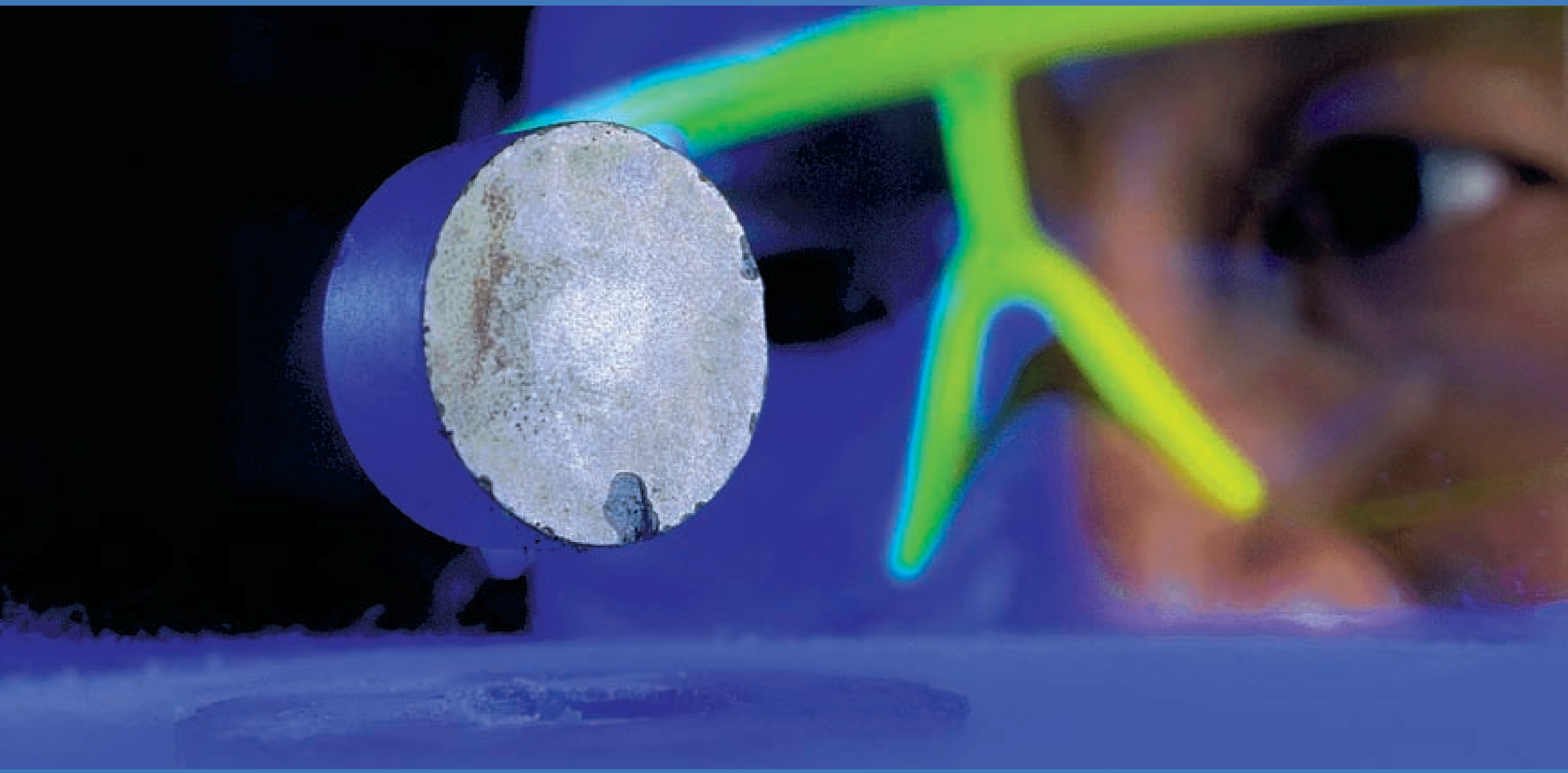
# PASREG 2010

The 7th International Workshop on Processing and Applications of Superconducting (RE)BCO Large Grain Materials

## Program and Abstracts

PASREG2010.ORG



July 29—31, 2010

Omni Shoreham Hotel

Washington, D.C., USA

# PROGRAM AT A GLANCE

Note: All technical sessions are in the Diplomat Room and breakfasts in the Diplomat Foyer.

## THURSDAY, JULY 29

8:00 am—6:00 pm
Registration

8:00 am—6:00 pm
Poster Set Up

2:00 pm
Opening/Welcome

2:10—6:15 pm
**Innovative Applications Session A**

4:20
Coffee Break [1]

6:30—7:30 pm
Light Wine/Beer Reception [1]

## FRIDAY, JULY 30

7:30 am
Continental Breakfast

8:00—10:25 am
**Innovative Applications & Processing Session B**

10:25—11:25 am
Poster Session & Coffee Break [1]

11:30 am—12:30 pm
Poster Discussion

12:30—1:50 pm
Lunch [2]

1:50—3:00 pm
**Processing & Optimization Session C**

3:00—3:15 pm
Coffee Break

3:15—3:55 pm
**Processing & Optimization Session-*cont*.**

3:55—5:40 pm
**Characterization & Pinning Session D**

6:45 pm
Meet in Omni Lobby

7:00 pm
Dinner at New Heights Restaurant

## SATURDAY, JULY 31

7:30 am
Continental Breakfast

8:00—9:05 am
**Characterization & Pinning Session-*cont*.**

9:05—10:15 am
**$MgB_2$ Session E**

10:15—10:30 am
Coffee Break

10:30 am—12:00 N
Round Table/Roadmap

12:00 N—1:00 pm
Summaries & Conclusions;
Closing Remarks

*Poster removal by 12:00 N*

1. Bird Cage Walk 2. Congressional Room

# PASREG 2010

The 7th International Workshop on Processing and Applications of Superconducting (RE)BCO Large Grain Materials

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# Program and Abstracts

**July 29—31, 2010**

**Omni Shoreham Hotel**

**Washington, D.C., USA**

Notice: The abstracts in this publication were received prior to May 28. Additions and corrections will be found on the Change Sheets located in the Registration Packets available at the Workshop.

# PASREG 2010 ORGANIZING COMMITTEES

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Michael Strasik, Boeing, Seattle (US)

David A. Cardwell, U Cambridge (UK)

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**DEAR PASREG 2010 PARTICIPANTS,**

Welcome to the 7th International Workshop on the Processing and Applications of Superconducting Large Grain (RE)BCO Materials (PASREG) at the Omni Shoreham Hotel in Washington D.C. This continues a series of international workshops that started in Cambridge in 1997. We hope that the proximity of PASREG to the 2010 Applied Superconductivity Conference will intensify discussion, foster exchange of information and pave the way for sustainable future vision. The scope of PASAREG 2010 has also been extended to reflect the evolving field, and will cover (i) processing and characterization aspects of the broader spectrum of bulk high-temperature superconducting materials, including melt-cast Bi-HTS and bulk $MgB_2$, (ii) recent developments in the field and (iii) innovative applications of bulk HTS. A technical round table discussion will be held at the workshop for the first time to summarize state-of-the-art achievements in processing, characterization and applications, to identify bottlenecks to progress and efforts to overcome these, and to establish novel directions for future research.

We are very grateful for the support of a number of individuals for making this Workshop possible: The members from the Organizing and the International Advisory Committee, in particular to Kamel Salama and Roy Weinstein, but more so to Sue Butler, who is the soul of the Local Committee, and her capable staff. The workshop was made possible with the generous support of The Texas Center for Superconductivity at the University of Houston (TcSUH) and the Boeing Company.

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

*Herbert C. Freyhardt, Mike Strasik* and *David Cardwell*

# TECHNICAL SESSIONS: TOPICS AND AREAS OF FOCUS

**SESSION A** — **Innovative Applications**

TOPICS: Superconducting levitation systems for transportation and guidance, superconducting magnetic bearings, flywheels, trapped-flux bulk HTS in rotating devices, field-shaping, bulk HTS for fault current limiters

EMPHASES: Speakers are asked to discuss innovative applications and provide their list of bulk HTS characteristics that are essential for the specific application. The speakers should provide the respective requirements for commercialization, as well as the bare requirements necessary for pre-commercial operation.

**SESSION B** — **Innovative Application & Processing**

TOPICS: Superconducting levitation systems for transportation and guidance, superconducting magnetic bearings, flywheels, trapped-flux bulk HTS in rotating devices, field-shaping; cost effective processing of high-performance bulk HTS, recycling

EMPHASES: Speakers are asked to discuss innovative applications and provide their list of bulk HTS characteristics that are essential for the specific application. The speakers should describe cost effective methods for processing of high-performance bulk HTS, as well as recycling technologies.

**SESSION C** — **Processing & Optimization**

TOPICS: Cost effective processing of high-performance bulk HTS, seeding technologies and post-growth treatments, mechanical stabilization and recycling methodologies

EMPHASES: Speakers should describe cost effective methods for processing of high- performance bulk HTS, and methods of optimization of their superconducting and levitation properties as well as of their mechanical stabilization. Speakers should describe recycling technologies for optimized use.

**SESSION D** — **Characterization & Pinning**

TOPICS: Characterization techniques, effective pinning centers, optimized trapped fields

EMPHASES: Speakers are asked to address characterization methods (or a combination thereof) to determine bulk HTS performance in the most efficient and effective manner. Speakers should describe the introduction of effective pinning structures for enhanced critical currents and optimized flux-trapping properties of high-performance bulk HTS. Novel magnetization and flux-pumping methods should be addressed.

**SESSION E** — **$MgB_2$**

TOPICS: Processing, characterization and application of bulk $MgB_2$

EMPHASES: Speakers should describe efficient methods for processing of high-performance bulk $MgB_2$, and methods of optimization of their superconducting (particularly flux pinning) properties. Speakers should address characteristics that are essential for the specific application.

PASREG 2010

7th International Workshop on Processing and Applications of Superconducting (RE)BCO Large Grain Materials

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# PASREG HISTORY, GOALS AND VENUE

## HISTORY

PASREG 2010 is the seventh of a series of international workshops on the processing and applications of large grain (RE)BCO superconducting materials. Previous PASREG Workshops were held in Cambridge, U.K. (1997), Morioka, Japan (1999), Seattle, U.S.A. (2001), Jena, Germany (2003), Tokyo, Japan (2005), and Cambridge, U.K. (2007). PASREG 2010 was planned to coincide with the 2010 Applied Superconductivity Conference, which immediately follows during August 1st through 6th.

## SCOPE

The scope of PASAREG 2010 has been extended to reflect the evolving field, and will cover (i) processing and characterization aspects of the broader spectrum of bulk high-temperature superconducting materials, including melt-cast Bi-HTS and bulk $MgB_2$, (ii) recent developments in the field and (iii) innovative applications of bulk HTS. A technical round table discussion will be held at the workshop for the first time to summarize state-of-the-art achievements in processing, characterization and applications, to identify bottlenecks to progress and efforts to overcome these, and to establish novel directions for future research.

## VENUE

The 2010 PASREG Workshop will convene at the historic Omni Shoreham Hotel, centrally located in downtown Washington, D.C. at 2500 Calvert Street NW (at Connecticut Ave) with convenient Metro access. The hotel location gives attendees the opportunity to explore the U.S. Capitol and you will only be a short distance to the White House, U.S. Capitol Building, Historical Monuments and Memorials, Smithsonian Museums and the International Spy Museum.

Omni Shoreham Hotel
2500 Calvert Street NW (at Connecticut Ave)
Washington, DC 20008
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# THURSDAY, JULY 29

**8:00 AM–6:30 PM** **PASREG REGISTRATION**
*Diplomat Room Foyer*

**8:00 AM–6:30 PM** **POSTER SET UP**
*Bird Cage Walkway*

**2:00 PM** **Opening/Welcome -** *PASREG Co-Chairs*
*Diplomat Room*

## 2:10—6:15 PM
## INNOVATIVE APPLICATIONS SESSION A

***H. Freyhardt**, **M. Strasik**, Chairs*

**T1** *2:10–2:40*

### SupraTrans - a Pilot Superconducting Levitation System for Transportation

***B.Holzapfel**[1], **O. de Haas**[2], **L. Kühn**[2], **D. Berger**[1], **K. Iida**[1], **L. Schultz**[1]*

*[1]Institute for Metallic Materials, Leibniz Institute for Solid State and Materials Research Dresden, Helmholtzstr. 20, 01069 Dresden, Germany; [2]evico GmbH, Großenhainer Str. 101, 01127 Dresden, Germany; tel.: +49 351 4659 455, fax: +49 351 4659 9455; B.Holzapfel@ifw-dresden.de*

**Abstract:** Inherently stable magnetic levitation realized by flux pinning of HTSC melt textured bulk materials in inhomogeneous magnetic fields created by classical permanent magnets opens the way to a wide range of applications for transport systems due to the simple and frictionless levitation. Small scale levitation models were used to evaluate the optimal magnetic field configuration and the obtainable levitation and side tracking forces. SupraTrans I was developed some time ago to realize the first step towards a realistic transport system and comprised an seven m long track with a vehicle able to carry 1 passenger. Last year a new project "SupraTrans II" was launched to build a fully operational levitation demonstration system. SupraTrans II will consist of an 80m long closed track including a switch. Multiple vehicle operation and wireless energy transfer for acceleration systems will be possible. The talk will discuss the concept and the current status of this project as well as future directions of superconductivity based magnetic levitation for transport systems.

**T2** *2:40–3:05*

### Levitation Properties of Superconducting Magnetic Bearing using Superconducting Coils and Bulk Superconductors

***Y. Arai**, **H. Seino**, **K. Nagashima***

*Railway Technical Research Institute, 2-8-38 Hikari-cho, Kokubunji, Tokyo, 185-8540, Japan; Phone: +81-42-573-7301, fax: +81-42-573-7300, e-mail: arai@rtri.or.jp*

**Abstract:** It is already known that the railway train is an energy-saving transport system. Energy regenerated while an electrical train brakes is consumed by other accelerating trains at the same time. However, the energy is wasted by resistors or other electrical loads. A flywheel energy storage system (FESS) is able to store regenerated energy while braking and to discharge the energy while accelerating at any time. We have been developing superconducting magnetic bearings (SMBs) using superconducting coils and bulk superconductors to be applied to a 36 MJ FESS in order to enhance the feature. We prepared two models: one was a demonstration model which consisted

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of thrust SMBs and radial mechanical bearings to confirm load capacity of 19.6 kN, and the other was a demonstration model which consisted of thrust and radial SMBs to confirm the feasibility of SMBs without mechanical bearings. The miniature model had a rotor with liquid nitrogen cooled high temperature superconducting (HTS) bulks and a stator with cryo-cooled low temperature superconducting coils. We demonstrated successfully that 2,000 kg flywheel was levitated and rotated up to 3,000 rpm with the model. The demonstration model has a rotor with HTS bulks and a stator with HTS coils. The rotor was suspended by SMBs without any mechanical contact and charge/discharge energy is transmitted by a non-contact magnetic force coupling. In this paper, we will present the experimental results of the miniature model and recent progress in the demonstration model.

**T3** *3:05–3:30*

## The Superconducting Magnetic Bearings and Magnetic Clutches for Flywheel Energy Storage

***N.Koshizuka*, M.Ikeda, H.Seki, K.Nagashima* and M.Murakami**

*Shibaura Institute of Technology, Toyosu 3-7-5, Koto-ku, Tokyo 135-8548, Japan; Tel&Fax: 81-3-5859-8117, E-mail: kosizuka@sic.shibaura-it.ac.jp; *Railway Technical Research Institute, Hikari-cho 2-8-3, Kokubunji-shi, Tokyo 185-8540 Japan*

**Abstract:** Because of the strong levitation force and non-contact stable rotation, the rotation systems using YBCO bulks and permanent magnets are promising for various applications such as flywheel energy storage systems (FESS), superconducting pumps and mixers. Here, we present two topics associated with flywheel energy storage. The first is on the "R & D of superconducting magnetic bearings (SMB) for FESS" which was carried out as a NEDO project in Japan. We constructed a radial-type SMB model for 100kWh class FESS and evaluated the bearing characteristics. The SMB model consists of a superconducting stator of YBCO bulks and NdFeB permanent magnet circuit. The levitation force density reached 11N/cm$^2$ at 77K, and the time decay of levitation force was suppressed in allowable ranges by adopting a "pre-loading" method. The availability of radial-type SMB for FESS was demonstrated by constructing 10kWh class FESS using both SMB and active magnetic bearings. The operation test resulted in the energy storage of 5.0kWh at rotation speed of 11,250rpm. The performance of superconducting flywheel can be improved by using a non-contact system which can transfer the rotational torque from the motor/generator in FESS. The second work is on the magnetic clutch for transferring torque. A combination of two permanent magnets can transmit the power without contact. We calculated the torque forces and field distributions of two types of magnetic arrays; repulsive type and Halbach type. We found that a practical torque transfer and switching systems can be constructed with a combination of permanent magnet circuits.

**T4** *3:30–3:55*

## Concepts for Using Trapped-Flux Bulk HTS in Motors and Generators

***John R. Hull* and Michael Strasik**

*Boeing Research & Technology, P.O. Box 3707, MC 2T-50, Seattle, WA 98124-2207 USA; office phone: +1 (206) 544-0368; fax: +1 (206) 544-0409; john.r.hull2@boeing.com*

**Abstract:** We discuss concepts for using bulk HTS in motors and generators. We first briefly review the concepts that have been explored in the past, including both trapped-flux and non trapped-flux methods. We then discuss concepts for using trapped-flux HTS in motors and generators that have been recently investigated in our laboratory.

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## T5 *3:55–4:20*

## Large-Scale HTS Bulks for Magnetic Application

***Frank N. Werfel*, Uta Floegel - Delor, Thomas Riedel, Rolf Rothfeld, Dieter Wippich, Bernd Goebel, Peter Schirrmeister**

*Adelwitz Technologiezentrum GmbH (ATZ),Rittergut Adelwitz, 04886 Arzberg- Adelwitz, Germany; Phone 49 34 222 45 200; Fax 49 34 222 45 202; werfel@t-online.de*

**Abstract:** Stable magnetic levitation (MAGLEV) is one of the well known icons for HTS technology. ATZ is fabricating several hundred kilograms YBCO bulk material for bearing application using in-house produced Y123 and Y211 phase precursor powders. Larger Maglev applications require significant reduction of the material costs. Single crystals of YBCO up to diameter 60 mm diameter and 13 mm in thickness were fabricated by conventional cold top seeded melt growth (TMPG) processing. The efficiency of melt texturing process was improved through processing larger blocks (64 mm x 32 mm) with optimum multiple top-seeding on the surface. Typically, larger bearing components consist of individual YBCO single crystals assembled and glued into a copper ring. To raise the material quality, it is common to select single domain bulk samples by levitation and trapped field measurements. Single crystals have up to 1.1 T@1.4 T excitation at 77 K. We are testing a new measuring system for qualifying the YBCO tiles by integration the trapped flux over the total bulk area and show the sensitivity of trapped magnetic flux after cutting the as –grown bulks.

**4:20 PM COFFEE BREAK**
*Diplomat Room Foyer*

## T6 *4:35–5:00*

## Dynamic Analysis of a Potential HTS Levitation Device Applied to Testing instruments for Controlling Simulation of Space Satellites

***Wenjiang Yang*, Yu Liu, Xiaodong Chen [a]**

*403, School of Astronautics, Beihang University, 37, Xueyuan Road, Haidian District, Beijing 100191, P.R. China; tel: 86-10-82316855; fax: 86-10-82316100; yangwjbuaa@sa.buaa.edu.cn*

**Abstract:** Experimental simulations of controlling systems and methods of a space satellite are usually carried out in a large air suspension instrument in the last forty years. But the instrument is not an ideal one, besides complicated structures and difficult operating procedures, and it can not be used in a vacuum condition to avoid aerodynamic influences to the satellite. Magnetic bearings, especially high temperature superconducting (HTS) bearings which are based on good magnetic levitation stabilities and low coefficients of friction, give a potential approach to improve the test instrument and provide better simulating conditions for satellites. However, friction loss and dynamic levitation characteristics in the HTS bearing at low velocity may be two key problems affecting the simulating abilities of the test instrument. In this paper, the rotational dynamics of a permanent magnet (PM) rotor levitated over HTSs are studied experimentally and theoretically. The PM rotor is assembled with annular permanent magnets and a circular steel yoke, and the maximum diameter is 150mm. Twelve YBaCuO bulks are arranged circularly in a vacuum vessel cooled by liquid nitrogen. We investigated the free vibration frequency modes of the PM rotor levitated over the HTSs and the dynamic analyses of the levitation performances are performed by using a combination method of electromagnetic and mechanical analysis. The typical time history of the spinning PM rotor is recorded and it is found that the deceleration of the PM rotor becomes rapid at very low rotational speeds. This phenomenon can be considered as it is caused by the unbalanced PM around its centre of mass because of inhomogeneities in the PM or superconductors.

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**T7** *5:00–5:20*

## Stellarator Configuration Improvement Using High Temperature Superconducting Monoliths*

***L. Bromberg*[1], *T. Brown*[2], *M. Zarnstorff*[2], *A. Boozer*[3], *P. Heitzenroeder*[2], *J.V. Minervini*[1] *and G. H. Neilson*[2]**

[1]*Massachusetts Institute of Technology;* [2] *Princeton Plasma Physics Laboratory;* [3] *Columbia University; brom@psfc.mit.edu*

**Abstract:** Substantial advances have been made in the design of stellarator configurations to satisfy physics properties and fabrication feasibility requirements for experimental devices. However, reactors will require further advances in configuration design, in particular with regard to maintenance and operational characteristics, in order to have high availability. The diamagnetic properties of bulk high temperature superconductor (HTS) material can be used to provide simple mechanisms for magnetic field-shaping by arranging them appropriately in an ambient field produced by relatively simple coils.

A stellarator configuration has been developed based on this concept. A small number of toroidal field coils is sufficient to create a background toroidal field. Discrete HTS monoliths ("pucks" or "tiles") are placed on a shaped structure that can be split in the poloidal direction at arbitrary locations. This allows the stellarator to be designed with large openings that provide access to remove interior plasma facing components, no longer restricted by highly shaped back legs of the modular coil winding. Unlike a coil, the structure can be assembled and disassembled in pieces of convenient size, facilitating maintenance.

The excellent properties of HTS materials, e.g., YBCO operating at elevated temperatures (> 30 K), also offer operational advantages. Since the HTS monoliths require no insulation or copper for stability/quench protection, some of the typical irradiation limits on these materials are eliminated. Nuclear heating, due to the high temperature of operation of the HTS compounds, is also very much relaxed, since at 50 K it is possible to remove more than one order of magnitude higher cryogenic loads than at 4 K, for the same refrigerator power. At the same time, there are challenging issues, such as mechanical support and cooling of the monoliths, performance and lifetime limitations in the fusion environment, field creep, superconducting stability of the monoliths, and cryostat design.

Calculations of the effect of the use of monoliths for field modification in stellerators and tokamaks will be described.

*Research supported by the U.S. DOE under Contract No. DE-AC02-09CH11466 with Princeton University.

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**T8** *5:20–5:45*

## Melt-Cast Bi-HTS for Fault Current Limiting Devices

***J. Bock[1], R. Dommerque[1], S. Elschner[2], A. Hobl[1], and M. O. Rikel[1]***

*[1]Nexans SuperConductors GmbH, Chemiepark Knapsack, 50354 Hürth (Germany); [2]University of Applied Science Mannheim, D-68163 Mannheim, Germany; (Tel: +49 2233 486491; fax: +49 2233 486847; e-mail: Mark.Rikel@Nexans.com);*

**Abstract:** Nexans SuperConductors GmbH (NSC) has successfully produced first two HTS Fault Current Limiter (FCL) systems that were designed, built and tested on a commercial basis. The systems that are dedicated for two different application cases in Europe are live in the customer grids since last quarter of 2009; one of them is protecting the house load of a brown coal power station - the first HTS device operating in a power station worldwide.

These events sum up a long development period that started in early nineties with establishing technologies for producing HTS material, the melt-cast processed (MCP) BSCCO-2212 bulk; tuning its electrical and mechanical properties to the level suitable for FCL applications; designing and testing FCL elements and stabilizing their high-yield production; assembling these elements in modular FCL systems that meet the customer requirements. NSC is able to cover the whole production chain from raw materials to the final system also integrating the auxiliary equipment for cooling.

In this contribution, we will overview our current understanding of the MCP BSCCO-2212 bulk superconductor particularly focusing on the mechanisms that enable reliable long-range percolative connectivity in the absence of long-range texture and lead to a unique combination of accessible critical currents and normal state resistivities very suitable for FCL applications.

**T9** *5:45–6:15*

## Transforming the Grid with Superconductivity

***George Crabtree[1]*, John Sarrao[2] and Wai Kwok[1]***

*1Argonne National Laboratory Argonne, IL 60439; [2]Los Alamos National Laboratory, Los Alamos, NM 87545; *630 252 5509; 630 252 8042; crabtree@anl.gov*

**Abstract:** Electricity is the backbone of our energy system, unrivaled as an energy carrier for its versatility, cleanliness, and efficiency. Electricity accounts for 40% of our primary energy use; demand is projected to grow by 50% in the US and 100% globally by 2030. The electrification of transportation by plug-in hybrids and battery electric vehicles will significantly increase this demand, especially in urban and suburban areas where short distance commuting is common. Adding wind and solar electricity to the grid in response to state and federal renewable power mandates adds the challenges of high capacity long distance transmission and accommodating intermittency. The high power, low loss delivery of electricity by superconducting cables offers solutions to these challenges. DC superconducting cables operating at 200 kV can collect renewable electricity from multiple wind and solar farms at mid-continent and transmit it to multiple load centers east of the Mississippi or on the west coast without appreciable loss. AC superconducting cables deliver electricity in urban areas with up to five times the power of conventional cables in the same cross sectional area, dramatically increasing the capacity of urban power grids. The reliability of the grid can be increased with fast high capacity superconducting fault current limiters, and the output of wind turbines can be nearly doubled with lightweight, high capacity superconducting generators on wind towers. A survey of the current status of the electric grid and the transformative changes enabled by superconductivity will be presented.

**6:15 PM THURSDAY SESSIONS ADJOURN**

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**6:30–7:30 PM LIGHT WINE AND BEER RECEPTION**
*Bird Cage Walk*

**7:30 PM NO-HOST DINNER AT AREA RESTAURANTS**

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# FRIDAY, JULY 30

**7:30 AM** **CONTINENTAL BREAKFAST**
*Diplomat Room Foyer*

## 8:00—10:25 AM
## INNOVATIVE APPLICATIONS & PROCESSING SESSION B

***D. Cardwell**, Chair*

### F10 *8:00–8:30*
### Materials Process and Machine Application of Bulk HTS

***Motohiro Miki, Brice Felder, Keita Tsuzuki, Yan Xu, Mitsuru Izumi***

*Laboratory of Applied Physics , Tokyo University of Marine Science and Technology, 2-1-6 Etchu-jima, Koto-ku, Tokyo 135-8533, Japan; E-mail : d082025@kaiyodai.ac.jp*

**Abstract:** We report on the completion of the refrigeration system of bulk HTS rotating machines and materials processing of Gd123 bulk as a field pole. We have developed a new cryogenics for an axial-type bulk superconducting motor. The newly designed cryo-rotary joint and condensed neon gas were applied to a closed-cycle neon refrigeration system of the motor. The eight field-pole bulks on the rotor were cooled down to 35 K and successful rotation was achieved up to 720 rpm after pulsed-field magnetization of the bulks. Gd123 bulks, which have been used as field poles have to be improved for practical flux trapping. A series of studies of doping particles with high magnetic permeability are reported with respect to the enhancement of the flux trapping due to pinning centers. More than 20 % increase of the trapped magnetic flux density was achieved at liquid nitrogen temperature. The results will be discussed from the viewpoint of enhanced flux trapping as a practical application. The present work has been partly supported by Fundamental Research Developing Association for Shipbuilding and Offshore (REDAS) and the Iwatani Naoji Foundation.

### F11 *8:30–8:50*
### Multi-domain Bulk Y-Ba-Cu-O with Artificial Holes for Non-Contact Torque Transfer Applications

***A. Wongsatanawarid, H. Seki and M. Murakami***

*Superconducting Materials Laboratory, Shibaura Institute of Technology, 3-7-5 Toyosu Koto-ku Tokyo Japan 135-8548; Tel. +81-3-5859-8117; Fax. +81-3-5859-8101; e-mail: lot407@yahoo.com*

**Abstract:** We are developing a non-contact superconducting mixer in that rotational torque can be transferred without mechanical contact using a bulk high temperature superconductor coupled with permanent magnets. For a practical system, we need a relatively large sized bulk superconductor to achieve the target torque value of about 100 N-cm. However, for practical machines, a reduction of processing time and cost is also necessary for market competitiveness. We have studied that a multi-domain bulk superconductor can be used in superconducting torque transferring mechanism in place of a single domain sample at the same size. We have succeeded in fabricating four-domain Y-Ba-Cu-O sample 62 mm in diameter with a cold top-seeded melt growth process. The sample contains Y123/Y211 in 10/4 molar ratio doped with 1wt% of CeO2. Microstructure observations have confirmed that $CeO_2$ doping is effective in the refinement of Y211 phase particles, which lead to an increase in field trapping capability. We also added 1 wt% of PVA liquid binder into the green compact, so that we can mechanically drill several holes to the precursor in prior to the

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melt process. The melt processing conditions and sample preparation will be revealed in details. The four domain sample exhibited good grain orientation in a monolithic bulk. The trapped field measurements showed comparable quality to a single domain sample.

**F12** *8:50–9:15*

## Process Developments in Bulk (RE)BCO Bulk Superconductors

***N. Hari Babu**[1,2], Y. Shi[2], S. K. Pathak[2], A. R. Dennis[2], D. A. Cardwell[2]*

*[1]BCAST, Brunel University, Uxbridge, Middlesex, UB8 3PH, UK; [2]Department of Engineering, University of Cambridge, Trumpington Street, Cambridge, UK, CB2 1PZ*

**Abstract:** Large single grain (RE)-Ba-Cu-O superconductors have significant potential for engineering applications based on their ability to trap high magnetic fields and low surface resistance at microwave frequencies. Research to date has focussed on developing processing methods to increase the size of single grains through an understanding of the solidification process and improving flux pinning typically by refining the size and distribution of $RE_2BaCuO_5$ (RE-211) phase inclusions in the bulk microstructure and by the use of irradiation techniques. Flux pinning using a RE/Ba solid solution has also been fundamental in the development of light rare earth based high temperature superconductors (HTS) with good field trapping properties. Recently, the focus of research has shifted from refining the size of the RE-211 phase to the development of alternative, second phases such as $REBa_2(M_{1-x},Cu_X)Oy$, where M = U, W, Ta, Nb, Mo, Zr, Ru etc., with x = 0 and 0.5, which form effective flux pinning centres. Other significant advances in bulk processing include the development of an Mg-doped Nd-Ba-Cu-O generic seed and the use of Nd-Ba-Cu-O thin-films as seed crystals for the fabrication of light rare earth superconductors. In this paper, we will review recent process developments in the fabrication of bulk (RE)-Ba-Cu-O containing $RE_2Ba_4CuMO_y$ based nano-scale inclusions, in particular, and the use of the generic seed for batch processing. In addition, we will describe a cost effective recycling process for the fabrication of bulk single grains from scrap Y-Ba-Cu-O material and present the properties of recycled samples, which exhibit trapped fields that can be as high as primary-processed single grains.

**F13** *9:15–9:40*

## Cost-Effective Processing: Recycling of Large Single Grain Gd-Ba-Cu-O/Ag Bulk Superconductor

***Kazumasa Iida**, Konstantin Nenkov, Gunter Fuchs, Gernot Krabbes, Ludwig Schultz, and Bernhard Holzapfel*

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**Abstract:** We have developed the recycling process of Ag doped Gd-Ba-Cu-O (GdBCO/Ag) bulk superconductors for the aim of cost-effective production. Our preliminary investigation has clearly shown that the recycling of disused bulk samples, which were grown in the form of multigrain, is possible. In this contribution, we report on recycling process of GdBCO/Ag bulk materials and their electro-magnetic properties. All recycled bulk samples have been grown in the form of single grain albeit a slight decrease in the trapped magnetic field has been observed compared with reference samples. Nevertheless the repulsive force of the recycled Gd-Ba-Cu-O/Ag bulk samples is almost identical to that of the reference samples. It means that the recycled bulk sample is preferable for the use of levitation type application rather than quasi permanent magnet one. This work was partially supported by the EU Marie-Curie RTN NESPA.

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**F14** *9:40–10:05*

## Novel Seed Applicable for Mass Processing of LRE-123 Single Grain Bulks

***M. Muralidhar**, K. Suzuki, A. Ishihara, †M. Jirsa, Y. Fukumoto, and M. Tomita*

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**Abstract:** High-$T_c$ superconducting materials with high performance and low cost are extremely attractive for a variety of industrial, medical, public, and research applications. One of the key issues for the large-scale applications of these materials are the excellent electromagnetic performance and the production costs. Recently we developed a batch process with cold seeding, which considerably reduces the production cost. This batch process is appropriate for fabrication of various $LREBa_2Cu_3Oy$ (LRE: Gd, NEG, etc.,) compounds as it employs novel thin film Nd-123 seeds grown on MgO crystals, compatible with all LRE-123 materials. In this way we are able to fabricate materials with enhanced pinning due to nanometer size precipitates, with good quality, and a *dramatically reduced cost*. The superconducting and magnetic performance of the pellets was checked on several small test samples cut out at various standard positions within the bulk. Microstructure of batch processed material was checked by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The trapped field measurements showed that in the whole batch the samples were single-domain and of good pinning performance. The trapped field nearly 1 and 1.2 T was observed in the best 24 mm single-grain puck of Gd-123 and NEG-123, respectively. On basis of the program results the price, performance, and the grain size of LRE-123 material will be discussed with respect to use in a variety of industrial applications.

**F15** *10:05–10:25*

## Development of Compact, Lightweight, Movable Permanent Magnet System Based on High Temperature Bulk Superconductors

***M. Tomita**, Y. Fukumoto, M. Muralidhar, K. Suzuki, and A. Ishihara*

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**Abstract:** In recent years, there has been an increasing interest in the melt processed high $T_c$ superconducting permanent magnets, since these materials can trap magnetic fields by an order of magnitude higher than the best classical hard magnets. In particular, it is very important to develop the magnetization process to utilize these materials for several industrial applications. We developed a compact, lightweight, movable permanent high Tc superconducting magnet system using an GdBCO melt processed material. The magnet was constructed using ten annular c-axis oriented single domain bulk materials in vertical direction. Each bulk having the dimensions of 87 mm outer, 48 mm inner diameter, and 20 mm thickness respectively. All bulks are resin-impregnated and arranged inside an insulated material to minimize the liquid nitrogen losses. The magnet was magnetized to 5 T by a superconducting magnet by using the field cooling (FC) process at liquid nitrogen temperature. The whole system was removed slowly from the 10 T superconducting system. First we measured the magnet's magnetic field distribution and flux creep as a function of time by a Hall probe sensor scanning in vertical and horizontal directions, respectively. Eventually, using this new permanent magnet, we successfully magnetized several melt processed bulk samples and measured their trapped field distribution at 77 K. The high $T_c$ lightweight permanent magnet system is simple, compact and the magnetization process is quick. Such systems can be energized by using one main station. Magnetizing bulk melt processed materials by utilizing superconducting permanent magnet opens up new technological methods for several industrial applications.

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## 10:25—11:25 AM
## POSTER SESSION & COFFEE BREAK - *Bird Cage Walk*

***K. Marken**, Chair*

### FP16
### Improving the Performance of Trapped Field Magnets Made of Drilled Bulk High-Temperature Superconductors by Filling the Holes with a Soft Ferromagnetic Material

***Gregory P. Lousberg, J.-F. Fagnard, M. Ausloos, P. Vanderbemden, and B. Vanderheyden***

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**Abstract:** Drilled bulk high-temperature superconductors have been proposed as 'thin wall structures' where the reduced diffusion path helps improving the oxygenation and the temperature stability. By removing superconducting matter, however, one also reduces the maximum magnetic flux that can be trapped in such a structure with respect to that trapped in a plain sample with the same superconducting properties. This work shows that the trapped magnetic flux can be enhanced by filling the holes with a soft ferromagnetic material. Characterizations based on Hall probe mapping and magnetization measurements are used and demonstrate an increase of the trapped magnetic flux after impregnation. These results are further examined with the help of a 3D finite element model, where in order to keep a manageable number of mesh nodes, the ferromagnet material assumes a linear constitutive law. Although such an approach is a first-order approximation, it already confirms the experimental observations and indicates that the increase of magnetic flux due to the ferromagnetic material may compensate the magnetic loss incurred by the sample in the presence of the holes.

### FP17
### Development of Textured YBaCuO Bulk with Artificially Patterned Walls

***J.G. Noudem**[1] and X. Chaud[2]*

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**Abstract:** The recently reported superconducting $YBa_2Cu_3Oy$ (Y123) with artificially patterned holes is highly interesting in view to improve the material quality and also promising for a wide variety of applications. It is well known that, the core of plain bulk superconductors needs to be fully oxygenated and some defects like cracks, pores and voids must be suppressed in order that the material can trap high magnetic field or carry high current densities. To minimise the above defects, we have used the Top Seeding Melt Textured Growth (TSMTG) and Seed Infiltration Growth (SIG), to prepare the single domains of $YBa_2Cu_3Oy$ (Y123) bulk superconductors with multiple holes. The prepared samples have been performed and the ability of this novel geometry as a superconducting magnet will be discussed.

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## FP18
## Hyperconducting Joints Using HTS Powders

***L. Bromberg***

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*brom@psfc.mit.edu*

**Abstract:** Low resistance joints are of interest in cryogenic applications. Although some applications, such as MRI or NMR need to have superconducting joints, superconducting joints with High Temperature Superconductors have proven difficult. A method is presented for the reduction of resistance associated with conventional joining materials, using crushed HTS bulk materials, placed in an electrically conducting matrix. Calculations of the joint resistance are performed, and means of implementation are described. An experiment setup to test the concept is under construction.

## FP19
## Study of the Magnetic Shielding Performance in Relation to the *E(J)* Characteristics of Melt Cast Bi-2212 Tubes under DC Axial Magnetic Fields

***J.-F. Fagnard*[1], *S. Elschner*[2], *J. Bock*[3], *M. Dirickx*[1], *B. Vanderheyden*[4], *and P. Vanderbemden*[4]**

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**Abstract:** In this work, we aim at describing as widely as possible the shielding properties and the E(*J*) relationship of Bi-2212 tubes from non-destructive measurements on a whole cylinder. First, the threshold magnetic induction below which the shielding occurs, $B_{lim}$, is measured in a large temperature range between 10 K and 77 K. The temperature dependence of Blim is compared to that of similar superconducting hollow cylinders made of Bi-2223 previously studied in [Fagnard J-F et al. Supercond. Sci. Technol. **22** (2009) 105002] and shows that the magnetic shielding capabilities of Bi-2212 below $T$ = 60 K can exceed those of Bi-2223. In particular, the threshold value of shielded magnetic field is higher than 800 mT below $T$ = 20 K with a 5 mm thick cylinder. Next, the sweep rate dependence of Blim is determined and analysed under several simple assumptions relating $B_{lim}$ to the shielding currents, *J*, and the sweep rate of the applied magnetic field to the electric field, *E*, to give information about the non-linear *E(J)* relationship. Then, the relaxation of the shielding currents is studied at several temperatures and the results are used to confirm the values of the power law exponent of the *E(J)* relationship determined by sweep creep experiments. Finally, transport and AC-shielding measurements are carried out and exploited, together with the magnetic relaxation and the sweep creep measurements, to build a piecewise *E(J)* graph that extends over several decades.

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## FP20

## Novel Magnetizing Method for Permanent Magnet Using Static Magnetic Field Generated by HTS Bulk Magnet

***Tetsuo Oka*[1), *Tomoki Muraya*[1)], *Nobutaka Kawasaki*[1)], *Satoshi Fukui*[1)], *Jun Ogawa*[1)], *Takao Sato*[1)], *Toshihisa Terasawa*[2)], *Yoshitaka Itoh*[2)], *Ryohei Yabuno*[2)]**

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**Abstract:** In this study, we report that the demagnetized rare earth magnets (Nd-Fe-B) can be fully magnetized by placing them in the intense static field over 3 T which was generated by HTS magnets cooled to the superconducting state at a temperature range lower than 77K with the use of cryo-coolers. The permanent magnet was scanned just above the magnetic pole containing the HTS bulk magnet. We have examined the magnetic field distributions and their properties when the magnetic poles were scanned twice to activate the magnetic plates reversely with various overlap distances between the tracks of the HTS bulk magnet. The magnetic field of the 'rewritten' magnet has shown steep gradients at the border of each magnetic pole. Instead of employing conventional pulsed field magnetization methods, this technique is proposed to be utilized for designing the electromagnetic devices as a novel practical method for magnetizing the rare earth magnets which have excellent performances and require the intense fields more than 3 T to activate.

## FP21

## Non-Destructive Measurement of Critical Currents and *E-J* Characteristics in Cylindrical (RE)BCO Bulk Superconductors

***Zhihan Xu*, *Archie M. Campbell*, *David A. Cardwell***

*Bulk Superconductivity Group, Department of Engineering, University of Cambridge, Trumpington Street, Cambridge, CB2 1PZ, UK; Tel: +44 (0) 1223 330287; Fax: +44 (0) 1223 332662; E-mail: zhx20@cam.ac.uk*

**Abstract:** The critical current density $J_c$ is an important parameter for applications of bulk high temperature superconductors (HTS), such as RE-Ba-Cu-O [(RE)BCO], in high field, permanent magnet-like devices. It is very desirable to measure $J_c$ by a non-destructive method, since it cannot be deduced accurately from the mapping of trapped field given that a particular distribution of field in a bulk HTS may be generated by many different distributions of $J_c$. Most methods to-date, however, involve cutting a sample into small pieces before measurement in a SQUID or other apparatus. This paper describes a non-destructive method of determining the magnitude of $J_c$ in a cylindrical (RE)BCO bulk superconductor by measuring the induced voltage using a pick-up coil under the application of magnetic pulses on top of a background field. The magnetic field dependence of $J_c$ is obtained by varying the background field while the E-J characteristic can be derived from the frequency variation of the applied pulses. In addition, simulations are conducted using a theoretical model, and the results are in good agreement with those observed experimentally. This method, along with the experimental results, provides insight into the process of magnetization in bulk HTS of cylindrical and other geometries and enables optimization of the profile of multi-pulse magnetization in order to achieve the maximum trapped field.

**Acknowledgement:** The authors acknowledge Mr. Tony Dennis for his kind help during the set-up of the experimental devices.

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## FP29
## Superheating Property of REBCO Thin Films and its Application for Cold-Seeding in MT Growth

***X. Yao*[1], L. J. Sun[1], S. B. Yan[1], L. Cheng[1], M. Oda[2], and H. Ikuta[2] D. A. Cardwell[3]**

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**Abstract:** In this presentation, we report a superheating phenomenon of REBCO thin film. It was found that the complete decomposition of a c-oriented YBCO film occurred at a temperature up to 50 K higher than its peritectic temperature. Further, a systematic investigation was conducted on superheating mechanism of REBCO film and its correlation with film crystallinity. Moreover, using SmBCO thin films as cold-seeds, which may be prepared with highly controlled orientation (i.e. with a well-defined a-b plane and precisely known a-direction), high performance SmBCO bulks were successfully grown in the melt-textured process. Finally, REBCO thin films as multi-seeds have also been used successfully in a multi-seeded melt growth (MSMG) process, to gain a large diameter bulk sample.

## 11:30 AM—12:30 PM
## POSTER DISCUSSION - *Diplomat Room*

***K. Marken**, Chair*

*Note: Each presenter has 7 minutes, including 2 minutes for Q&A*

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|---|---|
| **FP16** | **B. Vanderheydan** |
| **FP17** | **J. G. Noudem** |
| **FP18** | **L. Bromberg** |
| **FP19** | **J. F. Fagnard** |
| **FP20** | **T. Oka** |
| **FP21** | **Z. Xu** |
| **FP29** | **Will not be orally presented** |

**12:30 PM** **LUNCH**

*Congressional Room*

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## 1:50 PM—3:00 PM
## PROCESSING & OPTIMIZATION SESSION C - *Diplomat Room*

***R. Sawh**, Chair*

### F22 *1:50–2:15*
### Growth of Melt-Textured (LRE)-Ba-Cu-O by Cold Seeding Using Sm123 Thin Film as Seed Crystal

***H. Ikuta**[1], **S. Ogino**[1], **M. Oda**[1], **X. Yao**[2] and **Y. Yoshida**[3]*

*[1]Department of Crystalline Materials Science, Nagoya University, Chikusa-ku, Nagoya 464-8603, Japan; [2] Department of Physics, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, People's Republic of China; [3]Dept. of Energy Engineering and Science, Nagoya University, Chikusa-ku, Nagoya 464-8603, Japan; e-mail (H.I.): ikuta@nuap.nagoya-u.ac.jp*

**Abstract:** (LRE)-Ba-Cu-O (LRE: a light rare-earth element) bulk superconductors were prepared in a reduced oxygen atmosphere by a top seeded melt growth (TSMG) method using $SmBa_2Cu_3Oy$ thin films deposited on MgO as seed crystals. TSMG methods can be classified into hot-seeding and cold-seeding methods by the difference of when the seed crystal is placed on the precursor. While the cold-seeding method is easier to apply, it requires a seed crystal that will not react with the melt at the highest processing temperature $T_{max}$, which is difficult to meet because of the small margin in the melting temperatures between available seed crystals and the precursor. Our results indicate that $SmBa_2Cu_3O_y$/MgO thin films retained their integrity at $T_{max}$, and samples up to 30 mm in diameter were successfully grown for LRE=Sm and Gd, and 18 mm for LRE=Nd. The reason why the films did not melt during the heating process can be attributed to a superheating effect. A small contamination of Mg from the film's substrate was observed, which reduced systematically with lowering $T_{max}$. This required a careful adjustment of $T_{max}$, because $T_{max}$ has to be high enough to ensure a homogeneous melting and a stable growth. After the optimization, the bulk samples obtained by the present cold-seeding method had a quality similar to or even better than our previously reported samples that were prepared by hot-seeding. Since cold-seeding is far easier to apply than the hot-seeding method, the present results certainly contribute for the simplification of the production process of bulk superconductors.

### F23 *2:15–2:35*
### Fabrication of Single Domain GdBCO Bulks with Different New Kind of Liquid Sources by TSIG Technique

***W. M. Yang**, G. Z. Li, X.X. Chao, J. W. Li, F. X. Guo, S. L. Chen, J. Ma*

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**Abstract:** Single domain GdBCO bulks have been fabricated with different new kinds of liquid sources by a top seeded infiltration and growth process (TSIG) technique. In the conventional TSIG process, we have to prepare three kinds of powders such as $RE_2BaCuO_5$, $REBa_2Cu_3O_{7-x}$ and $Ba_3Cu_5O_8$, but in our modified TSIG technique, we only need to make $RE_2BaCuO_5$ and $BaCuO_2$ powders during the fabrication of single-domain GdBCO bulk superconductors. The liquid source, used in the conventional process, is a mixture of $REBa_2Cu_3O_{7-x}$ and $Ba_3Cu_5O_8$ in a ratio of 1:1; the new liquid sources are a mixture of $RE_2BaCuO_5$+9$BaCuO_2$+6CuO or $RE_2O_3$+10$BaCuO_2$+6CuO. Single-domain GdBCO bulk superconductors have been fabricated with the new and conventional liquid sources respectively. The microstructure and levitation force of the GdBCO bulks have also been investigated. The results showed that the properties of the samples fabricated with the new

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liquid sources is nearly the same as the sample fabricated with the conventional liquid sources, which indicates that the new liquid sources are very important to reduce the cost and improve the working efficient on the fabrication of single-domain GdBCO bulk superconductors.

**F24** *2:35–3:00*

## Influence of Post-growth Thermal Treatments on Critical Current Density of TSMG YBCO Bulk Superconductors

***P. Diko**[1], K. Zmorayova[1], M. Šefčikova[1], V. Antal[1], V Kavečansky[1] X. Chaud[2], M. Eisterer[3], H. Weber[3]*

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**Abstract:** The promising solutions of pinning enhancement are now focused on the formation of nanosize pining centers. The influence of post-growth thermochemical treatments on the transition temperature and the field dependence of the critical current density at 77 K were studied in $Y_{1.5}Ba_2(Cu,M)_3O_y$ bulk superconductors prepared by the Top-Seeded Melt-Growth (TSMG) process. The dopants react in different ways during pre-annealing in an atmosphere with low and high oxygen partial pressure and this behaviour can be associated with the formation and dissolution of dopant clusters. As-grown YBCO bulks have low oxygen content, $YBa_2Cu_3O_{6.3}$, are not superconducting, and must be oxygenated to form $YBa_2Cu_3O_7$. During standard oxygenation at 400 - 450 °C the shortening of crystal lattice parameters causes intensive cracking. The created cracks cause that the effective cross section of the bulk is significantly reduced to the value about one third of the original sample cross section. High pressure high temperature oxygenation preserves the peak effect introduced by the dopants and leads to the elimination of oxygenation cracks and consequently to significant increases in the effective critical current density.

**3:00 PM** **COFFEE BREAK**

*Diplomat Room Foyer*

**F25** *3:15–3:35*

## Recycling of GdBCO-Ag Single Grain Bulk Superconductors

***Y. Shi**, A. R. Dennis, M. Strasik[1] and D. A. Cardwell*

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**Abstract:** (LRE)BCO (where LRE is a light rare earth element such as Nd, Sm, Gd or Y) single grain bulk superconductors have considerable potential for engineering applications due to their ability to trap large, stable magnetic fields at 77 K. However, the cost of processing these materials is relatively high, and particularly so when Ag is added to the precursor powder to improve the mechanical properties of the fully processed sample. The nature of the top seeded melt growth (TSMG) process used commonly to fabricate (LRE)BCO single grain superconductors results typically in a relatively high failure rate, particularly during optimisation of the thermal process, which results in a high materials wastage. In this paper, we report a simple, but economical method of recycling GdBCO-Ag bulk superconductors using the TSMG technique. The microstructure and the superconducting properties of the recycled single grains before and after re-processing are reported in detail.

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**F26** *3:35–3:55*

## Effects of Reinforcement with Fe-Mn-Si Shape Memory Alloy Ring on Mechanical and Magnetic Properties of Bulk Y-Ba-Cu-O Superconductors

***Hironori Seki*[1],a, Atikorn Wongsatanawarid[1], Yotaro Shimpo[1], Masato Murakami[1], Hiromi Sakai[2], Takashi Kurita[2], Tadakatsu Maruyama[2]***

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**Abstract:** Bulk Y-Ba-Cu-O superconductors are brittle ceramics and the mechanical strength under tensional stresses is quite low. Hence, the reinforcement of the bulk superconductors is needed for practical applications. It is common to use metal rings for its enforcement, in that compression stresses are applied to the bulk superconductor using a difference in thermal expansion coefficients. Fe-Mn-Si alloys are ferrous shape-memory alloys, and the amount of the strain due to the shape memory effects is large. Therefore, the shape memory alloy rings function as excellent reinforcement materials for the bulk superconductors. We made rings of the Fe-Mn-Si alloy and studied the effects of reinforcement on magnetic and mechanical properties of bulk Y-Ba-Cu-O superconductors. The amount of recovery strain of the shape memory ring was about 2%. The cracks were not introduced into the bulk superconductor with the treatment. It was interesting to note that the trapped magnetic field was improved after the reinforcement treatment.

## 3:55—5:40 PM
## CHARACTERIZATION & PINNING SESSION D - *Diplomat Room*

***D. Lee**, Chair*

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## F27 *3:55–4:20*

### Enhancement of Critical Current in Large Grain YBCO Superconductor with Nanometer-Sized Dopants

***Ravi-Persad Sawh**[*,1], Roy Weinstein[1], Drew Parks[1], and Victor Obot[2]*

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**Abstract:** Large grain YBCO high temperature superconductor can potentially be used as trapped field magnets (TFMs) in applications such as motors and generators. In order that large grain YBCO is used as TFMs, they must be able to retain high magnetic fields after activation. Increasing flux pinning through the creation of pinning centers is a route to achieve high trapped magnetic fields. Perhaps the most straightforward approach of introducing pinning in YBCO is by the method of chemical doping. With the advent of nanotechnology, the cost and availability of chemicals, from commercial suppliers, in nanometer sizes is competitive with micrometer-sized powders. In this presentation, we will report on the enhancement of flux pinning in melt-textured YBCO superconductor with various nanometer-sized dopants. Large grain YBCO samples doped with nanometer-sized powders were produced by a top-seeded slow cooling method. After processing, trapped magnetic field was measured and then analyzed to determine the increase of critical current density in self-field. We will present results of recent studies in which critical current was enhanced by substitution into the YBCO crystal matrix, and by the more efficient refinement of Y211 particles. We will also present results, which suggest that there exist sub-micrometer chemical deposits that are very ineffective pinning centers in self-field, and do not increase trapped magnetic field of large grain YBCO.

This work was supported by grants from the United States Army Research Office, the Welch Foundation, and the State of Texas through the Texas Center for Superconductivity at the University of Houston.

## F28 *4:20–4:40*

### Control of Pinning Mechanism in Single Domain YBCO Bulk by Morphology Controlled ZnO Dopant

*C.C. Wang[1], S.C. Huang[1], C.H. Chu[1], P. Diko[2], J. Kováč[2], and **I.G. Chen**[1*]*

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**Abstract:** Pinning center in top-seeded melt textured (TSMT) yttrium barium copper oxide (YBCO) superconductor dominate the critical current density $J_c(H,T)$, which is also the most important factor for engineering application. Pinning mechanism is the topic to explain the relationship between the pinning center and its pinning force under specific applied fields and temperatures. Many researchers have reported that the impurity dopants will affect the pinning mechanism by forming chemical substitution to act as a field-induced pinning center. In this study, our research indicates the morphology of the dopant will also affect the pinning mechanism. ZnO is adopted as dopant in our experiment in two different morphologies: nano particles (commercial powder) and nano rods (grown on the YBCO precursor by chemical vapor deposition in our lab). The results show that the nano-rod doped sample has a higher $J_c(H,T)$ and pinning force under every applied field than the nano particle doped one. And the peak of the "normalized pinning force $F_p(=F_p/$

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$F_{p,max}$)" vs. "reduced field h(=H/Hirr)" plot also appears much right-shifted due to an incline surface pinning mechanism (or δTc pinning) instead of volume pinning (or δl pinning). We can attribute this phenomenon to the columnar pinning center induced by the ZnO nano-rods dopant.

Acknowledgement: This study was supported by the National Science Council, Taiwan, Republic of China, under Contract NSC 96-2112-M-006-012-MY3.

**F30** *4:40–5:00*

## Improvement of Flux Trapping in Gd-Ba-Cu-O Bulk Using Magnetic Particle

***Keita Tsuzuki**, Shogo Hara, Kun Xu, Yan Xu, Christelle Harnois, Mitsuru Izumi*

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**Abstract:** The trapped magnetic flux of Gd-bulks has increased due to the improvement of its critical current density $J_c$. To obtain higher $J_c$, introduction of pinning centre is known as one of the effective methods. We have found that the doping of magnetic particle has potential to increase the $J_c$ under magnetic field. From the view point of magnetic properties, materials with higher permeability are focused to act as a positive reinforces for pinning centre. In this paper, three kinds of alloy particles as Fe-Cu-Nb-Si-Cr-B, Fe-Si-Al http://ja.wikipedia.org/wiki/å and Fe-Si are independently introduced into the Gd123 matrix. Various amounts of those particles ranging from 0 to 0.6 mol % of Gd123 were added into Gd123 matrix together with Gd211 particles. Top-seeded melt growth process has been done. Samples with 10 mm x 10 mm are annealed and polished to 7 mm in height. Trapped magnetic flux measurements have been done at 77 K with cooling under 1 T. As a result, trapped flux of the Fe-Cu-Nb-Si-Cr-B doped and Fe-Si doped samples exceed considerably those of the undoped ones. A value of B = 0.15 T was obtained for the local maximum in the center of the top surface in Fe-Cu-Nb-Si-Cr-B doped sample. The results will be discussed comparatively from the viewpoint of enhanced flux trapping.

**F31** *5:00–5:20*

## Magnetisation of (Re)BCO Bulks by the Flux Pumping Method

***T.A. Coombs**, Y.Yan, C.H.Hsu, Z. Hong[*]*

*Cambridge University, Department of Engineering, Trumpington Street, CB2 1PZ, United Kingdom; [*]Magnifye Ltd, 7 Chesterton Road, Cambridge CB4 3AD, United Kingdom; Tel: 44 1223 748315; Fax: 44 1223 740025; email: tac1000@cam.ac.uk*

**Abstract:** In order to use (RE)BCO bulks to their full potential as permanent magnets it is necessary to make the magnetisation process practical, controllable and compact so that the (Re)BCO magnet, complete with its magnetisation unit, is smaller than the magnet it replaces while still being up to 10 times stronger. Magnets created in this way have uses in many different machines.

The magnetisation process used exploits the change in permeability with temperature of a magnetic material close to its Curie point. A circular puck of magnetic material adjacent to a superconductor is heated on its rim. The heat diffuses into the material inducing a thermal and thence a magnetic "wave".

Raising and lowering the amplitude of a magnetic field induces positive and negative currents in the superconductor. Ordinarily a Critical state model treatment of this process would produce no net change after the first cycle. The total current induced over each cycle is always the same (zero) and when viewed in cross-section the total current on each side of the central axis is also zero.

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However if we use an E–J law to analyse the system then it becomes clear that the magnitude of the currents induced is dependent on both $J_c$ and the time at which they were induced. In this case the currents on either side of the central axis no longer total zero. This change is repeatable and can oppose or reinforce the applied magnetic field. We present results both modelled and experimental demonstrating this effect.

## F32 *5:20–5:40*

### Measurements of Flux Pumping Activation of Trapped Field Magnets

***R. Weinstein[1,2*], D. Parks[1,2], R.-P. Sawh[1,2], and K. Davey[2]***

*[1]Texas Center for Superconductivity at University of Houston, Houston, TX 77204 USA [2] Physics Dept., University of Houston, Houston, TX 77204 USA * Tel 713-553-7715; Fax 713-747-4527; Weinstein@uh.edu*

**Abstract:** Applications using trapped field magnets (TFMs) have lagged due to the problem of the high fields needed for activation or in situ reactivation of the TFMs after warming. We describe experiments on the characteristics of TFM activation obtained by using repeated applications of permanent ferromagnets, herein called "fluxoid pumping". It is found that significant partial activation can be accomplished using a non-uniform pumping field such as a small permanent magnet. The method is found to be applicable to TFMs which are unactivated, or to those which are only partly activated. In the case of partial activation by field-cooling or zero-field-cooling, and subsequent activation by pumping, it is found that the resulting fields and currents are additive. We observe evidence that activation by fluxoid pumping involves time dependence similar to creep. Activation by fluxoid pumping is conveniently accomplished in a TFM with a central hole, but can also be accomplished without such a hole. However, if full activation is the ultimate goal. both cases require a field which is higher in the center of the HTS than at the periphery, Zero-field-cooling, followed by pumping with such a non-uniform field, results in trapping the full applied field instead of half the applied field, as is trapped by application of a uniform activating field.

**5:40 PM DAILY SESSIONS END**

**6:45 PM MEET IN HOTEL LOBBY FOR WALK TO DINNER**

**7:00 PM DINNER OFF SITE: NEW HEIGHTS RESTAURANT**

*2317 Calvert St., NW (across from Omni)*

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# SATURDAY, JULY 31

**7:30 AM** **CONTINENTAL BREAKFAST**
*Diplomat Foyer*

## 8:00—9:05 AM
## CHARACTERIZATION & PINNING SESSION D-*cont.* *Diplomat Room*

***B. Holzapfel***, *Chair*

### S33 *8:00–8:20*

### Novel Magnetizing Method for Permanent Magnet Using Static Magnetic Field Generated by HTS Bulk Magnet

***Tetsuo Oka*[1)], *Tomoki Muraya*[1)], *Nobutaka Kawasaki*[1)], *Satoshi Fukui*[1)], *Jun Ogawa*[1)], *Takao Sato*[1)], *Toshihisa Terasawa*[2)], *Yoshitaka Itoh*[2)], *Ryohei Yabuno*[2)]**

*[1] Faculty of Engineering, Niigata University, 8050 Ikarashi-Ninocho, Nishi-ku, Niigata, 950-2181 Japan [2] IMRA MATERIAL R&D CO. LTD., 2-1 Asahimachi, Kariya, Aichi, 448-0032 Japan; Tel. +81-25-262-7668; Fax. +81-25-262-7010; e-mail okat@eng.niigata-u.ac.jp*

**Abstract:** In this study, we report that the demagnetized rare earth magnets (Nd-Fe-B) can be fully magnetized by placing them in the intense static field over 3 T which was generated by HTS magnets cooled to the superconducting state at a temperature range lower than 77K with the use of cryo-coolers. The permanent magnet was scanned just above the magnetic pole containing the HTS bulk magnet. We have examined the magnetic field distributions and their properties when the magnetic poles were scanned twice to activate the magnetic plates reversely with various overlap distances between the tracks of the HTS bulk magnet. The magnetic field of the 'rewritten' magnet has shown steep gradients at the border of each magnetic pole. Instead of employing conventional pulsed field magnetization methods, this technique is proposed to be utilized for designing the electromagnetic devices as a novel practical method for magnetizing the rare earth magnets which have excellent performances and require the intense fields more than 3 T to activate.

### S34 *8:20–8:45*

### Magneto-Thermal Phenomena in Bulk Melt-Processed (RE)BCO Superconductors Subjected to Large Alternating Magnetic Fields

***P. Laurent, J. F. Fagnard, B. Vanderheyden, and P. Vanderbemden***

*SUPRATECS, Department of Electrical Engineering & Computer Science, Bat B28, University of Liege, Belgium; Tel : +32 4366 2670; Fax : +32 4366 2950; e-mail : Philippe.Vanderbemden@ulg.ac.be*

**Abstract:** In several engineering applications where large bulk melt-processed (RE)BCO are used as permanent magnets, the sample may experience transient or periodic variations of the applied magnetic field. In such a case, the losses caused by the motion of vortices may give rise to a significant temperature increase and a degradation of the superconducting properties. In the present work, we study both theoretically and experimentally the self-heating phenomena in a bulk, large YBCO pellet subjected to AC magnetic fields up to 100 mT. Using a simple model for an infinite cylinder, we show that the thermal behaviour of the sample can be predicted using two specific threshold values of the AC magnetic field amplitude; these threshold values are determined analytically as a function of both the sample characteristics and the cooling parameters. Next we consider the more realistic case of a cylindrical sample of finite height and determine the losses in the bulk pellet using an algorithm based on the numerical method of Brandt. This algorithm is combined with a heat

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diffusion model in order to determine the time-dependence of the temperature distribution at the surface of the cylinder. The theoretical predictions of the temperature evolution of the bulk sample during a self-heating process agree nicely with the experimental data. Finally we examine the effect of a non-uniform distribution of critical current density, Jc, on the losses within the bulk sample.

## S35 *8:45–9:05*

## Wavelength-Dispersive Spectrometry Analysis of YBCO

***James Meen**, Karoline Müller, Andrea Baker, Yoon Kyoung Han*

*Department of Chemistry and Texas Center for Superconductivity at the University of Houston, Houston TX 77204 USA; Tel: (713)743-8287; Fax: (713)743-8201; Email: jmeen@uh.edu*

**Abstract:** Samples of bulk YBCO present special challenges for performing electron microprobe analysis using wavelength-dispersive spectrometry. High-quality analysis by wavelength-dispersive spectrometry requires a highly polished sample to ensure that the Bragg condition is met by the crystal spectrometer. Polishing YBCO immediately changes the O content of the grains because the surface is amorphized. Electron microbeam analysis samples the top 100-500 nm of the sample so the amorphous layer dominates the analyzed volume. There is then a further change in oxygen as the amorphous matter reacts with the environment, particularly with growth of $BaCO_3$. The amorphous layer may be removed by ion milling. This does not prevent further reaction of the YBCO with the environment but timed experiments demonstrate that the reactions are slowed. Coating the sample with a conductive layer slows the reaction down even more – the influence of different coating materials will be discussed. Thicker metal layers can effectively protect the YBCO from reaction but hugely degrade the quality of the analysis of the oxide. Careful work establishes that oxygen contents in the YBCO can vary within individual grains. These variations will be correlated with other properties of the YBCO determined by wavelength-dispersive spectrometry at the same time, particularly variations in the soft Cu L spectrum.

# 9:05—10:15 AM
# $MgB_2$ SESSION E

***K. Salama**, Chair*

## S36 *9:05–9:35*

## Enhanced Flux Pinning of SPS-processed $MgB_2$ Bulk Superconductors

***Sang-Im Yoo**[1], Jungwoo Lee[1], Geomyung Shin[1], and Masato Murakami[2]*

*[1] Department of Materials Science and Engineering, and Research Institute of Advanced Materials (RIAM), Seoul National University, Seoul 151-744, Korea; [2] Department of Materials Science and Engineering, Shibaura Institute of Technology, Shibaura 3-9-14, Minato-ku, Tokyo 108-8548 Japan*

Enhanced flux pinning could be achieved from dense $MgB_2$ bulk superconductors prepared by the spark plasma sintering (SPS) process. The SPS process was performed at the temperature region ranging from 1120 to 1300°C for 15 min in an external pressure of 72 MPa. A sharp superconducting transition with the onset temperature ($T_{c,onset}$) of 38.5 K was commonly obtained from the samples sintered below 1250°C, while $T_c$,onset was depressed and the transition became broad. Both the field-dependent critical current density, $J_c(B)$ and irreversibility field $H_{irr}(T)$ of $MgB_2$ bulk specimens, related to the flux pinning effect, were sensitive to the processing conditions. The highest $J_c$(B) and $H_{irr}$(T) properties could be obtained from the sample sintered at 1190°C. The maximum trapped field, measured with a Hall probe for $MgB_2$ bulk samples with the dimension of 45mm in diameter ´ 5mm thickness sintered at 1190°C, was ~ 1 Tesla at 27.5 K, and quenching occurred over 1 Tesla. Enhanced flux pinning is attributed to both grain boundaries and submicron-sized MgO particles

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dispersed in the MgB2 matrix. Detailed relationship between microstructures and flux pinning characteristics will be presented for a discussion. This work was supported by a grant from the Center for Applied Superconductivity Technology under the 21st Century Frontier R&D program funded by the Ministry of Education, Science and Technology, Republic of Korea.

**S37** *9:35–9:55*

## $MgB_2$-Based Materials Synthesized Under High-Pressure

***Tetiana Prikhna*** [1], ***Wolfgang Gawalek*** [2], ***Yaroslav Savchuk*** [1], ***Maxim Serga*** [1], ***Tobias Habisreuther,*** [2], ***Alexander Soldatov*** [3], ***Shujie You*** [3], ***Michael Eisterer*** [4], ***Harald W. Weber*** [4], ***Jacques Noudem*** [5], ***Vladimir Sokolovsky*** [6], ***Friedrich Karau*** [7], ***Jan Dellith*** [2], ***Michael Wendt*** [2], ***Mikhael Tompsic*** [8], ***Viktor Moshchil*** [1], ***Nina Sergienko*** [1], ***Christa Schmidt*** [2], ***Doris Litzkendorf*** [2], ***Peter Nagorny*** [1], ***Vladimir Sverdun*** [1], ***Istvan Vajda*** [9], ***János Kósa*** [9]

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The study of $MgB_2$-based materials synthesized under high pressure allows their superconducting properties to be studied as a function of the oxygen distribution in the material structure, which, in turn, is defined by the interrelations between the synthesis temperature, phase content and borides formation. Critical current densities, $j_c$'s, measured via a magnetic method of up to 1.8-1.0 x106 A/cm$^2$ in self field at 20 K, 103 A/cm$^2$ in an 8 T field at 20 K, and 3-1.5 x 105 A/cm$^2$ in self field at 35 K have been observed. An upper critical field of $H_{C2}$ = 15 T at 22 K and an irreversibility field $H_{irr}$ =13 T at 20 K have been attained. The estimated transport critical current and AC losses of $MgB_2$–based materials synthesized under high pressure (2 GPa) and hot pressure (30 MPa) suggest they have potential for application in inductive fault current limiters, electromotors, and for the generation of high magnetic fields.

The appearance, composition and structure of the so-called higher boride phases ($MgB_4$, $MgB_6$ or $MgB_7$, $MgB_{12}$ , $MgB_{16}$ or $MgB_{17}$ and $MgB_{20}$) is under reported in the literature. A large amount of higher borides, which are present in the materials, cannot be revealed by X-ray diffraction (XRD). Contrary to XRD, Raman spectroscopy may be of great help in distinguishing between phases of different stoichiometry in such cases. The Raman spectra of $MgB_7$ and other higher borides will be considered in this paper.

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**S38** *9:55–10:15*

## New Fully Superconducting Hybrid Bearing Concept using the Difference in Irreversibility Field of Two Superconducting Components

***Anup Patel*[1], *Ryszard Palka*[2], *Bartek A. Glowacki*[3]**

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**Abstract:** One of the major factors limiting levitation force for existing superconducting magnetic bearings is the maximum possible remnant flux density of 1.4T known to exist for permanent magnets of the rare-earth kind. This paper introduces the novel concept of a magnetic bearing which uses the difference in irreversibility field of two superconducting components to allow one component to be field-cooled in the field originating from the other component which is first magnetized at a higher temperature. Magnetized (RE)BCO pellets with high trapped fields can be used as one of the components instead of permanent magnets, significantly increasing the levitation force density that can be achieved between the two components given that magnetic forces are proportional to the square of field components. A variety of superconducting compounds could be used for the two components but this paper focuses on the $MgB_2$ – YBCO combination. Critical state modelling of the levitation forces that would exist between magnetized YBCO bulks inside a hollow $MgB_{2\_}$ cylinder is reported as well as modelling into the feasibility of pulsed magnetization of the pellets to create high field gradients. The engineering challenges facing designs for this type of bearing are also evaluated. Force densities produced by pairs of YBCO pellets magnetized with opposite polarity are significantly higher than that of a permanent magnet stack giving the new bearing concept potential in high load applications such as flywheel energy storage.

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|---|---|
| **10:15 AM** | **COFFEE BREAK** |
| **10:30—12:00 N** | **ROUND TABLE, ROADMAPPING PLANS** |
| **12:00—1:00 PM** | **SUMMARIES & CONCLUSIONS**<br>*Session Chairs* |
| **1:00 PM** | **WORKSHOP ADJOURNS** |

# PRESENTER LOCATOR INDEX

# INSTRUCTIONS FOR PRESENTERS

## INSTRUCTIONS FOR ORAL PRESENTERS

Please bring your presentation, in PowerPoint or PDF format on a CD or USB drive, to the registration table at least 30 minutes before your session starts. Files will be loaded onto a PC and prepared for your presentation. No personal computers shall be used. For governmental agency presenters: if required, please be sure clearance information is included on the first slide of your presentation. Please note the following guidelines for presentation times. All presenters should allow for 3 minutes of Q&A within their allotted timeframe. Keynote: 30 minutes; Invited Oral: 25 minutes; Contributed Oral: 20 minutes; Poster (oral, in addition to poster presentation): 7 minutes (with 2 minute Q&A).

## INSTRUCTIONS FOR POSTER PRESENTERS

**Format:** Large 4' (h) x 8' (w) (1.2 m x 2.4 m) cloth-covered boards will be provided for poster presenters. 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. Poster presenters should also note the time of their oral summary presentation and be sure their slides are loaded at least 30 minutes in advance of the session.

**Poster Set-up:** When PASREG Registration opens, but no later than Thursday, 6:30pm.

## POWERPOINT AND POSTER PRESENTATION MATERIALS

All speakers and poster presenters are asked to 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 Registration Table. Please visit the table to provide your presentation for uploading.

# PROCEEDINGS

## INVITED PAPERS

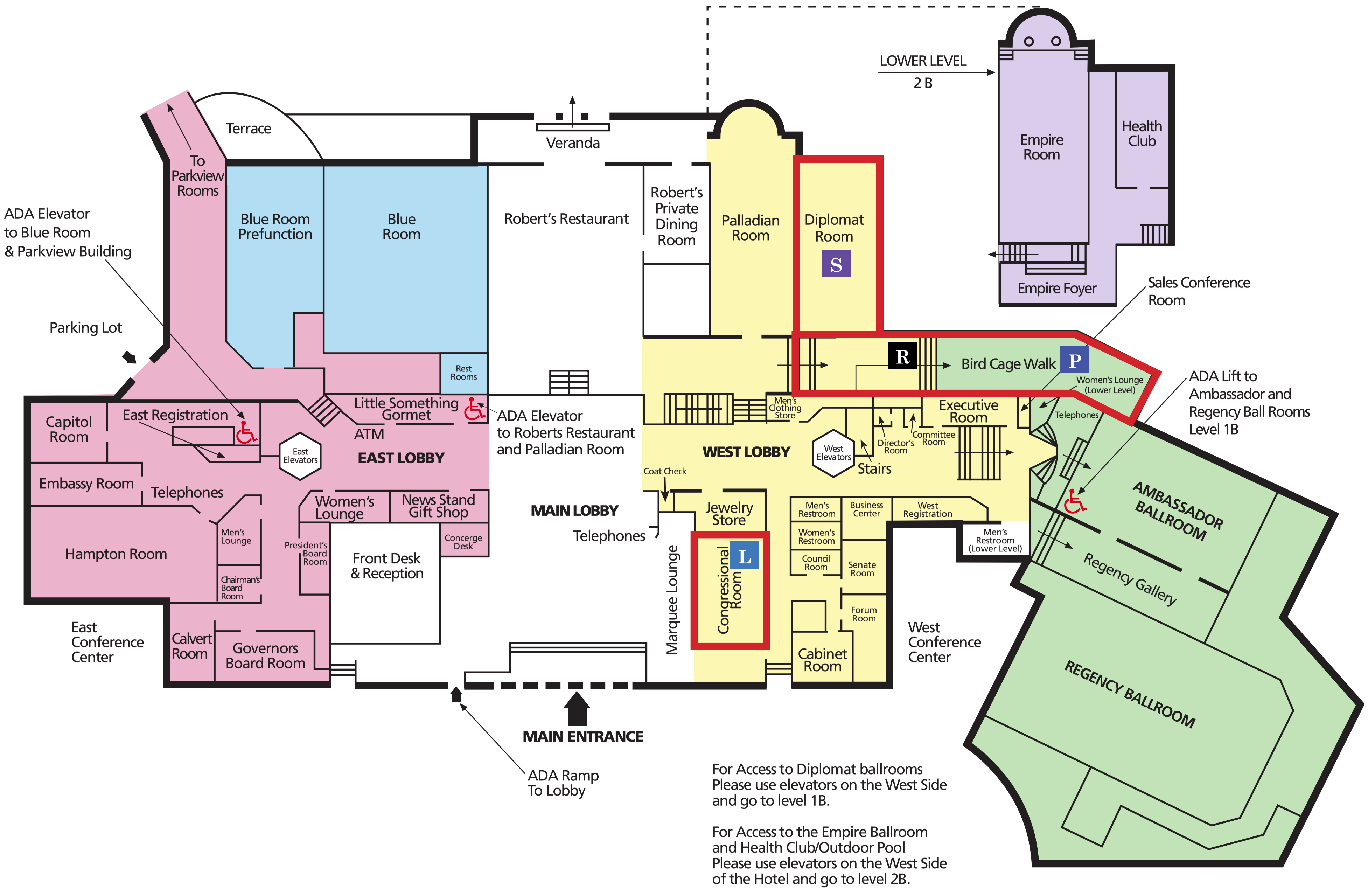
Full-length original research papers presented at the Workshop by the invited authors will be considered for publication in Superconductor Science and Technology (SuST) [ http://iopscience.iop.org/0953-2048/page/Scope ] published by the Institute of Physics (IOP), UK. Invited authors will be contacted individually. All papers submitted will be refereed according to the usual review procedure of SuST. The average length of submitted papers will be between 5 and 9 journal pages, assuming about 900 words per page (figures and diagrams to count as ~300 words).

The hardcopy publication date, assuming deadlines are met, will be December 2010. Papers will be published online as soon as they are ready in advance of the print version. As a service to authors and to the international physics community, all papers will be freely available online for 30 days from their electronic publication date. Guidelines on the preparation and submission of manuscripts and the Assignment of Copyright Form can be found at http://iopscience.iop.org/0953-2048/page/Scope. Please send completed

Assignment of Copyright Form together with the electronic file of your paper directly to IOP either by e-mail or via web as explained in the Guidelines for Authors. Electronic files of all manuscripts together with the Assignment of Copyright Form should reach IOP by July 30, 2010, the 2nd day of the meeting. Shortly after the submission, the papers submitted in the WORD format (only!) will be pre-published online in the as-received form by ESNF, the European Superconductivity News Forum - if the author(s) specifically agree to this.

## ORAL AND POSTER CONTRIBUTIONS

Contributing authors are invited to electronically publish their contributions in the European Superconductivity News Forum (ESNF) at http://www.ewh.ieee.org/tc/csc/europe/newsforum/. Submission deadline is July 30, 2010. The format for Science and Tech News can be found at:
http://www.ewh.ieee.org/tc/csc/europe/newsforum/guidelinesforauthors.html.
Submitted material should be sent to: superconductivityforum@ieee.org.




For Access to Diplomat ballrooms Please use elevators on the West Side and go to level 1B.

For Access to the Empire Ballroom and Health Club/Outdoor Pool Please use elevators on the West Side of the Hotel and go to level 2B.

P **Posters**

S **Sessions**

R **Registration**

L **Lunch 7/30**

OMNI SHOREHAM HOTEL