in-plane resistance in the dark and under light irradiation. In the dark, the film exhibits superconductivity below a critical temperature Tc = 25 K. The Tc is lower than the optimum value (Tc = 90 K) of this material, suggesting that the film is underdoped with certain amount of oxygen vacancies. Under an UV light irradiation, the enhancement of Tc is observed up to Tc = 30 K with increasing light irradiance, accompanied with a decrease in resistance. These changes are believed to result a result of hole carrier injection to the film in the underscoping degree when light is switched off. In fact, out-of-plane voltage measurements upon light irradiation reveal a large photocurrent of 1.2 V, which changes temperature, indicating that hole carriers are injected from the substrate to the film. The number of injected hole carriers into the film is estimated from the change of Tc, to be 0.02 per Cu in YBa2Cu3O7-δ. The present PCI method would apply to many TMOs or oxide materials as a novel way for achieving desired doping or controlling phase transitions. References [1] Y. Murakawa et al., J. Phys.: Condens. Matter 14 (2002) L1757. [2] Y. Murakawa and Z. Hiroi, J. Phys. Soc. Jpn. 72 (2003) 781.

EES 6

We have grown La0.3Ca0.7MnO3/YBa2Cu3O7 (YBCO) superlattices by high oxygen pressure sputtering technique epitaxially on SrTiO3 changing the thickness of the individual layers between 1 and 15 nm. A structural analysis using X-ray and transmission electron microscopy shows sharp interfaces with a high degree of structural perfection. Magnetic-field dependent resistance and transport measurements show the existence of magnetic order and superconductivity. While the thinnest LCMO layers (3 unit cells) lead the superconducting critical temperature almost unchanged, thicker LCMO layers result in a suppression of the critical temperature over a wide thickness interval of the organic layer.
These results suggest a long nanometer scale length for superconductivity depression in the ferromagnet. We discuss this result in terms of magnetic pinning by the ferromagnetic effect. Work supported by MCTF MAT 2000-1408, Fundacion Ramon Areces, CAM.

**EES 7**

**Growth and Microstructural studies of YBa$_2$Cu$_3$O$_{7-\delta}$ thin films.** Serina Sathariya$^{1,2}$, Kerry D Fields$^3$, Nicholas A Yust$^4$, Roma M Nekkanti$^{5,6}$, Lyle B Brucker$^3$, Angela L Campbell$^3$, Timothy J Haugen$^3$, Justin C Tiller$^3$ and Paul N Barnes$^3$.

$^1$ National Research Council, Air Force Research Laboratory, Wright-Patterson AFB, Ohio; $^2$Propulsion Research and Power Generation Branch, Air Force Research Laboratory, Wright-Patterson AFB, Ohio; $^3$U.S. Air Force Research Laboratory, Wright-Patterson AFB, Ohio; $^4$MLPE, Air Force Research Laboratory, Wright-Patterson AFB, Ohio.

The quality of superconducting films epitaxially grown highly depends on the substrate choice. It is well known that SrTiO$_3$(100), LaAlO$_3$(100), YSZ(100) and MgO(100) are suitable substrates for producing high quality superconducting thin films, especially YBa$_2$Cu$_3$O$_{7-\delta}$(YBCO). However, it has been reported that for 123 films deposited on MgO substrate, an interfacial barrier salt is formed at the interface if the processing temperature is above 700°C [1]. Also, another problem reported with the films grown on MgO is the presence of the phase-mixed grains [2] which degrade the crystalline quality of the deposited R$_2$Cu$_3$O$_y$(where R=Y, rare earths). A possible solution is to use a suitable buffer layer on the MgO substrate for the growth of the subsequent Y123 superconductor films. The same concept can be extended to coated conductor applications too.

In this paper, we report the epitaxial growth of YBa$_2$Cu$_3$O$_{7-\delta}$(YBCO) as a new dielectric buffer layer on MgO (100) substrates for the subsequent deposition of Y123 thin films. YBCO has a cubic structure and is easier to manipulate in terms of the processing variables compared to the conventional YBCO dielectric properties [4]. Our results on the growth and microstructural characterization of Y123 thin film on YBCO buffered MgO substrate will be discussed in detail. Extension of this buffer layer to other substrates will be considered.

**EES 8**

**Quantum Coherence In Y-Ba$_2$Cu$_3$O$_{7-\delta}$ Superconductors: Photoreponse, Ying Xu$^5$, Carlo Wilkin$^6$, Jan Mostovský$^7$ and Roman Scholz$^{8,9}$.

$^9$Department of Electrical and Computer Engineering and Laboratory for Laser Energetics, University of Rochester, Rochester, New York; $^8$Corning Inc., Cornings, New York; $^7$Institute of Physics, Polish Academy of Science, Warsaw, Poland.

Ultrafast optoelectroncs response of high temperature superconductors (HTS) has been the subject of intensive studies since the discovery of these materials. The basic physics research is focused on better understanding of the mechanism of the material, while applied-oriented work is aimed at promising applications, such as ultrafast photo-detection and photo-mixing. At temperatures for high brightness sources, macroscopic nonlinear photoreponse has been observed in optimally doped, epitaxial Y-Ba$_2$Cu$_3$O$_{7-\delta}$ microbridges, bimetal the current lower than the bridge critical current and excited with 100-fs optical pulses. The time-resolved voltage photoreponse signal consists of very pronounced, fast-damped picosecond oscillations. Only the initial half of the biphasic transient, typical for the inductive response, can be successfully simulated using the phenomenological Rothwarf-Taylor equations. We propose here a novel quantum coherence model to explain the picosecond time scale Cooper pair dynamics in Y-Ba$_2$Cu$_3$O$_{7-\delta}$ thin films. Our model describes the coherent interaction between quasiparticles and the Cooper pair exchange field and is in excellent agreement with our experimental results. The coherence between the quasiparticle and the boson subsystems is significant, with the coherence time of around 1 ps. The presented formulation can be regarded as a quantum-mechanical equivalent of the Rothwarf-Taylor equations. This work was supported by the NSF grant DMR-0223566.

Y. X. acknowledges support from the Frank Horton Graduate Fellowship Program in Laser Energetics.

**EES 9**

**Magnetoo-Optical Studies of Thickness Dependence of Flux Pinning in YBCO Films Grown on Twinned LaAlO$_3$ Substrates.** Z. Xin Ye$^7$, Qiang Li and Weidong Shi$^7$.

$^7$Brookhaven National Lab, Upton, New York.

To investigate the pinning mechanisms which may be responsible for the generally observed thickness dependence of critical current density in YBCO coated conductors, we prepared a series of YBCO epitaxial films (0.2 to 1.6 micron thick) on heavily twinned LaAlO$_3$ substrates by pulsed laser deposition. Magnetoo-optical imaging (MOI) techniques were used to map the pinning strength of the film at various magnetic field and temperature. A decrease of the averaged critical current density over the entire film was observed. At the location of the substrate twin boundaries, enhanced pinning in the thin films was observed, while a substrate twin boundary in the 1.6 micron thick film. This remarkable evolution of pinning strength from strong to weak as the film thickness increases suggests that structural defects on the substrate played an important role in the critical current carrying capabilities of YBCO thick films. The nature of structural defects in YBCO films induced by these substrate twins is currently being investigated by the TEM on the same samples. We will discuss the correlation of the pinning behavior with the structural defects found in these films. *This work was supported by the U.S. Department of Energy, Division of Materials Sciences, Office of Basic Energy Sciences under contract No. DE-AC02-98CH10888.

**EES 10**

**99mTc Mossbauer Effect Studies of SrRuO3 Prepared with a Tc of 90K and 160K.** Michael Joseph De Marco$^{10,11}$, Piotr W. Klimut$^{12}$, Dermot Coffey$^1$, Michael Hink$^2$, Steve Toorongian$^3$, Michael Dobrosow$^4$ and Bogdan Dobrosow$^4$.

$^1$Physics Department, State College, Buffalo, New York; $^2$Physics, University at Buffalo, Buffalo, New York; $^3$Physics, Northern Illinois University, DeKalb, Illinois; $^4$Material Science, Argonne National Laboratory, Argonne, Illinois.

SrRuO$_3$ has a crystal structure which is compatible with high Tc and ferromagnetic compounds and has become a candidate for high Tc applications as a substrate. It is also similar in structure to Sr$_2$CuO$_2$Cl and other ruthenate cuprate superconductors. In this study SrRuO$_3$ has been prepared in the standard manner and has a Tc of 160K as measured by magnetization. The 99mTc Mossbauer effect shows a well-resolved hyperfine magnetic field of 31T at 4.2K and a single narrow line at 160T. The Tc of 160K sample showed a hyperfine magnetic field of 31T at 4.2K. Mossbauer measurements were made for both Tc samples at 99K and a Tc of 160K sample showed a single broadened line indicative of a phase transition. The SrRuO$_3$ sample with a Tc = 90K was annealed at ambient temperature to produce a Tc = 155K as measured by ac and dc magnetization. Mossbauer measurements of a well-resolved hyperfine magnetic field at 4.2K and a single narrow line at 100T(0.5K) above the critical temperature.

**EES 11**

**Photoemission Studies of YBa$_2$Cu$_3$O$_{7-\delta}$ Single Crystals Employing X-ray Standing Waves.** Sebastian Thiess$^{1}$, Tien-Lin Lee$^{1}$, Chengtian T Lin$^{1}$, Bruce C.C. Cowie$^2$, Nicholas Brookes$^3$, Christof Kunz$^4$ and Joerg Zegenhagen$^4$.

$^1$ESRF, Grenoble, France; $^2$MPI-FKF, Stuttgart, Germany.

The standing wave (XSW) technique uses an interference field typically generated by the superposition of the incident and the reflected X-ray beams to probe the microscopic properties of a thin film. In this work, a high resolution XSW beam was produced on a YBCO single crystal. The X-ray intensity distribution was measured using a polynomial fit to the data. The resulting intensity distribution was then used to calculate the X-ray standing wave pattern. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. These results are consistent with the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam. The XSW pattern was then compared to the X-ray standing wave pattern obtained from the high resolution XSW beam.

**EES 12**

**Search for Time-Reversal Symmetry-Breaking States in Cuprate Superconductors.** Sheng-Chiang Lee and Steven M. Anlage.

$^1$Physics, Center for Superconductivity Research, University of Maryland, College Park, Maryland.

Many theories predict a Time-Reversal Symmetry Broken (TRS) state in unconventional superconductors. For example, Varma's micro-current model in underdoped high temperature superconductors (HTSC), and Andreev bound states on certain surfaces of HTSC, are expected to show some manifestations of TRS, perhaps only new superconducting phases. However, experimentally, the question of TRS in HTSC is still controversial. Previous work has shown that our magnetically enhanced Near-Field Microwave Microscope is sensitive to TRS arising from Josephson vortices in a long bi-crystal grain boundary junction, through measurement of second harmonic generation. [Appl. Phys. Lett., 82, 1835 (2003)] Taking advantage of this microscope, this work presents our study of [110] surfaces of under-doped YBa$_2$Cu$_3$O$_{7-\delta}$ (YBCO), and [110] surface of YBCO, which are proposed to display TRS in
harmonic response. The oxygen content of the underdoped YBCO is adjusted so that the change due to different doping level is also explored. We find that underdoped YBCO is more nonlinear in both TTS (cond-mat/B064161) and TRSB channels. We will demonstrate the doping-dependent temperature and power dependences of the locally generated second and third order harmonic generation measured from the films with relevant models. We acknowledge the support of NSF GOALI DMR-2012621, and the Maryland/Rutgers/NSF MRSEC DMR-0805008.


The effect of growth condition and composition on the crystal growth of La-2126 phase superconducting materials has been studied by the floating zone method. The compositions of La-2126 phase single crystals prepared were $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ and $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ with $x = 0.05$ to 0.25. The crystals were grown under oxygen pressures of 1 and 11 bars. A phase solid-liquid growth interface of $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ with $x = 0.05$ to 0.16 and $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ with $x = 0.05$ to 0.25 tended to break down into a cellular interface when the growth velocity was lower than 0.2 mm/h. When the phase solid-liquid growth interface broke down into a cellular interface, the crystal single crystals grown were abrupt and the $\alpha$-grown rod was not of single phase. Various compositions were found in the $\alpha$-grown single crystals of $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ with $x = 0.05$ to 0.16. The occurrence of these second phases $\alpha$-phase inside the $\alpha$-grown crystals, the estimated solubility of $\alpha$-phase in the $\alpha$-phase single crystals is $x = 0.075$ for $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$, and $x = 0.125$ for $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ respectively. The melting point of the La-2126 materials increases with increasing oxygen pressure. Cubic centimeter size single crystals were successfully grown for both $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ with $x \leq 0.05$ and $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ with $x = 0.075$. The $\alpha$-phase single crystals of $(\text{Ln}_{2-x} \text{Sr}_{x} \text{Ca}_{2}\text{Cu}_{3}\text{O}_{6+y})$ with $x = 0.125$ were not superconducting. The superconducting transition temperature in the $\alpha$-phase single crystals, grown at 11 bars oxygen pressure increases with increasing the $\alpha$-phase concentration $x$ from $T_c \approx 40K$ ($x = 0.05$) to $T_c \approx 40K$ ($x = 0.25$). The work was supported by the DOE under contract No. DE-AC05-000R18888.

EES. 14 Ru$_{2-x}$Sr$_x$Eu$_5$Co$_5$Cu$_{24}$O$_{40}$-a: 1223-type ruthenocuprates. Tuning the magnetic and superconducting properties with Cu-to-Ru substitution and oxygen content. Peer W. Klemm, J. Marx, M. Mixter, V. Jelinek, J. Felner, U. Anot and F. Bitter.

The 1223-type magnetic superconductors are extensively investigated for the microscopic coexistence of magnetism and superconductivity observed thereon. The magnetic transition temperature $T_C = 47K$.

Ru$_{2-x}$Sr$_x$Eu$_5$Co$_5$Cu$_{24}$O$_{40}$-a (RFM, Ef) phases of the 1212-type, we have performed high pressure oxygen annealing for stabilizing the 1223-type structure of the Ru$_{2-x}$Sr$_x$Eu$_5$Co$_5$Cu$_{24}$O$_{40}$ system. Accomplishing dilution of the Ru subsitute with Cu atoms leads to pronounced magnetic ordering and as a consequence the compound becomes a nonmagnetic superconductor for $x < 0.4$. Subsequent change of the oxygen content $d$, traces in the thermogroscopic measurements at various partial pressures of oxygen, tunes the properties of the materials. Measurements of $ac$ susceptibility in the superimposed $dc$ field led us to the field dependence of the critical currents, as well as the inter- and intragranular superconducting characteristics of these systems. Research is supported by the National Science Foundation (DML-0155381), and at Hebrew University by the Israel Science Foundation (2000).

EES. 15 Superconductor Properties of Nb$_{52}$S$_2$ Samples After Submitted to Different Doses of Electron Irradiation. Donald H. Galvin, William Valavanis, Jun Hyo Kim, Fabio Adego, Myra Angle, Episco Quimica, Centro de Ciencia de la Mater a Condensada, UNAM, Ensenada, Baja California Norte, Mexico; 3Physics Department and Institute of Pure and Applied Physical Sciences, University of California, San Diego, California; 4Electrocommunications Research Laboratory, 1-1 Hidaka, Shimo-Yokohama, Kanagawa, 243-0198, Japan; 5Yong-Gu Lo, 350-350, Korea, South Korea, "lnstituto de Fisica, UNAM, Mexico, D. F., Mexico.

We present experimental evidence for an increased pinning effect in the superconductor Nb$_{52}$S$_2$. Nb$_{52}$S$_2$ samples underwent 100, 250 and 500 Mrad of electron irradiation and then were studied with x-ray diffraction and magnetic susceptibility measurements. The magnetic measurements of the Nb$_{52}$S$_2$ samples revealed an enhancement in the critical current density with radiation dosage. This enhancement reached a maximum value at 500 Mrad with almost double the value of the unirradiated material. This enhancement indicates that the irradiation is causing more effective flux pinning in the material. Furthermore, the occurrence (superconductor transition temperature) was continuously monitored for all samples with no observable change due to irradiation.

EES. 16 Single Domain YBa$_2$Cu$_3$O$_x$ for RF Cavity Filters. Alton Feng, Hsin Bubu, David Cardwell, David Max 1, and Donghu Shi 2.

Large single domain YBa$_2$Cu$_3$O$_x$ materials have been successfully fabricated with superb RF properties by employing the seeded melt growth (SMG) method. Commercially available Y-123 and Y-211 phase precursor powders were mixed thoroughly and pressed into various cylindrical cavity geometries. Following sintering, the cavities were then oxygenated in an oven for at least 7 days. The cavities were then tested in a closed cycle cryocooler from room temperature down to 20K. Using a Vector Network Analyzer, the cavity resonance frequency and quality factor were measured. Two cavity modes, TM010 and TE111 modes, were used for the measurements. From the measured Q values, the surface resistances of the cavity surfaces were calculated. Measured results and various combinations of cavity structures for realizing highly selective RF filters will be presented.

EES. 17 The Internal Oxidation in Solid Solutions Based on Bi2212 with Simultaneous Substitution Bi on Pb and Ca or Sr on Rare Earth Elements. Alexander V.Knizhko, 1, Yuri G. Shagisultanov, 1 Valery I. Putykhin, 1 Alexey V. Gerasim, 2, Mikhail P. Polkov, 2, Nikolay M. Pevaskov, 2, and Stepany I. Morozov, 3.

Phase transformations in high-Tc materials leading to a formation of a superconductor/matrix interface are a good example of composite that is a prospective way to improve pinning properties of the material. Since a cation diffusion in Bi2212 [Bi-2212] based compounds is quite sluggish at undermelting temperature, phase transformations in Bi2212 solid solutions can be triggered off by oxidation of alkali cations incorporated into such solutions. To control the process one can perform simultaneous substitution in different cation sites (e.g., Bi on Pb and Ca or Sr on rare earth elements). Solid solutions of Bi(2-x)[Pb]Bi$_x$Sr$_2$Ca$_2$Cu$_{2+2x}$O$_{6+2x}$ ($y(\text{Nd})$) were fabricated at 760°C in N$_2$ flow. Samples were tested with XRD, TEM, inelastic neutron scattering and AC-susceptibility measurements. Earlier for solid solutions Bi(2-x)[Pb]Bi$_x$Sr$_2$Ca$_2$Cu$_{2+2x}$O$_{6+2x}$ the two-stage oxidation process was found, at that the first stage can related to the oxygen redistribution and second - to oxidation of Nd cations. The substitution of Ca on Y or Nd significantly decelerates the first stage of the oxidation and therefore allows to escape the a coarsening of the obtained spinal dendritic microstructure. A difference between the homogeneity areas of Pb - containing solid solutions based on Bi2212 with substitution Ca on Y and Nd was established. This difference probably related to the several distribution of Nd in crystallographic cationic sites of Bi2212 structure [because to the diffusion of its atomic radius]. The photon spectra of solid solution Bi(2-x)[Pb]Bi$_x$Sr$_2$Ca$_2$Cu$_{2+2x}$O$_{6+2x}$ ($y(\text{Nd})$) were investigated by the inelastic neutron scattering on the direct geometry spectrometer DIP-2PI [installed on neutron beam of pulsed reactor IBR-2, FLNP JINR, Dubna, Russia]. Comparison of the high frequency parts of photon density of states spectra (related to oxygen vibrations) allows to make the conclusion concerning the nature of substitution effect on oxidation kinetics of Pb-doped solutions. The work was supported by Russian Foundation for Basic Research (grant #02-03-33017), National Program "High-priority...
problems of condensed matter (subprogram "Neutron researches of condensed matter").

EES 18
Atomic force microscopy and transmission electron microscopy studies on (Hg,Re)Ba$_2$Ca$_2$Cu$_2$O$_{y}$ thin films deposited on Ag via laser ablation. Jordan Su$^1$, Justin Schwartz$^1$, 2, 3, 4

$^1$Magnet Science and Technology, National High Magnetic Field Laboratory, Tallahassee, Florida, 2Mechanical Engineering, FAMU-FSU College of Engineering, Tallahassee, Florida, 3Center for Advanced Power Systems, Tallahassee, Florida

(Hg,Re)Ba$_2$Ca$_2$Cu$_2$O$_y$ thin films were fabricated on Ag by reacting laser deposited Re$_2$Ba$_2$Ca$_2$Cu$_2$O$_y$ precursor films with Ca$_2$O$_2$ in selective areas. The as-prepared thin films with thickness up to 1 micron showed good oxide-oriented texture and an on-set superconducting transition temperature (Tc) of 124 K. The influence of the Ag interface on the nucleation and growth of the (Hg,Re)Ba$_2$Ca$_2$Cu$_2$O$_y$ thin films have been analyzed using transmission electron microscopy (TEM). The TEM investigation showed that the (Hg,Re)-1212 thin film usually nucleates and grows on the flat area of the Ag surface with its a-b plane simply parallel to the Ag-surface plane, regardless of whether the Ag surface is a low-index or high-index crystal plane. On defective surfaces, such as surface valleys or hilts, however, the (Hg,Re)-1212 thin film cannot grow directly, instead, there is an intermediate layer with some other oxide phases. The atomic force microscopy (AFM) images of thin films showed a two-dimensional terraced layer-by-layer growth mode. The growth unit is multiple-unit-cell in the c direction. No example of spiral growth, which was thought to be the typical structure of YBCO thin films, was found in these thin films.

EES 19
Abstract Withdrawn

EES 20
Transport properties of Ag and Au doped YBCO superconducting samples. Julio E. Rodriguez and Alvaro Moran.

Department of Physics, Universidad Nacional de Colombia, Bogota, Colombia.

Polycrystalline samples of Ag and Au doped YBCO superconducting samples were synthesized from oxides by solid-state reaction. Electrical resistivity, $\rho$(T), thermoelectric power, $S$(T) and thermal conductivity, $k$(T) were measured in the temperature range between 77K and 300K. The doping content increases both $\rho$(T) and $S$(T) while the thermal conductivity decreases. On the other hand the dimensionless figure of merit $ZT$(T) shows an enhancement more than one order of magnitude with the doping.

EES 21
Abstract Withdrawn

EES 22
In-situ RHEED observation of yttria incorporation in laser-ablated YBCO thin films. Radhika A Chakalakal$^1$, Chris Jeyes$^1$, Pavel Mikheenko$^2$, Mark S Colclough$^2$ and Chris M Maude$^1$, 2

$^1$Physics and Astronomy, The University of Birmingham, Birmingham, United Kingdom, 2University of Surrey Ion Beam Centre, University of Surrey, Guildford, United Kingdom

Pulsed laser ablation of single stoichiometric target is widely used as gainful method for deposition of excellent YBCO thin films. However, the crystal lattice quality at microscopic level still needs improvement. Common problem is the formation of secondary phase inclusions in a stoichiometric film matrix, especially as the technique is limited in means of elemental composition variation. We have used in-situ RHEED observation of YBCO thin film growth in combination with post-deposition analysis by XRD and RBS to study film composition and crystallographic peculiarities. It was found that simples prepared under optimal conditions (in terms of high critical temperature and high critical current density) show additional set of diffraction spots in the RHEED patterns. We were not successful in correlating these spots with any feasible YBCO surface phase. XRD evidenced for highly-oriented YBCO crystal lattice with no secondary phases, elemental depth profiling by RBS clearly showed small excess of yttria distributed homogeneously over the film thickness. More detailed consideration of the electron diffractionograms proved that the two sets of spots originate from YBCO and yttria sublattices epitaxially related as [001]YBCO/[001]yttria, [100]YBCO/[110]yttria. Such ordered incorporations may have acted as pinning centres and result in the best superconducting properties observed.

EES 23
YBa$_2$Cu$_3$O$_7$ and DyBa$_2$Cu$_3$O$_7$ superconducting thick films produced by an electrochemical deposition method: investigation of a new process for getting optimised large-scale magnetic screening systems. Rudi G. Clots$^1$, 2, 3

Laurent Dussoulier$^1$, Philippe Vanderbeneden$^1$ and Marcel Ausloos$^2$

$^1$Department of Physics, University of Liege, Sart-Tilman, Belgium, 2Physics department, University of Liege, Sart-Tilman, Belgium, 3Electrochemistry department, University of Liege, Sart-Tilman, Belgium.

Thick films of superconducting materials were fabricated by an electrochemical deposition method. This technique allows us to produce complex shape of superconducting devices for magnetic screening. Nickel or stainless steel electrodes were used in the presence of Pt and buffer layer. YBCO and DyBCO powders were prepared by a classical solid state reaction and dispersed in acetone for electrochemical deposition. Experimental parameters (e.g. voltage, size of the electrodes, size distribution of the superconducting particles) were investigated and the process has been optimised based on microstructure analyses, leading to a crack-free adherent deposit at the surface of the electrodes. Superconducting properties have been reported for the best samples.

EES 24
Ni-422 doped Dy-123 superconducting single domain produced by the top-seeded melt-growth process: a better control of the dissolution of the Nd-123 single crystal seed. Philippe Vanderbenda$^1$, Jean-Philippe Mathieu$^1$, Jean-Francois Fagnard$^2$, 2

Marcel Ausloos$^2$ and Rudi G. Clots$^1$, 2

$^1$Chemistry Department, University of Liege, Sart-Tilman, Belgium, 2Physics Department, University of Liege, Sart-Tilman, Belgium, 3Electricity Department, University of Liege, Sart-Tilman, Belgium.

Several factors limit the manufacture of large 123 superconducting single-domain products produced by an isotothermal top-seeded melt-growth process. The partial dissolution of the Nd-123 single crystal seed leads to secondary nucleation sites which limit severely the growth of the 123 single-domain. The addition of a few percent of Ni-422 to the bulk is proved as a beneficial action to avoid the dissolution of the seed. Perfectly oriented 123 single domains in a square shape can be manufactured and are characterized by good superconducting properties. Levitation forces and critical current density are reported for the best samples. A microstructural investigation of the distribution of the Ni-422 particles and their reactivity with the 123 matrix and Dy-211 particles is also presented.

EES 25
Comparative studies on the properties of YBa$_2$Cu$_3$O$_{7}$ films and Sm$_1$Ba$_2$Cu$_3$O$_{7}$ films. Daejeon Youm, Physics, KAIST, Daejeon, South Korea.

We comparatively studied the growth properties and the superconducting properties of YBa$_2$Cu$_3$O$_{7}$ (YBCO) films and Sm$_1$Ba$_2$Cu$_3$O$_{7}$ (SBCO) films deposited on buffered and bi-axis textured Si wafers. The window of substrate temperature for proper growth of SBCO films was several times wider than that of YBCO.

The appropriate oxygen pressure for SBCO film growth was about 20 times lower than that of YBCO. The critical current density (Jc) of SBCO film at zero field was 2 times smaller than that of YBCO. However, above 3 Tesla of external field, Jc of SBCO was always larger than that of YBCO. The reduction rate of Jc of SBCO film at the grain boundaries of high angle misorientation was one order of magnitude smaller than that of YBCO. All of these properties indicate that it should be considered to develop the fabrication technology of SBCO based coated conductors in stead of YBCO based coated conductors.

EES 26
Fabrication and Transport Properties of High Quality ErBa$_2$Cu$_3$O$_{7-d}$ films By Pulsed Laser Deposition. Masahiko Masukado$^1$, 2, 3, 4, 5, 6

Takashi Okuma$^1$, 2, 3, 4, 5, 6, Shigeru Hori$^1$, 2, 3, 4, 5, 6, Kanae Masumoto$^1$, 2, 3, 4, 5, 6, Yuutoh Yoshida$^1$, 2, 3, 4, 5, 6, Atsushi Ichinose$^1$, 2, 3, 4, 5, 6, Atsushi Saito$^1$, 2, 3, 4, 5, 6, Shigetoshi Osaki$^1$, 2, 3, 4, 5, 6, 7, 8, 9

$^1$Electrical Engineering, Yamagata University, Yamagata, Japan, 2Supercond., University of Tokyo, Bunkyo-ku, Tokyo, Japan, 3Materials Sci. and Eng, Kyoto University, Sakyo-ku, Kyoto, Japan, 4Energy Eng. and Sci, Nagoya University, Chikusa-kku, Aichi, Japan, 5Electrical Phys., CRIEI, Komine, Tokyo, Japan, 6JST Corporation, Kusagushi, Saitama, Japan

Fabrication and transport property measurements of ErBa$_2$Cu$_3$O$_{7-d}$ films are discussed. Since the discovery of REBa$_2$Cu$_3$O$_{7-d}$ superconducting thin films, these films have been developed to achieve high Jc. In order to attain high Jc, the superconductors must be high quality and have strong pinning centers. Among the REBa$_2$Cu$_3$O$_{7-d}$ superconductors, ErBa$_2$Cu$_3$O$_{7-d}$ is one of the most materials to dope carriers with codoping. But in other words, homogeneous films are easy to obtain for ErBa$_2$Cu$_3$O$_{7-d}$ films with respect to carrier doping. Then we selected ErBa$_2$Cu$_3$O$_{7-d}$ as a mother film for introduction of strong pinning centers. ErBa$_2$Cu$_3$O$_{7-d}$ films are grown by conventional pulsed laser deposition with Ar.
excimer laser on (100) SrTiO$_3$ substrates. Crystallinity of ErBa$_2$Cu$_3$O$_7$-d films is examined by x-ray diffraction and x-ray phase contrast for crystal orientation, AFM and FE-SEM observation for surface morphologies. Superconductive shielding characteristics are evaluated by MO images. Transport properties are characterized by a four-probe method in a magnetic field. Surface resistance of the films is measured by a dceterometer method. ERGSHS. Consequently, obtained as-grown ErBa$_2$Cu$_3$O$_7$-d films were homogeneous in superconductive shielding characteristics as evaluated by MO images and showed low surface resistance around, however the Jc of the film was very low around 0.3MA/cm$^2$. We believe there may be no effective pinning centers in the as-grown films. We have increased the Jc of the film by oxygen annealing. At the optimum annealing condition, the Jc of the film was almost one order of magnitude enlarged to $\sim$3MA/cm$^2$. In this presentation we will also discuss preliminary results on the artificial pinning center introduction to the film by electron beam lithography. Reference: J. Shimoyama et al., Mat. Res. Soc. Symp. Proc., 659 (2001) 265-270.

EES 27 Phase Relations in the Ba-Ru-Cu-O (R = Nd, Sm, Eu, Gd, Ho, Y, and Er) System. Atmospherically-Controlled Conditions.

Winnie Kwei-Wah Wong-Ng, Julian Suh and Lawrence P. Cook; Ceramics, NIST, Gaithersburg, Maryland.

Phase diagrams provide guidelines for processing of high-temperature materials. For the application of the second-generation coated conductors, it is critical to build a phase diagram database for the barium-yttrium- ruthenium-oxide and the lanthanides-substituted materials. Research is being carried out at NIST as part of a DOE-funded project to construct phase diagrams of the carbonate-free Ba-Ru-Cu-O (R=Nd, Sm, Eu, Gd, Ho, Y, and Er) systems under atmospherically-controlled conditions (purified air and 100 Pa oxygen partial pressure). We describe first experimental results for preparing BaRuO$_3$ starting material and for the handling and heat-treatment of samples. In this paper, a discussion of the crystal chemistry and reaction pathways of high-temperature superconductors will be presented. A comprehensive comparison of these diagrams as well as those that were prepared under different atmospheric conditions will be summarized.

EES 28 Femtosecond Carrier Dynamics in Hg-Based Superconducting Thin Films. Yang Xu, Na Li, Steve Chronik, Vladimir Strikha, Dominique De Ferrari, Philippe Odier, and Roman Scholwercker.

1Department of Electrical and Computer Engineering and Laboratory for Laser Energetics, University of Rochester, Rochester, New York; 2Institute of Engineering, Slovak Academy of Science, Bratislava, Slovakia; 3Institute of Physics, Polish Academy of Science, Bratislava, Poland; 4Laboratoire de Cristallographie-CNRS, Grenoble, France.

Superconducting thin films of Hg-based cuprates were fabricated and tested using the spray-coated, femtosecond-laser, and probe-spectroscopy. The films (500-nm thick) were prepared from rMgMn-sputter Re-Ba-Cu-O precursor films, followed by an excimermediated process to form the superconducting phase. The XRD analysis indicated that the resulting films were predominantly composed of c-axis oriented Hg1212 and Hg1223 phases. Their superconducting transition was rather broad with the onset at 136 K and the zero resistance value at 116 K. The time-resolved optical pump-probe measurements were performed using 100-fs-wide pulses, generated from a Ti:sapphire laser operating at the 800-nm wavelength. The relative change of the probe-beam reflectivity was measured in the temperature range between room temperature and 10 K. The room temperature signal was characterized as a single-exponential subsondianted relaxation and was independent of the incident optical excitation power. With decreasing temperature below the superconducting transition, the carrier relaxation process became more significant. At 1 K, the lowest optical excitation power (1 mW), the relaxation was characterized by a decay time constant of $\sim$0.1 ps. The increase of the optical power lead to a gradual change in the quasiparticle relaxation process, eventually leading to 10 mW to the biexponential relaxation with the initial decay time of $\sim$35 ps, followed by the 10-ps component. This work was supported by the NSF grant DMR-0023666 (Rochester) and the Slovak Scientific Grant Agency (grant VEGA 2/98/20). Y. X. acknowledges supports from the Freire Foundation, the Franz Kafka Foundation, the National Science Foundation, and the Laboratory for Laser Energetics and X. L. acknowledges supports from the Spruill Fellowship.

EES 29 Enhancement of Flux Pinning Properties on Impurity-Doped Bi(Pb)2212 Single Crystals. Shigeru Hori; Manabu Shimogori; Satoshi Ukida; Takemori Sugiuca; Jun-ichi Shimoyama; and Koichi Kishio.

1Department of Superconductivity, Univ. of Tokyo, Tokyo, Japan; 2RIENST-JST, Saitama, Japan.

Critical current properties of Bi2212 were dramatically improved by heavily doping and control of oxygen content. This improvement can be understood in terms of decrease of electromagnetic anisotropy and generation of lamella structures. For further improvement of critical current properties in Bi(Pb)2212 system, in the present study, doping of small amount of impurities in CuO$_2$ plane which generates locally weak superconducting region were attempted. Critical temperatures of grown crystals by the floating zone method with nominal compositions of Ba$_{1-x}$Pb$_x$Cu$_{1-y}$Sn$_{y}$O$_{2-x}$ (x=0, 0.002, 0.005, 0.02) were drastically decreased by the M-doping levels, while the Bi(Pb)2212 crystals with x = 0.002 and 0.005 showed remarkably enhanced flux pinning properties below 50 K. This is indicating that point-defect-type pinning sizes were successfully introduced by small amount of M-doping. Similarly with x = 0, these crystals showed both anisotropic behavior of pinlap J$_c$ and temperature-induced pinning effect.


Using the trifluoroacetic acid and metal organic deposition (TFA and MOD) methods, thin films of YBa$_2$Cu$_3$O$_{7-\delta}$ (Y123) with yttrium substituted by rare earth elements were grown by radio frequency magnetron sputtering, including samarium, dysprosium and erbium, were prepared. With the differences in radii of the dopants and orthorhombicity of each unit cell in mind, the resulting films were compared to each other and to undoped samples by x-ray diffraction, scanning electron microscopy, electrical transport, and transmission electron microscopy (i.e., XRD, SEM, and TEM, respectively). The superconducting transition temperatures and critical current densities, measured with a four-probe setup, were determined as well. The results and their implications will be discussed.


1Propulsion Directorate, Power Group, U.S. Air Force Research Laboratory, Wright-Patterson AFB, Ohio; 2Department of Materials Science and Engineering, Ohio State University, Columbus, Ohio; 3Superconducting Materials Group, Oak Ridge National Laboratories, Oak Ridge, Tennessee.

The inclusion of YBaCuO$_2$ (211) phase nanoparticles by island-growth deposition into multilayer nanosized structures was investigated in an attempt to enhance the physical-electrical-magnetic properties of YBa$_2$Cu$_3$O$_{7-\delta}$ (123) thin films, for possible use in coated conductor superconductor applications. Multilayer (211/123)n composite films were deposited by pulsed laser deposition onto LaAlO$_3$, SrTiO$_3$, or buffer-coated biaxially textured Ni or Ni-Nb alloys substrates. The 211 average particle thickness was between 1.04-0.0 nm, with the 123 layer thickness varying from 4-20 nm and the total composite film thickness up to 3 microns (N=200 bi-layers). The inclusion of 211 nanoparticles into 123 films was observed to enhance film properties including providing an unusually smooth surface allowing thicker film growth. Improvement of transport current densities Jc(H, T) properties ranged from 100-500 A/cm$^2$ in magnetic fields of about 1.5 T and temperatures between 20-70 K. Additional enhancements in film structure and performance including the dependence of Jc on angle variations, as well as mechanical strength and crack resistance properties of the films.


1INESC, Lisbon, Portugal; 2IESFP, Grenoble, France; 3MPI-FKF, Stuttgart, Germany.

Understanding the relationship between growth, structure and electronic properties of high-temperature superconductor (HTS) epitaxial thin films is of prime importance from a fundamental point of view as well as for future applications. For probing electronic properties of materials photoemission has been widely used. With photoemission from core states and the valence-band excited by an
x-ray standing wave (XSW) field, latticesite-specific electronic information - originally not available from standard XPS - can be obtained. The XSW method allows identifying the chemical origin of different features observed in photoemission spectra. In the present study, we employed the XSW technique to characterize the interfacial structure as well as the electronic properties of epitaxial HTS films. Underlying precursors Nb3Sn/2O4 (or Sn = Gd, Y) were grown by pulsed-laser deposition on perovskite Nd2/3D2O (011) and SrTiO3 (011) single crystal substrates. Measurements were carried out at room temperature by ab initio DFT2 of the ESRF using a photon energy of 2 eV. The XSW family of films showed superconductivity in the configuration 2H1 (Sn = Gd, Y),2 the Cu-O-NbO interface distance to be 0.19 nm, which is identical to the Nd-DG02 spacing of Nd2/3D2O (011)'. The GdBCCO valence band and the CuO2 energy bands show identifications on the STM modifications; this suggests a dominating Cu contribution to the valence band yield. A chemically shifted 01s peak towards higher binding energy is indicative of surface contamination due to air exposure during the transfer.

**ES9.3**

**Flux pinning behavior and positron annihilation study on (Pb,Sn)-doped Bi-2212 superconductors**

Jian Li,1 Department of Materials Physics, University of Science and Technology Beijing, Beijing, China; Laboratory of Nuclear Analysis Techniques, Chinese Academy of Science, Beijing, China; Physics, Texas A&M University, College Station, Texas; Center for High Temperature Superconductivity, Blackett Laboratory, Imperial College of Science, Technology and Medicine, London, United Kingdom.

The flux pinning behavior of (Pb,Sn)-doped Bi2−xancements and Bi2−xancements was studied by using magnetic measurements, positron annihilation techniques (PAT), scanning electron microscopy and X-ray diffraction. Analysis shows that most of (Pb,Sn)-doped superconductors the Bi-2212 lattice. The PAT results show that the electron concentration on Bi-O layers increases with Sn doping in Bi2−xancements and Bi2−xancements improves the magnetic properties of Bi2−xancements and Bi2−xancements. The magnetic properties of ceramic samples of Bi2−xancements and Bi2−xancements superconductors have been investigated using a vibrating sample magnetometer (VSM) from 20 to 50 K and up to 5 T. Magnetization hysteresis loops of the (Pb,Sn)-doped samples exhibit strong pinning behavior in the higher temperature range, close to 50 K. We discuss the experimental results within a model of (Pb,Sn)-cluster pinning in blocking layers. Doping by (Pb,Sn) clusters into the Bi-2201 layers provides effective pinning centers, as well as significant redistribution of charge and lattice. This work supported by EYTP, National Science Foundation of China, UN and Engineering and Physical Sciences Research Council, the Robert A. Welch Foundation and the NSF.

**SESSION ES9: Basic Properties/RF Properties**

Chairs: Jim Eckstein and John Talvacchio

Thursday Morning, December 4, 2003

Fairfax A (Seratoga)

**8:30 AM *EE9.1**

Enhanced TRR for the Metal/Insulator Transition: A New Tool in the Search for Superconducting Materials

Michael Ochilie and Robert J. Soulen, code 8340, Naval Research Laboratory, Washington, District of Columbia.

The search for materials with enhanced superconducting transitions, Tc, has been, and is still, carried out for the most part without the benefit and guidance of a firm theoretical framework. Instead, various empirical correlations [such as Tc versus e/a or versus φ (a residual resistance ratio for low Tc superconductors and Tc versus number of Cu-O layers in high Tc superconductors) have been used and with moderate success. Alternatively, band theory can be used to estimate Tc on a case-by-case basis. We demonstrate empirically that several dispersed superconductors (dispersed metals, oxide conductors [including high temperature superconductors], semiconductor materials, organic conductors and various forms of C60), whose only common feature is proximity to a metal/insulator transition (MIT), share a common phase diagram. This remarkable phenomenon may be plausibly explained by explicitly incorporating an enhancement of the electron screening length, which occurs near the MIT, into the BCS equation for Tc. These results can be used to optimize high-Tc superconductors in the vicinity of the MIT, thus providing the basis for a new paradigm in the search for new superconducting materials.

**9:00 AM *EE9.2**

Fourier Transform Scanning Tunneling Spectroscopy (FT-STS) Studies of Electronic Structure in the Cuprates

J. C. Scuseria Drew1, K. McElroy1, J. E. Hoffman1, D. H. Lee1, H. Einskie2, S. Uchida2, Dept. of Physics, Cornell University, Ithaca, New York; Dept. of Physics, University of California-Berkeley, Berkeley, California; 3RISE, Tokyo University of Physics, Tokyo, Japan.

In Fourier transform scanning tunneling spectroscopy (FT-STS), the STM tip-sample differential tunneling conductance (g = dI/dV) is mapped at each bias voltage V. The result, g(ω, V), is proportional to $\text{LDOS}(\omega, V)$, the local density of states at location $\omega$ and energy $\omega = eV$. The vectors of any spatial modulations in $\text{LDOS}$ are then determined from the location dependence in $g(\omega, V)$. Using FT-STS techniques, we explore the relationship between the real-space and momentum-space characteristics of the electronic structure of the cuprates, Bi$_2$Sr$_2$CaCu$_2$O$_8$+4 (Bi-2212). Weak incommensurate $\text{LDOS}$-modulations which disperse with energy are ubiquitous in this system. It has been proposed that these $\text{LDOS}$-modulation patterns are produced by scattering-induced quasiparticle interference and that this competition with energy is due to the specific quasiparticle structure of the system. And, indeed, analysis of our data within the context of such models yields the Fermi surface and the d-wave superconducting energy gap $\Delta(\omega, V)$ in reasonable agreement with ARPES. Our earlier observation of extensive spatial variations in the superconducting electronic structure at the nanoscale was made in the context of granular superconductivity. However, by applying FT-STS, we can now better understand these observations as a very unusual type of electronic disorder located in a specific part of momentum-space near $k = (\pi\delta, 0)$. Finally, FT-STS studies of local electronic states at individual impurity atoms are also beginning to reveal new insights.

**9:30 AM *EE9.3**

**Structure and Electronic Properties of the Na$_2$CoO$_3$, Lattice Superconductors**

Robert J. Cava2, Maw Linfoo2, Raymond Schafk2, Tommas Klimczak2, Qinfeng Huang2, Jerry Lynn2, Peter Schiffer2, Benjamin Uceli2, Ying Wong2 and Nai Pham Ong2, Physics, Princeton University, Princeton, New Jersey; Chemistry, Princeton University, Princeton, New Jersey; Physics, Pennsylvania State University, State College, Pennsylvania; Center for Neutron Research, National Institute of Standards, Gaithersburg, Maryland.

The complex chemistry of the recently discovered Na$_2$CoO$_3$, Lattice superconductors makes determination of the structure-property relations in this and related materials unusually difficult. Here we will describe the experiments that determine the variation of superconducting properties with concentration. The data suggest that there are both similarities and differences between this material, based on triangular Co$_3$O$_2$ layers, and the high Tc superconductors, based on square Co$_2$O$_2$ layers. Structural determination by neutron diffraction will also be described, shedding light on the role of water in the superconductivity. Finally, some of the elementary characteristics of the superconductor, derived from transport and specific heat measurements, will be described.

**10:15 AM *EE9.4**

**Novel Characterization of Coupled Magnetic and Superconductor Order in Thin Film Hybrid Structures.**

Stephen Leggett3, Allan J. Dreau4, Alessandro Porzera3, Christopher Morris2, Elvise Morenzoni3 and Demetris Chronakis3, 1School of Physics and Astronomy, University of St. Andrews, St. Andrews, Fife, United Kingdom; 2Department of Physics, University of Leeds, Leeds, United Kingdom; 3LMU, Paul Scherrer Institut (PSI), Villigen, Switzerland; 4School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom.

The coexistence of magnetism and superconductivity is found in only a few naturally occurring compounds. For a conventional spin-pairing state the exchange interaction between the conduction electrons and the ordered magnetic moments leads to a 'pair breaking' effect, which in general makes the signature of two forms of quantum coherence mutually exclusive. There is therefore much interest in systems where both magnetism and superconductivity occur simultaneously. This is especially true where the electrons aepare to reside within the same band, as has been suggested for ZrRu$_2$. Such systems exhibit unconventional superconductivity, such as spin triplet pairing or magnetically mediated superconductivity. Over recent years there has been increasing interest in artificially fabricated thin film hybrid superconducting-magnetic systems. Theoretical treatments have suggested that in the vicinity of magnetic interfaces the superconducting order parameter may lock to an incommensurate spin density wave. This leads possible explanations to experimental observations of non-monotropic variations of the superconducting order parameter, such as spin triplet pairing or the transition temperature on the ferromagnetic layer thickness. It may also lead to the existence of 'r-junctions', at which the superconducting order parameter switches phase. We have studied thin film superconducting-magnetic hybrids using a combination of polarised neutron reflectometry (PNR) and a unique low-energy
10:30 AM EE9.5

HTS thin films have been widely used in commercial wireless systems. Currently more than 2500 cellular telephone base stations in the United States have superconducting filters developed and manufactured by Superconductor Technologies Inc. protecting their receivers from out of band interference. This talk will present the current status of thin film HTS materials used in the production of HTS wireless filters for cellular telephone base station receivers, and also address some of the challenges facing these technologies going forward. The relevant thin film and substrate properties will be discussed: microwave surface resistance, intermodulation distortion, substrate microwave loss, etc. Also, the status and plans for HTS film production will be reviewed.

11:00 AM EE9.6
Temperature Dependence of Intermodulation Distortion in YBCO, Single Crystal, Daniel E. Oates, and Daniel Agnese.

11:45 AM EE9.9
Percolation, Surface Impedance and Pinning in MgB$_2$, Nb, Nb$_3$N, and HTS-Superconductors. Juergen Hallerstorfer, IMF I, Forschungszentrum Karlsruhe, Karlsruhe, Germany.

The hindrance of electric transport by grain/blade boundaries in distances $d_{ij}$ (1 μm) is well accepted in the normal conducting state, whereas related critical Josephson current densities $j_{ij}$ are less well known. For neglegible interlayer capacitance $r(T) = R_{ij} + p(T'/T)$, residual resistivities inside grains $\rho(0) \leq 100$ μΩcm and percolation factors $p > 1$ by current diverting boundaries with $R_{ij} \leq \mu$m $\Omega$.

The results $p > 1 - 10$, critical current densities $j_c [H(B)] \leq j_c [H(0)]$ by Josephson flux pinning with $j_{ij} R_{ij} \rho \approx 10^{-9}$ V$m/cm^2$, residual local normal linearity $\alpha_{ij} \approx 1/a_j^{1/2}$, $j_{ij} R_{ij}$, and boundaries $R_{ij}$.

In MgB$_2$ films percolation with $p < 1 - 20$, with $j_{ij} [H(B)] \leq j_c [H(0)]$ and with $j_{ij} R_{ij} \rho \approx 0$ is found. For Nb-films $p \leq 1$ and pinning of Josephson fluxons is the function of $j_{ij} R_{ij} \rho \approx 0$ and of Albrektsen fluxons in the correlation layer holds and is difficult to separate. Whereas percolation decreases conductivities via the boundary resistances $R_{ij}$, the normal state always, pinning of Josephson fluxons enhances $j_{ij} [H(B)] \leq j_{ij} [H(0)]$ dominated in dc transport by the strongest links. In contrast surface impedances via $R_{ij} \rho j_{ij} \approx 0$ and $R_{ij} \rho j_{ij} \approx 0$ are dominated by the weakest links and deteriorate by weak links always. But in all cases RRR values don't yield the material quality, but a proper percolation analysis allows via $R_{ij} \rho j_{ij} \approx 0$ in $[1 - 2] \Omega$ to forecast percolating properties in dc and rf. [1] J. Hallerstorfer, Phys. Rev. B 48, 9255 (1993) and Supercond. Sci. Technol. 12, 883 (1999). [2] J. Rowell et al., submitted to Appl. Phys. Lett.
Making thin films as a perfect crystallinity is possible has long been an issue in the semiconductor industry. The epitaxial growth of thin films on substrates has been a major area of research for many years. The development of thin film technologies has led to the production of high-quality, single-crystal epitaxial films that can be used in a wide range of applications, including electronic devices and photovoltaic cells.

Thin films are often grown on a substrate that is already in place. This process is called epitaxial growth. Epitaxial growth occurs when a film is grown on a substrate in a way that ensures that the film and the substrate have the same crystal structure. This is done by controlling the temperature, pressure, and other conditions during the growth process.

Thin films can be used to create high-performance electronic devices, such as transistors, that are much smaller and more efficient than their bulk counterparts. They can also be used in a variety of other applications, including solar cells, optical devices, and magnetic storage media.

In this talk, we will discuss the growth and properties of epitaxial thin films, including their applications in electronic devices. We will also explore the potential for using thin films in new and innovative applications, such as biosensors and energy storage devices.

Epitaxial growth is a critical process in the production of high-quality thin films. By controlling the growth conditions, we can produce films with the desired properties, including high crystallinity, low defect density, and good adherence to the substrate.

In conclusion, epitaxial thin films have great potential for use in a wide range of applications. As technology continues to advance, we can expect to see increasing use of epitaxial thin films in a variety of new and innovative products.
series is of interest due to its fixed oxygen stoichiometry and
anisotropy in its physical properties. The goal is to obtain phase pure,
highly oriented Y123 films by depositing YBa2Cu3O7−x (Y123) and
CuO layers using pulsed laser deposition technique (PLD). We found
that the properties of the Y123 films are very sensitive to the ratio of
Y123 and CuO. In addition, the characteristic bulk diffusion lengths
of the deoxidized atoms could be investigated by depositing layers
with an equivalent thickness of multiple unit cell of Y123/CuO rather
than single unit cell. We also have performed Transmission electron
microscopy (TEM) X-ray diffraction (XRD) and transport
measurements on our samples.

4:15 PM EE10.7
Enhancement of Flux-Line Pinning in Oxide
Ferromagnet /Superconductor Heterostructures.
Hans-Ulrich Habermacher, Joachim Allersdorff, and Soltau Soltau;
MPL-TRI, Stuttgart, Germany.

Heterostructures and superlattices consisting of ferromagnetic and
superconducting oxides are currently of increasing scientific interest
and their application potential for three terminal devices and for
spin-injection devices is discussed. Additionally, the interaction of
the magnetic domain structure of the ferromagnetic layers with the
flux-line arrangement and the potential modification of flux-line
pinning in superconductor heterostructures is a topic of current
concern. We have grown bilayer heterostructures of the
ferromagnet SrRuO3 and the high temperature superconductor
YBa2Cu3O7 on single crystal LnSrGaO4 substrates by pulsed laser
deposition. Using the quantitative magneto-optical Frenkel-effect
technique, the critical current densities in the superconducting film is
measured locally with a resolution of 0.1 square millimeter. The results show a
strong dependence of the critical current on the magnetization state
of the ferromagnetic layers and a hysteretic behavior strongly reduced to the
magnetic hysteresis loop of the ferromagnet. The quantitative analysis of the critical currents as determined by the magneto-optical
techniques shows a pronounced enhancement of j_c, especially in the
remnant state. The results are discussed within the frame of the
magnetic interaction of the fluxlines and the ferromagnetic domain
structure.

4:30 PM EE10.8
Fabrication of Faster HTS Josephson Junctions.*
John Talvacchio, J. M. Murdock, D. A. Kuhler and A. Kirschbenaum;
Advanced Materials & Electronic Device Research, Northrop
Grumman Corporation, Baltimore, Maryland.

This work follows well-developed principles in Josephson junction
performance that were recently summarized by Kudin, et al.** We apply these general considerations for junction switching speed and
critical damping to the case of HTS junctions with modeling and
experiment. For LTS junctions, where junction uniformity is better,
junction speed directly impacts applications in both digital signal
processing and mixed-signal circuits. For HTS junctions, speed is
most important for high over sampling rates in signal-delta
analog-to-digital converters. High-speed HTS junctions also have high
IcRn products that make it easier to transfer bits off chip at high
data rates. All HTS junction configurations that have been used in recent
years for microwave circuits, including the typical SNS ramp-edge
dunctions that we fabricated in our laboratory with YBCO films, have
IcRn products no greater than about 2 mV at 50 K. On the other
hand, much higher IcRn products have been demonstrated with
several junction configurations that could not easily be reproduced or
scaled up in number. In contrast with LTS trilayer tunnel junctions,
where higher current densities up to 100 kA/sq cm have yet to be
achieved reproducibly, most practical HTS junctions are already at
similarly current densities and need to have reproducibly higher
junction resistances to increase speed. In either case, smaller junction
areas are desirable and our approach has been to use several
techniques to reduce the area of our SNS junctions. Another difference is
that typical LTS trilayer junctions have these capacitances and are
under-damped unless shunt resistors are placed in parallel. Our HTS
dedge junctions are over-damped and we have been led to fabricating
shunt capacitors in parallel to realize critical damping.** supported in
part by AFOSR Agreement F49620-03-1-0046 ** A.M. Kudin, A.W.
Conf, Houston, August, 2002.

4:45 PM EE10.9
Materials Development for Josephson Waveform Generator
Circuits.* David Kuhler, J. Talvacchio, A. Kirschbenaum and J. M.
Murdock; Advanced Materials & Electronic Device Research,
Northrop Grumman Corporation, Baltimore, Maryland.

Pulse-driven Josephson arrays are being developed for voltage
standards and generation of arbitrary waveforms. The primary
junction requirements are a match of the IcRn product to the bit rate
of the input, uniformity of critical currents, and sufficient density so