PASREG 2023

13^{th} International Workshop on Processing and Applications of Superconducting (RE)BCO Materials

31^{st} August – 1^{st} September 2023

CRISMAT Caen

https://pasreg2023.sciencesconf.org

PASREG’2023

Welcome to PASREG2023

Dear PASREG attendees,

We are delighted to extend our warmest welcome to all of you for the 13th International Workshop on Processing and Applications of Superconducting (RE)BCO Materials (PASREG 2023), taking place in Caen, France from August 31st to September 1st, 2023. We are excited to have you joining us in Normandy for these days.

Caen, despite being nearly destroyed during the events of the 1944 landing, has managed to rebuild itself while preserving its architectural treasures. The castle and abbeys, which stand as testament to the city's medieval history intertwined with the legacies of Mathilde and William the Conqueror, showcase this resilience. Alongside these historical marvels, contemporary architecture that emerged from the reconstruction also graces Caen. Additionally, Caen is renowned for its distinctive limestone known as "Pierre de Caen." This medium-hard, white stone was predominantly quarried in Normandy but found its way across borders, adorning structures like Westminster Abbey and the Tower of London in England, and even Saint Patrick's Cathedral in New York, across the Atlantic.

The PASREG workshop was initially established in Cambridge in 1997 and has been held biennially ever since. The primary objective of this event is to foster the exchange of knowledge and advancements in bulk superconductor processing, characterization, and applications. Given the growing interest in green energy and the increasing number of participants, PASREG 2023 has expanded its scope to include the following areas: i) Advances in seed-assisted solidification and materials recycling, ii) Densification mechanisms/modeling: exploring multi-physics phenomena, iii) Optimization of functional properties, iv) Recent developments in superconducting tapes and cables for current transport, energy storage, high magnetic field applications, coil fabrication, and fusion. This workshop offers not only captivating presentations in the fields of basic research and materials science but also showcases the progress made in the promising applications and utilization of superconducting materials - a trend eagerly anticipated by all of us.

I would like to express my sincere gratitude to all those who have contributed to the preparation of this workshop, including the members of our organizing committee, guest editors, and the generous sponsors of this event. Your support and assistance have been invaluable during these preparations. We anticipate that this event will provide an excellent opportunity to exchange ideas and collaborate in a conducive environment focused on our research themes.

On behalf of the PASREG 2023 local Organizing Committee, I wish you an interesting and fruitful workshop. We hope that PASREG 2023 conference will be both successful and enjoyable for all participants.

Jacques Noudem

On behalf of the

PASREG’2023 local Organizing Committee

Contents

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Exposants

Useful Information

Conference Venue

The Pasreg 2023 conference will be hosted in the **AULA MAGNA Hall of Caen-Normandy University, Campus 1** (Esplanade de la Paix, 14032 Caen Cedex 05).

Travel to Caen

By train

Trains to Caen leave from Paris: 2 hours between Paris-Saint-Lazare train station (13 rue Amsterdam, Paris) and Caen railway station

Caen City train station is located 20 minutes away from the University of Caen Normandy. The tram lines T1, heading towards Hérouville Saint-Clair (in front of the station), and tram T2, heading towards campus 2 (behind the station, Parcotrain exit), allow you to reach UNICAEN, Campus 1, with a frequency of approximately 10 minutes. The stop you need to get off at is called "UNIVERSITE".

By bus

Buses from Paris Charles-de-Gaulle Airport to Caen train station take on average 3 h 50 min.

By Airplane

Caen-Carpiquet airport (*9 km from the city centre*)

Acces to the city centre by bus N°3 (direction Jean Vilar)

Internet Access

WiFi is available on the premises of the University of Caen Normandy. You can access it using your credentials through the "eduroam" network. Each participant has login information on the back of their badge to connect to the Internet on the UNICAEN network.

Loading of Oral Presentations

Please use the computer in the Amphitheater to upload your presentation. Ensure that your oral presentations are uploaded no later than the end of the session preceding your speaking slot. For instance, for Session A, please upload it before 8:50 AM on August 31st, and for Session B, before 10:50 AM on the same date.

Ensure that your slides, in .ppt or .pptx format, maintain their original layout without any modifications. Also, consider having a .pdf version as a backup. Additionally, please make sure to adhere to the allocated presentation time, which is 15 minutes for oral presentations (12 minutes for the presentation and 3 minutes for questions) and 25 minutes for invited talks (20 minutes for the presentation and 5 minutes for questions).

The local committee is available to guide and assist you if needed. Thank you for your cooperation.

Poster

The posters will be exhibited in the AULA MAGNA Hall.

Exhibition of Industrial Companies

The industrial sponsors of the conference are present in the AULA MAGNA hall throughout the duration of the conference.

Coffee Breaks – Lunches - Social Event - GALA Dinner

●All coffee breaks will take place in the AULA MAGNA hall around the Posters and the industrial stands.

●The lunch on **August 31st** will take place (self-service) at the university restaurant (Reserved area)

- Collect a tray at the entrance,

- Serve yourself (buffet: a starter + a main course + a dessert of your choice),

- Hand the ticket provided at the cash desk and

- Go to the room reserved for speakers and all conference participants.

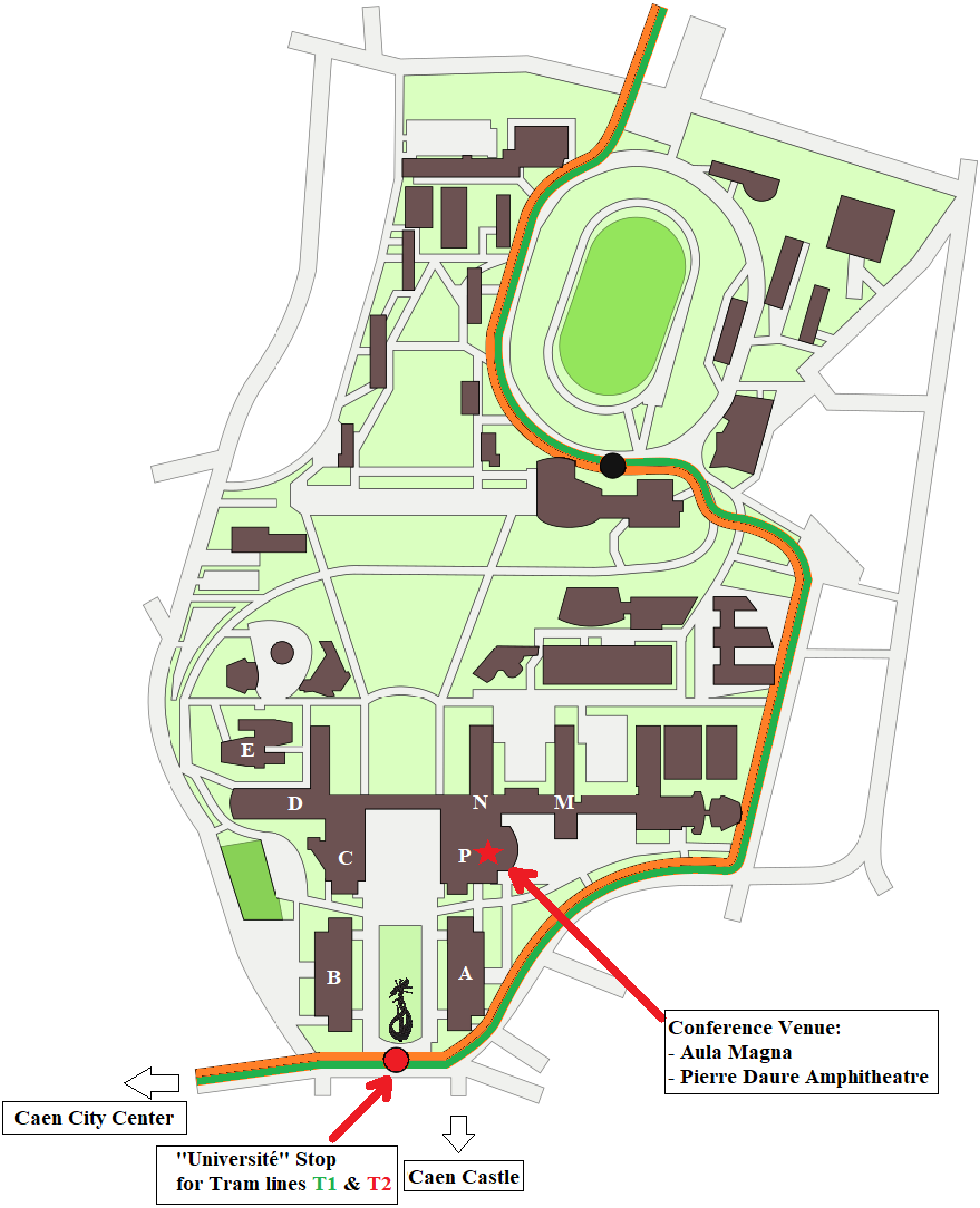
●The lunch on **September 1st** will take place on AULA MAGNA hall around the Posters and the industrial stands. Buffet : self-service

● Social event (departure by bus at 5:00 p.m from the campus) : visit of the Caen City Hall/men's abbey (Abbaye aux hommes), meeting with the Caen city Mayor

● Conference dinner (departure by bus at 7:30 p.m from the city Hall) : La Cremaillere restaurant in front to the seaside.

● Return to hotels by bus around 10:30 p.m

Access Map


E
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Conference Venue:
- Aula Magna
- Pierre Daure Amphitheatre
Caen City Center
"Université" Stop
for Tram lines T1 & T2
Caen Castle

Program

31st August, Thursday	
8:00 to 8:40	**Opening day: Registration & Coffee break**
8:40 to 9:00	**Welcome Speech**

Session A: Innovative applications (Chairman: Pr. P. Vanderbemden/Pr. J. Durrell)	
9:00 to 9:25 **A-I**	**Invited speaker: Mitsuru Izumi** *National Institute of Technology & Tokyo University of Marine Science and Technology, Japan* **Status and prospects for low-speed bulk superconducting electric machines**
9:25 to 09:50 **A-II**	**Invited speaker: John Durrell** *University of Cambridge, United Kingdom* **The Characterisation of Bulk Rare-Earth Superconducting Undulators**
9:50 to 10:05 **A-III**	**Tetsuo Oka** *Shibaura Institute of Technology, Japan* **HTS Bulk Magnets Cooled by a Refrigerator and Latest Efforts for Their Application Research**

Industrial session: Dialogue between users and manufacturers (Chairman: Pr. P. Vanderbemden/Pr. J. Durrell)	
10:05 to 10:20 **I-I**	**Plechacek Jan** *CAN SUPERCONDUCTORS, Czech Republic* **Current Progress in HTS Bulks and Materials for Industrial Applications**
10:20 to 10:35 **I-II**	**Bai Song** *Shanghai Superconductor, China* **The progress of the second generation high temperature superconductor tapes in Shanghai Superconductor Technology Co., Ltd.**
10:35 to 11:00	**Coffee break & Poster presentation**

Session B: Innovative applications and characterization (Chairman: Pr. M. Izumi/Pr. D. Zhou)	
11:00 to 11:25 **B-I**	**Invited speaker: Zhihao Ke** *Southwest Jiaotong University* **The Development Status and Prospect of HTS Pinning Maglev in SWJTU**
11:25 to 11:50 **B-II**	**Invited speaker: Taketsune Nakamura** *Kyoto University, Japan* **R&D Status and Future Prospects of High Temperature Superconductor induction/Synchronous Motors Cooled by Liquid Hydrogen**
11:50 to 12:15 **B-III**	**Invited speaker: Philippe Vanderbemden** *University of Liège, France* **Superconducting magnetic shields combining bulk superconductors and tapes**
12:15 to 12:30 **B-IV**	**Tetsuo Oka** *Shibaura Institute of Technology, Japan* **HTS Bulk Magnets Cooled by a Refrigerator and Latest Efforts for Their Application Research**
12:30 to 14:00	**Lunch**

Session C: Processing and optimization of ReBCO bulk-I (Chairman: Pr. T. Prikhna/Dr. J. Plechacek)

14:00 to 14:25 **C-I**	**Invited speaker: <u>Xin Yao</u>** *Shanghai Jiao Tong University, China* **Natural strategies for creating non-equilibrium morphology with self-repairing capability towards rapid growth of YBCO bulks**
14:25 to 14:50 **C-II**	**Invited speaker: <u>Pavel Diko</u>** *Institute of Experimental Physics SAS, Slovak Republic* **Microstructure and superconductig properties of REBCO bulks studied at DMP IEP SAS Košice**
14:50 to 15:05 **C-III**	**<u>Cuiping Zhang</u>** *SMRC, Northwest Institute for Non-ferrous Metal Research, China* **Crystallographic Phase Transition and Growth Mechanism of Bulk Superconductor TSPMP-YBCO Single Domain and its Application on Superconducting Bearing**
15:05 to 15:20 **C-IV**	**<u>Josef Baumann</u>** *University of Cambridge, United Kingdom* **Understanding the mechanical and flux trapping properties of non-oxygenated YBCO, YBCO and YBCO(Ag) single grains**
15:20 to 15:45	**Coffee break & Poster presentation**

Session D: Processing and optimization of ReBCO bulk-II (Chairman: Pr. X. Yao/Dr. B. Savaskan)

15:45 to 16:10 **D-I**	**Invited speaker: <u>Filip Antoncik</u>** *University of Chemistry and Technology Prague, Czech Republic* **Advancements in Melt-assisted Single-domain REBCO Bulk Growth**
16:10 to 16:35 **D-II**	**Invited speaker: <u>Difan Zhou</u>** *Shanghai University, China* **REBCO bulk superconductors prepared by liquid assistant growth and their trapped field performance**
16:35 to 16:50 **D-III**	**<u>Daniela Volochova</u>** *Institute of Experimental Physics SAS, Slovak Republic* **Macroscopic superconducting properties of GdBCO bulk superconductors with different height**
17:00 to 19:00	**Social Event**
20:00 to 23:00	**Gala Dinner**

1st September, Friday

Session E: Characterization and Simulation (Chairman:Pr. L. Gozzelino/Pr. M. Miryala)

8:30 to 8:55 **E-I**	**Invited speaker: Wanmin Yang** *Shaanxi Normal University, China* **A new kind of flux pinning centers of $Gd_2Ba_2Sr_2CuZrO_y$ nanoparticles to fabricate high quality GdBCO bulk superconductors**
8:55 to 09:10 **E-II**	**Sait Baris Guner** *Recep Tayyip Erdogan University, Turkey* **Trapped Field and Levitation Performances of YBCO Bulk Superconductors**
9:10 to 09:25 **E-III**	**Michel Houbart** *University of Liège, France* **Overcoming the demagnetization of superconducting linear Halbach array**
9:25 to 09:40 **E-IV**	**Bakiye Çakır** *Artvin Çoruh University, Turkey* **Critical Current Density Distribution Map of the Bulk YBCO Superconductor**
09:40 to 09:55 **E-V**	**Akash Garg Agarwal** *Shibaura Institute of Technology, Japan* **Investigation of the Impact of Liquid Sources on Levitation Force and Trapped Field Performance of Ternary Bulk (Gd, Y, Er)-123 Fabricated Using Infiltration Growth Process**
09:55 to 10:10 **E-VI**	**Jean-Guy Caputo** *INSA Rouen, France* **Mathematical analysis of the flux-jump model**
10:10 to 10:25 **E-VII**	**Cyril Tain** *Université de Rouen Normandie & INSA Rouen, France* **Use of gauges in the Time Dependent Ginzburg Landau model of superconductivity**
10:25 to 10:50	**Coffee break & Poster presentation**

Session F: Recent trends of MgB_2 application (Chairman: Pr. A. Yamamoto/Dr. J-G. Caputo)

10:50 to 11:15 **F-I**	**Invited speaker: Muralidhar Miryala** *Shibaura Institute of Technology, Japan* **Recent developments in Bulk MgB_2: Affordable and High-Performance Material for Practical Use**
11:15 to 11:40 **F-II**	**Invited speaker: Tetiana Prikhna** *V. Bakul Institute for Superhard Materials, Ukraine; Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden e. V., Germany; Institut de Ciencia de Materials de Barcelona, Spain* **Magnesium diboride- and ReBCO - based materials for application in liquid hydrogen**
11:40 to 12:05 **F-III**	**Invited speaker: Laura Gozzelino** *Politecnico di Torino & Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Italy* **Thermo-magnetic instability influence on the shielding properties of MgB_2 bulk samples**
12:05 to 12:20 **F-IV**	**Burcu Savaşkan** *Karadeniz Technical University, Turkey* **MgB_2 bulk superconductors fabricated by in-situ route for levitation applications**
12:20 to 12:35 **F-IV**	**Yiteng Xing** *Laboratoire de Cristallographie et sciences des matériaux, France* **Investigation of Superconducting Magnetic levitation with MgB_2 bulk cryomagnets: the effect of the sample size and working temperature**
12:20 to 14:00	**Lunch**

Session G: Processing and characterization of iron-based & MgB_2 & HTS materials: (Chairman: Pr. P. Diko/Pr. Y. Ma)

14:00 to 14:25 **G-I**	**Invited speaker: Yanwei Ma** *Institute of Electrical Engineering, Chinese Academy of Sciences, China* **Fabrication of High Performance Iron-Based Superconducting Materials**
14:25 to 14:50 **G-II**	**Invited speaker: Akiyasu Yamamoto** *Tokyo University of Agriculture and Technology & JST-CREST, Japan* **Process machine learning, twinning network graph analysis & record high trapped magnetic field of Ba122 polycrystalline bulk superconductors**
14:50 to 15:05 **G-III**	**Minoru Maeda** *Kangwon National University, South Korea* **Structural disorder and its anisotropy in multi-band MgB_2 materials with high critical current performance**
15:05 to 15:20 **G-IV**	**Nicolas Rotheudt** *University of Liège, France* **Design of a bespoke 3-axis cryogenic Hall probe and application to measuring the flux density produced by bulk superconductors with a triangular cross-section**
15:20 to 15:35 **G-V**	**Michela Fracasso** *Politecnico di Torino & Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Italy* **Trapped field ability of a MgB_2 disk: experimental and numerical investigation**
15:35 to 16:00	**Conclusions and end of the conference**

31st August - 1st September
Session H: Poster Presentation

H-I	**Şeyda Duman** *Artvin Çoruh University & Karadeniz Technical University, Turkey* **A Study of Fluctuation Induced Conductivity Analysis for Welded TSMG YBCO Using a Solder Material Produced by Different Melting Methods**
H-II	**Tatsuki Tagashira** *Keio University, Japan* **Application of superconducting levitation to vibration-based energy harvesters**
H-III	**Kento Takemura** *Shibaura Institute of Technology, Japan* **Control of joint part properties in GdBCO bulk superconductor joined by ErBCO superconductor**
H-IV	**Yuhi Yamanouchi** *Tokyo University of Marine Science and Technology, Japan* **Design of a linear generation module for undulator-type tidal current power generation**
H-V	**Koyo Kimura** *Keio University, Japan* **Effectiveness of LCR electromagnetic shunt damper for superconducting magnetic levitation system with nonlinear vibration characteristics caused by magnetic forces**
H-VI	**Bruno Douine** *Université de Lorraine, France* **High Temperature Superconducting bulks for electrical machine application**
H-VII	**Katarína Zmorayová** *Institute of Experimental Physics SAS, Slovak Republic* **Microstructure of DyBCO bulk superconductors prepared using single-direction melt growth (SDMG) method.**

H-VIII	<u>**Veronika Kucharova**</u> *Institute of Experimental Physics SAS, Slovak Republic* **Preparation, microstructure and superconducting properties of EuBCO-Ag bulk samples**
H-VIV	<u>**Minato Hiroki**</u> *Keio University, Japan* **Relationship between magnetic support configuration and vibration suppression effect by a gyroscopic damper for a high-temperature superconducting levitation system**
H-X	<u>**Sébastien Lemonnier**</u> *Institut franco-allemand de recherches de Saint-Louis,France* **Spark Plasma Sintering of pure dense MgB_2 ceramics: myth or reality?**
H-XI	<u>**Akira Murakami**</u> *National Institute of Technology, Ichinoseki College, Japan* **Tensile properties of superconducting bulk $REBa_2Cu_3O_y$ material fabricated by the infiltration growth technique without Pt addition**
H-XII	<u>**Nagisa Kawasumi**</u> *Tokyo University of Marine Science and Technology, Japan* **Transient measurement of two-dimensional magnetic flux density distribution on HTS bulk surface**
H-XIII	<u>**Jefry-Samson Thonikuzhiyil**</u> *Normandie Univ, ENSICAEN, UNICAEN, CNRS, CRISMAT, 14000 Caen, France* **Magnetic Performance Study on NdFeB/ Sr-Ferrite composite Permanent magnets: towards a new track for magnetic levitation**
H-XIV	<u>**Yiteng XING**</u> *Normandie Univ, ENSICAEN, UNICAEN, CNRS, CRISMAT, 14000 Caen, France* **High critical current density of MgB_2 bulk superconductor fabricated by Spark Plasma Sintering**
H-XV	<u>**Pierre Bernstein**</u> *Normandie Univ, ENSICAEN, UNICAEN, CNRS, CRISMAT, 14000 Caen, France* **Magnetic Dipoles Including Magnets and Superconductors with Adjustable Field**

Invited Talks

A-I

Status and prospects for low-speed bulk superconducting electric machines

Mitsuru Izumi*[1,2], Tetsuya Ida[2], Kota Yamaguchi[1], Keita Tsuzuki[3], Masahiro Watasaki[4], and Erasmus Shaanika[5]

[1]National Institute of Technology, Toba College – Japan
[2]Tokyo University of Marine Science and Technology – Japan
[3]National Institute of Technology, Toyota College – Japan
[4]National Institute of Technology, Hiroshima College – Japan
[5]University of Namibia – Namibia

Abstract

Bulk high-temperature superconductors (HTS) trap large magnetic fields, which enables us to develop high-specific power electric machines. However, a small number of bulk HTS machine prototypes have been developed worldwide. On the other hand, the HTS coils of 1 G and 2 G are enablers that reinforce large-scale ship propulsion motors in both power and torque density per volume and weight. To evaluate the potential of bulk HTS in propulsion power application, we try to conduct a comparative study from the perspective of social implementation between a radial-flux synchronous machine with the HTS coils as field poles and a radial-flux synchronous machine with the bulk. This trial challenge may provide a base for the next step of constructing scenarios for practical installation, which renovate the potential of bulk superconductivity, and provides an opportunity to think about its new value creation for the era of GX and carbon neutrality as well. As a possibility of future development, we also mention the application of bulk materials to tidal current power generation.

References:

Kiruba S Haran et al. 2017 Supercond. Sci. Technol. 30 123002 Erasmus Shaanika et al. 2020 IEEE Trans. Appl. Supercond. 30 5200106 Masahiro Watasaki et al. 2021 Supercond.
Sci. Technol. 34 035015 Yohei Murase et al. 2021 Eng. Res. Express 3 025020 Kota Yamaguchi et al. 2019 Int. J. Thermal Sci. 142 258 Shinji Takei et al. 2022 IEEE Trans. Appl. Supercond. 32 5201305

Keywords: Motors and generators, Trapped field magnets, tidal generators

A-II

The Characterisation of Bulk Rare-Earth Superconducting Undulators

Anthony Dennis[1], Marco Calvi[2], Sebastian Hellmann[2], Kai Zhang[3], and John Durrell*[1]

[1]Department of Engineering, University of Cambridge, Cambridge, UK – United Kingdom
[2]Paul Scherrer Institute – Switzerland
[3]Zhangjiang Laboratory – China

Abstract

Rare earth bulk superconducting material where the rare element earth is Y, Gd or Eu, in bulk form have potential for a wide range of applications. One such application is as high trapped field substitutes for permanent magnets. In this work we report on the development and characterisation of a series of 10 mm period staggered array undulators using bulk superconductor pseudo-permanent magnets. The motivation for this work is the development of a meter-long bulk HTS based undulator to feed into the hard x-ray I-TOMCAT beamline designed for the upgrade of the Swiss Light Source (https://www.psi.ch/en/sls). Samples are field cooled in a 10.0 T solenoid field to 10 K before the external field is removed and the undulator field measured along with flux creep. We also look at the deviation in field between each period, flux creep and reduction of flux creep. In addition, we report initial measurements on a helical undulator. An undulator field in excess of 2.0 T, exceeding that previously reported in such systems, has been achieved.

Keywords: undulators, trapped fields

B-I

The Development Status and Prospect of HTS Pinning Maglev in SWJTU

Zigang Deng[1], Zhihao Ke*[1], Jun Zheng[1], and Weihua Zhang[1]

[1]Southwest Jiaotong University – China

Abstract

As a typical representative of the novel maglev system, high-temperature superconducting (HTS) pinning maglev becomes an important development direction of rail transit in the future by its merits of passive stabilization and no inherent magnetic resistance. Since the birth of the first manned HTS pinning maglev test vehicle “Century” in 2000 and the accomplishment of the test platform for HTS Maglev Evacuated tube transport (HTS Maglev-ETT) “Super-Maglev” in 2014, quantities of efforts have been continuously done to promote this technology into engineering application in Southwest Jiaotong university (SWJTU). Then, in 2021, SWJTU officially launched the first full-sized high-speed HTS pinning maglev engineering prototype train. Besides, a high-speed running test-platform for HTS pinning maglev assessment has achieved the speed of 335 km/h, and further aims at the speed of 430 km/h. And, an ultra-high-speed moving-rail test-platform for HTS pinning maglev, which is designed at the higher speed of 600 km/h, is also completed recently. All those prototypes and test-platforms built in SWJTU aspire to promote the development of HTS pinning maglev transit. Therefore, being anticipated to provide a relatively clear illustration for its development skeleton, this paper reviewed the development procedure of above prototypes and apparatus hitherto implemented, summarized relevant achievements with adoption of them, and discussed the future prospect of HTS pinning maglev.

Keywords: High Temperature Superconducting Pinning Magnetic Levitation, Engineering Proto- type, High, Speed Test Platform, Research Progress and Future Prospect

B-II

R&D Status and Future Prospects of High Temperature Superconductor Induction/Synchronous Motors Cooled by Liquid Hydrogen

Taketsune Nakamura*[1]

[1]Kyoto University – Japan

Abstract

Our group is researching and developing a High Temperature Superconductor Induction/Synchronous Motor (HTS-ISM) with HTS squirrel-cage windings. In this presentation, I will introduce the R&D status of the liquid hydrogen cooled HTS-ISM system, which is being promoted as a Japanese national project and a corporate project, for automobiles, aircraft, and pumps, and discuss the future prospects.

Keywords: Airplane, Automobile, High temperature superconductor, Induction/synchronous motor, Pump, Transportation equipment

B-III

Superconducting magnetic shields combining bulk superconductors and tapes

Sébastien Brialmont[1], Jean-François Fagnard[1], Julien Dular[1], Pengtao Yang[2], Wanmin Yang[2], Anup Patel[3], Seungyong Hahn[4], Christophe Geuzaine[1], Benoit Vanderheyden[1], and Philippe Vanderbemden*[1]

[1]University of Liège - Department of Electrical Engineering Computer Science – Belgium

[2]Shaanxi Normal University – China

[3]AAC Technologies – United Kingdom

[4]Seoul National University – South Korea

Abstract

Due to their ability to oppose to an external magnetic field, superconducting materials can be used to make very efficient low frequency magnetic shields [1]. One of the key advantages of type-II superconducting shields is their ability to operate at much higher fields than conventional ferromagnetic materials, the latter being limited to their saturation magnetization. For superconductors, the maximum magnetic field at which magnetic shielding becomes ineffective depends on both the critical current density J_c and the geometric parameters of the shields. These geometric parameters are mainly the thickness of the wall and the length of the superconducting current loops induced by the applied field. Although their geometries differ significantly from each other, bulk superconductors [2-3] and coated conductor tapes [4-5] offer the opportunity to design remarkable magnetic shields or screens: bulk superconductors can be manufactured in the form of plates or cylinders of thick walls and moderate size, while coated conductor tapes involve thin superconducting films over significant lengths. In this contribution, the main design requirements for magnetic shields made of either bulk superconductors or coated conductor tapes will be reviewed, together with their performance levels at low frequency. Then various configurations for which bulk superconductors and coated conductor tapes can be combined efficiently will be investigated. We will consider the situations for which the magnetic shields or screens made of bulk superconductors can benefit from the presence of superconducting tapes and vice-versa. These situations will be illustrated with experimental results at 77 K and finite element modelling of magnetic shields made of bulk large grain (RE)$Ba_2Cu_3O_7$ (RE = Rare Earth), bulk poly-crystalline $Bi_2Sr_2Ca_2Cu_3O_{10}$ and 2nd generation (RE)$Ba_2Cu_3O_7$ coated conductor tapes, either of nominal width (10-12 mm) or larger (40 mm).

References

[1] J. Claycomb *Magnetic shields* In: Applied Superconductivity: Handbook on Devices and Applications ed. P Seidel (New York: Wiley) vol 1 pp 780–806 (1999).
[2] J. H. Durrell et al., Supercond. Sci. Technol. **31**, 103501 (2018).
[3] L. Gozzelino et al., Supercond. Sci. Technol. **29**, 034004 (2016).
[4] L. Bortot et al., Supercond. Sci. Technol. **34**, 105001 (2021).
[5] Y. Nagasaki et al., IEEE Trans. Appl. Supercond. **28**, 6601905 (2018).

Keywords: bulk superconductors, coated conductors, magnetic shielding

C-I

Natural strategies for creating non-equilibrium morphology with self-repairing capability towards rapid growth of YBCO bulks

Xin Yao*[1], Yanhan Zhu[1], Pavel Diko[2], and Difan Zhou[3]

[1]Shanghai Jiao Tong University – China
[2]Institute of Experimental Physics, Slovak Academy of Science – Slovakia
[3]Shanghai University – China

Abstract

The fabrication of sizable $YBa_2Cu_3O_{7-\delta}$ (YBCO) bulks in top-seeded melt-growth can be realized by multiple-seeds and large-sized seed with a rapid coverage on the *a*-*b* plane. However, in the former one, imprecision in seeding alignment leads to a detrimental impact on grain boundaries. For the latter case, bulbs hardly release from growing samples, resulting in an increased porosity in bulks. Those demerits negatively affect superconducting properties. Here, we developed two novel seeding strategies for creating incomplete crystallographic shapes (i.e., right-angled concave corners) of YBCO superconducting crystals with self-repairing capability. One is in situ self-assembly seeding, by which self-reparability promotes YBCO growth, while the other is vertically-connected seeding, by which self- reparability triggers YBCO nucleation. Consequently, due to the nature of non-equilibrium morphology, rapid surface crystallization originated at concave corners and swiftly generated initial growth morphology approaching equilibrium. Furthermore, these rapid-growth regions including the concave crystal or seed innately functioned as sizable effective seeding regions, enabling the enlargement of *c*-oriented growth sector and the enhancement of properties for YBCO crystals. This nature-inspired self-repairing work offers insights into the design of seeding architecture with non-equilibrium morphology for inducing sizable high-performance crystals in the YBCO family and other functional materials.

Keywords: YBCO bulk, seeding construction, self-repairing, rapid growth, non-equilibrium morphology

C-II

Microstructure and superconductig properties of REBCO bulks studied at DMP IEP SAS Košice

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Abstract

REBCO bulk single-grain superconductors (BSS) based on Y, Gd, Eu and Dy are currently being studied at the Department of Materials Physics (DMP), IEP SAS Košice. Single grain bulks of YBCO, GdBCO-Ag and EuBCO-Ag are grown at DMP. External samples are mainly from CAN Superconductors, SJTU Shanghai and from AGU Kanagawa. Macroscopic superconducting properties at cryogenic temperatures are measured in collaboration with CRISMAT Caen. We have shown that the addition of $BaCeO_3$ instead of CeO_2 changes positively the growth conditions, microstructure and superconducting properties of YBCO and GdBCO-Ag BSS. For GdBCO-Ag BSS, we point out that their levitation force and trapped field depend not only on the height of the bulk, but also on its microstructure. The introduction of holes in YBCO, GdBCO and EuBCO BSS improves the macroscopic superconducting properties mainly by reducing the porosity in the upper part of the bulks. In addition, the introduced holes serve as a sensor of mass rearrangement during BSS growth. The effect of double seed arrangement in YBCO BSS is significant for the quality of the bi-crystal contact. The effect of single-direction melt growth (SDMG) of DyBCO BSS on their microstructure is also studied, and the peculiarities of the microstructure of these BSS are discussed.

Acknowledgment

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D-I

Advancements in Melt-assisted Single-domain REBCO Bulk Growth

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Abstract

The preparation of REBCO bulks by the widely used Top-Seeded Melt Growth (TSMG) technique is associated with several major drawbacks, including the presence of growth interfaces, coupling of growth time and diameter, and high failure rate. Such shortcomings limit superconducting properties, manufacturing capacity and economics of REBCO bulk production. In recent years, a wide range of improvements to melt-assisted growth has been developed. Among these, a completely novel approach, Single-Direction Melt Growth (SDMG), shows a potential to solve most of the outlined issues. Recent advancements in the preparation of REBCO systems with higher peritectic temperatures will be showcased. A detailed characterization of the SDMG-grown bulks showed an outstanding homogeneity in key superconducting properties. Moreover, the microstructural comparison to TSMG- grown bulks showed a lower defect area, with significantly more consistent defect dispersion throughout the bulks. Thus, it appears that SDMG carries significant benefits in comparison to TSMG, with notable improvements in the key properties of SDMG-grown bulks, especially their homogeneity. Even more importantly, the decoupling of the growth time and bulk diameter hints that SDMG might supersede TSMG as the main production technique of large REBCO melt-grown bulks once it reaches maturity. This could open up new markets and help to address some of the key limitations of the TSMG technique.

Keywords: REBCO, SDMG, single-domain bulks

D-II

REBCO bulk superconductors prepared by liquid assistant growth and their trapped field performance

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Abstract

HTS trapped-field magnets (PFMs) can be times stronger than the NdFeB permanent magnets (PM) therefore attractive for various engineering applications such as PM rotating machines. The quality of the single-grain bulk superconductors and the efficiency of the magnetization process are two critical issues for such applications. We report firstly the influence of liquid phase on the melt growth of single grains and secondly the demagnetization effect of the TFMs under external magnetic fields. We investigated the magnetization results of bulk superconductors at various temperatures, and discussing the potential influence from neighboring bulk superconductors in a multi-superconductor scenario. And then we show the influence on the trapped field from the cross external field during and after the magnetization.

E-I

A new kind of flux pinning centers of $Gd_2Ba_2Sr_2CuZrO_y$ nanoparticles to fabricate high quality GdBCO bulk superconductors

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Abstract

A new kind of $Gd_2Ba_2Sr_2CuZrO_y$ (GdBaSrCuZr-22211) nanoparticles have been designed and prepared by solid state reaction. The effect of the GdBaSrCuZr-22211 on the growth morphology, microstructure, levitation force (FL), trapped field (B_{tr}) of the single-domain GdBCO bulks have been investigated at the first time. It is found that: the GdBaSrCuZr-22211 phase is of excellent chemical stability and not react with the other phases during the Gd+011 TSIG process. The GdBaSrCuZr-22211 particles are of 120 nm and uniformly distributed in the well textured GdBCO bulk superconductors. Both of the levitation force (FL), trapped field (B_{tr}) of the samples have been enhanced from 32.870 N (77 K, 0.5 T) and 0.3357 T (77 K) to 49.440 N (77 K, 0.5 T) and 0.4344 T (77 K) when x increases from 0 to 4 wt%, and then gradually decreased to a lower value when x is great than 4 wt%. The results indicate that the GdBaSrCuZr-22211 particles can act as effective flux pinning centers to improve the performance of REBCO bulk superconductors.

Keywords: GdBCO bulk superconductor, $Gd_2Ba_2Sr_2CuZrO_y$ nanoparticles, Gd+011 TSIG method, levitation force, trapped field

F-I

Recent developments in Bulk MgB_2: Affordable and High-Performance Material for Practical Use

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Abstract

The increasing demand for high-performance, helium-free superconductors has driven the interest in high-temperature superconductors (HTS). Among them, MgB_2 has emerged as a promising HTS due to its excellent performance without the need for helium cryogenics. Although it requires lower temperatures compared to other HTS materials like perovskites, MgB_2 possesses several advantages that make it highly desirable for widespread use. These advantages include a simpler fabrication process, lower cost base materials, and robust superconducting properties. One technique for producing bulk MgB_2 is through the ultrasonication of commercially available boron, resulting in the formation of nano boron. Numerous experiments have demonstrated that ultrasonication can significantly enhance the critical current density (J_c) of MgB_2. This improvement is attributed to the cavitation effect induced by intense ultrasonic waves, which break down the boron particles into nanoscale dimensions, typically around 160nm. The precise control over the boron particle size achieved through this method has led to a remarkable 40% enhancement in J_c compared to the previous year. This observation strongly suggests that the development of low cost high performance bulk MgB_2 materials can be fabricated for various applications such as superconducting motors and medical devices.

F-II

Magnesium diboride- and ReBCO - based materials for application in liquid hydrogen

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Abstract

It is considered that application of hydrogen in different brunches of industry should bring them on the next level of development and connected with solution of logistic problems, i.e. transportation of hydrogen. One of the decisions can be transportation of liquid hydrogen (LH_2) having temperature 20 K, what makes promising application of high temperature superconductors. In [1], for example, was proposed to construct a centrifugal type LH_2-pump (with superconducting bearings, immersed in liquid hydrogen, with an impeller diameter of 32 mm and rotating speed 15 000 rpm.) to fill a 100 l mobile Dewar in about 5 mins. Because of this it is of great importance to understand which comparatively well developed superconducting material can be more stable and efficient in such working conditions.

The present work connected with analysis of functional superconducting characteristics of MgB_2-based bulks without and with additions of Ti, Ti-O and TiC, prepared by hot pressing (30 MPa), spark plasma sintering (50-96 MPa) and under high quasyhydrostatic pressure (2 GPa) conditions, or ReBCO (Re=Y, Eu) – based materials: melt textured or coated conductors. Their stability in liquid hydrogen is under the study. The trapped magnetic fields were studied using hollow cylinders of the same geometry prepared from magnesium diboride-based materials and MT-YBCO. The high critical current densities and critical magnetic fields should ensure high trapped fields in all these materials. Indeed all materials demonstrated the required performance; however, flux jumps are a serious issue in MgB_2 even in crack free cylinders and impeded higher trapped fields.. An inhomogeneous and porous MgB_2 structure was found to be less stable against flux jumps. On the other hand, deviations of the material matrices from MgB_2 stoichiometry did not impede high J_c and trapped fields. The superconducting properties of all materials investigated in this study occurred to be sufficient for magnets in submersible liquid hydrogen pumps with a required trapped field of about 500-600 mT.

Reference

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Acknowledgment

This work was supported by the project NATO SPS G5773 and National Academy of Sciences of Ukraine projects III-11-21 (0781).

Keywords: Magnesium diboride bulk, ReBCO, based materials: melt, textured and coated conductors, trapped field, critical current density, structure

F-III

Thermo-magnetic instability influence on the shielding properties of MgB_2 bulk samples

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Abstract

Bulk superconductors are a proven solution for fabricating permanent magnets and magnetic shields [1]. Regarding the latter application, they can indeed provide very-low field background for ultra-sensitive devices or strong magnetic mitigation over a short distance, cutting down electromagnetic compatibility problems [2]. Among superconducting materials, MgB_2 is a promising choice since it combines the use of low-cost and non-toxic precursors - not including rare earth elements, a low weight density and the feasibility of manufacturing large polycrystalline samples [3].

In this work, we investigated the shielding ability of MgB_2 bulks shaped as hollow-cylinders with a capped end (henceforth called cups) with an aspect-ratio of height to diameter approaching one, meeting the practical requirement of great shielding performance in small volumes. These shields were manufactured by Spark Plasma Sintering of MgB_2 powder added with hexagonal-BN powder, an approach allowing the fabrication of fully machinable bulks [4].

The experimental measurements evidenced the achievement of shielding factors (SFs) exceeding 104 up to an axial applied field of 1.8 T at the temperature T = 20 K [5]. However, above this field the SF sharply drops due to flux-jump occurrence. Since this phenomenon significantly affects the shielding properties up to 32.5 K, predicting and even preventing its occurrence are crucial aspects.

To this aim, we developed a numerical model coupling heat diffusion and magnetic equations, the latter based on a vector potential (**A**)-formulation [6]. This model was implemented using the commercial finite-element software COMSOL Multiphysics® v.6.0, allowing us to successfully reproduce the experimental data at several working temperatures and to correlate the local magnetic flux density, current density and temperature inside the superconductor with its SF in correspondence to the flux-jump occurrence [7]. The as-validated numerical procedure was then exploited as a guide for future experiments, investigating how the enhancement of the MgB_2 thermal conductivity, the improvement of the thermal exchange with the coolant, and the superimposition of a ferromagnetic shell can minimize the development of thermo-magnetic instabilities.

Acknowledgment
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Keywords: magnetic shielding, MgB_2 bulk, thermomagnetic instabilities

G-I

Fabrication of High Performance Iron-Based Superconducting Materials

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Abstract

Iron-based superconductors (IBS) are very promising candidates for high-field magnet applications owing to their ultrahigh upper critical fields and very small anisotropy. In recent years, tremendous progress has been made on the critical current density (J_c) of IBS wires and tapes based on a powder-in-tube technique, e.g., high transport J_c up to 2.2×10^5 A cm^{-2} at 4.2 K and 10 T was achieved in 122 type IBS tapes. Furthermore, the transport J_c of IBS tapes with high-strength composite metal sheath such as Cu/Ag and Stainless steel/Ag was enhanced above 10^5 A cm^{-2} at 4.2 K and 10 T as well. On the other hand, with hot isostatic pressing process, the J_c-performance of IBS round wires was also significantly improved. With the achievement of high-performance multifilamentary IBS long-length tapes, the first IBS single pancake coil and double pancake coil were fabricated and tested at 24 T and 30 T background field, respectively. Two IBS racetrack coils using 100- meter long IBS tapes were successfully made and tested in a superconducting dipole magnet which provided a maximum background field of 10 T at 4.2 K. These results demonstrate the great potential of IBS wires in high-field applications in the future.

G-II

Process machine learning, twinning network graph analysis & record high trapped magnetic field of Ba122 polycrystalline bulk superconductors

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Abstract

122 phase iron-based superconductors show high upper critical field (H_{c2} > 50 T) with small electromagnetic anisotropy (γ ~ 1-2) [1] and large critical grain boundary angle (θc ~ 9°) [2], and therefore is a promising material for applications in polycrystalline form. Foreseeing bulk magnet applications, Weiss et al. have reported demonstration of trapped field of 1 T for K-doped $BaFe_2As_2$ (Ba122) polycrystalline bulks synthesized by hot isostatic pressing [3]. In this study, K-doped Ba122 bulks were synthesized from mechanically alloyed precursor powder which was prepared by high-energy ball-milling of elemental metals with the molar ratios of Ba:K:Fe:As = 0.6:0.4:2:2 in a Ar glove box [4, 5]. The precursor powder was then spark plasma sintered. Two approaches to optimizing the processing conditions were considered: optimization by researchers' experience and intuition and by data driven process based on machine learning [6]. Bayesian optimization was applied to find the best input parameters that maximize the target output property, critical current density (J_c), on the experimentally available range of processing conditions using BOXVIA [6]. High J_c value exceeding 10^5 A/cm^2 was developed by both experiments guided by researchers and such an adaptive experimental optimization process. High trapped magnetic field exceeding the previous record by Weiss et al. [3] was measured. Detailed trapped magnetic field properties of Ba122 bulk magnets and the key microstructural features revealed by 3-dimensional multiscale analysis [7], precession electron diffraction (PED) nano-orientation STEM analysis and the twinning network graph analysis [8] will be discussed.

Acknowledgement:
This work was supported by JST CREST (JPMJCR18J4 & JPMJCR17J1).

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Keywords: Iron based superconductors, trapped field, machine learning, twinning network graph

Industrial Session

I-I

Current Progress in HTS Bulks and Materials for Industrial Applications

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Abstract

Since 1996, CAN SUPERCONDUCTORS has been developing its REBCO and BSCCO HTS bulks and supplied thousands of pieces to industrial customers as well as to major academic organizations worldwide.

We will present CAN's recent research and development efforts, our current standard products, improvements in batch production processes, and our quality assurance mechanisms.

The presentation will also include selected case studies and applications of our materials, as well as future projections for their further adoption. Main challenges and key focus areas for further expanding HTS bulks based on market demand will be presented.

Considering the market's growth, requirements for HTS production scale-up need to be addressed, and CAN's latest strategies and plans in this respect will be presented.

Keywords: REBCO Bulks

I-II

The progress of the second generation high temperature superconductor tapes in Shanghai Superconductor Technology Co., Ltd.

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Abstract

With the features of high irreversible filed, high superconducting transition temperature and high critical current density, the second generation high temperature superconductor (2G-HTS) tapes have reached the stage of mass production and a large number of superconducting power and superconducting magnets have been developed by using 2G-HTS tapes. Recently, due to the demand for 2G-HTS tapes in compact nuclear fusion, Shanghai Superconductor Technology Co., Ltd. (SST) has started a new round of production expansion, hoping to further improve the performance and yield of the 2G-HTS tapes and further reduce the cost throughout this production expansion. Meanwhile, the practical research of 2G-HTS tapes has been carried out in the face of specific application scenarios. Based on the main development trend of 2G-HTS tapes worldwide, this presentation introduces the main progress of the research and development of 2G-HTS tapes for practical applications in SST

Oral Presentation

A-III

Magnetization method of HTS bulk by single pulse magnetic field with waveform control

Tetsuya Ida*[1], Hayato Imamichi[1], Mizuki Tsuchiya[1], Kawasumi Nagisa[1], Kazushi Yanagi[1], and Mitsuru Izumi[1,2]

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Abstract

Pulse field magnetization of high-temperature superconducting (HTS) bulk is attractive in facilitating various commercial applications of superconducting technology (1). We have developed a waveform control pulse magnetization (WCPM) method to obtain a strong trapped magnetic flux density with a single pulse field because it was necessary to magnetize the GdBCO bulk by applying a small number of pulsed magnetic fields when we drove our superconducting rotating machines (1-3). In order to trap strong magnetic field by pulsed magnetization, a pulsed magnetic field with a flux density high enough to cause flux jump to appear must be applied to the bulk. However, according to this method, it is believed that the rapid flux motion produced from increasing or decreasing the high flux density causes flux creep, making it difficult to trap the strong magnetic field. We consider that WCPM with negative feedback (NFB-WCPM), in which the applied flux density is adjusted each time based on the behavior of the magnetic flux penetrating the bulk, is the key technology to realize strong magnetic field trapping by the magnetic field characteristic of the HTS bulks (4). Our experimental results suggest that NFB-WCPM is suitable for obtaining strong trapped magnetic fields at 40 K. In this presentation, we show the experimental results trapped the strong magnetic field in GdBCO by NFB-WCPM method.

Keywords: pulse field magnetization, PFM, waveform control pulse magnetization, WCPM, trapped magnetic field: magnetic flux density, flux jump, NFB, WCPM

B-IV

HTS Bulk Magnets Cooled by a Refrigerator and Latest Efforts for Their Application Research

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Abstract

The performance of high-temperature superconductors is dramatically improved by cooling them below the temperature of liquid nitrogen. Therefore, the performance of magnetic field trapping and magnetic levitation in the temperature range that can be easily obtained by using a small refrigerator far exceeds that of conventional permanent magnets. The performance is practical, but the problems on such as materials, refrigerators, heat insulation, and magnetization methods have slowed down its industrial spread. On the other hand, there definitely exist the application fields that expect their unique performances, and the application research have been actively conducted in fields such as NMR, magnetic levitation, magnetic orientation, and magnetic separation. In NMR, following the development of a compact NMR spectrometer, the world's first result was obtained in measuring the diffusion coefficient of ions in liquids. Magnetic levitation, a phenomenon peculiar to bulk magnets, has been commercialized for new applications. Magnetic orientation and magnetic separation using a strong and steep magnetic field have the advantage to use the strong magnetic fields easily and inexpensively, rather than using large superconducting magnets. Thus, bulk magnets and refrigerators have changed their activities from application research to practical industrial applications.

Keywords: superconductor, bulk magnet, refrigerator, NMR, levitation, magnetic separation

C-III

Crystallographic Phase Transition and Growth Mechanism of Bulk Superconductor TSPMP-YBCO Single Domain and its Application on Superconducting Bearing

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Abstract

It has been studied that the crystallographic phase transition of the TSPMP-YBCO superconductor single crystal domain growth by the high temperature in-situ magnetic susceptibility measurement. The growth mechanism of TSPMP-YBCO single domain has been discussed, as well as its microstructure characteristics, superconducting critical current density J_c and magnetic levitation force F. It is showed that our experimental results in preparing large-sized 100mm in diameter bulks in recent years. The application study on Superconductor and Hydrodynamic Fluid-film Compound Bearing in cooperation with Xi'an Jiaotong University has been presented.

Powder melting process (PMP) is a method of synthesizing YBCO superconductors invented by Prof. Zhou Lian in NIN. The PMP-YBCO has the uniformly distributed 211 particles, fine dispersion, so as to have high critical current density J_c. We used this advantage to YBCO single domains fabrication with top-seeded method. This top-seeded powder melting process for preparing single crystal domain YBCO named as TSPMP.

There were several key phase transitions in the growth of TSPMP-YBCO single domain. During the heating stage, there were 123 phase formation and decomposition, CuO decomposition and synthesis. During the slow cooling stage, there were the 123 crystals nucleate and growing. It was also found that different heating rates significantly affect the phase transition of TSPMP-YBCO samples. The interface morphology, nucleation and growth formation of TSPMP-YBCO crystal were theoretically summarized, and the growth rate of the experiment was theoretically calculated and simulated.

Batch of Φ30mm×15mm TSPMP-YBCO single domain had been prepared, and achieving critical current density J_{cm} ~1.2×10^5 Acm^{-2} (77K), the magnetic levitation force density could reach 16N/cm^2 (77K, 0.5T) in our lab.

In recent years, we attempted to prepare 100mm in diameter YBCO single domain through powder gradient process. We collaborated with the Xi'an Jiaotong University to create a "Superconducting Liquid Film Bearing Testing Platform" by using our YBCO superconductors. The doctoral thesis of this research project won the "National Doctoral Dissertation Excellence Award" from the China Machinery Association in 2018.

Acknowledgements This work is supported by the Chinese NSFC project fundNo.52172274.

Keywords: Superconductor TSPMP, YBCO, Crystallographic phase transition, Growth mechanism, Superconducting bearing

C-IV

Understanding the mechanical and flux trapping properties of non-oxygenated YBCO, YBCO and YBCO(Ag) single grains

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Abstract

The influence of the microstructure on the trapped field and the mechanical properties was studied in 12 non-oxygenated YBCO, 12 YBCO and 12 YBCO(Ag) bulk superconductors using high field magnetisation and Brazilian testing. The tensile strength depends on the longest compaction crack in the *ab*-plane. Added silver in YBCO bulk materials deflects cracks when stress is applied to the material. Whereas the average tensile strength in YBCO(Ag) bulk superconductors is higher than for YBCO, the average trapped field is lower. The trapped field decrease is due to the increased agglomeration of liquid phase and secondary grain growth in YBCO(Ag) bulk samples. Consequently, any method to decrease the length of compaction cracks increases the mechanical properties in YBCO bulk materials. Furthermore, procedures reducing the agglomeration of liquid phase and secondary grain growth in YBCO(Ag) bulk samples could increase the trapped field in these technologically important materials.

Keywords: YBCO(Ag), microstructure, mechanical properties, tensile strength, trapped field, statistics

D-III

Macroscopic superconducting properties of GdBCO bulk superconductors with different height

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Abstract

Bulk single-grain GdBCO superconductors with nominal composition 1 mol $GdBa_2Cu_3O_{7-\delta}$ + 1/2 mol Gd_2BaCuO_5 + 20 wt% Ag_2O + 0.95 wt% $BaCeO_3$ and with different height were fabricated using the top-seeded melt-growth process. The diameter of the prepared GdBCO samples was 20 mm and their height varied in the range from 11 mm to 5 mm. Additionally, the highest GdBCO sample was cut to reach gradually the same heights as prepared samples. Macroscopic superconducting properties of the samples were measured at 77 K and their microstructure was analysed using polarised light microscopy and SEM. It is shown that the maximum trapped magnetic field as well as the levitation force decrease with decreasing sample's height. The relation between sample's height, the maximum trapped magnetic field, levitation force and their microstructure is discussed.

Acknowledgment
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Keywords: GdBCO bulk superconductors, trapped field, levitation force, microstructure

E-II

Trapped Field and Levitation Performances of YBCO Bulk Superconductors

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Abstract

The over the last 20 years, significant progress in processing of bulk Y-Ba-Cu-O superconductors in the form of large single and or controlled multi-seeded samples has been made. Superconducting crystal samples, have high levitation force and high trapped magnetic field, are used in many applications such as magnetic bearing, flywheel, motor, generator, high magnetic field permanent magnets and conveying systems. A top-seeded melt-growth (TSMG) process is commonly used to fabricate single domain YBCO bulk superconductors. Pores are frequently found in the YBCO samples by TSMG because of oxygenation process. Newly, top seeded infiltration growth (TSIG) method is well-known to be efficient in diminishing the pore formation and in refining the size of Y2BaCuO5 (Y211) particles distributed in YBa2Cu3Oy (Y123) matrix. In this work, we discuss recent developments in the process- ing of these materials that enable high performances bulk superconductors to be fabricated by TSMG and TSIG methods. These include the development of magnetic levitation and trapped field of samples, the development of practical, batch processing routes for the fabrication of light rare earth superconductors, the processing of complex shaped geometries via controlled multi-seeding with various orientations of scrap bulk samples into high performance, single grains.

Keywords: TSMG, TSIG, Multiseeded YBCO samples, Levitation Force, Trapped Field

E-III

Overcoming the demagnetization of superconducting linear Halbach array

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Abstract

Combining trapped-field superconducting magnets with mutually orthogonal magnetization directions in a linear Halbach array configuration offers the prospect of generating both high fields and large field gradients. For a Halbach array made of 3 magnetized bulk large grain melt-textured $YBa_2Cu_3O_{7-\delta}$ superconductors of given size and critical current density, it was previously shown [1] that the main limitation of the field generated by the array arises from the modification of the current density distribution within the superconductors during the assembly process.

In this work, two methods are explored to mitigate the impact of such demagnetization on the field generated by the array. In the first method, an additional bulk superconductor is placed above the central one, magnetized simultaneously with it and maintained in place while approaching the left and right peripheral samples to form the array. The additional sample is then removed from the structure, which induces a re-organisation of the supercurrents in the central superconductor. In the second method, the geometric shape of the peripheral samples is modified to reduce the field experienced by the sides of the central superconductor. Starting from cubic superconductors, the samples are cut at 45° with respect their *c*-axis, which gives samples having a square cross-section parallel to the ab-planes and a triangular cross-section parallel to the *c*-axis. Experiments with such arrays are carried out at 77 K with bulk $YBa_2Cu_3O_{7-\delta}$ superconductors of 13 mm side.

The spatial distribution of above the assembly is measured with a recently developed cryogenic 3-axis Hall sensor [2] and is compared to analytical calculations and finite-element simulations. This set of results makes it possible to understand in detail the advantage brought by the two methods mentioned above. A noticeable increase of the flux density generated above the array is found for both methods (~ 5% with samples used in experiments). For the first method, finite-element simulations show that this increase gets higher when using a taller additional sample, which allows to almost recover the full potential of the array.

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Keywords: Bulk superconductor, trapped field magnet, magnetic field gradient, interacting bulk superconductors, flux pinning

E-IV

Critical Current Density Distribution Map of the Bulk YBCO Superconductor

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Abstract

Bulk Y123 sample (with 20 mm diameter) was growned by the Top-Seeded Melt-Growth (TSMG) method by using a NdBCO/YBCO/MgO film (300 nm NdBCO with 20 nm YBCO buffer layer on MgO substrate) seed and the sample was oxygenated after the growing process. The annealed sample cut into 21 small specimens (each size of the sample are approximately 3×3×2 mm^3) and magnetization measurements of the 15 specimens selected from the symmetrical regions of the cutting sample was performed. The superconducting transition temperature (T_c) value of the all specimens were determined from the resistivity measurements at around 92 K. J_c of the 15 specimens were calculated from the magnetization hysteresis loops based on the extended Bean model. Intermediate value estimation was made by performing Conditional Gaussian simulation for the unmeasured samples by using the J_c values of the measured samples, and the J_c distribution map was obtained throughout the sample.

Keywords: Critical Current Density Distribution Map, Conditional Gaussian simulation, YBCO

E-V

Investigation of the Impact of Liquid Sources on Levitation Force and Trapped Field Performance of Ternary Bulk (Gd, Y, Er)-123 Fabricated Using Infiltration Growth Process

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Abstract

Bulk superconductors have a wide range of applications and properties, such as trapped field and levitation force, which are crucial for the practical usage of the bulk [1-2]. Various $REBa_2Cu_3O_x$ bulks have been processed through top-seeded melt growth (TSMG) or top- seeded infiltration growth (TSIG) processes using conventional or modified liquid sources to enhance their superconducting performance [3-5]. In this study, we investigated the effect of different liquid source compositions on the levitation force and trapped field performance of the ternary bulk (Gd,Y,Er) $Ba_2Cu_3O_y$ system. Using $Ba_3Cu_5O_8$, Yb_2O_3:$BaCuO_2$: CuO (1:10:6) and Er123+ $Ba_3Cu_5O_8$(1:1) as liquid sources, ternary single-grain bulks (Gd, Y, Er) $Ba_2Cu_3O_y$ were fabricated using the TSIG process in the air. The investigation revealed that liquid sources play a crucial role in achieving single-domain growth and controlling the final microstructure of the bulk material. Consequently, the utilization of Er123+ $Ba_3Cu_5O_8$ as a liquid source led to a remarkable 81.09% improvement in J_c for the superconductor. Furthermore, both experimental conditions had a high impact on the levitation force and trapped field performance, as observed during the tests. Among the tested materials, the bulk fabricated with an Er123+ $Ba_3Cu_5O_8$(1:1) liquid source showed the highest value of the trapped field value and superior levitation force performance. These results highlight the significance of liquid sources in regulating the performance of the ternary bulk (Gd, Y, Er) $Ba_2Cu_3O_y$, which is fabricated by the IG process in an air environment. The cost-effective method makes this approach highly attractive for large-scale industrial production.

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Keywords: TSIG process, Liquid Sources, Trapped Field, Levitation force, Critical current density

E-VI

Mathematical analysis of the flux-jump model

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Abstract

1. TODO

- intro
  λ the London penetration length gives the decay of the field inside the superconductor for small applied external fields (Meissner effect), typically $\lambda \approx 1\mu m$. [1].
- abstract (JG → Nathan)
- latex (Nathan → JG)
- exploration parametres $(\alpha, \beta, B_e, T_e)$
- analyse : traveling wave solutions ?
  solutions statiques
- calcul adimensionement a integrer ds texte

2. Physical model

The magnetic behavior of a type II superconductor is given by the Maxwell equations and a constitutive law. The Maxwell equations read

$$\nabla \times \mathbf{E} = -\partial_t \mathbf{B}, \tag{1}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J}, \tag{2}$$

where $\mathbf{E}, \mathbf{B}$ are the electric and magnetic fields, $\mathbf{J}$ is the current density and the term $\partial_t \mathbf{E}$ is neglected (quasi-static regime). The constitutive law is

$$\mathbf{E} = \mathbf{E}(\mathbf{J}), \tag{3}$$

where $\mathbf{E}$ and $\mathbf{J}$ are parallel. The evolution of the temperature of the sample is given by

$$\rho_d C \partial_t T = \mathbf{E} \cdot \mathbf{J} + \kappa \Delta T, \tag{4}$$

where $\mathbf{E} \cdot \mathbf{J}$ is the power heating per unit volume due to the magnetic field.

2.1 Simplified 1D configuration

To understand in detail the interplay between the magnetic field and the temperature, we follow the authors of [2] and reduce the problem to one dimension.

Figure 1: Simplified configuration: infinite supraconducting plate of thickness d.
Following [2], we consider a supraconducting plate of thickness $d >> \lambda$, infinite along y and z, see Fig. 1. An external field $\mathbf{B}_e$ is applied along z. Then we can write

$$\mathbf{B} = (0, 0, B(x))^T, \quad \mathbf{E} = (0, E(x), 0)^T, \quad \mathbf{J} = (0, J(x), 0)^T$$

so that the equations (1,2) reduce to

$$B_x = -\mu_0 J, \tag{5}$$

$$B_t = -E_x, \tag{6}$$

The constitutive relation reads

$$E = s(J) \tag{7}$$

where

$$s(J) = 0.5\rho\left(1+\tanh(\frac{J-J_c}{w})\right)(J-J_c), \tag{8}$$

$$J_c = (1-\frac{T}{T_c})(1-\frac{B}{B_c})^2, \tag{9}$$

where T_c is the critical temperature and B_c is a threshold magnetic field (not to be confused with the critical fields typical of type II superconductors. The form of $s(J)$ is a regularized version of the one used by Romero-Salazar et al [2].

Collecting equations (5,6,7) and the temperature equation, we obtain the final system of equations

$$B_t = -\partial_x(s(-\frac{B_x}{\mu_0})) \tag{10}$$

$$\rho_d C T_t = -\frac{B_x}{\mu_0}s(-\frac{B_x}{\mu_0}) + \kappa\Delta T. \tag{11}$$

on the domain $[0, d]$ together with boundary conditions $B(x = d) = B_e$, $T(x = d) = T_e$ and where symetry is assumed at $x = 0$ like in [2].

To gain intuition, assume a simple ohmic behavior $E = sJ$. Then the two equations above reduce to diffusion equations and we do not expect any singular behavior. On the other hand, the nonlinearity of the two equations (8, 9) will give rise to very interesting effects. There are two typical times associated with equations (10,11), a magnetic time t_0 and a thermal time t_T built using typical values of E and J

$$t_0 = \frac{\mu_0 d^2}{\rho}, \quad t_T = \frac{E_0 J_0}{\rho_d C T_c}. \tag{12}$$

To study the problem (10,11) in detail, we normalize the equations as follows

$$x = dx', \quad t = \frac{\mu_0 d^2}{\rho}t', \quad B = B_c B', \quad T = T_c T', \quad J = \frac{B_c}{\mu_0 d}J'. \tag{13}$$

Finally, we obtain after dropping all the primes

$$B_t = -\partial_x(s(-B_x)) \tag{14}$$

$$T_t = -\alpha B_x s(-B_x) + \beta\Delta T, \tag{15}$$

where

$$\alpha = \frac{t_0}{t_T} = \frac{B_c^2}{\mu_0 \rho_d C T_c}, \quad \beta = \frac{\kappa\mu_0}{\rho\rho_d C} \tag{16}$$

Table **??** shows typical the parameters that we used in the simulations, these have been obtained from [2] and [4].

3. Numerical results

Equations were discretized in space using second order finite difference and the time advance was done using an ordinary differential equation solver. Since the scheme is explicit, the stability condition is

$$\frac{\Delta t}{\Delta x^2} < 0.5$$

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E-VII

Use of gauges in the Time Dependent Ginzburg Landau model of superconductivity

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Abstract

Gauge choices is essential when modelling superconductors with the TDGL model. There are three main gauges : the Coulomb gauge, the Lorentz gauge and the temporal gauge. It has been noticed in [1] that these gauges can be continuously related by a single parameter considering the more general ω-gauge where ω is a real parameter. In this article, we systematically study convergence orders for the TDGL model under the unified ω gauge framework. We compare a mixed finite element scheme with a Lagrange scheme; known results for extreme cases $\omega = 0$ and $\omega = 1$ are recovered.

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F-IV

MgB_2 bulk superconductors fabricated by in-situ route for levitation applications

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Abstract

MgB_2 bulks were prepared by an *in-situ* solid synthesis route from mixtures of Mg and B powders. The B powders were produced by two methods: the first is a self-propagating high temperature magnesiothermic synthesis (SHS) process followed by acid and fluorine cleaning and a heat treatment in inert atmosphere and the second is a diborane pyrolysis process. In the SHS process produced boron powders with purities between 86 and 97 %, where the main impurity was Mg. Amorphous lower purity boron (86-97 %) obtained by the first processing route was found to promote the largest levitation forces of the MgB_2 bulks and, among the samples, the best levitation results were recorded when using boron with a purity of 95-97%. Slightly lower values, but significantly higher force values when compared with samples fabricated from the amorphous boron with high purity of 99% or crystalline boron with purity 95-97% were measured for samples obtained from amorphous boron with low purity of 86-93 %. Critical current density, pinning force aspects and magnetic levitation force (including guiding force) details were assessed. Results show that cheap boron, i.e. boron with a low purity, can be used to fabricate MgB_2 bulk magnets for levitation devices, promoting large scale industrial production and new applications.

Keywords: MgB_2, Critical current density, levitation force, guidance force

F-V

Investigation of Superconducting Magnetic levitation with MgB_2 bulk cryomagnets: the effect of the sample size and working temperature

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Abstract

Superconducting Magnetic levitation system (SML) is widely used for some promising applications of superconductors, especially Maglev trains and superconducting bearings. The levitation force and its stability are closely related to the superconducting material, the system generating the magnetic field and their geometrical dimensions. The simple fabrication process of large-size MgB_2 bulks with a levitation force similar to that of the superconducting cuprates [1] shows the enormous potential of this material for magnetic suspension device applications.

This study investigates the effects of various factors on the levitation and lateral forces in a system consisting of a cylindrical NdFeB permanent magnet and MgB_2 bulk: i) dimensions of the superconductor, ii) dimensions of the permanent magnet and iii) the working temperature. Two batches of samples were prepared by Spark Plasma Sintering (SPS) [2] process with the MgB_2 powder purchased from Pavazyum company (Turkey). The first one consisted of 50 mm diameter cylindrical bulks, the thicknesses h_{SC} of which were in the range 2-10 mm. The other one consisted of 10 mm thick bulks, with diameters, D_{SC}, ranging between 50 mm and 70 mm. The magnetic force measurements were carried out at 20-30 K in a vacuum cryostat system that allows measuring forces down to a very low separation between the magnetic source and the superconductor. The results have shown that the levitation force, F_Z increases with the sample diameter and that there is a linear relation between F_Z and D_{SC}^3 as indicated in [1]. Otherwise, the levitation forces do not depend on the thickness h_{SC} of the samples above some threshold and are slow varying functions of h_{SC} below the threshold. Furthermore, the loss of stability corresponds to the positive stiffness of lateral force. The results suggest that the stability of the system could be optimized using a large size superconductor and a small size permanet magnet. Concerning the effect of working temperature, stability can be significantly improved by increasing the temperature from 28 to 30 K, but that this causes a decrease of the levitation force as a consequence of the reduction of the critical current density J_c. As a consequence, large diameter MgB_2 discs can be good candidates for SML system using a cryogenic fluid such as hydrogen or neon.

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G-III

Structural disorder and its anisotropy in multi-band MgB_2 materials with high critical current performance

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Abstract

Critical current performance of superconducting materials is one of the most important criterions for innovative applications (e.g., hybrid energy storage systems combined with hydrogen technologies). The transport performance depends on structural states of grain/crystallite boundary, stacking fault, dislocation, vacancy, substitutional atom/ion, lattice strain/distortion, and so on. These structural defects and strain can disorder material structures. Accordingly, structural optimization by introducing structural disorder has been so far studied in terms of vortex pinning and/or charge-carrier scattering. In the case of polycrystalline MgB_2 superconducting materials (e.g., bulks, wires, and tapes), carbon doping, mechanical milling/alloying, and low-temperature sintering have been utilized to introduce structural disorder. However, the structural evaluation has been conducted by using isotropic models in most cases, although anisotropic disorder may form due to different bonding states (forming the layered crystal structure of MgB_2). In addition, if the disorder anisotropy in MgB_2 materials is not negligibly small, the influence on the transport critical current performance should be clarified. In this presentation, we therefore introduce and discuss the disorder anisotropy of multi-band MgB_2 materials with experimental results. In terms of pinning and scattering, we also argue structural modification to achieve enhancement beyond the currently attainable transport performance.

Keywords: MgB_2, Critical current, Grain size, Coherence length, Defect, Strain, MgB_2 wire, Polycrystalline materials

G-IV

Design of a bespoke 3-axis cryogenic Hall probe and application to measuring the flux density produced by bulk superconductors with a triangular cross-section

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Abstract

Mapping simultaneously the three components of the magnetic flux density *B* at 77 K and above the mT range is of particular significance in several applications involving high-temperature superconductors. However, finding Hall probes operating in these conditions is nowadays almost impossible. Hence, we recently designed our own device able to perform such measurements [1]. The device uses a commercial, room-temperature 3-axis Hall sensor located in a cylindrical insert whose temperature is carefully controlled to be 25°C, while the outer temperature is 77 K. The active area of the Hall sensor is placed at 2.2 ± 0.25 mm from the bottom of the insert. The sensor shows a linear and temperature-independent response over ±217.5 mT for the axial direction and ±159 mT for the transverse directions. We give details of the experimental set-up and show that the measurement uncertainty is typically around a few hundred μT.

We then demonstrate the successful operation of this 3-axis cryogenic Hall probe by measuring the spatial distribution of *B* generated by a permanently magnetized bulk with a shape differing from the usual parallelepipeds or cylinders. We investigate large grain $YBa_2Cu_3O_7$ superconducting cube (13 mm side) cut at 45° with respect to the *c*-axis. The resulting sample has a square cross-section parallel to the *ab*-planes and a triangular cross-section parallel to the *c*-axis. Mapping *B* along a line parallel to the *c*-axis, at ~3.5 mm of the largest face, shows that the component parallel to the *c*-axis is strongly asymmetric while |*B*| appears almost constant over ~5 mm. We also investigate how the three components of *B* evolve along a line *z* perpendicular to the *c*-axis and parallel to the triangular cross-section. The results point out a strongly off-centred and asymmetric *B* distribution, with |d*B*/dz| differing by a factor ~1.4 on both sides of the maximum. Interestingly, the main features of the *B* distribution can be understood by analytical calculations assuming a homogeneously magnetized sample with uniform critical current density.

More generally, the bespoke 3-axis cryogenic Hall probe enables mapping the vectorial flux distribution around large, bulk superconductors with no particular symmetry. The measured flux distribution can then be compared to that predicted by various models.

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G-V

Trapped field capability of a MgB_2 disk: experimental and numerical investigation

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Abstract

Thanks to their ability to trap high magnetic flux density, superconductors (SCs) could be key materials for the energy transition and ideal options for a next generation of electrical machines [1-3]. Among SCs, MgB_2 is one of the most promising candidates for superconducting bulk applications, not suffering from current-limiting by grain-boundary misorientation [4]. However, the fulfilment of the applicative targets requires the availability of a growing technique allowing the fabrication of highly dense and homogeneous pellets with high superconducting performances [5] and of a numerical modelling technique able to predict the superconductor behavior under various magnetizing and operating conditions, to properly guide and optimize future devices design.

In this work, we investigated the trapped field capability of the MgB_2 discs (10 mm thick and 20 mm diameter) processed by unconventional Spark Plasma Sintering (1200°C, 50 MPa under dynamic vacuum). After field-cooling down to the working temperature (with the field in the axial direction), the magnetic flux density, B_z, was measured during the applied magnetic field, H_{appl}, removal using a Hall probes array located along a diameter of the disk, 1.5 mm above its top surface. Then, after the external field zeroing, the trapped field, B_{trapp}, was evaluated as a function of the distance between the Hall probes and the sample surface. The study was carried out for different working temperatures (20, 25 and 30 K) and fields (up to $\mu_0 H_{appl}$ = 4 T), reaching B_{trapp} values over 1.4 T at 20 K.

Lastly, the experimental data were successfully reproduced using a computational approach based on a magnetic vector-potential (**A**) formulation [6, 7]. The numerical model was implemented by means of the commercial finite-element software COMSOL Multiphysics® 6.0, using a 2D axisymmetric approach. The as-validated model was then employed to investigate how changes in the MgB2 bulk shape or addition of ferromagnetic bulk layers can improve the trapped field performances.

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Posters

H-I

A Study of Fluctuation Induced Conductivity Analysis for Welded TSMG YBCO Using a Solder Material Produced by Different Melting Methods

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Abstract

In this study, each group consisting of four bulk Y123 + *x* % (*x* = 20, 25, 30) Y211 main samples were fabricated by Top-Seeded Melt-Growth (TSMG) method. Y123 + *x* % (*x* = 20, 25, 30) Y211 + 20%Ag_2O solder materials were fabricated in two groups by TSMG and Melt Powder Melt-Growth (MPMG) methods. A thin slice of the solder sample with the same Y211 ratio was placed between two main samples with the same Y211 ratio and stacked. The stacked samples were joined using an appropriate heat treatment. Thus, the welded samples with MPMG and TSMG YBCO solder material were obtained in two groups. A small piece of 6 mm × 2.5 mm was cut from each welded sample, close to the vertical central axis and including the welding region. Resistivity measurements of rectangular samples were performed by a standard four-probe method at temperatures between 40 and 300 K at a rate of 4 $K.min^{-1}$ using Physical Properties Measurement System (PPMS) under 0 T magnetic fields. Fluctuation induced conductivity analysis was experimentally performed by using the Aslamazov-Larkin theory. The presence of mean field and short-wave fluctuation regions, which play a role in determining the variety of fluctuations, was observed for all samples. The λ critical exponents representing these regions were in agreement with the theory. Additionally, it was seen that the welded sample with TSMG solder material and containing 20% Y211 has the highest c-axis coherence length. A large coherence length reduces thermal fluctuations and improves superconductivity properties positively. Thus, it enables the superconductor to be used more effectively in the application areas.

Keywords: Ag, added solder material, Welding process, Welded TSMG YBCO, Fluctuation induced conductivity

H-II

Application of superconducting levitation to vibration-based energy harvesters

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Abstract

A system in which a mass can move along a beam-like structure can resonate when it is subjected to external excitation, with the mass moving on its own to the antinode of the vibration mode in response to the vibration frequency. This phenomenon is called passive self-resonance. This system is expected to be applied to power generation, or energy harvest- ing, because of its wide resonance frequency bandwidth. The system is usually supported by contact, but if this is replaced by a non-contact support using high-temperature super-conducting bulk material, a larger amplitude can be obtained at resonance due to lower damping. Furthermore, the use of superconducting levitation tends to produce nonlinear vibration characteristics due to the nonlinearity of the magnetic force. One of these characteristics is the broadening of the resonance frequency band. Thus, if contactless support by nonlinear magnetic force derived from superconductivity is introduced into a passive self-resonant system, further increase in resonance amplitude due to low damping and further broadening of the resonance frequency band due to nonlinearity can be expected, and the application of this system to energy harvesters is expected to be more effective. In this study, we focus on a passive self-resonant system consisting of a beam magnetically supported by GdBCO bulk material at both ends and a slider that can move along the beam, and investigate the effects of its low damping and nonlinearity on the amplitude and frequency bandwidth of the resonance of the system from the perspective of applications to energy harvesting.

Keywords: GdBCO bulk materials, Superconducting levitation, Energy harvesting, Nonlinear vibration

H-III

Control of joint part properties in GdBCO bulk superconductor joined by ErBCO superconductor

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Abstract

In order to fabricate larger RE-Ba-Cu-O (RE: rare earth elements) bulk superconductors and bulk suitable for pulse magnetization, we investigated the fabrication conditions of the joint part using the local melting method and examined the improvement of superconducting properties of the joint part. Although tahe local melting method is a good Superconducting joining technology, but under some conditions, the superconducting properties are degraded. It was confirmed that many pores and segregation of the second phase occur in the center of the joint part depending on the fabrication conditions of the joint, such as the bonding orientation and melting conditions. In a previous report, the (110) orientation was appropriate for the joining orientation, while the segregation was concentrated in the center of the (100) orientation, resulting in deterioration of superconducting properties. However, it was confirmed that the superconducting properties were improved by increasing the crystal growth rate.

Keywords: Bulk superconductor, Superconducting joint, GdBCO, ErBCO, Melting method, Crystal Growth

H-IV

Design of a linear generation module for undulator-type tidal current power generation

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Abstract

Tidal current power generators, which is anticipated to be utilized in the near future, are driven at low speeds, so using high-temperature superconducting (HTS) materials. The new mechanism, which we call undulator-type tidal current power generator, uses a linear generator rather than a rotating generator to obtain power from the undulation of the membrane exposed to the tidal current [1]. The system is attractive because it achieves both environmental conservation and power generation without involving fishery resources in the turbine. Therefore, we need a small, short-stroke, and high-power linear generation module that does not restrict the movement of the membrane. Recently, we have devised a multi-layered Halbach array for use in undulator-type tidal current power generator, and are developing a linear generation module based on this [2,3]. One of the features of the multi-layered Halbach array is the magnets that effectively converge the magnetic field to the multiple armatures, where the use of HTS bulk can greatly increase the power output. In this presentation, we will show the results of electromagnetic field analysis of a hybrid type linear generation module with permanent magnets and HTS bulk magnets.

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Keywords: linear generator, tidal current power generator, halbach array, bulk magnet

H-V

Effectiveness of LCR electromagnetic shunt damper for superconducting magnetic levitation system with nonlinear vibration characteristics caused by magnetic forces

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Abstract

Superconducting magnetic levitation systems have the advantage of low energy loss, because they are supported contact-free by magnetic forces and are stable without the need for control. However, due to the low damping caused by the non-contact nature of the system, it is necessary to suppress the resonance amplitude. The LCR electromagnetic shunt damper, which uses electromagnetic coupling as a means of achieving this, is compatible with superconducting magnetic levitation systems in terms of its non-contact nature. The parameters of this damper - coil inductance, capacitance, and resistance - are adjusted to match the resonance frequency of the main system. However, superconducting magnetic levitation systems tend to exhibit nonlinear vibration characteristics due to the low damping and nonlinear support force. In particular, the primary resonance exhibits soft spring characteristics, i.e., the resonance frequency decreases with amplitude. Therefore, it is necessary to investigate whether an electromagnetic shunt damper can work effectively against this shift in resonance frequency with amplitude. This study examines the effectiveness of series and parallel types of LCR dampers in suppressing the resonance of a superconducting magnetic levitation system using GdBCO bulk material, based on their frequency responses for various excitation amplitudes.

Keywords: GdBCO bulk materials, Superconducting levitation, Nonlinear vibration, Vibration suppression, Electromagnetic shunt damper

H-VI

High Temperature Superconducting bulks for electrical machine application

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Abstract

High Temperature Superconducting (HTS) bulks can be used in electrical applications. HTS bulk can be used as magnetic shield or permanent magnet in superconducting electrical machines. In this paper, firstly, HTS bulks used in electric motor are presented with their specific parameters. Secondly, different electric motors with different topologies are presented. GREEN lab in France designed, build and tested many HTS machines using magnetic shielding producing magnetic field concentration. If HTS YBaCuO bulk are cooled down and then submitted to magnetic field pulses, HTS bulks traps magnetic field. This method, called Pulse Field Magnetization, allows the production of prototypes where HTS bulks on a rotor, are magnetized and used as permanent magnets. In Japan, Professor Izumi and his team have been working on this topic for many years and build several prototypes. In England, Dr Coombs build another prototype. GREEN lab studied the magnetization of HTS bulk in an iron core and they concluded that the trapped magnetic field in the HTS bulk increased and the current of the optimal pulse decreased. So, the iron around HTS bulk improves the magnetization process.

Keywords: electric motor, HTS bulks

H-VII

Microstructure of DyBCO bulk superconductors prepared using single-direction melt growth (SDMG) method.

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Abstract

Microstructure of DyBCO bulk single-grain superconductors (BSS) with a nominal composition of 7 mol $D_yBa_2Cu_3O_{7-\delta}$ + 3 mol Dy_2BaCuO_5 (Dy211) + 10 wt. % Ag_2O + 0.5 wt. % CeO_2 prepared by single-direction melt growth was studied using polarized light and electron microscopy. Microstructural parameters such as subgrain structure, porosity, size and macroscopic distribution of Ag and Dy211 particles, contamination of the sample by EuBCO seed as well as the position of the remaining tetragonal non-oxygenated regions in the sample were characterized. It turns out that at the beginning of growth, the structure is more inhomogeneous, which is also reflected in the oscillation of the Dy211 concentration. The cause of these oscillations is discussed in connection with the possible influence of the structure of the used EuBCO BSS wafer seeds. The sub-grain structure of large-scale seeds can lead to the formation of steps on the growth front, which causes the formation of growth sub-sectors with different concentrations of Dy211 particles.

Acknowledgment
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H-VIII

Preparation, microstructure and superconducting properties of EuBCO-Ag bulk samples

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Abstract

High-temperature $REBa_2Cu_3O_x$ (where RE is the rare element) superconductors have potential for wide range of practical applications, e.g. in NMR/MRI facilities. In this study, a series of bulk single-grain EuBCO-Ag superconductors with different addition of $BaCeO_3$ and BaO_2 have been prepared by top-seeded melt-growth process on air. All samples have been investigated by microstructural analysis using optical microscopy in polarised light and scanning electron microscopy with focus on the dependence of the size and volume fraction of Eu211 particles, Ag particles and oxygenation cracks. The levitation force and the trapped magnetic field at 77 K of selected samples as well as microscopic superconducting properties (J_c, T_c) will be presented.

Acknowledgment
This work was supported by Slovak grant agencies: grant no. APVV-21-0387, APVV-17-0625 and VEGA 2/0094/22.

Keywords: EuBCO superconductors, microstructure, micro, and macroscopic superconducting properties

H-VIV

Relationship between magnetic support configuration and vibration suppression effect by a gyroscopic damper for a high-temperature superconducting levitation system

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Abstract

This study investigates the relationship between the magnetic support configuration and the vibration suppression effect of a gyroscopic damper in a high-temperature superconducting magnetic levitation system. While a magnetic levitation system using high-temperature superconducting bulk materials can achieve stable levitation without the need for control, it is prone to large resonance due to the low damping caused by the non-contact support. In our previous studies, we have found the possibility of suppressing resonance by employing a gyroscopic damper, which is a passive vibration suppression technique. Our system, which consists of GdBCO bulk materials and permanent magnets embedded in a levitator, has achieved a vibration reduction of about 40% for both translational and tilting directions when equipped with a gyroscopic damper. However, it is unclear whether similar effects can also be obtained with different magnetic configurations of the support, i.e., the number, size, orientation, and arrangement of magnets, as well as the levitation gap during magnetic field cooling. In this report, the relationship between the magnetic support configuration and the vibration suppression effect of the gyroscopic damper is evaluated from numerical and experimental results.

Keywords: Gyroscopic damper, Amplitude reduction, GdBCO bulk materials, High temperature superconducting levitation system

H-X

Spark Plasma Sintering of pure dense MgB_2 ceramics: myth or reality?

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Abstract

Abstract: Although known since the 1950s [1], the intermetallic compound MgB2 has been studied mainly since the discovery of its superconducting properties (T_c = 39 K) in 2001 [2]. Moreover, magnesium diboride is a light material (density of 2.63 g.cm^{-3}) and exhibits good mechanical properties (Young's modulus of about 300 GPa, toughness close to 13 MPa.m1/2) [3]. In the literature, many studies on the superconductivity of MgB_2 have been conducted on low density or non-single-phase compounds. According to Kim et al. [4], high pressures would shift MgB_2 decomposition of towards higher temperatures. Therefore, Spark Plasma Sintering under high pressure was tested by Xing et al. [5] to obtain ceramics with 95% of the theoretical density and critical current densities J_c at 20 K of up to 675 kA.cm^{-2} in the self-field and greater than 10 kA.cm^{-2} at 4 T.

However, the careful analysis of the microstructure reveals that the obtained ceramics present several compounds with high boron content. Therefore, it appears necessary to study in depth the stability of the Mg-B binary system in order to find the optimum conditions to achieve ceramics with high density and high superconducting properties. This study will be focused on the stability of the MgB_2 compound from its synthesis, starting with elemental Boron and Magnesium, to its sintering under high pressure high temperature conditions. This will allow conclusions to be drawn for Spark Plasma Sintering conditions in order to achieve pure MgB_2 bulk superconductors.

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Keywords: MgB_2, magnesium diboride, synthesis, stability, SPS, Spark Plasma Sintering

H-XI

Tensile properties of superconducting bulk $REBa_2Cu_3O_y$ material fabricated by the infiltration growth technique without Pt addition

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Abstract

Superconducting bulk $REBa_2Cu_3O_y$ (REBaCuO) materials, where RE denotes yttrium and rare-earth elements, are subjected to electromagnetic force and thermal stress in the superconducting devices. Since electromagnetic forces and thermal stress increase with larger bulk size and critical current, improvements in the mechanical properties are useful for the development of high performance superconducting devices. REBaCuO bulk materials usually contain pores that degrade the mechanical properties. On the other hand, bulk REBaCuO materials fabricated by the infiltration growth technique have lower porosity compared to those fabricated by conventional processing. Pt addition is commonly carried out to disperse fine 211 secondary phase particles into the superconducting matrix, which effectively improves the superconducting properties. However, it has been reported that segregation of Pt in low porosity bulk REBaCuO materials may cause the fractures instead of pores. In this study, in order to investigate the mechanical properties of bulk REBaCuO materials fabricated by the infiltration growth technique without Pt addition, tensile tests were carried out on specimens cut from the bulk material. The relationship between the tensile strength and porosity will be discussed in association with the Pt addition and the size of secondary phase particles.

Keywords: REBaCuO, Infiltration growth, Mechanical properties

H-XII

Transient measurement of two-dimensional magnetic flux density distribution on HTS bulk surface

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Abstract

In recent years, with the global demand for energy conservation and low carbon emissions, there are high-temperature superconducting (HTS) bulk is expected to be used in motors and generators to reduce size and increase efficiency [1]. Even though the application of pulse magnetic field is suitable for magnetization to the HTS bulk incorporated in such electrical equipment, pulse field magnetization (PFM) is more difficult to trap strong magnetic fields in the HTS bulk than field cooling magnetization [2]. To improve the trapped magnetic field property by PFM, we have expected to continuously measure transiently increasing and decreasing flux changes in the bulk in two dimensions. Therefore, we have developed a system called a two-dimensional magnetic field sensor that can measure the magnetic flux density distribution at intervals of approximately 1ms [3]. Using this system, we measured the magnetic flux density distribution when a pulsed magnetic field was applied to a GdBCO bulk of 60 mm diameter and 19 mm thick. In this presentation, we show the behavior of the magnetic flux density observed on the bulk surface based on detailed information compared to the conventional measurement method obtained from the limited penetration flux density using a few Hall elements.

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Keywords: magnetic field measurement, magnetic flux density distribution, pulse field magnetization, Hall elements

H-XIII

Magnetic Performance Study on NdFeB/ Sr-Ferrite composite Permanent magnets: towards a new track for magnetic levitation

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Abstract

Scientific community has been focusing on permanent magnets in the past few years for seeking alternate solutions from the so-called the rare-earth crisis. Composite based permanent magnets appear to be a promising solution for this dilemma[1][2]. In this work, NdFeB/ Sr-Ferrite/ NdFeB on the one hand and NdFeB/ steel/ NdFeB stacked bulk composites on the other hand were fabricated with different magnet thicknesses by affixing them together. Magnetic measurement of such a system with 16 to 20% of Sr- ferrite has shown coercivity and remanence in the range of 800 kA/m and 1T, respectively. Results on the remanent magnetization, normal and intrinsic coercive fields of the investigated composite magnets will be presented. The obtained performances confirm the results of Feng *et al.*[3] showing that composite magnets could be used for the construction of Maglev guideways.

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H-XIV

REBCO bulk superconductors prepared by liquid assistant growth and their trapped field performance

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Abstract

In this study, we investigated the superconducting properties of highly dense bulk MgB_2 samples prepared by unconventional "Spark Plasma Sintering" (SPS). Different precursors were used: i) the commercial powder MgB_2 ii) mixtures of magnesium and nano boron powder (Mg + 2B) and iii) mixtures of Mg and MgB_4 powder for an "in-situ" reactive synthesis. The density of obtained MgB_2 bulks was up to 99 % of the theoretical density of the material. Then structural and microstructural characterizations were carried out with these samples and correlated to their superconducting properties, in particular their critical current densities (J_c) measured at 20 K. A high J_c = 675 kA/cm^2 was obtained in self-field. Remarkably for a bulk MgB_2, J_c was above 10kA/cm^2 at 4T.

H-XV

Magnetic Dipoles Including Magnets and Superconductors with Adjustable Field

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Abstract

In a synchrotron the electrons are guided and focused along their trajectory by magnetic dipoles, quadrupoles and other magnetic devices. Along some sections of the synchrotron, the employed dipoles consist of permanent magnets, the magnetic field and field gradient of which must be tuned very accurately. For this purpose, in many cases, the magnet gap is modified mechanically to generate the desired values. We have investigated another possibility to tune the magnetic properties of a dipole, which is to insert a superconductor bulk and a magnetizing coil in the magnetic circuit. The magnetization of the superconductor by high current pulses flowing in the coil modifies the magnetization of the superconductor and as a result, the field in the gap of the dipole. The main advantage of this system is the possibility to tune finely the dipole field without any mechanical action. In this contribution, we describe the experimental set-up which was built and some of the magnetic circuits we have investigated. We show that: i) contrary to the proposition in [1] appreciable changes in the gap are possible only if the superconductor is not in the immediate vicinity of soft iron; ii) the field in the gap can be adjusted accurately below or above its normal value up to 10% by applying an adequate serie of pulses to the coil and iii) the field changes are reversible by applying another serie of pulses.

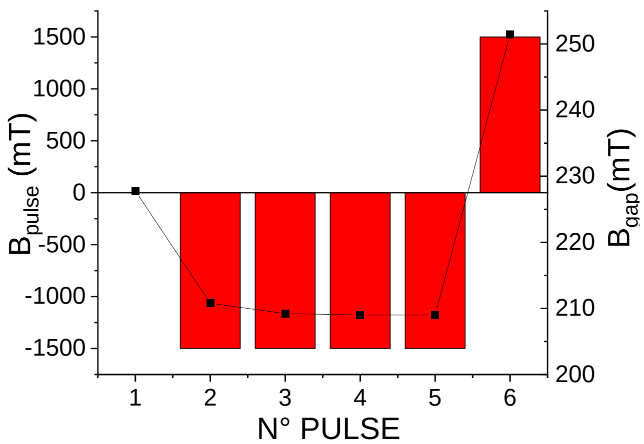

Fig.1. modulation of the field in the dipole gap (black points) by a sequence of field pulses (in red).

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