

# CCA08

International Workshop on  
Coated Conductors for Applications

## PROGRAM AND ABSTRACTS

**December 4-6, 2008**  
UH Hilton Hotel  
Houston, Texas USA



## PROGRAM AT A GLANCE

### THURSDAY, DECEMBER 4

2:00 - 6:00 pm

Registration <sup>1</sup>

2:00 - 10:00 pm

Internet Café <sup>2</sup>

4:00 - 4:20 pm

Welcome & Opening Plenary Remarks <sup>3</sup>

4:20 - 7:20 pm

**SESSION A** <sup>3</sup>

HTS Applications Requirements

7:30 - 9:00 pm

Welcome Reception <sup>4</sup>

### FRIDAY, DECEMBER 5

7:15 am - 9:00 pm

Registration <sup>1</sup>

7:15 am - 12:30 pm

Poster Set-up <sup>5</sup>

7:00 am - 10:00 pm

Internet Café <sup>2</sup>

7:15 - 8:30 am

**BREAKFAST BUFFET** <sup>4</sup>

8:30 - 10:45 am

**SESSION B** <sup>3</sup>

Challenges in Long Length Scale Up of  
High-Performance CCs

10:45 - 11:00 am

Morning Coffee/Tea Break <sup>1</sup>

11:00am - 12:30 pm

**SESSION C** <sup>3</sup>

Strategies Toward Low-Cost  
Coated Conductors

12:30 - 1:45 pm

**LUNCH** <sup>4</sup>

1:45 - 2:55 pm

**SESSION C: Continued**

2:55 - 3:10 pm

Afternoon Coffee/Tea Break <sup>1</sup>

3:10 - 6:30 pm

**SESSION D** <sup>3</sup>

Effective Approaches to Enhance Coated  
Conductor Performance

6:30 - 8:00 pm

**BANQUET** <sup>4</sup>

8:00 - 9:30 pm

**SESSION E** <sup>5</sup>

Invited Posters on Innovative Ideas  
and Achievements

*(with Post-Banquet Coffee/Desserts)*

### SATURDAY, DECEMBER 6

7:15 am - 4:00 pm

Registration <sup>6</sup>

7:00 am - 4:00 pm

Internet Café <sup>2</sup>

7:15 am - 4:00 pm

Posters on View *(removal by 4:00 p.m.)* <sup>5</sup>

7:15 - 8:30 am

**BREAKFAST BUFFET** <sup>7</sup>

8:30 - 10:20 am

**SESSION F** <sup>8</sup>

Coated Conductor Properties  
Beyond Critical Current

10:20 - 10:35 am

Morning Coffee/Tea Break <sup>6</sup>

10:35 - 11:45 am

**SESSION F: Continued** <sup>8</sup>

11:45 am - 12:30 pm

**SESSION G** <sup>8</sup>

Oral Poster Summaries

12:30 - 1:45 pm

**LUNCH** <sup>7</sup>

1:45 - 2:45 pm

**SESSION H** <sup>8</sup>

Technical Round Table Discussions

2:45 - 3:45 pm

**SESSION I** <sup>8</sup>

Summaries of Technical Sessions and  
Feedback from Applications Panelists;  
Closing Remarks

4:00 pm

**OPTIONAL TOUR**

Texas Center for Superconductivity  
at the University of Houston  
*(sign-up at registration desk)*

1. Hilton UH Waldorf Astoria Lobby (2nd Floor)

2. The Plaza Room 247

3. Waldorf Astoria 210

4. Shamrock Hilton Ballroom 261

5. South Wing Lobby (S104) 1st Floor

6. Conrad N. Hilton Ballroom Lobby

7. Conrad N. Hilton AD, S202

8. Conrad N. Hilton BC, S202



# CCA08

International Workshop on  
Coated Conductors for Applications

## **PROGRAM AND ABSTRACTS**

DECEMBER 4 - 6, 2008

HILTON UNIVERSITY OF HOUSTON

HOUSTON, TEXAS USA

[CCA08.COM](http://CCA08.COM)

Notice: The abstracts in this publication were received between October 14, 2008 and November 11, 2008.  
Additions and corrections will be found on the Change Sheets located in the Registration Packets available at the Workshop.

# HISTORY, GOALS AND VENUE

## SCOPE

The 2nd generation of high temperature superconductors, coated conductors (CC), have experienced a remarkable advancement in R&D and processing as well as in applications. CC will have a large impact on electrical and power engineering devices such as cables, fault current limiters, feeder lines, motors, generators and transformers, and on transportation and processing technologies as well as magnet systems, e.g. for medical diagnostics. The benefits of employing CC in future novel systems are lower costs, reduced energy consumption, higher efficiency of components with reduced volume and weight (thereby saving resources), fewer environmental concerns, and new functionalities. CCA 2008 will continue a series of international topical workshops on CCs for applications. The series was initiated in 2000 at the University of Göttingen, Germany, followed by workshops at Honolulu, Hawaii (2001), Gatlinburg, USA (2002), Orta S. Giulio, Italy (2003), Oiso Prince Hotel near Kamakura, Japan (2004), Santa Fe, USA (2005), Schloss Monrepos, Ludwigsburg, Germany (2006) and Jeju Island, Korea (2007). The venue at the University of Houston will provide an atmosphere for intense discussions on substrate materials and buffer layers, processing technologies and strategies toward improved critical current performance and requirements and designs of CC for applications and future opportunities.

## GOAL

The overall goal of CCA2008 is to establish the basic coated conductor (CC) characteristics necessary for use in the fabrication of practical HTS devices, and to identify the most efficient and effective means to achieve them. To realize these goals, requirements for practical HTS devices must first be established. The workshop program committee has, therefore, limited the scope to several areas of conductor development that are generally agreed upon as the top priority items to be addressed from a wire developer's point of view. It is critical to solicit feedback from device manufacturers on these wire development efforts as well as any glaring area of importance that has been overlooked. Each workshop participant has been asked to come prepared to share opinions as to the top high priority requirements and give a brief rationale for each, as well as any "lessons learned."

## STRUCTURE OF TECHNICAL SESSIONS

Sessions consist of brief invited and contributed presentations that address specific items of concern. Presentations are meant to provoke thought and insight for open discussion to follow, and not exclusively as a forum for providing latest updates and achievements. Each session ends with a discussion with the speakers, guided by a moderator. During open discussion, speakers may clarify their presentations, and are encouraged to contribute to the session topic in general. An Invited Poster Session is scheduled, where innovative solutions and latest achievements can be shown and discussed at a more leisurely pace. Selected poster presenters will also give 5-minute summary talks on Saturday. Each participant is asked to attend the Saturday roundtable discussion session, choosing one of four topical areas where ideas will be shared. A moderator will keep track of innovative ideas or achievements as they emerge, and will share them with the Session Summaries speakers in preparation for the closing session.

## VENUE

**HOUSTON**, fourth largest city in the U.S. and regarded as the Energy Capitol of the World, is a leader in technology, business, entertainment, and the arts. Home of NASA's Johnson Space Center and the largest concentration of medical professionals in the world, the city is known for its cutting-edge research and technology development. It is also renowned for its superb arts and entertainment scene. Houston houses five major league sports teams, including the 2005 National League Champion Houston Astros. Our Museum District is home to 15 institutions, including the Museum of Fine Arts, Houston, the sixth largest museum in the country, and the Houston Museum of Natural Science. Houston is one of only five cities in the U.S. with resident companies in the four disciplines of the performing arts.

**THE UNIVERSITY OF HOUSTON (UH)** is a public doctoral/research university located in Houston, Texas. The 560-acre campus is the flagship institution and the only doctoral degree-granting university in the UH System, which includes three other universities and two multi-institution teaching centers. Founded in 1927, the University serves more than 35,300 students in 12 academic colleges and in the interdisciplinary Honors College on a 560-acre (2.3 km<sup>2</sup>) campus southeast of Downtown Houston. UH offers 109 bachelor's, 131 master's, 51 doctoral, and three professional degree programs. It currently is the third-largest university in Texas and twenty-third largest university in the United States by enrollment, awarding more than 6,600 degrees annually. UH is ranked second among national universities for Campus Ethnic Diversity by U.S. News & World Report, with over 130 countries represented. UH conducts research in each academic department and operates more than 40 campus research centers and institutes.

**TEXAS CENTER FOR SUPERCONDUCTIVITY (TcSUH)** is the largest university-based multidisciplinary superconductivity and advanced materials research effort in the U.S., where over 200 faculty, postdoctoral fellows, graduate and undergraduate students work to discover new high temperature superconducting-, energy- and nano-materials, advance their applications in partnerships with industry, and disseminate knowledge through education, outreach and technology transfer for the benefit of the public and the environment. Housed in the \$22.5 million Houston Science Center and several other buildings on the UH campus, TcSUH personnel work in multidisciplinary laboratory groups to create and advance new knowledge while preparing the next generation of scientists and engineers.

## WELCOME TO HOUSTON

### DEAR CCA08 PARTICIPANTS,

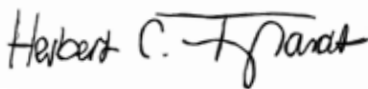
Welcome to the ninth International Workshop on Coated Conductors for Application at the University of Houston, where in 1987 Paul Chu and his colleagues discovered, with the YBaCuO high-temperature-superconductor materials family, the basis for the 2nd generation of HTS, the coated conductors. With the remarkable progress achieved in R&D and processing of this new class of materials, novel applications in electrical and power engineering as well as magnet technologies are within reach and can pave the way for the implementation of energy-saving and ecologically beneficial devices and systems.

CCA08 is not a conference but rather a topical workshop, which – we hope – will provide an atmosphere and forum for intense discussions. Our major question: What can we do for making coated conductors ready for applications? The program reflects this intention by first addressing the application needs, then asking what has to be done for achieving enhanced performance of coated conductors with specifications required by a particular application, and which processing technologies will allow coated conductors to be manufactured at low cost. Each session will conclude with an open discussion led by the moderator that highlights the major issues. The final Technical Round Table Discussions will summarize the present achievements, name bottlenecks and efforts to overcome them, and point out novel directions and visions.

We owe thanks to significant and engaged individuals for making this Workshop possible: The Program Chairman, Dominic Lee from Oak Ridge National Laboratory; Program Committee members; International Committee members; and particularly the Local Committee members Venkat Selvamanickam, Sue Butler and her accommodating staff. The workshop was made possible with the support of the U.S. Department of Energy, Los Alamos National Laboratory, Oak Ridge National Laboratory and TcSUH at the University of Houston, which we greatly acknowledge.

We look forward to an inspiring topical workshop that will generate novel ideas in our exciting field of research and development.

Sincerely,



**Herbert C. Freyhardt**



**Kamel Salama**

## TECHNICAL SESSIONS: TOPICS AND AREAS OF FOCUS

<b>SESSION A</b>	<b>HTS Applications Requirements</b>
TOPICS	Cables, fault current limiters, transformers, rotating machineries, high-field magnets, etc.
EMPHASES	Speakers are asked to provide their list of top several wire characteristics that are essential for the specific application, and the logic for this priority. The speakers should provide the respective requirements for broad commercialization, as well as the minimum requirements necessary for pre-commercial operation.
<b>SESSION B</b>	<b>Challenges in Long Length Scale Up of High-Performance Coated Conductors</b>
TOPICS	Substrates, HTS, CC, splices.
EMPHASES	Speakers are asked to address selected issues and suggest solutions. Issues include: CC/substrate/HTS performance and uniformity; CC throughput while maintaining high performance; CC reliability (mechanical, thermal, long-term); Splice as a means to increase CC length and their impact on performance.
<b>SESSION C</b>	<b>Strategies Toward Low-Cost Coated Conductors</b>
TOPICS	Substrates, HTS, CC, high-rate methods, quality control, yield.
EMPHASES	Speakers are asked to address selected issues and suggest solutions. Issues include: High-rate fabrication methods (substrate and HTS) that are amendable to scale up; Innovative approaches to CC cost reduction in the absence of mass production; Quality control to maximize CC throughput; Strategies to increase CC yield.
<b>SESSION D</b>	<b>Effective Approaches to Enhance Coated Conductor Performance</b>
TOPICS	Thick films, effectiveness of pinning centers, scalable methods to incorporate pinning centers, characterization techniques.
EMPHASES	Speakers are asked to address selected issues and suggest solutions. Issues include: Methods to produce thick films with minimum $J_c$ reduction; Effectiveness of different pinning centers and their operative temperature-field-angle regimes; Suitability of various pinning strategies for different HTS methods (e.g. PLD, MOD, MOCVD, co-evaporation); Innovative and potentially scalable ways to incorporate effective pinning centers; Characterization methods (or a combination thereof) to determine CC performance in the most efficient and effective manner.
<b>SESSION E</b>	<b>Posters on Innovative Ideas and Achievements</b>
TOPICS	All, as outlined in other sessions.
<b>SESSION F</b>	<b>Coated Conductor Properties Beyond Critical Current</b>
TOPICS	AC losses, stability, electromechanical properties, splices.
EMPHASES	Speakers are asked to address selected issues and suggest solutions. Issues include: Strategies to reduce AC losses in CC; Modeling and simulation of losses; Stability of CC with different stabilizers; CC architecture – AC loss – Stability inter-relationship; Losses in coils and systems; Electromechanical properties of CC and splices; Splice fabrication and performance (production splices, field joints, standards, thermal, long term).
<b>SESSION G</b>	<b>Poster Summaries and Discussion</b>
LOGISTICS	Selected speakers will summarize their Posters (5 minutes each).
<b>SESSION H</b>	<b>Technical Roundtable Discussion</b>
	Choose topic as outlined in Sessions B, C, D, or F. Participants should attend one of the four breakout discussions to share thoughts and additional ideas resulting from the Workshop talks. A Moderator for each discussion group will then summarize the results and include them in the closing Technical Summary talks.
<b>SESSION I</b>	<b>Summaries of Technical Sessions and Feedback from Applications Panelists</b>
LOGISTICS	Session chairs will summarize their technical sessions, with emphases on what issues are being addressed and what directions are being pursued on these issues. Panelists of Session A (Applications Requirements) will give their feedback and impressions in an open moderated discussion.

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## THURSDAY, DECEMBER 4

**2:00–9:00 PM**

### REGISTRATION

*2nd Floor Waldorf Astoria Lobby, UH Hilton*

**2:00–10:00 PM**

### INTERNET CAFÉ

*2nd Floor, Room 247*

**4:00–4:20 PM**

## Welcome & Opening Plenary Remarks

*Waldorf Astoria 210*

### Welcome

*Kamel Salama, TcSUH*

### CCA08 Workshop Overview

*Herbert C. Freyhardt, TcSUH*

**1P-01** 4:05—4:20

## Practical HTS Coated Conductors: Maximization and Optimization

**Paul C. W. Chu**

*TcSUH/UH & HKUST*

**4:20—7:20 PM**

## SESSION A: HTS Applications Requirements *Waldorf Astoria 210*

*Chairs/Moderators: Chris Rey (ORNL) and Bill Schwenterly (ORNL)*

**1A-01** 4:20—4:35

## HTS Cable Topical Overview

**M. J. Gouge**

*Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, 37831-6305 TN, USA*

High Temperature Superconducting (HTS) cables have been operating in industrial applications and on the electric grid throughout this decade and there is a growing database on their technical performance, cost and reliability. The following list highlights some major cable demonstrations in the US, Asia and Europe, starting with a pioneering low temperature superconducting (LTS) cable:

- Brookhaven Cable: LTS, 330 MVA, 138 kV (80 kV phase to ground), 1971-1986
- Southwire, Carrollton: HTS Cold Dielectric, 27 MVA, 12 kV, 30-m, 1998-2006
- Detroit, Pirelli/AMSC: HTS Warm Dielectric, 100 MVA, 24 kV, never on grid
- SEI/TEPC Japan: HTS Cold Dielectric, 114 MVA, 66 kV, 100-m, 2001-2002
- NKT-Copenhagen: HTS Warm Dielectric, 100 MVA, 30 kV, 30-m, 2001-2003
- CRIEPI/Furukawa Electric: HTS Cold Dielectric, 77 kV, 1 kA, 500-m, 2004-2005
- Albany, SuperPower/SEI: HTS Cold Dielectric, 48 MVA, 34.5 kV, 350-m, 2006-2008
- KEPCO/KERI: HTS Cold Dielectric, 22.9 kV, 1.25 kA, 100-m, 2007
- Columbus, Ultera: HTS Cold Dielectric, 69 MVA, 13.2 kV, 3 kA, 200-m, 2006-
- LIPA, AMSC/Nexans: HTS Cold Dielectric, 215 MVA, 138 kV, 610-m, 2008-

Of interest to this conference, the SuperPower/SEI HTS cable had a 30-m long section made of SuperPower 2nd generation (2G) YBCO tapes retrofitted into the 350-m long cable. There were three YBCO conductor layers in the phase conductor and two in the shield conductor. This cable

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## NOTES

with the 2G section operated from January-April 2008. The highest phase current demonstrated to date is about 2700 Arms by the Columbus cable and the highest voltage is 138 kVrms by the LIPA cable, energized in April 2008. The longest length cable is the LIPA cable at 610-m with a recently approved cable project managed by Ultera near New Orleans, LA with a planned length of 1700-m. Outstanding issues in HTS cables include operation for longer demonstration periods on the grid to get better statistics on system availability; cost and reliability of cryogenic cooling systems and cable flexible cryostats; ac loss minimization and, for 2G cables, the impact of magnetic substrates on cable ac losses; splice/joint resistance/strength and cable/termination cryogenic dielectric insulation performance, especially at transmission level voltages (110 kV and higher).

**1A-02** 4:35—4:45

### **2G Wire Requirements for Commercial HTS Cables**

**D. Lindsay**

*Southwire Company, One Southwire Dr., Carrollton, GA 30199 USA*

Several successful HTS cable projects in the US and around the world have demonstrated the technical viability of building and operating these cables in the utility grid. As 2G wire production is developed and expanded to support the transition from 1G to 2G, various technical requirements must be met to support large scale production of HTS cables. These requirements include mechanical and electrical properties in addition to the obvious needs for cost reduction. Technical specifications and requirements of large volume production of 2G wires will be discussed as related to ongoing commercial HTS cable projects.

**1A-03** 4:45—4:55

### **Current State of Yttrium-based Superconducting Power Cable in Japan**

**S. Mukoyama**

*Furukawa Electric Company, LTD*

A high temperature superconducting (HTS) power cable is expected to serve as a future power cable because of features such as large power transmission, compact size, low loss and low cost. In particular, a coated conductor holds potential to facilitate the practical use of HTS cable. We studied an applicability of a coated-conductor to a HTS cable in the last NEDO project, and we verified that a coated conductor is good for a HTS cable. We report the current state of Yttrium-based HTS cable development in Japan, and will discuss required specifications of the wires that we found through experiments of HTS cables.

**1A-04** 4:55—5:05

### **Utility Needs Survey for Fault Current Limiters**

**S. Eckroad**

*Electric Power Research Institute, 1300 West WT Harris Blvd., Charlotte, NC 28269 USA*

In response to unprecedented restructuring of electric markets and a power delivery system in the U.S. that is not optimized to meet today's loads and customer needs, electric utility companies are undertaking a focused effort in re-assessing fault current mitigation methods. Similar efforts are underway in other countries, albeit perhaps in response to different economic drivers. Novel fault current limiter (FCL) technologies are of growing interest because of their potential to replace existing (and increasingly often unsatisfactory) methods. The superconducting FCL (SFCL) is one such technology. SFCLs attracted interest soon after the discovery of HTS materials but have only lately been seriously considered as it became apparent that coated conductors might better enable

the cost and performance desired by utility companies. Cost-benefit studies as well as significant field demonstrations are still needed to determine the full potential of a significant penetration of SFCLs into the market place. A number of developers around the world are designing and testing SFCLs, or preparing to do so. As these developments proceed it will be important to understand the characteristics of the intended market – the needs of the utility industry and the desirable characteristics of a FCL. The Electric Power Research Institute (EPRI) has recently undertaken a series of utility needs and technology readiness surveys for FCLs. This topic will be briefly explored in this paper, drawing upon the results of those surveys.

**1A-05** 5:05—5:15

### **Conductor Requirements for Superconducting Fault Current Limiters (SFCL)**

**C. S. Weber**

*SuperPower Inc, 450 Duane Ave, Schenectady, NY 12304 USA*

Electric utilities and large industrial customers have long sought solutions to mitigate the effects of large fault currents flowing through their power networks. Several conventional technologies, including current limiting reactors (CLR), pyrotechnical devices, and conventional circuit breakers have been employed to date but each of these has inherent limitations or drawbacks. Superconducting Fault Current Limiters (SFCLs) hold great potential to offer the benefits of conventional technology without many of the limitations. Development of SFCLs is being pursued by a growing number of organizations around the world and several different approaches have emerged to address utilities' needs. Each of these design concepts has unique requirements for the superconducting materials that enable them. This paper will briefly discuss the current status of SFCL projects and compare the HTS material requirements for each.

**1A-06** 5:15—5:25

### **Fault Current Limiter Using Coated Conductor**

**T. Yazawa<sup>1</sup>, M. Urata<sup>1</sup>, Y. Iijima<sup>2</sup>, T. Saitoh<sup>2</sup>, N. Amemiya<sup>3</sup>, Y. Shiohara<sup>4</sup>**

*<sup>1</sup>Toshiba Corporation, <sup>2</sup>Fujikura Ltd., <sup>3</sup>Kyoto University, <sup>4</sup>ISTEC, Japan*

As one of the programs in the Ministry of Economy and Trade and Industry (METI) project carried out in FY2006 and 2007, a coated conductor utilized for resistive-type superconducting fault current limiter (SFCL) was developed and evaluated. The conductors used in this work were ReBCO tapes, such as YBCO and GdBCO, formed on ion-beam-assisted deposition (IBAD) substrates by using a pulse laser deposition (PLD) process. In order to obtain high resistance of the conductor, which is preferable to an SFCL, the thickness of the protecting layer made of silver was decreased as possible. Then high-resistive metal stabilizing layer was attached on the silver layer to improve stability. The critical current of the conductor with this configuration was increased up over 300A/cm. When excess current was applied to the developed conductor, uniform voltage distribution was obtained in the longitudinal direction. In the program, three-phase 6.6kV superconducting fault current limiter (SFCL) was finally fabricated and some evaluation tests were implemented.

*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.*

## NOTES

**1A-07** 5:25—5:35**Development of HTS Motor – Present Status and Future Prospect****K. Hayashi***Sumitomo Electric Industries, LTD, 1-1-3 Shimaya, Konohana-Ku, Osaka 554-0024 Japan*

400kW class axial gap-type motor for ship propulsion system consists of HTS armature winding and permanent magnets have developed by industry – university collaborative research group (IHI, Fuji Electric, Hitachi, Nakashima Propeller, Niigata Power System, Sumitomo Electric, Taiyo Nippon Sanso and University of Fukui). Sumitomo Electric has also developed prototype electric vehicle equipped with a DC motor including HTS field winding. In these cases, bismuth based superconducting wire (DI-BSCCO) were used for HTS windings and cooled down by liquid nitrogen. In order to realize high power and compact motor, operating temperature, current density, and electrical, mechanical and thermal performance under the magnetic field should be considered. Current status of these developments will be presented and wire requirements for future rotating machine applications will be also mentioned.

**1A-08** 5:35—5:50**Development of REBCO Superconducting Transformers and Motors in Japan****M. Iwakuma<sup>1</sup>, H. Hayashi<sup>2</sup>, H. Okamoto<sup>2</sup>, Y. Hase<sup>3</sup>, T. Satou<sup>3</sup>, A. Tomioka<sup>4</sup>, M. Konno<sup>5</sup>, Y. Iijima<sup>6</sup>, T. Saitoh<sup>6</sup>, Y. Yamada<sup>7</sup>, T. Izumi<sup>7</sup> and Y. Shiohara<sup>7</sup>**

*<sup>1</sup>Kyushu University, Fukuoka 819-0395, Japan; <sup>2</sup>Kyushu Electric Power Co. Inc., Fukuoka 815-8520, Japan; <sup>3</sup>Japan Motor & Generator Co. Ltd., Tokyo 101-0054, Japan; <sup>4</sup>Fuji Electric Advanced Technology Co. Ltd., Hino 191-8502, Japan; <sup>5</sup>Fuji Electric Systems Co. Ltd., Tokyo 141-0032, Japan; <sup>6</sup>Fujikura Ltd., Tokyo 135-8512, Japan; <sup>7</sup>Superconductivity Research Laboratory, Tokyo 135-0062, Japan*

In Japan we started a national project to develop superconducting power machines and devices with REBCO superconducting tapes two years ago. In this workshop I will report the progress of the development of transformers and motors.

The target transformer is a 66/6.9kV-20MVA one for a substation in a power grid. Superconducting transformers are expected to give us the merits of compactness, light-weight and high efficiency. To produce such merits, it is necessary to reduce a 1-turn voltage, which is the important parameter for the design of a transformer, in comparison to conventional transformers. It corresponds to increasing the turn number of windings and reducing the cross-sectional area of an iron core. By making the most use of low loss and high  $J_c$  properties of superconducting tapes, the superconducting windings will be compact even if the turn number increases. We proposed a new idea to reduce the ac loss in REBCO superconducting thin tapes and verified it even in coil configuration. In addition, in order to satisfy the dielectric strength regulated in Japanese standards on transformers, we got data on the basically required insulation distance in the system which is mainly composed of REBCO thin tapes and subcooled liquid nitrogen. Further we verified the applicability of the method of enhancing the current capacity by forming transposed parallel conductors with REBCO thin tapes though the tapes are bent edgewise at transposition points.

As for motors, we successfully fabricated a 7.5kW@360rpm motor with a superconducting rotor with REBCO tapes. The rotor was cooled down to 40K by forced-flowed helium gas. 6-pieces of field coils were racetrack-shaped 19-layer solenoidal ones. The armature winding was wound with copper wires. We carried out the factory test in the same way as conventional motors. We confirmed 11kW power output applying the field current up to 70A beyond the design one of 60A.

**1A-09** 5:50—6:00

## Conductor Requirements for HTS Utility Power Transformers

**E. F Pleva<sup>1</sup>, V. Mehrotra<sup>1</sup> and S. W. Schwenterly<sup>2</sup>**

<sup>1</sup>Waukesha Electric Systems, 400 S. Prairie Avenue, Waukesha, WI 53186-5969; <sup>2</sup>Oak Ridge National Laboratory, P.O. Box 2008, MS 6305, Oak Ridge, TN, 37831-6305 USA

HTS coated conductors in utility power transformers must satisfy a set of operating requirements that are driven by two major considerations— HTS transformers must be economically competitive with conventional units, and the conductor must be robust enough to be used in a commercial manufacturing environment. Spreadsheet estimates of HTS transformer costs will be summarized and compared with those of conventional units that have been recently delivered by Waukesha Electric Systems. Lifetime cost of ownership is also determined by operating costs of ac losses, core losses, and lead heat loads, as well as periodic maintenance costs for the cryocoolers. Capital and operating costs can be traded off in the design stage to minimize the lifetime costs. These estimates allow us to predict the cost and allowable ac loss requirements in HTS coated conductors under various customer scenarios. HTS conductors in the transformer-manufacturing environment must have specific properties. Short-circuit currents can be an order of magnitude above the operating current, producing large forces and heating. Additional copper must be applied to the standard HTS tape to handle the forces and reduce heating. This can be either a co-wound strip or material that is directly plated or laminated onto the tape. The conductor must then be covered with a thick layer of high voltage insulation that is wound onto it in high-speed machines. Tension must be applied as the conductor is wound onto the coil form, and a certain amount of twisting and sideways deformation in the “hard” direction is needed to transition the conductor between pancakes. It must be possible to make joints and splices quickly and easily on the shop floor. Completed coils may need to be baked to remove moisture from the insulation. The transformer manufacturing process will be described in order to highlight these requirements.

**1A-10** 6:00—6:10

## Coated Conductors for High Field Magnets

**D. Larbalestier, Z. Chen, J. Jaroszynski, J. Jiang, F. Kametani, P. Li, D. Markiewicz, P. Noyes, U. Trociewitz, H. Weijers, A. Xu**

National High Magnetic Field Laboratory, Florida State University, 2031 East Paul Dirac Drive, Tallahassee FL 32310 USA

Although no all-superconducting, HTS-containing magnet has yet challenged the capabilities of classical Nb-base magnets at 4K, the time when this will occur seems near at hand. From this point of view the very strong Hastelloy substrates employed for a number of coated conductor designs are very attractive. Recent SuperPower tapes made by the MOCVD route are particularly attractive since their overall  $J_c(4K, H)$  exceeds that of  $Nb^3Sn$  by a substantial amount, even if the fraction of superconductor in the cross-section is 1%, rather than 30-50%. We have been making extensive characterizations of such conductors. LTLSM shows that IBAD-MgO tapes with FWHM of 2-3° exhibit little local contrast by low temperature laser scanning microscopy, implying a high uniformity of current flow that is consistent with their low YBCO grain boundary misorientation distribution of 2-3°. The tape magnetization also shows few signs of flux jumps at 4K, even with field perpendicular to the broad face of 4 mm wide tapes. As expected from many evaluations of the angular dependence of  $J_c$  at higher temperatures and low fields, there is extensive evidence for correlated pinning defect detail in specific ranges of temperature and field. The recent test of a coil made from such tape which generated a total field of 2.8 T in a 31 T background field following an earlier coil generating 7.8T in a 19 T background shows that all superconducting magnets above 30 T are now conceivable.

*\*We are grateful to SuperPower for partial support of some of these tests.*

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**1A-11** 6:10—6:20**An Introduction of HTS-SMES Project in Korea****K. Seong***Korea Electrotechnology Research Institute, P. O. Box 20, Changwon, 641-120, Korea*

These days, a momentary power interruption or a voltage sag has increased in the factories and distribution lines due in part to the widespread use of power electronics devices and renewable energy sources. Within this background, the high temperature superconducting magnetic energy storage (HTS-SMES) Project started during 10 years since Sept. 2004. We successfully developed a 600kJ HTS-SMES pilot system in 2007. We have also studied on “A Development of 2.5MJ Class HTS-SMES” for four years. Our final target will be the commercialization of this system. This paper describes on an overview of HTS-SMES Project in Korea.

**1A-12** 6:20—6:35**R&D Status of HTS Coated Conductor in Korea****S.-S. Oh***Korea Electrotechnology Research Institute, 70 Bulmosangil, Changwon 641-120, Korea*

In Korea, HTS coated conductors (CC) are being developed under the DAPAS program. In the CC project of the program, we selected the reactive co-evaporation (RCE) technique as a main fabrication process to deposit REBCO superconductor on IBAD substrates. After the modification of EDDC, which is a batch type RCE equipment, we fabricated long length SmBCO CC samples and investigated the relationship between critical currents and deposition parameters of oxygen partial pressure, composition, etc. However, the fabrication length is limited to 100 m when we use the EDDC.

In phase III of DAPAS program, which was started in 2007, the development of reel-to-reel RCE process became a main subject for scaling up the CC. Recently, we have manufactured the reel-to-reel RCE equipment for research use and will develop high  $I_c$  REBCO CCs using the equipment.

The final goal of the CC project in Korea is the development of 1 km - long CC. KERI is cooperating with SuNAM Co., an industrial partner in DAPAS program, and the company has a plan to install the reel-to-reel pilot line for the stable fabrication of longer CC with a few hundred meters to 1 km.

In order to employ a lower cost process in the fabrication of the LMO capping layer, a reactive sputtering was tried instead of PLD which was mainly used, and c-axis epitaxial growth of LMO layer was confirmed on the MgO layer. SmBCO film deposited on LMO deposited by reactive sputtering showed a comparable high critical current density.

**1A.13** 6:35—7:20**Open Discussion Led by Moderator****7:30–9:00 PM****Welcome Reception***Shamrock Hilton Ballroom 261**Greetings from Host: **Allan J. Jacobson**, Director, TcSUH**Welcome from the University of Houston: **Renu Khator**, Chancellor, UH System and President, University of Houston*

## FRIDAY, DECEMBER 5

**7:15 AM–9:00 PM**      **REGISTRATION**  
*2nd Floor Waldorf Astoria Lobby, UH Hilton*

**7:15 AM–12:30 PM**      **POSTER SET-UP**  
*1st Floor South Wing Lobby (S104), UH Hilton*

**7:00 AM–10:00 PM**      **INTERNET CAFÉ**  
*2nd Floor, Room 247*

**7:15–8:30 AM**      **BREAKFAST BUFFET**  
*Shamrock Hilton Ballroom 261*

### 8:30—10:45 AM

#### **SESSION B: Challenges in Long Length Scale Up of High-Performance Coated Conductors** *Waldorf Astoria 210*

*Chairs/Moderators: **Xavier Obradors** (ICMAB) and **Dominic Lee** (ORNL)*

**2B-01**    8:30—8:45

#### **A U.S. Perspective on the Challenges for Scale-Up**

**K. Marken**

*Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, NM 87545 USA*

U.S. efforts to develop long, high performance coated conductors span a wide range of materials and process methods. While specific issues apply to particular materials and processes, there are also challenges common to all materials and processes. Some examples of common challenges include homogeneity of starting materials particularly metal for substrates, uniformity of substrate processing, stability and rate of deposition processes, and methods of continuous characterization. The homogeneity of substrate metal, including composition, chemical impurities, and surface roughness, directly impacts epitaxy and ultimately critical current. Stability of deposition processes, no matter what the method, is also crucial for consistent properties over long lengths. Related to stability of processing is the deposition rate, which directly impacts time scales over which the process must be controlled. In order to monitor and improve homogeneity, new and improved tools are needed to continuously monitor key parameters and provide feedback on the long length processing.

**2B-02**    8:45—9:00

#### **Challenges in Long Length Scale Up of High-Performance Coated Conductors in Japan**

**Y. Yamada<sup>1</sup>, T. Izumi<sup>1</sup>, Y. Shiohara<sup>1</sup>, Y. Iijima<sup>2</sup> and T. Saitoh<sup>2</sup>**

*<sup>1</sup>ISTEC-SRL; Shinonome 1-10-13, Koto-ku, Tokyo, 135-0062; <sup>2</sup>Fujikura Lt; 1440, Mutsuzaki, Sakura-shi, Chiba, 285-8550 Japan*

Challenges in the long length coated conductor by IBAD-PLD method in Japan will be presented. By using IBAD and PLD method, Superconductivity Research Laboratory (SRL) and Fujikura Ltd. have been developing the long length coated conductor and technologies. This year Fujikura Ltd. achieved 504m GdBCO tape with high  $I_c$  of 350A/cm-width. In this achievement, various types of technical challenges were incorporated such as GdBCO and BaZrO<sub>3</sub> artificial pinning center

## NOTES

for the material side, PLD-CeO<sub>2</sub> self-epitaxy effect as the new phenomena and the multi-plume multi-turn PLD for the new production technique. These techniques brought about the large advance in the IBAD-PLD coated conductor in Japan. In these 5 years, Fujikura increased the wire performance of  $I_{cL}$  by 2 orders. Furthermore, about 6km of total quantity of the coated conductor was delivered from Fujikura and SRL last year to the feasibility studies of the power application such as transformer, cable and motor.

In this presentation, by referring to the above results up to now and our newly developed IBAD-MgO with more simplified architectures, we will consider and discuss the challenges needed for the industrial scale production from the material side, the production technology, quality control, stability and homogeneity control to satisfy the application requirement with the minimum cost effort.

*This work was supported by New Energy and Industrial Technology Development Organization (NEDO) as the Project for Development of Materials & Power Application of Coated Conductors, M-PACC.*

**2B-03** 9:00—9:10

### **Kilometer Long 2G HTS Wires Demonstrated: Where Do We Go From Here?**

**V. Selvamanickam**

*University of Houston and SuperPower, Inc.*

In summer 2008, an important milestone was reached in 2G HTS wire technology. The very first demonstration of a kilometer-long, complete 2G HTS wire with a critical current exceeding 200 A/cm over the entire length was reported. That marked the end of a long journey that was undertaken at the dawn of this millennium to scale up 2G wire from lengths of just a few centimeters with a critical current at a fraction of the routine performance of today's long wires. With this achievement, 2G HTS wire is now in the realm of conventional LTS wire lengths. However, several challenges exist before 2G HTS wire technology can be labeled as being ready for large-scale commercial applications. Uniformity of critical currents over kilometer lengths is the first challenge. A clear understanding of sources of defects that cause local critical current drops needs to be established. The next challenge is the achievement of high critical currents that have been demonstrated in short samples. Even in the regions of good uniformity, the critical current of long 2G wires is about a factor of two less than that achieved in short samples. Microstructural differences between short samples and long tapes and the process implications need to be elucidated. This talk will discuss these and other challenges that are being addressed as 2G wire begins its transformation into a mature product.

**2B-04** 9:10—9:20

### **Efforts for Long Length Coated Conductors with High Performance by TFA-MOD Process in Japan**

**T. Izumi<sup>1</sup>, M. Yoshizumi<sup>1</sup>, M. Miura<sup>1</sup>, K. Nakaoka<sup>1</sup>, Y. Ichikawa<sup>1</sup>, Y. Sutoh<sup>1</sup>, Y. Yamada<sup>1</sup>, Y. Shiohara<sup>1</sup>, Y. Aoki<sup>2</sup>, T. Koizumi<sup>2</sup>, T. Nakanishi<sup>2</sup>, T. Kaneko<sup>2</sup>, T. Hasegawa<sup>2</sup>**

*<sup>1</sup>Superconductivity Research Laboratory, ISTEC, 1-10-13, Shinonome, Koto-ku, Tokyo 135-0062, Japan; <sup>2</sup>Showa Cable Systems Co., Ltd., 4-1-1, Minami-hashimoto, Sagamihara, Kanagawa 229-1133, Japan*

Efforts for scaling up of coated conductor processing by the Tri- fluoroacetates Metal Organic Deposition (TFA-MOD) method in Japan are addressed. In this process, there are roughly three major steps, which are coating, calcinations and crystallization steps. The reel-to-reel (RTR) system

has been developed for the coating and calcinations processes, and the RTR and Batch systems have been attempted for the crystallization one in Japan. In the coating/calcinations process, the uniformities in properties for both end-to-end and edge-to-edge directions and optimization of heat-treatment conditions are main challenges for long tapes with high performance.

On the other hand, there are several issues to be solved for each system of RTR and Batch types in the crystallization step. For example, the steady state growth condition for the RTR system should be achieved. When the appropriate steady state conditions were fixed, it should have no limitation for production with regard to the length. In the Batch system, the scaling-up of the furnace size is required to obtain the long tapes. Then, the temperature and gas flow uniformity in the large furnace are typical issues to be fixed. Through the extensive efforts to overcome the problems, a 500m long tape with a high critical current of 310 A/cm-width was achieved by the Batch type crystallization step.

*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” and “Development of Materials and Power Applications of Coated Conductors (M-PACC)”.*

**2B-05** 9:20—9:30

## **Development of REBCO Coated Conductors on Low Magnetic Textured Metal Substrate**

***H. Ota, M. Konishi, Y. Shingai, T. Nagaishi, T. Taneda, K. Ohmatsu***

*Sumitomo Electric Industries, LTD., 1-1-3, Shimaya, Konohanaku, Osaka, 554-0024 Japan*

We have been trying to develop REBa<sub>2</sub>Cu<sub>3</sub>O<sub>x</sub> (RE: rare earth elements) coated conductor tapes. The architecture of the coated conductor was REBa<sub>2</sub>Cu<sub>3</sub>O<sub>x</sub>/CeO<sub>2</sub>/YSZ/CeO<sub>2</sub>/Ni-alloy substrate. The CeO<sub>2</sub>/YSZ/CeO<sub>2</sub> layers and the superconducting layers were grown by RF sputtering and by PLD (pulsed laser deposition), respectively. For AC applications, we had to reduce the magnetization of the substrate. So, we developed a low magnetic clad type substrate. The AC loss of the clad type substrate was confirmed to be comparable to that of a non magnetic substrate. The surface roughness (Ra) and the in-plane alignment of 3rd buffer layer made on the clad type substrate were about 20 nm and about 7 degree, respectively. Buffer layers were made at an average speed of 7 m/h. The I<sub>c</sub> and J<sub>c</sub> at 77.3K, self field of the HTS layer were 379A/cm-width and 1.9MA/cm<sup>2</sup>, respectively. In addition, we have studied to speed up the process speed of buffer layers. As a result, an average speed of 20m/h was achieved. The thickness, the surface roughness (Ra) and the in-plane alignment of buffer layers at 20m/h were similar to those at 7m/h. The more detail results including HTS properties will be reported.

*A part of this work was supported by the New Energy and Industrial Technology Development Organization (NEDO).*

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**2B-06** 9:30—9:40**Development of High Rate  $Y_2O_3$  Seed Layer by Reactive Sputter Deposition for Second Generation High Temperature Superconducting Wire****S. N. Sambandam<sup>1,\*</sup>, X. Xiong<sup>1</sup>, A. Rar<sup>1</sup>, K. P. Lenseth<sup>1</sup> and V. Selvamanickam<sup>2</sup>**<sup>1</sup>SuperPower Inc., 450 Duane Avenue, Schenectady, NY 12304; <sup>2</sup>Mechanical Engineering, University of Houston, Houston, Texas 77204 USA

Second generation (2G) high temperature superconducting (HTS) wire has been demonstrated to have potential importance in energy industries, medical diagnostics, and military applications. One of the factors controlling its commercial success is cost-effective product development and manufacturing. As a consequence, high throughput, cost-effective and high-quality processing is necessary. This work presents the development of a high-rate Yttria seed layer deposition. Yttria has been routinely used as the nucleation seed layer that enables the biaxial texture of MgO and has been previously manufactured using ion beam assisted deposition (IBAD). In order to increase the throughput and cost reduction, we develop a new process of reactive magnetron sputtering to produce yttria deposition. Yttria coatings can be manufactured 10 times faster than the existing process. Good feedback control was developed to achieve reliable manufacturing at high-rate deposition with quality coatings. To optimize the processes for yielding required thicknesses, the deposited coatings were characterized by spectroscopic ellipsometry using a simple three-layer model. The effective feedback control employed in this process enables tailoring of the oxygen concentration in the seed layer.

**2B-07** 9:40—9:50**Challenges in Long-Length Scale Up of High  $I_c$  Coated Conductors Processed via HRPLD and ABAD****A. Usoskin<sup>1</sup>, L. Kirchoff<sup>1</sup>, J. Knoke<sup>1</sup>, B. Prause<sup>1</sup>, A. Rutt<sup>1</sup>, K. Schlenga<sup>1</sup>, R. Delmdahl<sup>2</sup>**<sup>1</sup>Bruker HTS GmbH, Siemensstrasse 88, 63755 Alzenau, Germany; <sup>2</sup>Coherent GmbH, Hans-Boeckler-Strasse 12, 37079 Goettingen, Germany

Challenges in up-scaling of technological means for processing of HTS coated conductors (CC) via High Rate Pulsed Laser Deposition (HRPLD) and Alternating Beam Assisted Deposition (ABAD) are considered and discussed. Related techniques are already recognized as attractive routes for producing HTS coated conductors while they allow to achieve both high critical currents and efficient tape processing. This was recently confirmed by Fujikura who processed a 500 m long coated conductor with critical current of almost 400A/cm-width (Fujikura, 2008), the highest current ever observed in such long tapes.

We report here (i) an industrial up-scaling of the deposition equipments and techniques towards production speeds of 50-75 m/hour, (ii) a progress in improvement of technological parameters and performance of coated conductors (CC), and (iii) economical aspects of CC tape processing.

Challenges in reaching sufficient processing yields, uniformity of parameters of coated conductors, processing stability are discussed.

Alternatives in upgrading strategy which were partly employed and also partly premeditated for the future are displayed.

Comparison of different processing routes is given regarding substrate types, means for film deposition and material costs.

**2B-08** 9:50—10:00**Challenges in Long-Length Scale Up of High  $I_c$  MOD-YBCO/RABiTS™-based Coated Conductors*****M. W. Rupich, S. Fleshler, X. Li, S. Sathyamurthy, C. L. H. Thieme, D. Buczek and K. DeMoranville****American Superconductor Corporation, 64 Jackson Rd., Devens, MA 01434 USA*

The MOD-YBCO/RABiTS route has been identified as a low-cost manufacturing process for high performance 2G wire. AMSC has used this approach to design a full-scale production line based on a “wide-strip” manufacturing process. The “wide-strip” process is designed to be inherently low-cost and has the flexibility to produce wire with varying dimensions and properties which can be tailored for specific applications. The current production scale equipment is designed to process strips with a width to 10 cm and length to 1 km; however, the initial operation of the equipment uses a 4-cm wide strip. As with any new manufacturing technology, a number of start-up issues were experienced during the commissioning of the production line. This presentation will describe some of the successes in addressing these issues, as well as ongoing efforts to improve processing yield. We will also summarize the performance of the 2G wire currently being produced and describe further performance improvements under development.

**2B-09** 10:00—10:10**Long Length Scale Up of Coated Conductor: Status & Perspective in Korea*****S.-H. Moon****SuNAM***2B-10** 10:10—10:45**Open Discussion led by Moderator****10:45–11:00 AM**      **COFFEE/TEA BREAK***Waldorf Astoria Lobby***11:00 AM—12:30 PM****SESSION C: Strategies Toward Low-Cost Coated Conductors***Waldorf Astoria 210**Chairs/Moderators: **Alexander Usoskin** (Bruker HTS GmbH), **Yutaka Yamada** (ISTEC-SRL)*

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**2C-01** 11:00—11:10**Development of Strengthened/Non-Magnetic Cube Textured Templates for Coated Conductors****B. Holzapfel***IFW Dresden, Institute for Metallic Materials, P.O. Box: 270116, 01171 Dresden, Germany*

The talk will summarize the various strategies toward the fabrication of strengthened and/or non-magnetic metallic textured templates and discuss the challenges in obtaining such templates with sufficiently high degree of texture. Special emphasis will be dedicated to the transition from laboratory scale samples towards commercial length production.

**2C-02** 11:10—11:20**Chemically Grown YBCO Superconducting Multilayers\*****X. Obradors, R. Vlad, M. Coll, T. Puig, A. Pomar, J. Gutiérrez, A. Palau, S. Ricart, P. Abellán, F. Sandiumenge, K. Zalamova, R. Hühne<sup>2</sup>, B. Holzapfel<sup>2</sup>, Y. Morilla<sup>3</sup>, J. García-López<sup>3</sup>, A. Usoskin<sup>4</sup>**

*Institut de Ciència de Materials de Barcelona, CSIC, Campus U.A. Barcelona, 08193 Bellaterra, Spain; <sup>2</sup>IFW-Dresden, Institute for Metallic Materials, P.O. Box: 270116, 01171 Dresden, Germany; <sup>3</sup>Centro Nacional de Aceleradores, Av. Thomas A. Edison nº 7, Isla de La Cartuja, E-41092 Sevilla, Spain; <sup>4</sup>European High Temperature Superconductors GmbH & Co. KG D-63755 Alzenau, Germany*

Chemical solution deposition (CSD) is a very competitive technique for obtaining highly epitaxial multilayered structures and so it is widely investigated as cost-effective production of all-chemical YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub> (YBCO) coated conductors. However, there is still a need to simplify the conductor architectures and so a detailed analysis of the different issues influencing the quality of the multilayers is required.

In this presentation we will discuss which are the required advances to engineer the multilayered structures when YBCO is grown from TFA precursors. We will show that the atomic planarity of buffer layers, instead of surface roughness, plays the key role in achieving high quality epitaxy and high critical currents. The degree of buffer layer epitaxy has been investigated by means of RBS-channeling and RHEED and it has been correlated with (001) atomically flat area determined from AFM images. This quantitative methodology has been applied to doped Ce<sub>1-x</sub>M<sub>x</sub>O<sub>2</sub> (M=Gd, Zr) cap layers in several types of metallic substrates (RABiT and IBAD) and we have determined which flatness is required to achieve all chemical CSD multilayers with high J<sub>c</sub> values (J<sub>c</sub> > 5 MA/cm<sup>2</sup> at 77 K).

*\*We acknowledge financial support from MEC (MAT2005-02047, NAN2004-09133-C03-01, MAT2006-26543-E), Consolider Nanoselect, Generalitat de Catalunya (Pla de Recerca SGR-0029 and XaRMAE), CSIC (PIF-CANNAMUS) and EU (HIPERCHEM, NESPA).*

**2C-03** 11:20—11:30

## Development of Simplified RABiTS and IBAD Architectures for Coated Conductors

**M. Parans Paranthaman**

*Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA*

High performance second generation superconducting wires can be fabricated in excess of 100 meter lengths based on four different templates such as IBAD-YSZ, IBAD-GSZ, IBAD-MgO, and RABiTS. In order to further reduce the manufacturing cost of these wires, it is necessary to simplify the buffer architectures. In this talk, we will address the current status of the simplified buffer architectures that have been developed for IBAD and RABiTS templates. In addition, we will also address the following important questions: (1) What are the important characteristics that must be exhibited by effective coated conductor substrates? (2) What are some of the possible issues that have prevented these simplified architectures from being incorporated into prototype coated conductors? and (3) To what extent must these architectures be developed before a wire manufacturer will consider implementing this technology into their prototype conductor?

*Research sponsored by the US Department of Energy, Office of Electricity Delivery and Energy Reliability - Superconductivity Program, under contract DE-AC05-00OR22725 with UT-Battelle, LLC managing contractor for Oak Ridge National Laboratory.*

**2C-04** 11:30—11:40

## Solution Deposited Layers for Joining Coated Conductors

**G. Kotzyba<sup>1</sup>, A. Will<sup>1</sup>, R. Nast<sup>1</sup>, W. Goldacker<sup>1</sup>, O. Stadel<sup>2</sup>**

*<sup>1</sup>Forschungszentrum Karlsruhe, Institut für Technische Physik, Postfach 3640, D-76021 Karlsruhe; <sup>2</sup>PerCoTech AG, Bienroder Weg 53, D-38108 Braunschweig*

The two great challenges in the development of 2G YBCO high temperature superconductors are the enhancement of the critical current density on the one hand and the reduction of hysteresis losses on the other hand. Therefore the superconducting layers have to be structured to get parallel filamentary percolation paths with periodic transposition in addition. Transposition requires a multilayer system. The motivation of our work is the generation of a suitable architecture and preparation routes to satisfy this criteria by joining YBCO structured layers.

We present an economical solution derived procedure with a simple buffer layer design consisting of a 200 nm  $\text{La}_2\text{Zr}_2\text{O}_7$  and a 50 nm  $\text{CeO}_2$  layer dip coated on Ni-4at.% W RABiTS tape. The high quality of the crack-free layers was shown by MOCVD deposition of YBCO on top with critical current densities up to 2 MA/cm<sup>2</sup>. Chemical deposition of YBCO from non-fluorine 2,4-pentanedionate precursors in pyridine, propanoic acid and methanol was successfully performed on  $\text{SrTiO}_3$  (100) single crystals with critical current densities up to 2.8 MA/cm<sup>2</sup>. On buffered RABiTS tapes deposited YBCO showed inhibited transport currents from  $\text{BaCO}_3$  formation.

The results are discussed with respect to future development of a low cost deposition route in combination with structuring and joining YBCO layers to get low AC loss coated conductors.

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**2C-05** 11:40—11:50**Reel-to-Reel, All-MOD YBCO//Buffer//NiW Coated Conductors with Ultrafast Pyrolysis****P. G. Clem, C. V. Edney, D. L. Overmyer, M. P. Siegal***Sandia National Laboratories, PO Box 5800, Albuquerque, NM 87185-1411 USA*

All-solution deposition routes have been developed for processing epitaxial YBCO film coated conductors on Ni-W RABiTS, and recently extended to 10 meter lengths. Recent results are presented detailing all-solution deposited reel-to-reel buffer layers (SrTiO<sub>3</sub> and CeO<sub>2</sub>/LZO) and modified TFA method YBCO coated conductors with critical current densities  $J_c$  (77K) > 1 MA/cm<sup>2</sup> on rolling-assisted, biaxially textured, (200) oriented Ni-W alloy tapes. The reel-to-reel YBCO deposition utilizes an instant pyrolysis (< 2 minutes) to enable rapid linear production speeds of up to 90 meters/hour. Important all-solution deposition process variables will be discussed, including the influence of substrate orientation, buffer layer roughness, and buffer layer thickness.

*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's NNSA under contract DE-AC04-94AL85000.*

**2C-06** 11:50—12:00**Efforts for Lowering Cost of TFA-MOD Coated Conductors in Japan****T. Izumi<sup>1</sup>, M. Yoshizumi<sup>1</sup>, M. Miura<sup>1</sup>, K. Nakaoka<sup>1</sup>, Y. Ichikawa<sup>1</sup>, Y. Sutoh<sup>1</sup>, Y. Yamada<sup>1</sup>, Y. Shiohara<sup>1</sup>, Y. Aoki<sup>2</sup>, T. Koizumi<sup>2</sup>, T. Nakanishi<sup>2</sup>, T. Kaneko<sup>2</sup>, T. Hasegawa<sup>2</sup>***<sup>1</sup>Superconductivity Research Laboratory, ISTEK, 1-10-13, Shinonome, Koto-ku, Tokyo 135-0062, Japan <sup>2</sup>Showa Cable Systems Co., Ltd., 4-1-1, Minami-hashimoto, Sagami-hara, Kanagawa 229-1133, Japan*

Efforts for lowering the cost of coated conductor processing by the Tri-/ fluoroacetates Metal Organic Deposition (TFA-MOD) method in Japan are addressed. In this process, there are roughly three major steps, which are the coating, calcinations and crystallization steps. The reel-to-reel (RTR) system has been developed for coating and calcinations processes, and the RTR and Batch systems have been attempted for the crystallization one in Japan. In the coating/calcinations process, the high production rate should be realized which strongly depends on the tape traveling speed and the single coating thickness. For overcoming the problems, development of starting materials and enlargement of the multi-turning system have been carried out. A uniform 500 m precursor tape was realized by the large scale furnace with 5 m/h of the traveling rate.

Concerning the crystallization step by the RTR system, a high production rate has to be realized for further lower cost, although it could be expected in the Batch type. The multi-turning RTR method with a vertical gas flow system is one approach to solve the problem. It has been confirmed that several ten's m/h of the production rate was expected in this way.

Additionally, realization of higher critical current under the conditions used for the applications is another approach to reduce the cost due to the unit of \$/Am. The composition control of the starting solution and the artificial pinning center control are effective to achieve higher superconducting performances. A high critical current value of 760 A/cm-width under the self-fields and the isotropic critical current of 115 A/cm-width under the applied magnetic field of 1T were realized by a Y(Gd)BCO film with dispersion of BZO nono-particles.

*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" and "Development of Materials and Power Applications of Coated Conductors (M-PACC)".*

**2C-07** 12:00—12:10**Fabrication of HTS Coated Conductors by Reactive Coevaporation*****B. Moeckly*<sup>1</sup>, *V. Matias*<sup>2</sup>**<sup>1</sup>Superconductor Technologies, Inc. 460 Ward Dr., Santa Barbara, CA 93111 <sup>2</sup>Los Alamos National Laboratory, Mail Stop T004, Los Alamos, NM 87545 USA

At Superconductor Technologies, Inc. we have developed the growth technique of reactive coevaporation to be a reliable, high-throughput, low-cost deposition method for production of HTS films on single-crystal substrates for RF filters. In collaboration with Los Alamos National Laboratory, we are now exploring the use of this technique for deposition of HTS thin films on IBAD-MgO Hastelloy templates for coated conductor applications. We will discuss initial results of the growth, crystallinity, and superconducting properties of HTS thin films deposited on short lengths of IBAD-MgO tapes. The in-plane misorientation of the YBCO films is less than 3 degrees and the out-of-plane orientation rivals that of YBCO deposited on single-crystal MgO substrates. Initial YBCO films grown at STI have demonstrated critical currents greater than 250 A/cm-width for 700-nm-thick films at liquid nitrogen temperature, and thick films grown at LANL by reactive coevaporation have demonstrated 950 A/cm-width. We will present results on templates with a reduced number of buffer layers. We believe this growth technique will offer substantial advantages in terms of performance and cost over competing coated conductor production methods.

**2C-08** 12:10—12:20**Development of High Rate Deposition Technique for PLD-GdBCO Coated Conductors*****N. Chikumoto, S. Lee, K. Tanabe****Superconductivity Research Laboratory, ISTEC, 1-10-13, Shinonome, Tokyo, 135-0062, Japan*

Pulsed-laser deposition (PLD) technique has been shown to be one of the promising methods to fabricate long-length REBCO coated conductors (CC) with high quality. However, for the future commercialization of CC, we have to reduce production cost by speeding up the deposition process as well as by raising  $I_c$  values. Here we show our achievement of high-rate fabrication of high- $I_c$  GdBCO tapes by developing a novel “inside-plume deposition” (IP-PLD) technique. The main idea of the IP-PLD technique is to increase the deposition rate simply by reducing substrate-to-target (ST) distance. We also employed very large laser energy density,  $>3\text{J}/\text{cm}^2$ , for further increasing the deposition rate. As a result, the production rate increased up to about 3 times higher compare to the conventional PLD method.

However, the IP-PLD technique requires appropriate adjustment of target compositions, since the enrichment of Ba and Gd composition occurs with decreasing the ST distance. According to the systematic study of the relationship between the chemical nonstoichiometry of the tape composition and  $J_c$ , we found that adjustment of tape composition to a slightly Ba-deficient composition very effectively suppresses formation of impurity phases, such as  $\text{BaCuO}_2$ , and thus improves  $J_c$  properties. By combining the Ba-poor composition, and addition of 5 mol %  $\text{BaZrO}_3$  as pinning centers, we obtained very high  $I_c$  values at 77 K of 700-1000 A/cm(s.f.) and 135A/cm @ 3 Tesla ( $J_c$ ) for short samples with an about 5  $\mu\text{m}$  thick GdBCO layer. We also show some recent results of reel-to-reel fabrication of long-length tapes using the IP-PLD technique.

*This work is supported by the New Energy and Industrial Technology Development Organization (NEDO).*

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**2C-09** 12:20—12:30**All-MOCVD Technology for YBCO Layer/Buffer Layer Fabrication for Coated Conductors****A. Molodyk, M. Novozhilov, S. Street, A. Delaney, L. Castellani, and A. Ignatiev***Metal Oxide Technologies Inc., 8807 Emmott Rd., Suite 100, Houston, TX 77040 USA*

The unique technology to deposit buffer and YBCO layers for coated conductors via MOCVD developed by Metal Oxide Technologies Inc. represents one of the lowest possible capital and operational cost approaches to coated conductor manufacturing. An overview of the current state of MetOx technology will be given. Modular design of the prototype production MOCVD system allows for either in-line or parallel fabrication of any number of buffer layers and YBCO layers. The system is operated in air-to-air, reel-to-reel mode. World class results of  $J_c = 3.34 \text{ MA/cm}^2$ ,  $I_c = 480 \text{ A/cm}$  on short samples, and  $I_c > 300 \text{ A/cm}$  on 1+ m long tapes have been achieved in MOCVD YBCO on established buffer layer architectures. In addition,  $I_c > 130 \text{ A/cm}$  has been reproducibly demonstrated on a proprietary all-MetOx all-MOCVD architecture, which is being rigorously advanced. Further, research activities focused on pinning enhancement, thick YBCO films and ultra-fast MOCVD growth will also be discussed.

**12:30–1:45 PM****LUNCH***Shamrock Hilton Ballroom 261***1:45—2:55 PM****SESSION C: Strategies Toward Low-Cost Coated Conductors**– *Continuation/Discussion* Waldorf Astoria 210**2C-10** 1:45—1:55**Strategy Toward Low Cost Coated Conductor in IBAD-MgO and PLD Method****Y. Yamada, M. Yoshizumi, S. Miyata, H. Fukushima, A. Ibi, T. Izumi and Y. Shiohara***ISTEC-SRL; Shinonome 1-10-13, Koto-ku, Tokyo, 135-0062 Japan*

Strategy toward low cost coated conductor will be presented from IBAD/ PLD experiments which we have done in SRL and with Fujikura.

Up to now, we have succeeded in obtaining 41m long IBAD-MgO and PLD-GdBCO coated conductor with a 4 layered buffer structure. IBAD-MgO was fabricated at the rate of 24m/h. The  $I_c$  values recorded 500 to 600 A/cm at 77 K and 0T. The highest  $I_c$  was 608 A/cm with the  $J_c$  value of  $2.43 \text{ MA/cm}^2$ .

Based on these results and the conventional IBAD-GZO results, we have compared the cost effective parameters. In the IBAD-GZO, when using  $I_c$  of 300A and 5m/h, we can reach the cost value of 12 Yen /Am (\$120/kAm). On the contrary, in the new IBAD-MgO/PLD method, we obtained a perspective for a lower cost. This can be done by the fast production rate of IBAD-MgO and the layer number reduction to 4 layers, consisting of  $\text{Gd}_2\text{Zr}_2\text{O}_7$  (GZO) / IBAD-MgO/  $\text{LaMnO}_3$ /  $\text{CeO}_2$ . For the cost target applied to many commercial superconducting devices, we have to increase the  $I_c$  to 500A/cm and the production speed to 15m/h for the superconductor layer, and to 120m/h for

IBAD-MgO and to 20- 80m/h for the buffer layer. From these cost calculations, I will discuss the effect of processing parameters such as throughput, yield,  $I_c$  and  $J_c$  on the cost and the strategy for the cost reduction considering the impact factor and the milestones for R&D.

*This work was supported by New Energy and Industrial Technology Development Organization (NEDO) as the Project for Development of Materials & Power Application of Coated Conductors, M-PACC.*

**2C-11** 1:55—2:05

## **Reducing the Price-Performance Ratio of 2G Wire**

***S. Fleshler, D. Roy, M. Rupich, A. Santamaria***

*American Superconductor Corporation, 64 Jackson Rd., Devens, MA 01434 USA*

Broad commercial acceptance of HTS wire is expected to occur when the price-performance ratio approaches that of copper ranging from \$30-50/kA-m. The factors which directly influence the price-performance ratio are the electrical performance ( $I_c$ ) and the cost to produce the wire. The electrical performance, as well as various wire-cost components, are intimately related so that they cannot be treated independently and they often must be traded-off to optimize the price-performance ratio. Some general aspects of the interactions between production rates, volume capacity and producing high ampacity wire are considered in this presentation. These points will be illustrated by applying them to AMSC's approach to low-cost high performance wire manufacturing using a RABiTS™/MOD process on wide strips to enhance production rates, reduce labor costs while simultaneously producing high current wire. Opportunities for further improvement in price-performance reduction will be discussed within the existing RABiTS/MOD production platform as well as alternative longer-term approaches.

**2C-12** 2:05—2:15

## **Strategies to Reach 2G HTS Wire Price of \$50/kA-m without High Volume Production**

***Venkat Selvamanickam***

*University of Houston and TcSUH/SuperPower*

2G HTS wire has been available in lengths of several hundred meters with uniformly good performance for the last two years. Significant reductions in price have been achieved and a standard 2G HTS wire commands a price of \$ 400/kA-m in 2008. This is a factor of about eight higher than the target of \$ 50/kA-m that has been established for wider acceptance of 2G HTS wire in commercial products. Depending on wire volume to achieve this price target appears to be impractical given the scope and demands of the various prototype HTS projects worldwide over the next four years. Hence, there is critical need to reach a price level of \$ 50/kA-m without benefits of economies of scale. There are multiple technological opportunities to achieve this goal. At present, since the tape speed during deposition is quite high at more than 100 m/h, non-deposition time is the limiting factor in the overall product output which affects labor and overhead cost. Appropriate modification to the conductor architecture can be made to reduce this non-deposition time. Yield is arguably the single most important factor in determining wire cost, especially with high current wires. Simplification of processes and architecture as well as novel on-line monitoring techniques can be highly beneficial to improve yield. Finally, raw material cost in vapor deposition processes

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can be substantially reduced by improving precursor/target to film conversion efficiency. These and other strategies to reduce conductor cost to reach price levels of \$ 50/kA-m without high volume production will be discussed.

**2C-13** 2:15—2:25

### HTS Coated Cylinders Processed via Alternating Beam Assisted Deposition (ABAD)

**A. Rutt<sup>1</sup>, L. Kirchoff<sup>1</sup>, N. Freytag<sup>2</sup>, A. Usoskin<sup>1</sup>**

<sup>1</sup>Bruker HTS GmbH, Siemensstr. 88, 63755 Alzenau, Germany; <sup>2</sup>Bruker Biospin AG, Industriestr. 26, 8117 Fällanden, Switzerland

HTS coated cylinders as a variant of coated conductors were always attractive because of lossless circumferential currents. Different application fields of coated cylinders as superconducting fault current limiter of inductive type, field gradiometers, NMR field formers have been listed earlier, and certain deposition techniques (as e.g. inclined substrate deposition) were developed to provide bi-axially textured buffer layer on cylindrical surfaces.

Here we report recent progress in manufacturing of bi-axially textured buffers on cylinders via ion beam technology. Ultimately, these buffered substrates should allow processing of HTS coated cylinders with small radius.

The bi-textured yttria stabilized zirconia (YSZ) layers on a cylindrical surface were manufactured by an alternating ion-beam assisted deposition technique where the film is periodically exposed to deposition pulses and to etching pulses. As a long sequence of alternations of these two pulses is needed, this method was called “alternating beam assisted deposition” (ABAD).

Two types of substrates were employed: a segment of the sapphire single crystal cylinder with diameter of 12 mm and length of 60 mm, and a 100 μm thick stainless steel tape which simulated metallic cylinder of the same diameter.

Mechanically polished substrates exhibited a roughness of typically 6 nm. The thickness of the textured YSZ layer was 2.5 μm. The sapphire substrates were preliminarily covered with an amorphous layer of chemically neutral material in order to prevent non-desirable orientations in YSZ film.

It was confirmed by XRD ( $\theta$ -2 $\theta$  and  $\varphi$ -scan) that the YSZ [001] direction is normal to the substrate surface and the in-plane misalignment was better than FWHM=9 degrees for the both substrate types. These results were additionally confirmed by X-ray measurements of YBCO films deposited onto these bi-textured buffers.

**2C-14** 2:25—2:55

### Open Discussion led by Moderator

**2:55-3:10 PM**

**AFTERNOON COFFEE/TEA BREAK**

*Waldorf Astoria Lobby*

**3:10—6:30 PM**

### SESSION D: Effective Approaches to Enhance Coated Conductor Performance *Waldorf Astoria 210*

*Chairs/Moderators: David Larbalestier (NHFML/FSU) and Sang-Soo Oh (KERI)*

## D1. Enhanced Coated Conductor Performance: Pinning

**2D-01** 3:10—3:20

### Enhancement of Activity of Technical Oxide Buffers as a Pathway for Higher Performance of 2G Wires

**S. Solovyov**

*Brookhaven National Laboratory, Upton, NY 11973 USA*

The second generation coated conductors are oriented structures which rely on epitaxy to achieve desirable texture. The substrate has a dual role: that of a template and a catalyst. The first role of a substrate is to provide desired orientation for the epitaxial layer. The substrate texture has been significantly improved in the last decade, probably reaching its limit. We will discuss the one important property of a substrate, its catalytic activity, which can be defined as an ability of a substrate to provide low energy nucleation sites.

The importance of the substrate activity becomes important as long-scale buffered tapes are made at an increasingly faster rate to reduce cost of the 2G conductors. While the substrate orientation stays the same, the buffer activity is declining. The low activity hurts the conductor performance because secondary phases are allowed to nucleate along with YBCO. The secondary phase formation becomes especially acute as the YBCO layer thickness is increased. In YBCO layers deposited by meta-organic deposition the low buffer activity results in granularity. In granular samples YBCO nuclei are far apart and the YBCO grain has to grow laterally to make a continuous film. We demonstrate by using transmission electron microscopy how the non-superconducting secondary phases form on the grain periphery and block the super-current, thus reducing performance of the conductor.

In the case of metal-organic chemical vapor deposition the low substrate activity seems to allow nucleation of the copper-rich secondary phases along with YBCO. The grains of copper-rich phases grow faster than YBCO as the film gets thicker, eventually taking over a high portion of the film cross-section as the film becomes thicker than 2 microns.

We discuss possible strategies for the buffer activities enhancement on example of 20 nm  $\text{CeO}_2$  film on buffers. It is concluded that well-defined, dislocation free (001) terminations are essential to achieve high activity in oxide buffers.

**2D-02** 3:20—3:30

### Thick Film Processes and Their Effects on the Connectivity and Pinning in Thick Film RBCO Coated Conductors

**T. G. Holesinger**

*Los Alamos National Laboratory, Los Alamos, NM 87545 USA*

High critical current densities ( $J_c$ ) in  $\text{YBa}_2\text{Cu}_3\text{O}_y$  (YBCO) coated conductors depend directly upon the connectivity and defect density within the films. Hence, one needs to develop methodologies for controllably introducing defect structures that are sufficient for tailoring the superconducting properties while, on the other hand, maintaining high critical current properties over lengths exceeding several hundred meters. Aspects of thick film development for physical and chemical deposition processes will be discussed with respect to the types of defects that can be expected to form and effects of thick film growth on connectivity.

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**2D-03** 3:30—3:40**Pinning Strategies to Enhance HTS Performance****J. L. MacManus-Driscoll<sup>1</sup>, S. Harrington<sup>1</sup>, S. Wimbush<sup>1</sup>, J. Durrell<sup>1</sup>, H. Wang<sup>2</sup>, J. H. Lee<sup>2</sup>, L. Sahonta<sup>1</sup>, B. Maiorov<sup>3</sup>, G. Ercolano<sup>1</sup>, and A. Kursumovic<sup>1</sup>**<sup>1</sup>Department of Materials Science and Metallurgy, University of Cambridge, Pembroke Street, Cambridge CB2 3QZ, UK;<sup>2</sup>Department of Electrical and Computer Engineering, Texas A&M University, College Station, TX 77843-3128 (USA); <sup>3</sup>MPA-STC, K763, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

This talk will address a range of issues related to pinning strategies in HTS. Both core pinning and magnetic pinning will be covered, as well as the possibility of including both these mechanisms together. The different aspects of the nanomaterials engineering to be considered include the control of chemical compatibility, and the size, geometry, orientation, distribution and population density of the second phases. Also, the suitability of the different methods for in-situ versus ex-situ processing will be considered, as well as potential issues for moving from lab-scale to commercial length samples. New data using pinning additives with very high performance will be used to illustrate the points to be covered.

**2D-04** 3:40—3:50**Thick Films with Enhanced Pinning via Self-Assembled Columnar Defects****A. Goyal**

Oak Ridge National Laboratory, P.O. Box 2008, MS 6116, Oak Ridge, TN 37831 USA

This talk will summarize the work on flux-pinning via self-assembled columnar defects in REBCO-type coated conductors. Data will be presented for films made via both the in-situ PLD and MOCVD techniques, highlighting the similarity in the morphology of self-assembled columnar defect structures and the resulting effects on flux-pinning. Challenges in the fabrication of reproducible, high performance thick films and how the incorporation of columnar defects mitigates some of these effects will be discussed. Different types of second phase material which can be incorporated as self-assembled columnar defects and their effectiveness in pinning will be reviewed.

*Research was sponsored by the US Department of Energy, Office of Electricity Delivery and Energy Reliability- Superconductivity Program, under contract DE-AC05-00OR22725 with UT-Battelle, LLC managing contractor for Oak Ridge National Laboratory.*

**2D-05** 3:50—4:00**Highly Tunable, Rare Earth Tantalate Pyrochlore Nanoparticles for Superior Flux Pinning in YBaCuO Films****S. A. Harrington<sup>1</sup>, J. H. Durrell<sup>1</sup>, B. Maiorov<sup>2</sup>, H. Wang<sup>3</sup>, S. C. Wimbush<sup>1</sup>, A. Kursumovic<sup>1</sup>, J. H. Lee<sup>3</sup>, J. L. MacManus-Driscoll<sup>1</sup>**<sup>1</sup>Department of Materials Science and Metallurgy, University of Cambridge, Pembroke Street, Cambridge CB2 3QZ, UK;<sup>2</sup>Superconductivity Technology Centre, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA; <sup>3</sup>Department of Electrical and Computer Engineering, Texas A&M University, College Station, Texas 77843, USA

Practical flux pinning in the high temperature superconductor, YBaCuO (YBCO), was first demonstrated around five years ago. Since that time, significant progress has been made in materials optimisation and the various candidate pinning additives show several factors higher current carrying performance in magnetic field than standard YBCO. Despite the major advances, there has been little basic understanding about what is the optimum additive and how to achieve the 'perfect'

pinning microstructure. Here, through a simple understanding of the kinetic and thermodynamic factors at play, combined with a knowledge of the materials chemistry of candidate pinning phases, we propose a new pinning additive,  $\text{RE}_3\text{TaO}_7$  (where RE is rare earth). We demonstrate a very fine pinning nanostructure from the phase as well as exemplary flux pinning. The nanoparticle self-assembly is readily tunable, allowing for both strong random and correlated pinning. State-of-the-art or better pulsed laser deposition current densities,  $J_c$ 's, of  $1.2 \text{ MA}\cdot\text{cm}^{-2}$  at 1 T,  $0.55 \text{ MA}\cdot\text{cm}^{-2}$  at 3 T, and  $0.2 \text{ MA}\cdot\text{cm}^{-2}$  at 5 T, were achieved in the first grown films.

**2D-06** 4:00—4:10

### Microstructural and Pinning Properties of $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ Thin Films Doped with Magnetic Nanoparticles

**H. Wang<sup>1\*</sup>, C. F. Tsai<sup>1</sup>, and J. Wang<sup>1</sup> and D. G. Naugle<sup>2</sup>**

<sup>1</sup>Department of Electrical and Computer Engineering, Texas A&M University, College Station, TX 77843-3128, USA;

<sup>2</sup>Department of Physics, Texas A&M University, College Station, TX 77843-4242, USA

In this research, we conducted a systematic study on the microstructural and physical properties of the  $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$  (YBCO) thin films doped with magnetic nanoparticles. We incorporated different magnetic nanoparticles (i.e., Ni,  $\text{Fe}_2\text{O}_3$ , etc.) with various particle doping concentrations (from 1 to 5 atom %). The dopants were incorporated either by laser ablation of a composite target through premixing the YBCO and dopant powders, or by alternative growth of the YBCO and dopant targets. Film thickness was controlled at 200nm range for all the samples. We conducted a detailed microstructural characterization on all the doped samples by X-ray diffraction (XRD), scanning electron microscopy (SEM), and cross-sectional transmission electron microscopy (TEM). The critical current densities at both self-field and in-field ( $J_c^{sf}$  and  $J_c^{in-field}$  (H//c)) and the critical transition temperature ( $T_c$ ) of the doped YBCO thin films and a reference YBCO sample were measured by a Superconducting Quantum Interference Device (SQUID). The  $T_c$  of the doped YBCO films varies from 85K-89K and the  $J_c$  is in the range of  $1.2\text{-}2\text{MA}/\text{cm}^2$  (at liquid  $\text{N}_2$ , 75.5K) depending on the dopant and doping approach. The pinning properties of these doped YBCO films were explored at different temperatures and correlated with their microstructural characteristics.

**2D-07** 4:10—4:20

### Isotropic Magnetic Field Angular Dependence of Critical Current of Nanoparticles Dispersed $\text{Y}_{1-x}\text{RE}_x\text{Ba}_2\text{Cu}_3\text{O}_y$ Coated Conductors

**M. Miura<sup>1,2</sup>, T. Kato<sup>3</sup>, M. Yoshizumi<sup>1</sup>, Y. Yamada<sup>1</sup>, T. Izumi<sup>1</sup>, T. Hirayama<sup>3</sup>, and Y. Shiohara<sup>1</sup>**

<sup>1</sup>Superconductivity Research Laboratory, International Superconductivity Technology Center, 1-10-13, Shinonome Koto-ku, Tokyo 135-0062, Japan; <sup>2</sup>Japan Society for the Promotion of Science, 8 Ichibancho, Chiyoda-ku, Tokyo 102-8472, Japan;

<sup>3</sup>Materials R&D Laboratory, Japan Fine Ceramics Center, 2-4-1 Mutsuno, Atuta-ku, Nagoya 456-8587, Japan

In order to enhance the critical current density ( $J_c$ ) under the magnetic fields, we prepared  $\text{Y}_{1-x}\text{RE}_x\text{Ba}_2\text{Cu}_3\text{O}_y$  (RE: Gd, Sm) coated conductors (CCs) with artificial pinning centers by the trifluoroacetates (TFA)-metal organic deposition (MOD) of the Ba-poor (deficient from the stoichiometric ratio) starting solution containing Zr. According to microstructural observation,  $\text{BaZrO}_3$  (BZO) nanoparticles were uniformly dispersed in the film. High  $J_c$  values in the magnetic fields and isotropic magnetic field angular dependence of  $J_c$  for YSmBCO+BZO and YGdBCO+BZO CCs were realized since BZO nanoparticles pin the fluxons of all applied magnetic field orientations. Especially, YGdBCO+BZO CCs showed the highest self-field  $J_c$  ( $J_c^{s.f.}$ ) =  $4 \text{ MA}/\text{cm}^2$  and  $J_{c,\min}$  =  $0.64 \text{ MA}/\text{cm}^2$  at 77K and 1 T, which were 3.36 times higher than these of YBCO CCs. Moreover, the

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YGdBCO+BZO CCs using a growth rate controlled process showed a high  $I_c^{sf}$  value of 760 A/cm-w for 1.9  $\mu\text{m}$  thick film. Additionally, this film revealed extremely high superconducting performance of  $I_{c,min}$ =115 A/cm-w under 1T and 35 A/cm-w under 3T at 77 K.

*This work was supported by the NEDO as Collaborative Research and Development project of Fundamental Technologies for Superconductivity Applications and the project of Development of Material & Power application of Coated Conductors, M-PACC. Part of this work was supported by the Japan Society for the Promotion of Science KAKENHI (20-4011).*

**2D-08** 4:20—4:30

### Vortex-Defects Engineering of YBCO Films by All Chemical Nanostructuring Routes

**T. Puig**

*Institut de Ciència de Materials de Barcelona, ICMAB-CSIC, Campus UAB, 08193 Bellaterra, Spain*

Understanding vortex pinning mechanisms and correspondingly the interaction between vortices and defects is still one of the major goals to enhance properties of coated conductors and consequently fine control of the micro and nanostructure of the superconducting material is required. Therefore, the capability to artificially nanostructure superconducting material is a major goal, especially in chemical solution based films where less knowledge is acquired due to the infancy of the field. Our group has devoted much effort on growing, by chemical routes, superconducting nanocomposites with different second phases embedded in the YBCO matrix ( $\text{BaZrO}_3$ ,  $\text{Y}_2\text{O}_3$ ) as well as YBCO superconducting films on top of non-superconducting oxide nanostructured templates generated by strained induced self-assembled processes ( $\text{La-Sr-O}$ ,  $\text{Ce}_{1-x}\text{Gd}_x\text{O}_2$ ). The pinning mechanisms associated to these nanostructured films have been thoroughly evaluated and correlated with the particular microstructure. Results will be discussed in terms of vortex contributions of the different pinning centers which have been separated and quantified in a wide temperature and magnetic field range. Recently, we have started to combine magnetic nanostructures with YBCO films and initial results will be presented.

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**2D-09** 4:30—4:40

### Pinning of the Vortex Lattice versus Current Blocking by Nano-Scale Columnar Inclusions in High- $T_c$ Films\*

**J. P. Rodriguez\*\***

*Department of Physics and Astronomy, California State University at Los Angeles, Los Angeles, CA USA*

The in-field critical current of a thin film of  $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$  (YBCO) can be enhanced considerably by the injection of nano-rod inclusions such as  $\text{BaZrO}_3$  (BZO) and  $\text{BaSnO}_3$  (BSO) aligned along the  $c$  axis. We report on the results of a linear elasticity analysis that yields that such nano-rod inclusions squeeze the YBCO matrix by pure shear due to an 8% lattice mismatch.<sup>1</sup> The sensitivity of the superconducting critical temperature in YBCO to pure shear strain implies that the phase boundary separating the nano-rod inclusion from the superconductor acts as a collective pinning center for the vortex lattice that appears in an external magnetic field; a dominant contribution to the in-field critical current can result. Recent measurements of the in-field critical current in thick films of YBCO + BSO nano-columns are consistent with this type of collective bulk pinning.<sup>2</sup> We

also find that the elastic energy of the YBCO + nano-rod inclusions can be weakly metastable as a function of the nano-rod density when the inclusions are softer than the matrix. This may well be what drives their epitaxial growth. Next, we revisit the standard calculation of the superconducting depairing current, but with insulating nanorod inclusions present. Study of the Ginzburg-Landau equations yields that it scales down linearly with the superconducting volume fraction in the limit that the coherence length is short compared to the diameter of the inclusions. A numerical solution of the Ginzburg-Landau equations finds a significantly larger reduction of the depairing current in the important regime where the diameter of the nanocolumn is comparable to the coherence length. These theoretical results are contrasted with similar reductions shown by the critical current of YBCO films in self-field as a function of the volume fraction of nano-rod inclusions.

<sup>1</sup>J.P. Rodriguez, P.N. Barnes, C.V. Varanasi, Phys. Rev. B 78, 052505 (2008).

<sup>2</sup>C. V. Varanasi, J. Burke, H. Wang, J. H. Lee, and P. N. Barnes, Appl. Phys. Lett. 93, 092501 (2008).

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*\*\*In collaboration with Paul N. Barnes and Chakrapani V. Varanasi, Air Force Research Laboratory at Wright-Patterson Air Force Base.*

## D2. Enhanced Coated Conductor Performance: Characterization

**2D-10** 4:40—4:50

### A Reconsideration of Edge-Barrier Pinning in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ Thin Films

***P. N. Barnes<sup>1</sup>, J. A. Connors<sup>1</sup>, R. L. Dunning<sup>1</sup>, M. J. Mullins<sup>1</sup>, T. J. Haugan<sup>1</sup>, J. R. Clem<sup>2</sup>***

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As improved pinning processes in thin films are made at various institutions, data are provided which are inevitably compared with each other. Most researchers account for the sample-thickness dependence when comparing the critical current density ( $J_c$ ) values reported from various institutions. Tahara et al. have previously indicated that in narrow bridges, edge-barrier effects might be increasing the measured  $J_c$  in sample films as the bridges became increasing smaller [1]. Zhao et al. subsequently claimed that the edge-barrier pinning did not play a role in bridges down to a micron width based on experimental results, even though their data also reflected increasing  $J_c$  as bridges were decreased from 10 to 2  $\mu\text{m}$  [2]. However, we provide theoretical calculations that suggest the edge-barrier pinning does play a substantial role in increasing  $J_c$  in  $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$  (YBCO) thin films. Experimental data will be presented in addition to the theoretical study for clarification of this issue. In this case, bridges were narrowed on the same sample to avoid sample to sample variation in the films. YBCO films  $\sim 300 \mu\text{m}$  thick were deposited by pulsed laser deposition on lanthanum aluminate substrates. A 500  $\mu\text{m}$  wide bridge was patterned on the sample using a photolithography process. After determining the critical current and resistivity of the films, the photolithography process was then repeated to further narrow the bridge to 200  $\mu\text{m}$ , 100  $\mu\text{m}$  and finally 50  $\mu\text{m}$ . The data by Zhao et al. will also be discussed in light of the new data. The enhancement of  $J_c$  can vary as a function of the applied field implying possible minor skewing of  $J_c(B)$  curves for a very narrow bridge.

[1] S. Tahara, S.M. Anlage, J. Halbritter, C.-B. Eom, D.K. Fork, T.H. Geballe, and M.R. Beasley, Phys. Rev. B **41**, 11203 (1989).

## NOTES

[2] Y.J. Zhao, W.K. Chu, D.K. Christen, E.C. Jones, M.F. Davis, J.C. Wolfe, S.C. Deshmukh, and D.J. Economou, *Appl. Phys. Lett.* **59**, 1129 (1991).

**2D-11** 4:50—5:00

### Thermal Fluctuations and the Limits to Vortex Pinning in Coated Conductors

**L. Civale**

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Based on present understanding, by engineering the appropriate vortex pinning landscape in a superconductor it should be possible to attain a critical current density  $J_c$  as large as the physical limit determined by the depairing current density  $J_0$ . However, after decades of large efforts and resources dedicated to pinning enhancement we are far below that limit. Presently, both the highest absolute values of  $J_c$  and the largest  $J_c/J_0$  ( $\sim 0.3$ ) are obtained for thin epitaxial  $\text{YBa}_2\text{Cu}_3\text{O}_7$  films. I will analyze what defects are effective vortex pinning centers in these films, and consider possible ways to increase  $J_c$  further. I will particularly focus on the influence of thermal fluctuations, which allow some vortex motion below  $J_c$ , resulting in a temporal decay of the supercurrents (flux creep) and consequently lower effective  $J_c$ . I will show that energy landscapes that combine several types of defects can reduce the detrimental flux creep effects.

*Work performed in collaboration with B. Maiorov, S.A. Baily, H. Zhou, T.G. Holesinger, I.O. Usov, M. Feldmann, S.R. Foltyn, Q.X. Jia, and P. Dowden.*

**2D-12** 5:00—5:10

### Angular Dependence of Critical Current in YBCO Coated Tapes

**A. Xu, Y. Viuchkov, J. Jaroszynski, and D. Larbalestier**

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It is now well established that YBCO can incorporate many different types of pinning centers with significant effect on the critical current. However, the angular anisotropy of the critical current density and the microscopic mechanisms behind it are still poorly understood in emerging YBCO coated conductors (CC). Here we present detailed measurements of the critical current in different YBCO CC fabricated by Super Power Inc. The measurements were performed in magnetic fields up to 31 T on short samples (length  $\sim 2$  cm, width  $\sim 1$  mm) at 4.2 K so as to be relevant for very high field magnet design. To make these measurements possible, we developed a high current (up to 500 A) rotator probe with angular resolution better than 1 degree. We studied tapes with dense nano-sized non-superconducting precipitates. Measurements performed in moderate magnetic fields showed nontrivial, and not fully understood, dependence of the critical current on field, temperature and angle. In particular, these pinning nanostructures strongly enhance critical current in the out-of-plane configuration with  $B \parallel c$ , and thus diminish the current anisotropy well below the effective mass anisotropy. However, at fields greater than  $\sim 15$  T these correlated pinning effects are washed out and the angular current anisotropy reaches a value of  $\sim 5$ . Importantly, a very sharp peak of the angular current dependence is observed around the in-plane configuration, with full-width half-maximum as small as  $\sim 14$  degrees. Our results lead to a better understanding of the pinning mechanism in YBCO CC. Angular characterization of the critical density provides data to optimize the design of superconducting magnets made of YBCO CC and discriminate whether it is the parallel field critical current that limits the highest field possible in the magnet, or if it is limited by the field at the ends of the coil where the field vector is far from the plane of the CC.

**2D-13** 5:10—5:20**Characterization and Analysis of Coated Conductors: Toward Improved Performance*****D. K. Christen, J. R. Thompson, Y. L. Zuev, S-H. Wee, A. Goyal****Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA*

With significant advances in the processing of 2G HTS coatings for the achievement of strong-pinning defects structures, it is important to adequately assess and relate the superconducting properties of prototype materials to the potential applications needs, and to provide feedback for optimization and tailoring of specific properties. Of particular interest are the characteristics and understanding of anisotropic flux pinning provided by self-assembled extended defects, when coupled with the intrinsic electronic anisotropy of RBCO cuprates. Recently, we have found that these competing effects can lead to near-isotropic critical currents under specific operational parameters. A model that adequately describes the phenomenon may provide insight into means to fine-tune the material properties for nearly isotropic performance characteristics at an interval of preferred field and temperature.

Because of practical difficulties in measuring transport properties of short prototype samples at lower temperatures and electric field levels, a new component of the work involves methodologies for characterization at previously inaccessible field, temperature, and dissipative regimes. These techniques include contactless dc magnetometry that determine orientation-dependent critical currents, and can also be extended to electric field levels that are several orders-of-magnitude lower than in transport, more commensurate with the very low dissipation levels required for coil-based devices such as motors, generators, air-gap transformers, SMES, etc. Results will be discussed in the context of providing pathways for further improvement of 2G performance.

**2D-14** 5:20—5:30**Nondestructive Characterization of Critical Current Distribution Across the Width of Coated Conductor Tapes*****K. Nakao, T. Machi, S. Adachi, K. Tanabe****Superconductivity Research Laboratory, ISEC, 10-13. Shinonome 1-chome, Koto-ku, Tokyo 135-0062, Japan*

The technology for producing long coated conductors has made a remarkable progress recently and its practical application is the next target. For the ac applications, superconductors must be thin enough to reduce the ac loss. The natural solution is the multi-filamentary structure realized by slicing or scribing wide tapes. Although the current-carrying capacity of many coated conductors with a width of 5-10 mm is enough for many applications as a whole, the homogeneity within the tape is not always perfect in many cases. If there is a substantial inhomogeneity in the critical current value across the width of the tape, slicing or scribing it into filaments may seriously degrade the final performance of the multi-filamentary conductor. Therefore, a technique is desirable for an efficient and nondestructive characterization of the critical current distribution across the width.

In the present work, we propose a simple procedure to characterize the homogeneity across the width based on a Hall sensor array measurement. In our scheme, the distribution of the critical current density is assumed to be expressed as a parabolic function of the lateral coordinate. The function has three parameters,  $j_c$ ,  $s$  and  $p$ , which represent the total critical current, the slope and the parabolicity, respectively. These parameters are deduced in the spirit of the least square fitting based on the data from the Hall sensor array measurement using a commercial system (Tapestar,

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Theva). Once the distributions of these parameters along the length are known, the current carrying capacity after the slicing or scribing treatment can be predicted within the parabolic approximation.

*This work was supported by the New Energy and Industrial Technology Development Organization (NEDO).*

**2D-15** 5:30—5:40

### Characterization of Coated Conductors Using Raman Spectroscopy Methods

**V. A. Maroni**

*Argonne National Laboratory, 9700 South Cass Ave., Argonne, IL 60439 USA*

This presentation will address the type of information gained from the use of Raman spectroscopy and Raman microscopy methods to examine REBCO coated conductor embodiments. The topics covered will include (1) the capabilities and limitations of Raman spectroscopy in providing guidance for coated conductor performance enhancement, (2) the potential applicability of Raman methods for use as ex-situ and in-situ probes of phase and microstructure development (considering both off-line and on-line implementation), (3) the features, details, differences, and length scales for which Raman is both suitable and informative for interrogating REBCO, (4) the extent to which Raman can be used to characterize other layers, such as buffers, diffusion barriers, and templates, and (5) information on the idiosyncrasies and limitations of Raman methods for the study of coated conductor embodiments based in large part on the presenters experience. The methodology for proper application of Raman spectroscopy, microscopy, and imaging techniques will also be addressed, including considerations pertaining to sampling depth, through-thickness measurement approaches, the creation of Raman-based chemical maps, and the interpretation of Raman spectral data. Features readily detected by Raman that are not generally observable in a collective manner using other individual characterization tools include oxygen stoichiometry of the REBCO phase, REBCO texture quality, the occurrence and approximate magnitude of lattice atom disorder in the REBCO, and the presence of typical non-superconducting second phases, such as CuO, Cu<sub>2</sub>O, Y<sub>2</sub>Cu<sub>2</sub>O<sub>5</sub>, and the various barium cuprates. Examples of Raman-based through-process tracking of phase transformations during precursor conversion to REBCO will also be presented and discussed.

*This research was sponsored by the U.S. Department of Energy (DOE), Office of Electricity Delivery and Energy Reliability, as part of a DOE program to develop electric power technology, under contract DEAC02-06CH11357 between UChicago, Argonne, LLC and the DOE.*

**2D-16** 5:40—5:50

### Raman Scattering Spectroscopy and Phase Stability of Rare-Earth Based Cuprate Thin Films for Coated Conductor Applications

**G. Kim<sup>1</sup>, W. Jo<sup>1</sup>, G. M. Shin<sup>2</sup>, and S. I. Yoo<sup>2</sup>**

*<sup>1</sup>Department of Physics, Ewha Womans University, Seoul 120-750, Korea; <sup>2</sup>School of Materials Science and Engineering, Seoul National University, Seoul 151-742, Korea*

We analyzed Gd<sub>1+x</sub>Ba<sub>2-x</sub>Cu<sub>3</sub>O<sub>7</sub> (GdBCO) thin films by using Raman scattering spectroscopy. Highly oriented GdBCO films were deposited on ion beam assisted deposition MgO templates by pulsed laser deposition. We used thin LaMnO<sub>3</sub> buffer layers between MgO layers and superconducting GdBCO films by pulsed laser deposition. X-ray diffraction studies show highly oriented c-axis

in-plane orientation as well as out-of plane textures less than 7 degree. Polarization dependent Raman scattering spectroscopy shows that the GdBCO film contains preferentially c-axis oriented grains and little cation disorder between  $Gd^{3+}$  ions and  $Ba^{2+}$  sites, which is very different from the case of Nd-based cuprates. Growth temperature and oxygen partial pressure of the GdBCO films is carefully compared with the known phase stability lines. The stoichiometric and well-ordered GdBCO films exhibit a high critical current ( $I_c$ ) of 90 ~ 100 Acm at 77 K and self-field. From the Raman spectra, the O(2)-O(3) vibration and the O(4) vibration were found at 328 and 448  $cm^{-1}$ , respectively. In particular, apical oxygen is well characterized around 500 ~ 505  $cm^{-1}$ , which is known to be important for high  $T_c$  and  $J_c$  in rare-earth based cuprates. We could not observe any Ba-Cu oxide peaks, indicating that our process conditions are not liquid-based, which is a possible route to increase growth rates.

*This work has been supported by the “Center for Applied Superconductivity Technology” under “21st Century Frontier R&D Programs” of the Ministry of Science and Technology.*

**2D-17** 5:50—6:00

### **Radiation Effects on Coated Conductors**

***H. W. Weber, R. Fuger, M. Chudy, M. Eisterer and M. Zehetmayer***

*Vienna University of Technology, Atomic Institute, Stadionallee 2, 1020 Wien, Austria*

In view of the “fast track scenario” for the design and construction of DEMO partly in parallel to ITER, the option of employing high temperature superconductors and operating the high field toroidal magnets in the liquid nitrogen temperature range is presently under serious consideration. We will report on a study of some currently available industrial conductors, which were analyzed with respect to their current carrying capability in the temperature and field range of relevance to DEMO, issues of conductor homogeneity over the long lengths required for this purpose, their response to the expected fast neutron fluence as well as issues of critical current anisotropy. We will show that this application target is not out of reach, but that substantial research and development programs will be needed to achieve it.

**2D-18** 6:00—6:30

### **Open Discussion led by Moderator**

**6:30–8:00 PM**

**BANQUET**

*Shamrock Hilton Ballroom 261*

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**8:00—9:30 PM****SESSION E: Invited Posters on Innovative Ideas and Achievements***S. Wing, 1st Floor Lobby – S104**(Post-Banquet Coffee and Desserts will be served)**Chair/Moderator: **Vic Maroni** (Argonne National Laboratory)***2E-01****Direct Growth of LaMnO Cap Layers on IBAD-MgO (without homo-epi MgO) Template for YBCO Coated Conductors****T. Aytug***Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA*

Simplification of the IBAD buffer architecture is one of the key issues for reduced manufacturing and labor costs of second generation superconducting wire production. Structural and chemical compatibility of LaMnO (LMO) buffer layers on homo-epi MgO in IBAD (MgO)-based architectures and the growth of high current density YBCO films on these LMO templates are well established. In this work, we studied various *rf*-magnetron sputter growth parameters/conditions for epitaxial growth of LMO layers *directly* on IBAD(MgO) without the need of the homo-epi MgO layers. LMO thicknesses ranged from 30 - 240 nm. The performance of the LMO/IBAD (MgO) samples was qualified by depositing 1  $\mu\text{m}$ -thick YBCO coatings by pulsed laser deposition. Detailed XRD, SEM, AFM, and transport measurements were done. Results showed that while the growth temperature has a substantial effect on the texture of LMO and hence on the  $J_c$  values of YBCO, neither LMO thickness nor different sputter gas ambients had a significant effect on the performance of YBCO films. In addition, surface roughness of LMO layers on IBAD (MgO) is found to be similar to that of LMO deposited on homo-epi MgO layers. The results underscore the strong potential of LMO as a single cap layer directly on IBAD (MgO) for the development of a simplified IBAD architecture.

*Research sponsored by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, Superconductivity Program for Electric Power Systems.*

**2E-02****Development of Conductive Buffer Architectures Based on IBAD-TiN****R. Hühne***IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany*

Ion Beam Assisted Deposition (IBAD) offers the possibility to prepare thin textured films on amorphous or non-textured substrates. It was shown within the last decade that cube textured MgO and TiN layers with a thickness of less than 10 nm can be produced on amorphous or nanocrystalline seed layers using this technique. In particular, the results corresponding to the in-plane textured growth of TiN are promising for the development of a conducting buffer layer architecture for YBCO coated conductors based on the IBAD approach. Accordingly, cube textured IBAD-TiN layers have been deposited reactively using pulsed laser deposition on polished Hastelloy tapes. An amorphous conducting  $\text{Ta}_x\text{Ni}_{1-x}$  seed layer was tested successfully for the IBAD-process leading to highly textured TiN films with an in-plane orientation below  $10^\circ$ . Different metallic buffer layers such as Au, Pt or Ir were grown epitaxially on top of the TiN layer showing texture values similar to the IBAD layer. Smooth layers were obtained on technical substrates using IBAD-

TiN with a double layer of Au/Pt or Au/Ir. Finally, biaxially textured YBCO layers were achieved using Nb-doped SrTiO<sub>3</sub> as a conductive oxide cap layer showing an in-plane alignment of about 7° and a resistively measured superconducting transition at about 88 K.

## 2E-03

### Rapid Fabrication of IBAD-MgO and LaMnO<sub>3</sub> Layers for REBCO Coated Conductor

**H. Fukushima<sup>1</sup>, M. Yoshizumi<sup>1</sup>, S. Miyata<sup>1</sup>, R. Kuriki<sup>1</sup>, A. Ibi<sup>1</sup>, Y. Yamada<sup>1</sup>, T. Izumi<sup>1</sup>, Y. Shiohara<sup>1</sup>, T. Kato<sup>2</sup> and T. Hirayama<sup>2</sup>**

<sup>1</sup>ISTEC-SRL; Shinonome 1-10-13, Koto-ku, Tokyo, Japan, 135-0062; <sup>2</sup>Japan Fine Ceramic Center; Mutsuno 2-4-1, Atsuta-ku, Nagoya, Japan, 456-8587

Highly textured development of CeO<sub>2</sub> by PLD method was found in Ion-Beam-Assisted Deposition (IBAD)-MgO substrate. The in-plane alignment was improved from 15 degrees in the MgO layer to 3.7 degrees in CeO<sub>2</sub>. Insertion of a thin LaMnO<sub>3</sub> (LMO) layer between IBAD-MgO and CeO<sub>2</sub> layers was indispensable to this phenomena (we call Self-Epitaxy of CeO<sub>2</sub>). The LMO layer is deposited by RF sputtering. It is considered to relax the large misfit between lattice constants of MgO and CeO<sub>2</sub>. Without the LMO layer, the in-plane alignment of CeO<sub>2</sub> layers was hardly improved. LMO deposition realized a production rate of 30 m/h in the small deposition area (6x13cm<sup>2</sup>). Using the self-epitaxy, we developed new architecture of buffer layers of textured substrate, CeO<sub>2</sub>/LMO/IBAD-MgO/Gd-Zr-O/Hastelloy. Using the new substrate with the self-epitaxy, the GdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$</sub>  (GdBCO) layer was deposited by the PLD method and high critical current of 500 to 600 A at 77K and self-field was obtained for short samples. We also developed a reel-to-reel deposition system with DC reactive sputtering for MgO deposition for long textured substrate fabrication. This system achieved a high production rate of 150 m/h and high I<sub>c</sub> over 200 A at 77 K in self-field. The high texturing degree and high production rate in this system were promising for low-cost coated conductor processing. Recently, the production rate of the LMO layer was further increased to 50 m/h using the above-mentioned small deposition area. We report the details of rapid fabrication of IBAD-MgO and LMO layers.

*This work was supported by New Energy and Industrial Technology Development Organization (NEDO) as the Project for Development of Materials & Power Application of Coated Conductors, M-PACC.*

## 2E-04

### Development of Long SmBCO/IBAD-MgO Coated Conductor

**H.-S. Ha<sup>1</sup>, R.-K. Ko<sup>1</sup>, S.-S. Oh<sup>1</sup>, C. Park<sup>2</sup>, S.-I. Yoo<sup>2</sup>, D.-J. Youm<sup>3</sup>, S.-H. Moon<sup>4</sup>**

<sup>1</sup>Korea Electrotechnology Research Institute, 70 Bulmosangil, Changwon 641-120, Korea; <sup>2</sup>Dept. of Materials Science & Engineering, Seoul National University, Seoul, Korea; <sup>3</sup>KAIST, Daejeon, Korea; <sup>4</sup>SuNam Co Ltd., Anyang, Korea

Thermal co-evaporation method is one of the candidates to develop high quality coated conductors (CCs) with low-cost that has benefits to deposit wide area uniformly and use cheaper thermal evaporation sources and raw materials. Good CCs have been usually made by using the Ion Beam Assisted Deposition (IBAD) template. In this study, we have used IBAD-MgO process to fabricate the biaxially textured template for CCs and co-evaporation method to deposit Sm<sub>1</sub>Ba<sub>2</sub>Cu<sub>3</sub>O<sub>y</sub> (SmBCO) superconducting layer on IBAD-MgO template. The batch type co-deposition system was specially designed and was named EDDC (evaporation using drum in dual chamber) that is possible to deposit superconducting layer with optimum composition ratio of materials at temperature over 700 °C and several mTorr of oxygen. Recently, the EDDC system was modified to improve the deposition

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rate, reproducibility of composition ratio and deposition conditions of the superconducting layer. We have investigated the influence of SmBCO thickness and deposition rate on the critical current density of CCs. Rotation speed and evaporation rates were increased to acquire higher growth rate over 3 $\mu$ m/h to make 100m long coated conductor. After deposition of 100m long CCs, critical current was measured using R2R hall probe measurement system and R2R transport  $I_c$  measurement system.

**2E-05****Improvement of Production Rate by Modified TFA-MOD Starting Solution**

***H. Ichikawa, K. Nakaoka, H. Hirano, M. Miura, Y. Sutoh, T. Ito, Y. Takahashi, H. Tobita, M. Yoshizumi, T. Izumi, Y. Yamada, Y. Shiohara***

*Superconductivity Research Laboratory, ISTEK, 1-10-13, Shinonome, Koto-Ku, Tokyo, 135-0062 Japan*

Long YBCO coated conductors with high  $I_c$  values over 200A/cm-width have been fabricated by the advanced metal organic deposition using the trifluoroacetates (TFA-MOD) process. Concerning the future mass-production stage, a high production rate is definitely required, which also leads to low cost.

In the TFA-MOD process, there are two steps; coating / calcination and crystallization steps. In our previous work, when the coated films were calcined at a high heating rate, which is necessary for a high production rate, the film quality was degraded and the  $I_c$  values became low. It was found that the degradation is caused by the high out-gas rate of HF from the coated films in the calcination step. In the worse cases, the gases were bubbled and a part of films disappeared. Based on the understandings, a new solution including F-free salt of Y was developed. The damages, such as bubbling, could not be recognized in the films after calcination using the new solution at a high heating rate. However, the films which revealed high  $J_c$  values of about 1.5MA/cm<sup>2</sup> are limited under the conditions only at lower heating rates than 2°C/min in the crystallization step. Then, the heat-treatment conditions in the calcination step, including the heating time and the maximum temperature, have been well investigated and controlled to realize a high heating rate in the crystallization step with high  $I_c$  values.

Through the investigation, it was found that the increment of the maximum temperature in the calcination step could improve the critical heating rate in the crystallization for the high superconducting properties. As a result, high  $J_c$  values of 1.4MA/cm<sup>2</sup> was confirmed in the film heat-treated for the crystallization with the high heating rate of 70°C/min.

*This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) as the project of Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications, and the project of Development of Materials & Power Applications of Coated Conductors, (M-PACC).*

**2E-06****Enhanced Flux Pinning by BaZrO<sub>3</sub> Doping in Fluorine-Free Metal-Organic Deposited YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> Films on Buffered RABiTS Substrates****F. Lu, F. Kametani, D. C. Larbalestier and E. E. Hellstrom***Applied Superconductivity Center, National High Magnetic Field Laboratory, Tallahassee, FL 32310 USA*

In this study, both pure and BaZrO<sub>3</sub> (BZO)-doped YBCO (YBCO + x BZO) films were fabricated on buffered RABiTS from AMSC by a fluorine-free metal organic deposition (MOD) process. In this work, we have succeeded in introducing nanoscale BaZrO<sub>3</sub> particles into YBCO by adding extra Ba and Zr organic salts. We were able to use multi-coating process to obtain highly-textured thick (up to ~ 1.1 μm) films of both pure and BaZrO<sub>3</sub> (up to x = 0.15) doped content. SEM images showed mainly c-axis oriented grains and dense structures. The in-field critical current density is enhanced for BaZrO<sub>3</sub>-doped samples though the self field critical current density at 77K is slightly lower than pure YBCO. Consequently, the pinning force density in all BaZrO<sub>3</sub>-doped YBCO samples is enhanced. The optimal BaZrO<sub>3</sub> doping content investigated in this work is x = 0.07 – 0.10. Maximum pinning force density exceeding 5.5 GN/m<sup>3</sup> is obtained in ~ 0.8 μm YBCO + 0.07 BZO film. The angular dependence of in-field critical current density measurements shows the critical current density anisotropy is strongly reduced by BaZrO<sub>3</sub> doping at 1 T and 4 T, and the critical current density is enhanced over a wide angular range compared to pure YBCO. This indicates that fluorine-free MOD with chemical doping is a promising fabrication technique to create high pinning in YBCO coated conductors.

*This work was supported by DOE-OETD.*

**2E-07****BaZrO<sub>3</sub> Nanorod Realignment in YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-x</sub> Thin Films by Surface Modulation Using Vicinal SrTiO<sub>3</sub> Substrates****F. J. Baca<sup>1</sup>, T. J. Haugan<sup>1</sup>, J. N. Reichart<sup>1</sup>, P. N. Barnes<sup>1</sup>, R. L. Emergo<sup>2</sup>, and J. Z. Wu<sup>2</sup>**

<sup>1</sup>Air Force Research Laboratories, Propulsion Directorate, 1950 Fifth St., WPAFB, OH 45433; <sup>2</sup>University of Kansas, Department of Physics and Astronomy, 1251 Wescoe Hall Dr., Lawrence, KS, 66045 USA

The self-assembled columnar defects formed by BaZrO<sub>3</sub> and BaSnO<sub>3</sub> nanorods in YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-x</sub> thin films provide effective vortex pinning, especially for magnetic fields aligned along the c-axis. However, to improve vortex pinning for other field orientations, it is desirable to control the defect orientation. Using transmission electron microscopy, we show that by increasing the vicinal angle of miscut SrTiO<sub>3</sub> substrates, the microstructural effect on BaZrO<sub>3</sub>-doped YBCO films becomes increasingly pronounced. We show that planar defects become more prominent up to a 10° vicinal angle, while at 20° the BaZrO<sub>3</sub> nanorods undergo a drastic reorientation and become aligned parallel to the YBCO a-b planes. The angular dependence of the in-field critical current density, J<sub>c</sub>(H,θ), confirms that as the vicinal angle is increased, the vortex pinning along the c-axis is reduced, while it is increased slightly along the a-b direction. Since the alignment of microstructural dislocations is considered to play a significant role in the formation of nanocolumnar defects, these results may indicate that the miscut angle strongly influences the occurrence of such dislocations, and hence, the direction of the BaZrO<sub>3</sub> nanorod alignment when a critical angle is exceeded.

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**2E-08****Magnetic Pinning in YBCO**

***S. C. Wimbush, J. H. Durrell, M. G. Blamire, R. B. Dinner, S. L. Sahonta, S. A. Harrington, R. Bali and J. L. MacManus-Driscoll***

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The practical introduction of effective flux pinning sites into high-temperature superconductors is of paramount importance for their eventual widespread application. The search for suitable processes for the generation of nanoscale defects to act as core pinning sites in the superconductor matrix has been extensive and highly fruitful, yielding improvements in the critical current density under specific experimental conditions approaching an order of magnitude. At the same time, many fundamental experiments have been performed on the formation of magnetic pinning sites in both low and high temperature superconductors, and their influence on the vortex lattice. However, to date no practical and effective approach to the formation of magnetic pinning centres for critical current enhancement in the high-temperature materials has been proposed.

We demonstrate the successful incorporation of nanoscale ferromagnetic pinning centres within YBCO thin films. For sufficiently low dopant concentrations, the suppression of transition temperature due to poisoning of the YBCO is overcome. Even at these low dopant levels, the resultant films exhibit a coexistence of superconductivity and ferromagnetism, and a consequent absolute enhancement of the critical current density up to a factor two under all applied fields and field orientations, including self field. The nature of the pinning is investigated, and a theoretical framework for the observed behaviour postulated. The potential for future development is outlined and discussed.

**2E-09****Angular Dependence of YBCO Coated Conductors at Low Temperature**

***A. Xu<sup>1</sup>, J. Jaroszynski<sup>1</sup>, F. Kametani<sup>1</sup>, Z. Chen<sup>1</sup>, F. Lu<sup>1</sup>, D. Larbalestier<sup>1</sup>, Y. Chen<sup>2</sup>, Y.-Y. Xie<sup>2</sup>, V. Selvamanickam<sup>2</sup>***

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To clarify the pinning mechanism of YBCO coated conductors at very high field and low temperature, we investigated the angular dependence of BZO-doped YBCO coated conductors at fields up to 30T at liquid helium temperature. The samples were grown by the metal organic chemical vapor deposition (MOCVD) method on very strong Hastelloy substrate. The results showed that the c-axis correlated peak of BZO-doped YBCO sample disappeared with the increase of field and was quite absent in fields of 15 T or more. At very high fields where the vortex density is greater than the density of pinning centers, the angular dependence of  $J_c$  shows a cusp-like peak which is inconsistent with the Ginzburg-Landau mass anisotropy scaling rule.

**2E-10****Microstructural Study of Strong Vortex Pinning in a Coated Conductor for Use in Specific Fields and Temperatures****F. Kametani<sup>1</sup>, Z. Chen<sup>1</sup>, D. Larbalestier<sup>1</sup>, Y. Chen<sup>2</sup>, Y.-Y. Xie<sup>2</sup> and V. Selvamanickam<sup>2</sup>**<sup>1</sup>Applied Superconductivity Center, National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL32301;<sup>2</sup>SuperPower Inc. Schenectady, NY 12304 USA

It is still unclear what type, size, shape and distribution of defects and nano particles in a coated conductor are optimum for specific temperatures and fields. Cross-sectional transmission electron microscope has been performed to study the microstructure of the YBCO films and coated conductors (CCs) with defects and nano particles in a different size, shape and distribution and its correlation of vortex pinning at various temperature and fields. The MOCVD CC we examined contains dense ab-plane stacking faults and three-dimensional  $Y_2O_3$  nanoprecipitates, which are ~12 nm wide and ~6 nm thick and with ~20 nm spacing perpendicular to the film surface. We also made PLD YBCO films containing  $Y_2O_3$  nanoprecipitates of smaller size and spacing. Although the volume fraction of  $Y_2O_3$  is comparable (~12-15%), the MOCVD CC shows higher  $H_{irr}$  at 77 K, indicating stronger resistance to thermal fluctuations at high fields. However, deconvolution of the strong and weak pinning components of the pinning derived from analysis of the  $J_c$ -T curves over a wide range of H and T using the Barcelona group approach indicates a crossover at lower temperatures where the PLD film with smaller nanoprecipitates shows stronger pinning. We are attempting to incorporate thermal fluctuation effects into our description of the optimum pinning nanostructures.

**2E-11 - WITHDRAWN****Properties of  $SmBa_2Cu_3O_{7-\delta}$  Thin Film with Oxide Impurities Grown by the Co-Evaporation Method****J. Yoo<sup>1\*</sup>, K. Kwak<sup>1</sup>, S.-M. Lee<sup>1</sup>, Y.-H. Jung<sup>1</sup>, J. Rhee<sup>1</sup>, K.-W. Han<sup>1</sup>, D. Nguyen<sup>1</sup>, D. Youm<sup>1</sup>, H. Kim<sup>2</sup>, H. Ha<sup>2</sup>, S.-S. Oh<sup>2</sup>, and S. Oh<sup>3</sup>**<sup>1</sup>Department of Physics, KAIST, 305-701 Daejeon, Republic of Korea; <sup>2</sup>Superconducting Materials Research Group, KERI, 28-1,Seongju-dong, Changwon, 641-120, Republic of Korea; <sup>3</sup>Material Research, National Fusion Research Center, Daejeon, 305-380,

Republic of Korea

Approximately 200 nm thick SmBCO films with oxide impurities were grown on  $LaAlO_3$  substrates by the coevaporation method. For the formation of the oxide impurities, the metal sources such as Sn and Zr were coevaporated with oxygen reaction or  $SnO_2$  powder was sublimated during the growth of SmBCO film. In the case of Sn impurity evaporation, the superconducting transition was observed until Sn concentration in the film was increased up to a few %. As the Sn concentration was increased further, the resistance-temperature curve revealed semiconducting phase, which was due to formation of  $SnO_2$  instead of  $BaSnO_3$ . The angle and field dependence of the critical current of the SmBCO films were investigated for various concentrations of the oxide impurities.

## NOTES

**2E-12****Hysteresis Loss in  $\text{Sm}_1\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$  Coated Conductor with Applied Magnetic Field and Current Varied in Out-of Phase*****J. Yoo<sup>1\*</sup>, S.-M. Lee<sup>1</sup>, Y.-H. Jung<sup>1</sup>, K. Kwak<sup>1</sup>, J. Rhee<sup>1</sup>, K.-W. Han<sup>1</sup>, D. Nguyen<sup>1</sup>, D. Youm<sup>1</sup>, H. Kim<sup>2</sup>, H.-S. Ha<sup>2</sup>, S.-S. Oh<sup>2</sup>****<sup>1</sup>Department of Physics, KAIST, 305-701 Daejeon, Republic of Korea; <sup>2</sup>Superconducting Materials Research Group, KERI, 28-1, Seongju-dong, Changwon, 641-120, Republic of Korea*

The hysteresis loss in a  $\text{Sm}_1\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$  coated conductor was estimated from magnetic field profiles measured by the scanning Hall probe method. Applied magnetic field ( $B_a$ ) and current ( $I_a$ ) were varied in a manner of out-of phase. The field profile data were measured while  $I_a$  were decreased stepwise from  $I_{peak}$  to  $-I_{peak}$ , and  $B_a$  was varied simultaneously from  $B_{peak}$  to  $-B_{peak}$  with  $90^\circ$  phase difference with respect to  $I_a$ . The phase difference between  $B_a$  and  $I_a$  was kept constant during variation of  $B_a$  and  $I_a$  for this study. For maximum values of  $B_{peak}$  and  $I_{peak}$ , two load lines were selected with values of  $\alpha I_a / B_a$  fixed; one was  $I_{peak} / B_{peak} = 80 \text{ A} / 200 \text{ mT}$  and the other was  $I_{peak} / B_{peak} = 120 \text{ A} / 60 \text{ mT}$ . From the measured values of magnetic field profiles, the current profiles were calculated by the iterative inversion method. From the current profiles, the flux density profiles and the hysteresis loss,  $Q$ , were then calculated for various values of  $I_{peak}$  ( $= \alpha B_{peak}$ ) in each load line. The results were compared with theoretical calculations based on Brandt's model.

**2E-13****In Field Low Temperature Laser Scanning Study of Artificial Defects on IBAD YBCO Coated Conductor*****P. Li<sup>1</sup>, D. Abramov<sup>1</sup>, D. Larbalestier<sup>1</sup>, Y.-Y. Xie<sup>2</sup>, Y. Chen<sup>2</sup>, V. Selvamanickam<sup>2</sup>****<sup>1</sup>Applied Superconductivity Center, National High Magnetic Field Laboratory, 2031 East Paul Dirac Drive, Tallahassee, FL 32310 USA; <sup>2</sup>SuperPower, Inc., 450 Duane Ave., Schenectady, NY 12304 USA*

Many types of commercial YBCO coated conductors (CC) have obstacles obstructing current flow, especially grain boundaries (GBs) with  $3\sim 10^\circ$  misorientation angles which partially block current and force percolative current flow around obstacles. Application of YBCO coated conductors requires understanding of the local dissipation caused by these grain boundaries. By using precisely controlled Focused Ion Beam, artificial obstructions were patterned on a quasi-single crystal-like IBAD-MOCVD YBCO CC sample to simulate real GBs. We used Low Temperature Laser Scanning Microscopy (LTLMS) to map the local electric field distribution on these samples and found the dissipation maps to depend on the orientation of external magnetic field with respect to the artificial GBs. Strong local dissipation was caused around artificial GBs by preferential flux penetration when GBs and the field were parallel. We also found dissipation became more non-uniform under Lorentz force-free (longitudinal magnetic field) configuration.

**2E-14****Vortex Diode Effect in Pinning Enhanced Thin Films*****J. H. Durrell<sup>1</sup>, S. A. Harrington<sup>1</sup>, H. Wang<sup>2</sup>, J. L. MacManus-Driscoll<sup>1</sup>****<sup>1</sup>Department of Materials Science and Metallurgy, University of Cambridge, Pembroke Street, CAMBRIDGE, CB2 3QZ, UK; <sup>2</sup>Dept. of Electrical and Computer Engineering, Texas A & M University, College Station, TX 77843 USA*

As an anisotropic material YBCO exhibits a distinct maximum for a critical current applied in-plane, which is often referred to as the "intrinsic pinning peak". This is due to both the layered structure, with this effect being more pronounced at lower temperatures, and to the mass anisotropy of the charge carriers the contribution of which is described by a scaling law. For in-plane fields in highly

geometrically anisotropic thin films this orientation also corresponds to that of maximum surface pinning. In vicinal YBCO thin films where the in-plane and surface parallel configurations are different surface pinning has been shown to be non-negligible. We have found that in YBCO thin films with rare earth tantalate dopants added to enhance pinning the magnitude of the intrinsic peak can be strongly controlled by the direction of the Lorentz force. We find that by reversing field or current direction a variation in  $J_c$  of over 10% can be observed at 77 K and 0.25 T. We explain this observation in terms of the microstructure of the films and the effect of the microstructure on surface pinning. We observe that such a thin film is, in effect, an inverse diode where voltage is zero up to a certain current, which depends on the current direction. In a conventional diode it is current that is zero up to a certain voltage, which depends on the polarity. There is potential to exploit this technique to make coated conductors with current direction sensitive critical current properties.

## 2E-15

### Critical Current Densities of Isolated Grains and Grain Boundaries in Coated Conductors

**M. Weigand<sup>1</sup>, J. H. Durrell<sup>1</sup>, N. A. Rutter<sup>1</sup>, S. Speller<sup>2</sup>, G. M. Hughes<sup>2</sup>, C. Grovenor<sup>2</sup>**

<sup>1</sup>Dept. of Materials Science and Metallurgy, University of Cambridge, Pembroke St, Cambridge CB2 3QZ, U.K.; <sup>2</sup>Dept. of Materials, University of Oxford, Parks Road, Oxford OX1 3PH, U.K.

In cuprate superconductors the critical current density  $J_c$  across grain boundaries (GBs) shows an exponential decrease with misorientation angle between the adjacent grains. Coated conductors (2nd generation high temperature superconductors) overcome this detrimental effect by epitaxial growth of the superconducting layer on a strongly textured substrate and buffer, thus offering a significantly higher critical current density compared to tapes of the 1st generation. As a consequence, in certain magnetic field and temperature ranges the grains, rather than the grain boundaries, limit  $J_c$ . The best method to ascertain what governs  $J_c$  is the electromagnetic characterisation of grains and grain boundaries isolated in coated conductor samples.

We have used Electron Backscatter Diffraction (EBSD) and a Focused Ion Beam microscope (FIB) to achieve this goal. This technique allowed us to isolate single grains and GBs on coated conductors manufactured by RABiTS (Rolling Assisted Bi-axially Textured Substrates). Our approach offers higher resolution and enables us to target specific areas of the samples more precisely. Consequently, unlike photolithographic techniques such as the one developed by Feldmann et al., it can be extended to systems with smaller grain sizes, down to about 1  $\mu\text{m}$ .

Critical current densities were obtained by a four-point measurement for magnetic fields applied both perpendicular to the film surface ( $H||c$ ) and swept in-plane ( $H||ab$ ). A single GB of the RABiTS conductor showed a hysteretic dependence of  $J_c$  on field for  $H||c$ , due to flux trapped in the grains. For fields in-plane the critical current density was limited either by the grains or the GBs, depending on the angle between applied field and macroscopic current direction. We explain this result by the advantageous properties of meandering GBs, as are found in samples produced by chemical routes. Our findings should allow manufacturers to assess how growth parameters affect properties of grains and grain boundaries, enabling them to optimise their production processes to obtain higher critical currents.

## NOTES

**2E-16****Thickness Dependence of Critical Current Density in Thick MgB<sub>2</sub> Films*****M. Hanna<sup>1</sup>, S. Wang<sup>2,3</sup>, J. M. Redwing<sup>3</sup>, X. X. Xi<sup>2,3</sup> and K. Salama<sup>1</sup>****<sup>1</sup>Department of Mechanical Engineering and Texas Center for Superconductivity, University of Houston, Houston, TX 77204, USA; <sup>2</sup>Department of Physics, The Pennsylvania State University, University Park, PA 16801, USA; <sup>3</sup>Department of Materials Science and Engineering, The Pennsylvania State University, University Park, PA 16801, USA*

Coated conductors have been the focus of study of scientists and researchers for the past two decades since the discovery of YBCO in 1987 at the University of Houston. For coated-conductor applications, it is necessary to deposit thick films in order to maximize the critical current in the wire or tape and enhance the engineering critical current density. However, the main obstacle to higher current in thicker films is that the critical current density ( $J_c$ ) in the superconductor drops dramatically as the coating thickness is increased. This limitation was first observed over 18 years ago in YBCO coated-conductors, yet only recently it became one of the most important remaining challenges in the coated conductors field as they are approaching the commercialization stage. As MgB<sub>2</sub> coated conductors started hitting the road since the discovery of superconductivity in MgB<sub>2</sub> in 2001, a study on  $J_c$  thickness dependence in MgB<sub>2</sub> films is deemed to be necessary.

MgB<sub>2</sub> coated conductors have many potential applications and are processed by many different techniques. The most common two are the hybrid physical-chemical vapor deposition (HPCVD) and the ex-situ high temperature annealing of Boron films in Mg vapor. We succeeded in fabricating high quality MgB<sub>2</sub> films that carry high  $J_c$  using the ex-situ annealing fabrication technique, and we examined the  $J_c$  behavior as a function of thickness in MgB<sub>2</sub> films. The study shows that critical current density in MgB<sub>2</sub> films decreases with increasing film thickness, similar to that observed in YBCO coated conductors, which is probably due to impurity diffusion during annealing and microstructural degradation for thicker films. The high  $J_c$  values carried by our films show that the ex-situ fabrication method can produce high quality MgB<sub>2</sub> films at low processing temperature, which is promising for resonance frequency cavity applications and coated-conductor wires and tapes.

**2E-17****Stress States and Electromechanical Behavior of YBCO Coated Conductor under Combined Tension and Torsion*****G. Majkic<sup>1</sup>, R. J. Mensah<sup>1</sup>, V. Selvamanickam<sup>1,2</sup>, Y.-Y. Xie<sup>2</sup> and K. Salama<sup>1</sup>****<sup>1</sup>Texas Center for Superconductivity, University of Houston, Houston, TX; <sup>2</sup>SuperPower Inc., Schenectady, NY USA*

For many coated conductor applications, most notably various coil configurations, a combination of tensile and torsion strain is expected to be routinely present in the superconducting wire, which makes it of interest to study the electromechanical response of coated conductors, as well as to develop models for quantifying the stress/strain states under these loading conditions. We present experimental results on the electromechanical behavior of an IBAD/MOCVD YBCO coated conductor subjected to combined tensile and torsion strains, as well as analytical and numerical results of modeling the stress states in multilayered coated conductors, based on a continuum mechanics formulation. In pure torsion, the upper strain limit was found to be approx. 51.4°/cm where the critical current dropped significantly upon applying even minute tensile loads. In the mixed tensile/torsion regime, three distinct regions are identified: negligible effect of torsion up to 26°/cm, near-linear decrease of critical current between 26 and 47°/cm and sudden drop of critical current between 47 and 52°/cm. The model of the stress/strain states reveals the following features in a coordinate frame where x and y axes coincide with the long and short wire cross section directions, respectively. The xz stress is discontinuous across interfaces due to different elastic

constants of the layers, and high uniformity of the xz stress is noted in the YBCO layer, approx. 475 MPa/(rad/cm). The yz shear stress, and the corresponding interface tractions are non-negligible only near the wire ends in the x direction. By neglecting the yz stresses, we present an approximate analytical solution for xz stresses and strains as a function of applied twist angle.

## 2E-18

### Development of Application-Ready Second-Generation HTS Wire

***Y.-Y. Xie, K. Lenseseth, M. Marchevsky, Y. Chen, X. Xiong, Y. Qiao, A. Rar, R. Schmidt, A. Knoll, D. Hazelton, and V. Selvamanickam***

*SuperPower, Inc., 450 Duane Ave., Schenectady, NY 12304, USA*

SuperPower's 2G HTS wire technology is based on IBAD-MgO for textured buffer template and MOCVD for REBCO HTS layer. Recently we reported 2G HTS wires with single piece length (L) more than 1 km and critical current at 77 K and self-field ( $I_c$  (77K, 0T)) above 227 A/cm-w. While continuing to improve  $I_c$  (77K, 0T) and L, the application-readiness of 2G HTS wire has been one of the focuses of our technology development, in which performance parameters including in-field  $I_c$ , ac losses, joints, insulation, and fault current limiting performance are investigated in order to meet the technical requirements for real-world applications including transmission cables, superconducting magnets, fault current limiters, motors and generators. This paper will report the progress in the development of application-ready 2G HTS wire. Artificial pinning centers such nano-precipitates, nano-clusters and nano-rods have been induced into MOCVD-based REBCO films through modification of chemical composition, and significant enhancement in in-field performance has been shown in magnetic fields parallel and perpendicular to the wire surface and at intermediate angles as well. ROEBEL conductor is a proven technology to reduce ac loss through the transposition of current flow. In a ROEBEL conductor, current flows along the wire length and across the wire width, which poses a unique challenge to 2G HTS fabrication since two-dimensional (2D) uniformity is required; we developed a technique to analyze the 2D uniformity based on magnetic measurement results and compared with transport current measurement results. For joints, we have developed a production operation so that the joint resistance can be maintained consistently low at ~33 nano-ohm for 10 cm long joints. Wire with insulated with polyimide films is routinely fabricated with our in-house insulation machine and also demonstrates good performance. These developments in application-readiness will promote the wide use of 2G HTS wire.

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**SATURDAY, DECEMBER 6****7:15 AM – 4:00 PM****REGISTRATION***2nd Floor, Conrad N. Hilton Ballroom Lobby, South Wing***7:00 AM – 4:00 PM****INTERNET CAFÉ***2nd Floor, Room 247***by 4:00 PM****POSTER REMOVAL***1st Floor South Wing Lobby (S104)***7:15–8:30 AM****BREAKFAST BUFFET***Conrad N. Hilton AD, S202***8:30—10:20 AM****SESSION F:****Coated Conductor Properties Beyond Critical Current***Conrad N. Hilton BC**Chair/Moderator: **Mike Gouge** (Oak Ridge National Laboratory) and **Fedor Gömöry** (Slovak Academy of Sciences)***3F-01** 8:30—8:40**Losses in YBCO Strands and Quench in YBCO Coils*****M. D. Sumption, M. Majoros, and E. W. Collings****LASM, MSE, The Ohio State University, Columbus, OH 43210, USA*

Transport and external field losses were measured for YBCO strands. Various kinds of IBAD YBCO coated conductors with Cu stabilizing layer of different thickness added either on one side only, or on both sides as well as at the edges have been measured in an applied magnetic field up to 140 mT (peak) in frequency range of 50 – 200 Hz. Measurements of striped conductors are also shown for conductors striped along 30 cm segments placed in uniform external fields. Computationally, different configurations of multifilament geometry with filaments embedded in ferromagnetic materials of different thickness and different magnetic permeability have been modelled in the past and a reduction of transport ac loss predicted by FEM calculations. In the present work we propose a much simpler and more practical method for magnetic decoupling of the strands in YBCO coated conductors. This method consists in filling just the inter-filamentary space between the filaments by a ferromagnetic material, rather than embedding the filaments completely. Calculations of transport ac loss reduction were performed using a finite element method where it was seen that the present method gives almost the same transport ac loss reduction as completely embedding the filaments in a ferromagnetic material. In the area of thermal propagation and quench, a series of small solenoidal YBCO coils have been made and measured for thermal conductivity and for quench propagation both along the tape length as well as in the radial direction. Results for mylar insulation are compared to those from a very thin ZnO insulation. Radial thermal conductivities, in the neighborhood of 2-3 W/m<sup>1</sup>K<sup>1</sup>, were somewhat higher with the ZnO insulation, mostly because of its reduced thickness, while winding  $J_e$  for these coils was increased significantly with the ZnO insulation. It was found for the given coil geometry, the large aspect ratio of the YBCO coated conductors caused the quench to propagate predominantly in a radial direction, in the sense that the heat quenching a given layer of conductor came from the winding directly under it, even though the radial NZP was less than the longitudinal NZP.

**3F-02** 8:40—8:50**[AC losses: characterization and analysis]****Takanobu Kiss***Kyushu University***3F-03** 8:50—9:00**AC Losses in Coated Conductors Integrated for Practical Applications and Strategies for their Reduction****Naoyuki Amemiya***Kyoto University, Kyoto-Daigaku-Katsura, Nishikyo, Kyoto 615-8510, Japan*

AC loss reduction is one of the critical issues toward the practical applications of coated conductors. Coated conductors show varieties of AC loss characteristics because of their thin strip shape of superconductor, their composite structure, etc. In principle, AC losses are generated through the penetration of magnetic flux into superconductor. In case of thin strip of superconductor such as superconductor layer in coated conductor, the magnetic flux penetration from its edges generates much larger AC loss than the magnetic flux penetration from its wide faces. If the substrate of a coated conductor is magnetic, it attracts magnetic flux lines to change the magnetic flux distribution around the coated conductor and influence the AC loss characteristic of the coated conductor. When coated conductors are integrated into an electrical device, the shape of their assembly also influences the mode of magnetic flux penetration into each coated conductor.

We have been measuring AC losses of isolated coated conductor as well as assembled coated conductors. Combined with these experimental results with the results of numerical electromagnetic simulations, the AC loss characteristics of coated conductors integrated with various manners, such as mono and multi layer polygonal assemblies, tape-on-tape stack, will be discussed to find strategies for AC loss reduction. With respect to the composite structure, we will focus on superconductor and ferromagnetic composite structure in an isolated coated conductor and in assembled coated conductors. Influence of non-uniformity of critical current density will be discussed from the viewpoint post-fabrication processing such as cutting into narrow strips.

*This work was supported by the NEDO.*

**3F-04** 9:00—9:10**Influence of Ferromagnetic Substrate on the Properties of Coated Conductor****F. Gömöry, M. Vojenčiak, E. Pardo, J. Šouc***Institute of Electrical Engineering, Centre of Excellence CENG, Slovak Academy of Sciences, Dúbravská cesta 9, 842 39 Bratislava, Slovakia*

Critical current and AC loss have been calculated for typical coated conductor tapes, taking into account anisotropic field-dependent critical current density in superconducting layer and non-linear magnetic properties of the substrate. The predictions achieved for the tape with Ni-5%W magnetic substrate are compared to the case of a non-magnetic substrate. Two geometries have been considered: the substrate exactly fitting the superconducting layer, and the substrate exceeding in width the superconducting layer by 10%. Our results show that the substrate ferromagnetism reduces the critical currents in low magnetic fields. For parallel AC magnetic fields, the tape loss is given essentially by the hysteresis loss of the substrate. In an AC field perpendicular to the tape,

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the tape with ferromagnetic substrate exhibits the losses reduced compared to the non-magnetic substrate. In the case of transport loss, substantial increase of the loss in superconductor is predicted on top of the additional hysteresis loss in the substrate. The use of a wider substrate could slightly reduce the transport losses and the magnetization losses in perpendicular field.

**3F-05** 9:10—9:20

### Spatially Resolved Study of Dissipation at Different Magnetic Fields in RABiTS Coated Conductors

***D. Abraitmov<sup>1</sup>, P. Li<sup>1</sup>, D. Larbalestier<sup>1</sup>, X.G. Li<sup>2</sup>, M. Rupich<sup>2</sup>***

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To understand the influence of current limiting mechanisms (CLM) in  $\text{YB}_2\text{Cu}_3\text{O}_{7-\delta}$  coated conductor (CC) at different magnetic fields ( $B$ ) we employ Low Temperature Scanning Laser Microscopy (LTLSM) to reveal the local electric field ( $E$ ) distributions. This is combined with orientation imaging microscopy to reveal the grain boundary (GB) structure. Results with several different types of links will be discussed. For polycrystalline links, as the magnetic field is increased we observe a smooth transition from a GB to a bulk limited regime. At small  $B$ , the dissipation is strongly inhomogeneous and generally follows the GB network with enhanced values along low angle GBs and at the edges of bottlenecks defined by higher misoriented GBs. We observed that inhomogeneous flux jets can lose their structure at magnetic fields below 1 T. In links with an abundance of highly-misoriented grains (HMG) the HMGs are current limiting mechanisms up to 5T. For links with low concentrations of HMG, the dissipation pattern at 5 T is defined by the link geometry rather than the GBs, which means the risk of developing hot spots at GBs is considerably decreased. For narrow, one-dimensional CC links, the  $I_c$  distributions were calculated for different magnetic fields. In wider, two-dimensional links where we applied  $B // ab$ , the electric field is more homogeneous and appears as straight lines that follow the external magnetic field. In the nominal “Lorentz force free regime” where the field is nominally parallel to the current, the dissipation is highly sensitive to defects.

**3F-06** 9:20—9:30

### Alternating Current Losses of Infinite Stacks of Superconductor/Ferromagnet Tapes

***Y. Mawatari***

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Ferromagnetic materials (e.g., Ni-W alloys) are used as metal substrates for superconducting coated conductors, and such tapes have superconductor/ferromagnet (SC/FM) bilayer structures. The contributions of ferromagnetic hysteresis losses to the total losses of SC/FM tape are negligibly small, and the superconducting hysteresis losses are dominant especially in large current and/or magnetic field regions. Nevertheless, the superconducting hysteresis losses are affected by the ferromagnetic substrates, because the current/field (i.e., current density and magnetic field) distributions in superconducting layers are changed by the magnetic interaction between the superconductors and ferromagnets. By using the complex field approach and the ideal soft magnet model, we recently proposed an analytical model to investigate current/field distributions and ac losses of SC/FM tapes [1]. The ferromagnetic substrate is considered as an ideal soft magnet, which has an infinite permeability without magnetic saturation and has no ferromagnetic hysteresis. The critical state model with a constant  $j_c$  is adopted for superconducting layers, and the thickness/

width ratio of the SC/FM tapes is treated as an infinitesimal. This simplified model allows us to obtain analytical expressions of the current/field distributions and the ac losses of a single isolated SC/FM tape [1]. We have also theoretically investigated current/field distributions and ac losses of infinite stacks of SC/FM tapes, and we found that the effects of the ferromagnetic substrates on the ac losses of the stacks of SC/FM tapes are smaller than those of a single isolated SC/FM tape.

[1] Y. Mawatari, *Phys. Rev. B* 77, 140545 (2008).

**3F-07** 9:30—9:40

### Application of Textured Highly Alloyed Ni-W Tapes for Coated Conductor Architectures

**R. Hühne**

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The development of cube textured substrates with improved mechanical strength and reduced ferromagnetism at low temperatures is a major challenge for the preparation of coated conductors using the RABITS approach. Recently, highly textured Ni-W tapes with W-contents above 5 at.% as well as composite tapes, having a non-ferromagnetic core with high yield strength and a highly textured shell material, were successfully prepared. An epitaxial  $Y_2O_3/YSZ/CeO_2$  buffer architecture has been grown on these cube textured tapes using pulsed laser deposition. The buffer layer growth was studied in detail using X-ray diffraction and EBSD measurements, showing a perfect texture transfer throughout the buffer architecture. Afterwards, epitaxial YBCO layers were successfully deposited on the buffered tapes. The superconducting properties were measured and compared to films grown on  $SrTiO_3$  single crystals. A superconducting transition temperature  $T_c$  of about 90 K with a small transition width was observed on all developed metal substrates. A critical current density  $J_c$  of about 1 MA/cm<sup>2</sup> was measured at 77 K in self-field. It was found that  $J_c$  is mainly limited by the grain boundary network in magnetic fields below 4 T, whereas similar values as on  $SrTiO_3$  single crystals were measured at higher fields. Finally, the full anisotropy of  $J_c$  at various magnetic fields was determined for selected samples.

**3F-08** 9:40—9:50

### Development of the Low ac Loss Multifilamentary 2G Wire at SuperPower

**M. Marchevsky, E. Zhang, Y. Y. Xie and V. Selvamanickam**

*SuperPower, Inc., 450 Duane Ave., Schenectady, NY 12304 USA*

Reducing ac losses in coated conductors is critically important for cable and rotating machinery applications. In 2G HTS wire ac losses are mainly associated with the hysteretic magnetization of the superconducting layer. One recently proposed technique of reducing such losses is striation of the YBCO layer into narrow filaments. At SuperPower we developed a robust and efficient method of manufacturing the striated 2G HTS wire based upon photolithography and subsequent one-step dry etching process. The conductor consists of five parallel 0.6 mm wide superconducting filaments separated by 0.2 mm wide gaps etched down to the substrate layer. Continuously striated wire pieces up to 14.5 m in length have been fabricated; they show typical reduction of magnetization ac loss at low (0-200 Hz) frequencies up to 5.1 times compared to a non-striated wire of same critical current. Various aspects of wire design and fabrication, including inter-filament coupling and critical current retention will be discussed. Most recent ac loss test results for the pancake coils wound with the striated wire will be shown.

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**3F-09, 3F-10** 9:50—10:10**Striation and Diffusion Joint for Coated Conductor*****K. Tanabe, T. Machi, N. Sakai, J. Kato, T. Hato, and N. Chikumoto****Superconductivity Research Laboratory, ISTEC, 1-10-13 Shinonome, Koto-ku, Tokyo 135-0062, Japan*

It is indispensable to decrease AC loss in order to apply coated conductors (CCs) to power equipment such as transformers. It was previously demonstrated that striation into multi-filamentary structures effectively decreases AC loss of a coil wound with totally 70-m-long CCs. For practical transformers, however, much longer and narrower multi-filamentary CCs are required. There seem to be two major problems in fabrication of such multi-filamentary CCs. One is lower inter-filament resistance leading to larger coupling loss, and this would be caused by low resistance of the buffer layer or defects occurring in the striation process. The former cause could be eliminated by optimizing the buffer layer architecture, while the latter could be prevented by improving the striation process. We have recently improved our striation process by a laser-scribing method. By employing shallow laser scribing and two-step chemical etching for Ag and HTS layers, we have successfully reduced the slot width to less than 150 nm keeping high enough inter-filament resistance with high reproducibility. The other major problem is  $I_c$  non-uniformity across the width as well as along the length of CCs, which leads to a substantial decrease in the minimum filament  $I_c$ . Our strategy is to preselect CCs in terms of  $I_c$  uniformity using non-contact characterization techniques such as Hall-sensor-array and recently developed SQUID-array systems. The latter system can be also utilized to find the positions of macroscopic defects in striated CCs where we apply repairs using a diffusion joint technique. We will also discuss the prospects for the diffusion joint technique.

*This work was supported by the New Energy and Industrial Technology Development Organization (NEDO).*

**3F-11** 10:10—10:20**Current Distribution Effects in a 2.6 kA 2G-Robel Bar*****W. Goldacker, A. Frank, A. Kudymow, R. Heller, S. Terzieva, A. Kling, C. Schmidt****Forschungszentrum Karlsruhe, Institut f. Techn. Physik, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen*

Robel bars are a practicable way for high current flat AC-cables with fully transposed strands which are very well suited for windings in magnets, transformers and rotating machinery. Quite recently a 1.1 m long cable made from 45 SuperPower 12 mm wide CC with a transport current of 2.6 kA (77 K, s.f.) was presented. The new improved design, stacking several CC in the individual strands, allows application of a much higher number of coated conductors for the same transposition width and a significant increase of the transport current. Among the necessary technical features of cables an inter-strand connection with acceptable coupling loss contribution has to be considered. A detailed investigation of the current distributions in the strands of the cable was performed and will be presented. Inhomogeneities were observed between the strands and along the strands and depend on how the strands touch each other. In a smaller and only 4 mm wide cable, the strand coupling resistances were investigated more systematically applying an Ag filled resin and a pure resin. The pure resin allows fixing the touch contact between the strands. The reliability of this approach and the future prospects for further improvement of the cable properties will be discussed.

**10:20–10:35 AM****MORNING COFFEE/TEA BREAK***Conrad N. Hilton Lobby*

## 10:35—11:45 AM SESSION F: CONTINUED

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**3F-12** 10:35—10:45

### **Impact of Coated Conductor Architecture on Conductor Stability and ac Loss for Power Applications**

***R. Duckworth, Y. Zhang, F. List****Oak Ridge National Laboratory, Oak Ridge, TN USA*

Conductor stability and ac loss are two inter-related operational issues that can complicate the introduction of coated conductors in to high temperature superconducting applications. With respect to conductor architecture, conductor stability and ac loss are currently being explored in as-manufactured coated conductors as well as prototype conductor geometries. In as-manufactured coated conductors, materials that are used for stabilization have been shown to influence conductor stability at either steady state and/or transient operating conditions. Stabilization can be utilized to either limit faults and suppress temperature rise, but the thickness and material properties can impact the ac loss on a single tape basis and more importantly when multiple conductors are integrated into a given device geometry. In prototype conductor geometries, different methods are being pursued to produce filamentary conductors that reduce ac loss. Processes that lead to low ac loss could compromise conductor stability due to the lack of current sharing between filaments. To improve the viability of low ac loss geometries, conductor stability needs to be part of the evaluation for a given conductor architecture. Work at ORNL has been directed at establishing the connection between low ac loss and conductor stability through a series of simulations and experiments on geometries with and without electrical connections between the filaments. With respect to the concept of continuous stabilization between filaments, ac loss has been measured in a series of samples with different coatings between silver and YBCO filaments. It was found that low ac loss can be maintained through the manipulation of the interface conditions between the YBCO and silver and through the addition of high resistive materials between YBCO filaments and silver. However, a threshold was identified where the interface conditions cause a significant drop in conductor stability during fault currents.

**3F-13** 10:45—10:55

### **Electromechanical Properties of Coated Conductors and Splices**

***D. van der Laan****National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305 USA*

An overview of the current status on electromechanical properties of coated conductors is presented. Their mechanical strength has far exceeded that of any other high-temperature superconducting tape or wire. Especially their high level of elasticity could be very beneficial for high-field applications, but so far hasn't been fully exploited. Although mechanically coated conductors have come a far way, a full characterization of their performance under strain is not yet available. Especially the dependence of the critical current on strain, temperature, magnetic field, and field angle should be studied in detail. Such characterization is needed for a reliable operation of coated conductors in applications. Although coated conductors are being produced in relatively long lengths, coated conductor splices will always be a part of some superconducting devices, whether splices are needed to obtain the required conductor length, or when they are part of repairs that have to be performed in the field. So far, the electromechanical properties of symmetric splices have been studied, where the YBCO layers of both spliced conductors are facing each other. Other configurations that need

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to be tested will be discussed briefly, such as asymmetric splices, splices between coated conductors and normal metals, and splices between striated conductors. Based on the test results, proper procedures for splicing, or even standards, should become available.

**3F-14** 10:55—11:45

**Open Discussion led by Moderator**

**11:45 AM—12:30 PM**

**SESSION G: Oral Poster Summaries** *Conrad N. Hilton BC, S202*

*Selected speakers will summarize their Posters (5 minutes each)*

*Chair & Moderator: Vic Maroni (Argonne National Laboratory)*

**3G-01** 11:45—11:50

**Enhanced Flux Pinning by BaZrO<sub>3</sub> Doping in Fluorine-free Metal-Organic Deposited YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> Films on Buffered RABiTS Substrates**

**F. Lu, F. Kametani, D. C. Larbalestier and E. E. Hellstrom**

*Applied Superconductivity Center, National High Magnetic Field Laboratory, Tallahassee, FL 32310 USA*

In this study, both pure and BaZrO<sub>3</sub> (BZO)-doped YBCO (YBCO + x BZO) films were fabricated on buffered RABiTS from AMSC by a fluorine-free metal organic deposition (MOD) process. In this work, we have succeeded in introducing nanoscale BaZrO<sub>3</sub> particles into YBCO by adding extra Ba and Zr organic salts. We were able to use multi-coating process to obtain highly-textured thick (up to ~ 1.1 μm) films of both pure and BaZrO<sub>3</sub> (up to x = 0.15) doped content. SEM images showed mainly c-axis oriented grains and dense structures. The in-field critical current density is enhanced for BaZrO<sub>3</sub>-doped samples though the self field critical current density at 77K is slightly lower than pure YBCO. Consequently, the pinning force density in all BaZrO<sub>3</sub>-doped YBCO samples is enhanced. The optimal BaZrO<sub>3</sub> doping content investigated in this work is x = 0.07 – 0.10. Maximum pinning force density exceeding 5.5 GN/m<sup>3</sup> is obtained in ~ 0.8 μm YBCO + 0.07 BZO film. The angular dependence of in-field critical current density measurements shows the critical current density anisotropy is strongly reduced by BaZrO<sub>3</sub> doping at 1 T and 4 T, and the critical current density is enhanced over a wide angular range compared to pure YBCO. This indicates that fluorine-free MOD with chemical doping is a promising fabrication technique to create high pinning in YBCO coated conductors.

*This work was supported by DOE-OETD.*

**3G-02** 11:50—11:55**BaZrO<sub>3</sub> Nanorod Realignment in YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-x</sub> Thin Films by Surface Modulation Using Vicinal SrTiO<sub>3</sub> Substrates****F. J. Baca<sup>1</sup>, T. J. Haugan<sup>1</sup>, J. N. Reichart<sup>1</sup>, P. N. Barnes<sup>1</sup>, R. L. Emergo<sup>2</sup>, and J. Z. Wu<sup>2</sup>**<sup>1</sup>Air Force Research Laboratories, Propulsion Directorate, 1950 Fifth St., WPAFB, OH 45433; <sup>2</sup>University of Kansas, Department of Physics and Astronomy, 1251 Wescoe Hall Dr., Lawrence, KS, 66045 USA

The self-assembled columnar defects formed by BaZrO<sub>3</sub> and BaSnO<sub>3</sub> nanorods in YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-x</sub> thin films provide effective vortex pinning, especially for magnetic fields aligned along the c-axis. However, to improve vortex pinning for other field orientations, it is desirable to control the defect orientation. Using transmission electron microscopy, we show that by increasing the vicinal angle of miscut SrTiO<sub>3</sub> substrates, the microstructural effect on BaZrO<sub>3</sub>-doped YBCO films becomes increasingly pronounced. We show that planar defects become more prominent up to a 10° vicinal angle, while at 20° the BaZrO<sub>3</sub> nanorods undergo a drastic reorientation and become aligned parallel to the YBCO a-b planes. The angular dependence of the in-field critical current density,  $J_c(H,\theta)$ , confirms that as the vicinal angle is increased, the vortex pinning along the c-axis is reduced, while it is increased slightly along the a-b direction. Since the alignment of microstructural dislocations is considered to play a significant role in the formation of nanocolumnar defects, these results may indicate that the miscut angle strongly influences the occurrence of such dislocations, and hence, the direction of the BaZrO<sub>3</sub> nanorod alignment when a critical angle is exceeded.

**3G-03** 11:55—12:00 (2 Posters)**WITHDRAWN - Properties of SmBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> Thin Film with Oxide Impurities Grown by the Co-evaporation Method****J. Yoo<sup>1\*</sup>, K. Kwak<sup>1</sup>, S.-M. Lee<sup>1</sup>, Y.-H. Jung<sup>1</sup>, J. Rhee<sup>1</sup>, K.-W. Han<sup>1</sup>, D. Nguyen<sup>1</sup>, D. Youm<sup>1</sup>, H. Kim<sup>2</sup>, H.O. Ha<sup>2</sup>, S.-S. Oh<sup>2</sup>, and S. Oh<sup>3</sup>**<sup>1</sup>Department of Physics, KAIST, 305-701 Daejeon, Republic of Korea; <sup>2</sup>Superconducting Materials Research Group, KERI, 28-1, Seongju-dong, Changwon, 641-120, Republic of Korea; <sup>3</sup>Material Research, National Fusion Research Center, Daejeon, 305-380, Republic of Korea

Approximately 200 nm thick SmBCO films with oxide impurities were grown on LaAlO<sub>3</sub> substrates by the coevaporation method. For the formation of the oxide impurities, the metal sources such as Sn and Zr were coevaporated with oxygen reaction or SnO<sub>2</sub> powder was sublimated during the growth of SmBCO film. In the case of Sn impurity evaporation, the superconducting transition was observed until Sn concentration in the film was increased up to a few %. As the Sn concentration was increased further, the resistance-temperature curve revealed semiconducting phase, which was due to formation of SnO<sub>2</sub> instead of BaSnO<sub>3</sub>. The angle and field dependence of the critical current of the SmBCO films were investigated for various concentrations of the oxide impurities.

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### Hysteresis Loss in $\text{Sm}_1\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$ Coated Conductor with Applied Magnetic Field and Current Varied in Out-of Phase

**J. Yoo<sup>1\*</sup>, S.-M. Lee<sup>1</sup>, Y.-H. Jung<sup>1</sup>, K. Kwak<sup>1</sup>, J. Rhee<sup>1</sup>, K.-W. Han<sup>1</sup>, D. Nguyen<sup>1</sup>, D. Youm<sup>1</sup>, H. Kim<sup>2</sup>, H. Ha<sup>2</sup>, S.-S. Oh<sup>2</sup>**

<sup>1</sup>Department of Physics, KAIST, 305-701 Daejeon, Republic of Korea; <sup>2</sup>Superconducting Materials Research Group, KERI, 28-1, Seongju-dong, Changwon, 641-120, Republic of Korea

The hysteresis loss in a  $\text{Sm}_1\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$  coated conductor was estimated from magnetic field profiles measured by the scanning Hall probe method. Applied magnetic field ( $B_a$ ) and current ( $I_a$ ) were varied in a manner of out-of phase. The field profile data were measured while  $I_a$  were decreased stepwise from  $I_{peak}$  to  $-I_{peak}$ , and  $B_a$  was varied simultaneously from  $B_{peak}$  to  $-B_{peak}$  with  $90^\circ$  phase difference with respect to  $I_a$ . The phase difference between  $B_a$  and  $I_a$  was kept constant during variation of  $B_a$  and  $I_a$  for this study. For maximum values of  $B_{peak}$  and  $I_{peak}$ , two load lines were selected with values of  $\alpha I_a / B_a$  fixed; one was  $I_{peak} / B_{peak} = 80 \text{ A} / 200 \text{ mT}$  and the other was  $I_{peak} / B_{peak} = 120 \text{ A} / 60 \text{ mT}$ . From the measured values of magnetic field profiles, the current profiles were calculated by the iterative inversion method. From the current profiles, the flux density profiles and the hysteresis loss,  $Q$ , were then calculated for various values of  $I_{peak}$  ( $= \alpha B_{peak}$ ) in each load line. The results were compared with theoretical calculations based on Brandt's model.

**3G-04** 12:00—12:05

### Development of Long SmBCO/IBAD-MgO Coated Conductor

**H.-S. Ha<sup>1</sup>, R.-K. Ko<sup>1</sup>, S.-S. Oh<sup>1</sup>, C. Park<sup>2</sup>, S.-I. Yoo<sup>2</sup>, D.-J. Youm<sup>3</sup>, S.-H. Moon<sup>4</sup>**

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Thermal co-evaporation method is one of the candidates to develop high quality coated conductors (CCs) with low-cost that has benefits to deposit wide area uniformly and use cheaper thermal evaporation sources and raw materials. Good CCs have been usually made by using the Ion Beam Assisted Deposition (IBAD) template. In this study, we have used IBAD-MgO process to fabricate the biaxially textured template for CCs and co-evaporation method to deposit  $\text{Sm}_1\text{Ba}_2\text{Cu}_3\text{O}_y$  (SmBCO) superconducting layer on IBAD-MgO template. The batch type co-deposition system was specially designed and was named EDDC (evaporation using drum in dual chamber) that is possible to deposit superconducting layer with optimum composition ratio of materials at temperature over  $700^\circ\text{C}$  and several mTorr of oxygen. Recently, the EDDC system was modified to improve the deposition rate, reproducibility of composition ratio and deposition conditions of superconducting layer. We have investigated the influence of SmBCO thickness and deposition rate on the critical current density of CCs. Rotation speed and evaporation rates were increased to acquire higher growth rate over  $3\mu\text{m}/\text{h}$  to make 100m long coated conductor. After deposition of 100m long CCs, critical current was measured using R2R hall probe measurement system and R2R transport  $I_c$  measurement system.

*This research was supported by a grant from Center for Applied Superconductivity Technology of the 21st Century Frontier R&D Program founded by the Ministry of Sciences and Technologies, Republic of Korea. HTS coated conductor (CC) is being developed under the DAPAS program.*

**3G-05** 12:05—12:10**Vortex Diode Effect in Pinning Enhanced Thin Films****J. H. Durrell<sup>1</sup>, S. A. Harrington<sup>1</sup>, H. Wang<sup>2</sup>, J. L. MacManus-Driscoll<sup>1</sup>**<sup>1</sup>Department of Materials Science and Metallurgy, University of Cambridge, Pembroke Street, CAMBRIDGE, CB2 3QZ, UK; <sup>2</sup>Dept. of Electrical and Computer Engineering, Texas A & M University, College Station, TX 77843 USA

As an anisotropic material YBCO exhibits a distinct maximum for a critical current applied in-plane, which is often referred to as the “intrinsic pinning peak”. This is due to both the layered structure, with this effect being more pronounced at lower temperatures, and to the mass anisotropy of the charge carriers the contribution of which is described by a scaling law. For in-plane fields in highly geometrically anisotropic thin films this orientation also corresponds to that of maximum surface pinning. In vicinal YBCO thin films where the in-plane and surface parallel configurations are different surface pinning has been shown to be non-negligible. We have found that in YBCO thin films with rare earth tantalate dopants added to enhance pinning the magnitude of the intrinsic peak can be strongly controlled by the direction of the Lorentz force. We find that by reversing field or current direction a variation in  $I_c$  of over 10% can be observed at 77 K and 0.25 T. We explain this observation in terms of the microstructure of the films and the effect of the microstructure on surface pinning. We observe that such a thin film is, in effect, an inverse diode where voltage is zero up to a certain current, which depends on the current direction. In a conventional diode it is current that is zero up to a certain voltage, which depends on the polarity. There is potential to exploit this technique to make coated conductors with current direction sensitive critical current properties.

**3G-06** 12:10—12:15**Critical Current Densities of Isolated Grains and Grain Boundaries in Coated Conductors****M. Weigand<sup>1</sup>, J. H. Durrell<sup>1</sup>, N. A. Rutter<sup>1</sup>, S. Speller<sup>2</sup>, G. M. Hughes<sup>2</sup>, C. Grovenor<sup>2</sup>**<sup>1</sup>Dept. of Materials Science and Metallurgy, University of Cambridge, Pembroke St, Cambridge CB2 3QZ, U.K.; <sup>2</sup>Dept. of Materials, University of Oxford, Parks Road, Oxford OX1 3PH, U.K.

In cuprate superconductors the critical current density  $J_c$  across grain boundaries (GBs) shows an exponential decrease with misorientation angle between the adjacent grains. Coated conductors (2nd generation high temperature superconductors) overcome this detrimental effect by epitaxial growth of the superconducting layer on a strongly textured substrate and buffer, thus offering a significantly higher critical current density compared to tapes of the 1st generation. As a consequence, in certain magnetic field and temperature ranges the grains, rather than the grain boundaries, limit  $J_c$ . The best method to ascertain what governs  $J_c$  is the electromagnetic characterisation of grains and grain boundaries isolated in coated conductor samples.

We have used Electron Backscatter Diffraction (EBSD) and a Focused Ion Beam microscope (FIB) to achieve this goal. This technique allowed us to isolate single grains and GBs on coated conductors manufactured by RABiTS (Rolling Assisted Bi-axially Textured Substrates). Our approach offers higher resolution and enables us to target specific areas of the samples more precisely. Consequently, unlike photolithographic techniques such as the one developed by Feldmann et al., it can be extended to systems with smaller grain sizes, down to about 1  $\mu\text{m}$ .

Critical current densities were obtained by a four-point measurement for magnetic fields applied both perpendicular to the film surface ( $H||c$ ) and swept in-plane ( $H||ab$ ). A single GB of the RABiTS conductor showed a hysteretic dependence of  $J_c$  on field for  $H||c$ , due to flux trapped in the grains. For fields in-plane the critical current density was limited either by the grains or the GBs, depending

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on the angle between applied field and macroscopic current direction. We explain this result by the advantageous properties of meandering GBs, as are found in samples produced by chemical routes. Our findings should allow manufacturers to assess how growth parameters affect properties of grains and grain boundaries, enabling them to optimise their production processes to obtain higher critical currents.

**3G-07** 12:15—12:20

### Magnetic Pinning in YBCO

***S. C. Wimbush, J. H. Durrell, M. G. Blamire, R. B. Dinner, S. L. Sahonta, S. A. Harrington, R. Bali and J. L. MacManus-Driscoll***

*Department of Materials Science and Metallurgy, University of Cambridge, Pembroke Street, Cambridge CB2 3QZ, UK*

The practical introduction of effective flux pinning sites into high-temperature superconductors is of paramount importance for their eventual widespread application. The search for suitable processes for the generation of nanoscale defects to act as core pinning sites in the superconductor matrix has been extensive and highly fruitful, yielding improvements in the critical current density under specific experimental conditions approaching an order of magnitude. At the same time, many fundamental experiments have been performed on the formation of magnetic pinning sites in both low and high temperature superconductors, and their influence on the vortex lattice. However, to date no practical and effective approach to the formation of magnetic pinning centres for critical current enhancement in the high-temperature materials has been proposed.

We demonstrate the successful incorporation of nanoscale ferromagnetic pinning centres within YBCO thin films. For sufficiently low dopant concentrations, the suppression of transition temperature due to poisoning of the YBCO is overcome. Even at these low dopant levels, the resultant films exhibit a coexistence of superconductivity and ferromagnetism, and a consequent absolute enhancement of the critical current density up to a factor two under all applied fields and field orientations, including self field. The nature of the pinning is investigated, and a theoretical framework for the observed behaviour postulated. The potential for future development is outlined and discussed.

**3G-08** 12:20—12:25

### Stress States and Electromechanical Behavior of YBCO Coated Conductor under Combined Tension and Torsion

***G. Majkic<sup>1</sup>, R. J. Mensah<sup>1</sup>, V. Selvamanickam<sup>1,2</sup>, Y.-Y. Xie<sup>2</sup> and K. Salama<sup>1</sup>***

*<sup>1</sup>Texas Center for Superconductivity, University of Houston, Houston, TX; <sup>2</sup>SuperPower Inc., Schenectady, NY USA*

For many coated conductor applications, most notably various coil configurations, a combination of tensile and torsion strain is expected to be routinely present in the superconducting wire, which makes it of interest to study the electromechanical response of coated conductors, as well as to develop models for quantifying the stress/strain states under these loading conditions. We present experimental results on the electromechanical behavior of an IBAD/MOCVD YBCO coated conductor subjected to combined tensile and torsion strains, as well as analytical and numerical results of modeling the stress states in multilayered coated conductors, based on a continuum mechanics formulation. In pure torsion, the upper strain limit was found to be approx. 51.4°/cm where the critical current dropped significantly upon applying even minute tensile loads. In the mixed tensile/torsion regime, three distinct regions are identified: negligible effect of torsion up to 26°/cm, near-linear decrease of critical current between 26 and 47°/cm and sudden drop of critical current between 47 and 52°/cm. The model of the stress/strain states reveals the following features

in a coordinate frame where  $x$  and  $y$  axes coincide with the long and short wire cross section directions, respectively. The  $xz$  stress is discontinuous across interfaces due to different elastic constants of the layers, and high uniformity of the  $xz$  stress is noted in the YBCO layer, approx. 475 MPa/(rad/cm). The  $yz$  shear stress, and the corresponding interface tractions are non-negligible only near the wire ends in the  $x$  direction. By neglecting the  $yz$  stresses, we present an approximate analytical solution for  $xz$  stresses and strains as a function of applied twist angle.

**3G-09** 12:25—12:30

### Thickness Dependence of Critical Current Density in Thick $MgB_2$ Films

**M. Hanna<sup>1</sup>, S. Wang<sup>2,3</sup>, J. M. Redwing<sup>3</sup>, X. X. Xi<sup>2,3</sup> and K. Salama<sup>1</sup>**

<sup>1</sup>Department of Mechanical Engineering and Texas Center for Superconductivity, The University of Houston, Houston, TX 77204, USA; <sup>2</sup>Department of Physics, The Pennsylvania State University, University Park, PA 16801, USA; <sup>3</sup>Department of Materials Science and Engineering, The Pennsylvania State University, University Park, PA 16801, USA

Coated conductors have been the focus of study of scientists and researchers for the past two decades since the discovery of YBCO in 1987 at the University of Houston. For coated-conductor applications, it is necessary to deposit thick films in order to maximize the critical current in the wire or tape and enhance the engineering critical current density. However, the main obstacle to higher current in thicker films is that the critical current density ( $J_c$ ) in the superconductor drops dramatically as the coating thickness is increased. This limitation was first observed over 18 years ago in YBCO coated-conductors, yet only recently it became one of the most important remaining challenges in the coated conductors field as they are approaching the commercialization stage. As  $MgB_2$  coated conductors started hitting the road since the discovery of superconductivity in  $MgB_2$  in 2001, a study on  $J_c$  thickness dependence in  $MgB_2$  films is deemed to be necessary.

$MgB_2$  coated conductors have many potential applications and are processed by many different techniques. The most common two are the hybrid physical-chemical vapor deposition (HPCVD) and the ex-situ high temperature annealing of Boron films in Mg vapor. We succeeded in fabricating high quality  $MgB_2$  films that carry high  $J_c$  using the ex-situ annealing fabrication technique, and we examined the  $J_c$  behavior as a function of thickness in  $MgB_2$  films. The study shows that critical current density in  $MgB_2$  films decreases with increasing film thickness, similar to that observed in YBCO coated conductors, which is probably due to impurity diffusion during annealing and microstructural degradation for thicker films. The high  $J_c$  values carried by our films show that the ex-situ fabrication method can produce high quality  $MgB_2$  films at low processing temperature, which is promising for resonance frequency cavity applications and coated-conductor wires and tapes.

**12:30–1:45 PM**

### LUNCHEON

Conrad N. Hilton AD, S202

**Dominic Lee**, Program Co-Chair (Announcements)

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**1:45—2:45 PM****SESSION H: Technical Round Table Discussions***Conrad N. Hilton BC, S202**Choose topic as outlined in Sessions B, C, D, or F.***3H-01****Long Length Scale up of High Performance CCs***Discussion Leader: **Ken Marken, Jr.*****3H-02****Strategies Toward Low-Cost CC***Discussion Leader: **M. P. Paranthaman*****3H-03****Effective Approaches to Enhance CC Performance***Discussion Leader: **David Larbalestier*****3H-04****CC Properties Beyond Critical Current***Discussion Leader: **Mike Gouge*****2:45—3:45 PM****SESSION I: Summaries of Technical Sessions and Feedback from Applications Panelists; Closing Remarks***Conrad N. Hilton BC, S202**Chair & Moderator: **Herbert Freyhardt, TcSUH*****4:00 pm****Poster Removal Completed****4:00 pm****Optional Tour: Texas Center for Superconductivity at the University of Houston***(sign up at registration desk)*

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## GENERAL INFORMATION - CONFERENCE SITE & ACCOMMODATIONS

### THE HILTON UNIVERSITY OF HOUSTON HOTEL & CONFERENCE CENTER

All CCA08 Workshop sessions will be held in the Hilton University of Houston Hotel & Conference Center. Situated in the heart of the University of Houston campus, the Hilton University of Houston hotel is just three miles from the downtown Houston business district in Texas. The Hilton University of Houston hotel is a world famous facility for hospitality education. Many of the hotel guest rooms overlook the 545 wooded acres of the University campus. Hilton rooms feature wireless internet, two-line telephones with data ports and voice mail. Dining is available in the casual American Bistro fare of Eric's, and additional fast food restaurants are available across the street at the University Center. Adjacent to the Hilton is a complete health club, offering hotel guests the latest exercise and conditioning equipment. Please enquire at the Front Desk for more information on health club usage.

#### Hilton University of Houston Hotel (Campus Entrance #1)

4800 Calhoun Road

Houston, TX 77004 USA

Tel: (713) 741-2447; Fax: (713) 743-2498

Check-In: 4:00 pm

Check-Out: 12:00 Noon

## SHUTTLE VAN SCHEDULE

### Pick-Up & Drop-Off Locations:

Hilton UH: Circular Drive in front of hotel.

Club Quarters: Rusk Avenue entrance, valet zone

#### Thursday, December 4

2:00pm Depart Club Quarters for Hilton University of Houston  
2:45pm Depart Club Quarters for Hilton University of Houston  
3:15pm Depart Club Quarters for Hilton University of Houston  
8:30pm Depart Hilton University of Houston for Club Quarters  
9:15pm Depart Hilton University of Houston for Club Quarters  
9:45pm Depart Hilton University of Houston for Club Quarters

#### Friday, December 5

6:30am Depart Club Quarters for Hilton University of Houston  
7:00am Depart Club Quarters for Hilton University of Houston  
7:45am Depart Club Quarters for Hilton University of Houston  
8:30pm Depart Hilton University of Houston for Club Quarters  
9:00pm Depart Hilton University of Houston for Club Quarters  
9:30pm Depart Hilton University of Houston for Club Quarters  
10:00pm Depart Hilton University of Houston for Club Quarters

#### Saturday, December 6

6:30am Depart Club Quarters for Hilton University of Houston  
7:00am Depart Club Quarters for Hilton University of Houston  
7:45am Depart Club Quarters for Hilton University of Houston  
12:30pm Depart Hilton University of Houston for Club Quarters  
4:15pm Depart Hilton University of Houston for Club Quarters  
5:00pm Depart Hilton University of Houston for Club Quarters  
6:00pm Depart TcSUH (Tour) for Club Quarters

### CLUB QUARTERS HOTEL

The Club Quarters Hotel, a members-only property, serves as the CCA08 overflow property, and is located just five minutes away in downtown Houston. CCA08 is providing limited van transportation to and from the Hilton University of Houston in the morning and evening, or participants may take a short cab ride to the conference hotel. Please have your conference badge or other materials that identify you as a CCA08 attendee to show the van driver.

#### Club Quarters Hotel

720 Fannin Street (off Rusk & Main)

Houston, TX 77002 USA

Tel: (713) 224-6400; Fax: (713) 224-6417

Website: [http://www.clubquarters.com/loc\\_houston.aspx](http://www.clubquarters.com/loc_houston.aspx)

\*Check-In: 3:00 pm

Check-Out: 12:00 Noon

\*If arriving after 11pm, press outside buzzer for admittance to hotel.

### ADMISSION TO SESSIONS AND SOCIAL EVENTS

All participants must have a badge for entry to all technical sessions and social events. Events require tickets that are included behind name badges.

### CLIMATE/CONFERENCE ATTIRE

The Houston climate in early December is usually mild. The temperature may vary from 65°F to 43°F, with an average of 56°F; however, sudden changes can occur. The attire for all technical sessions and evening events is business casual, or a sports jacket is appropriate. Some Houston restaurants require coat and tie, so check with the restaurant when making your reservations.

### MAIL AND MESSAGES DURING CONFERENCE

Please send mail, fax and messages directly to the hotel and direct it to your room. Critical messages may be received at the Hilton University of Houston front desk (713) 741-2447, with notice to deliver to the CCA08 Registration Desk. A Message Board for sending and receiving messages, displaying Program Schedule Changes, and posting upcoming events will be available near the Registration Desk.

### SPECIAL NEEDS

Every effort will be made to accommodate special needs of disabled participants. If assistance is required, please contact the CCA08 Staff at the Registration desk in the Hilton UH. Contact the Hotel Registration Desk in the main lobby for information on special transportation needs. Hilton UH has passenger elevators located throughout the facility. There are handicapped restrooms located on every floor.

### HEALTH & MEDICAL EMERGENCIES

For medical emergencies while at the Hilton UH, dial the Front Desk at (713) 741-2447 and state your situation. You may also call '911' for life-threatening emergencies. For medical emergencies at the Club Quarters, dial 911. The call also rings at the front desk for verification.

### SAFETY

As in any major urban city, Workshop participants should be attentive to their surroundings, and at night walk in groups or take taxis. Please report any suspicious behavior to the UH Police Department at 713.743.3333. If in the Downtown Houston area, call 911.

### **INTERNET CAFÉ**

Room 247 at the Hilton University of Houston has been designated for internet access and recharging of personal laptops. Tabletop seating provides electrical outlets and laptop connections at each seat in the tiered room. In addition, four laptops are in the room for use by those who are not able to travel with their computers. The room will be open during hours posted outside the entrance. The room has no printer or other devices; please go to the 2nd Floor Business Center or the front desk for additional information on printing capability. The entire Hilton UH Hotel is wireless, and UserID and passwords are not needed for access. Please note that Technical Session rooms do not have plug-in capability at each seat, so if you plan to use your laptop in the sessions, plan to have them fully charged before bringing them into the Session.

### **BUSINESS CENTERS AT HILTON UH AND CLUB QUARTERS**

The Hilton UH Business Office is located in Room 207 (2nd floor), is open from 8am-5pm weekdays. For weekend service, please go to the front desk. Copying charges are b/w \$0.10/ea, color \$0.20/ea; Fax local (1st page \$3.US, 2nd+ \$2.US); Fax International (1st page \$5.US, 2nd+ \$2.US). A computer is available for use at no charge. The Club Quarters Business Center copying charges are b/w \$0.10/ea (no color), Fax local (\$1.US/page) and Fax International (1st page \$2.US, 2nd+ \$1.US).

### **POSTAL SERVICE/SUPPLIES**

Postal service is available at the UH Post Office, located at 4810 Calhoun in the UH Welcome Center. Hours are Monday – Friday, 8 am – 6:30 pm. The UH Bookstore is housed in the University Center across from the Hilton UH, and operating hours are Thursday (7:45am-6:30pm), Friday (8am-5pm), and Saturday (9am-3pm). The Downtown Houston Post Office is located at 401 Franklin, and is open from Monday through Friday, 6:00 am to 7:00 pm, and Saturday from 8:00 am to 12:00N.

### **FOREIGN CURRENCY EXCHANGE/FINANCIAL SERVICES**

Foreign currency exchanges are located at both Houston airports (IAH: Terminal C & Terminal D inside security area, and Terminal E outside security area, 7:30am – 9 pm; and Hobby: Main Lobby, 8 am – 6 pm). Participants are encouraged to make such exchanges at the airport, as CCA08 spans a weekend, when banking establishments are closed. The following Downtown Houston locations provide banking service on Monday through Friday until 5:00 pm: Bank of America, 700 Louisiana, (713) 247-6033 (limit \$250 per transaction/\$10 fee-for account holders only); and Chase Bank, 712 Main, (713) 216-4700, (limit \$2500 per transaction/\$5.00 fee). The conference hotels and most major establishments accept credit cards such as VISA, MasterCard, American Express, Discover, etc. ATM machines are located in the Hilton University of Houston. As Club Quarters does not have an ATM machine, visit the banks above for service.

### **EMBASSIES AND CONSULATES**

As a major center for international trade and commerce, Houston regularly welcomes visitors from all over the world and has more than 70 consulates in the city. Contact the Houston International Protocol Alliance at (713) 227-3395 for local information.

## **INSTRUCTIONS FOR PRESENTERS AND SESSION CHAIRS/MODERATORS**

### **SESSION CHAIR INFORMATION**

Information for Session Chairs will be included in the Registration Packets, and will contain speaker information and any last-minute changes to the schedule. Reserved seating will be available in the front row of the meeting room. Please plan to be at your session at least 15 minutes prior to the beginning of the session.

### **INSTRUCTIONS FOR ORAL PRESENTERS**

Please bring your presentation, in PowerPoint or PDF format on a CD or USB drive, to the Presentation Table (which will be clearly labeled at the meeting, and is near the Registration Desk) as early as possible, but at least 15 minutes before your session starts. These files will be loaded onto a PC and prepared for your session presentation. It is strongly recommended that presenters save their PowerPoint presentations with True Type fonts attached. If you must use your own computer, please notify the staff at the presentation table when you arrive for the meeting. Since swapping out computers creates delays and the program is extremely full, please only request this option if you have special software needs. For governmental agency presenters: if required, please be sure clearance information is included on the first slide of your presentation.

### **INSTRUCTIONS FOR POSTER PRESENTATIONS**

Large 4'h x 8'w (1.2 m x 2.4 m) cloth-covered boards will be provided for each presenter. Both sides of the boards will be used, allowing for two presenters per board. Posters can be affixed to these boards with Velcro or push pins. Push pins will be provided, but please bring Velcro if you would prefer this option. Please note the following set-up and removal times. All posters should be on boards by the close of the Friday luncheon.

**Set-up:** Friday, December 5 (7:15 am - 12:30 pm) – 1st Floor Lobby, South Wing (S104)

**Removal:** Saturday, December 6 (7:15 a.m. - 4:00 pm) – 1st Floor Lobby, South Wing (S104)

### **EXTENDED ABSTRACTS FOR WORKSHOP PROCEEDINGS**

Presentations consisting of two-page extended abstracts will be on Flash Drives and given to Participants at the meeting. All two-page extended abstracts that were submitted to info@cca08.com by November 14, 2008, are included.

### **POWERPOINT AND POSTER PRESENTATION MATERIALS**

All speakers and poster presenters should submit their PowerPoint Presentation or Poster Presentation in pdf format for publication on CD and/or the post-conference website. Each author should sign a release form that states the presentation can be published as a pdf file. Forms will be available at the Presentation Table in the Workshop Registration area. Please visit the table to provide your presentation for uploading.

## ADDITIONAL INFORMATION

### TRANSPORTATION

Houston is served by two major airports, with direct flights from most domestic and major Asian and European cities. Taxi, express shuttle, and METRO bus service are provided to UH from both facilities.

#### GEORGE BUSH INTERCONTINENTAL AIRPORT (IAH)

IAH, located 23 miles north of the city, is a major international and domestic facility providing non-stop service to 152 cities around the world. IAH is approximately 30 minutes to 1 hour away from UH, depending upon traffic. (281) 230-3100 or [www.houstonairportsystem.org](http://www.houstonairportsystem.org).

#### WILLIAM P. HOBBY AIRPORT (HOU)

Hobby Airport is located 12 miles south of downtown and principally serves major U.S. cities. Taxi, shuttle bus, and local bus services are available to and from the downtown area. (713) 640-3000.

### TAXI SERVICE

Taxi service is available from both airports to the University of Houston main campus and to Club Quarters Hotel. Fares range from \$20 from Hobby Airport, to \$49 - \$60 from George Bush Intercontinental Airport, and passengers can share to lessen cost. In addition, some local taxi services are Fiesta Cab (713) 255-2666, Liberty Cab (713) 695-6700 and Yellow Cab (713) 236-1111.

### AIRPORT SHUTTLE SERVICE

(713) 523-8888. Super Shuttle offers discounted one-way fares to Workshop participants from IAH (\$24) and Hobby Airport (\$19) for door to door service. Ticket counters are available in all lower level baggage claim areas.

### METRO BUS SERVICE

METRO, the city bus service, has routes to and from IAH and Hobby Airports to the University of Houston main campus, located at 4800 Calhoun. Current fare from IAH-Terminal C is \$2.50 USD (exact change needed for two \$1.25 fares). From Hobby the fare is \$2.50 USD (exact change needed for two \$1.25 fares). Participants traveling by METRO from IAH and Hobby will have to make one bus transfer each. To obtain route information, please contact METRO at (713) 635-4000 or [tripplanner.ridemetro.org](http://tripplanner.ridemetro.org). METRO schedules are also available at the Airport Information Desks, and baggage claim areas. METRO: (713) 635-4000. Check schedules when you arrive.

From **Bush** Intercontinental Airport Terminal C, take the bus #102 – Downtown Limited. You will arrive at Pierce Street and Main and will go to the Transit Center and take bus #77 - MLK to The University of Houston. Please let driver know you will need to get off at UH Welcome Center on Calhoun. The Hilton University of Houston is situated behind the Welcome Center.

From **Hobby** Airport, take the bus #88 - Downtown and transfer at Eastwood Transit Center to bus #77 - MLK to the University of Houston. Please let driver know you will need to get off at the UH Welcome Center on Calhoun. The Hilton University of Houston is situated behind the UH Welcome Center.

## PARKING

### DRIVING TO UH CAMPUS?

Parking is available in the Hilton University of Houston Hotel's underground garage for \$6.00 USD per exit. The UH Welcome Center and Parking Garage, located directly across the street from the UH Hilton, is also available for \$8.00 USD per day (Monday through Friday), and \$3.00 USD on weekends. Participants may also stop at the Entrance #1 Information Booth off Calhoun Road and obtain a pass to park in the Student Lots (1A, 5A and 20A) for \$3.00 USD. Student lots are free on weekends.

### STAYING AT CLUB QUARTERS HOTEL?

Club Quarters, located at 720 Fannin Street in downtown Houston, offers parking at the Valet Entrance, located on Rusk Avenue (N. entrance of hotel) for a cost of \$18+tax per night. The Chase Towers Parking Garage, two blocks North on Travis and Capitol Streets, offers parking from \$8.00 per exit as of this writing. The Chase Garage entrance is on Travis Street.

## CCA08 ORGANIZING COMMITTEES

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Herbert Freyhardt, Goettingen/University of Houston

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