WBP9-1

Optimization of growth parameters for fabricating single grain (Gd, Dy)BCO bulk superconductors in top-seeded infiltration growth process

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Fabrication of single grain bulk REBa2Cu3O7-δ (REBCO) superconductors with superior performance along with shape retaining is a recent topic. Mixed REBCO superconductors produced in melt growth (MG) technique had showed enhanced superconducting performance. However, this process offers many disadvantages such as macro-porosity, shrinkage in final products, inhomogeneous distribution of 211 secondary phase particles etc., which limit many practical applications. Infiltration growth (IG) process is advanced and superior to MG technique in several aspects. Recently, we fabricated (Gd, Dy)Ba2Cu3O7-δ ((Gd, Dy)BCO) bulk superconductors through systematic addition of Dy2BaCuO5 (Dy-211) content. The addition of 20 wt.% of Dy-211 in GdBCO was found to be optimum which resulted in enhanced superconducting performance. In the present work, in order to determine a suitable temperature window for fabrication of large single grain (Gd, Dy)BCO bulk superconductors, isothermal experiments were carried out at several constant temperatures in top-seeded IG process in air atmosphere. A systematic structural, microstructural, composition and magnetic properties were assessed and analysed. The 211 secondary phase particles are enlarged to as high as ~ 25 μm when the sample assembly is dwelled at high temperatures and reduced to ~ 2 μm – 4 μm in the samples dwelled at lower temperatures. Main emphasis will be given on the growth rate progress and difficulties involved in IG processing of mixed REBCO superconductors.

Keywords: Mixed REBa2Cu3O7-y, Infiltration Growth Process, Microstructure, Magnetic properties

WBP9-2

Effect of CeO_2 on the properties of single domain GdBCO bulk superconductors fabricated by Gd+011 TSIG Process

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Single domain GdBCO bulk superconductors have been fabricated by the top-seeded infiltration and growth process (Gd+011 TSIG) with solid phase compositions of (1-x)(Gd_2O_3+1.2$BaCuO_2$)+xCeO_2, (x=0, 0.25, 0.50, 0.75, 1.00, 1.25, 1.50 wt %). The effect of CeO_2 doping on the growth morphology, microstructure, levitation force and trapped field of single domain GdBCO bulks have also been investigated based on these samples. The results show that the single-domain GdBCO bulks can be fabricated when x is in the range of 0-1.50 wt%. Both of the levitation forces and trapped fields of the samples increase first and then decrease with the increase of x; both of the largest levitation force of 54.1 N(77 K, 0.5 T), the largest trapped field of 0.42 T(77 K, 0.5 T)and 1.11 T(77 K, 1.8 T) are obtained in the sample when x=0.10wt%. These results show that appropriate CeO_2 doping is an effective way to enhance the flux pinning force and the other physical properties of GdBCO bulk superconductors especially fabricated by the Gd+011 TSIG method.

Keywords: GdBCO bulk superconductor, Gd+011 TSIG process, CeO2 doping, trapped field

WBP9-3

Large single grain bulk $GdBa_2Cu_3O_y$ grown by IG process utilizing the $ErBa_2Cu_3O_y$+liquid as a liquid source

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We report a new methodology to produce the large single grain bulk $GdBa_2Cu_3O_y$ samples by the infiltration-growth (IG) process. Our recent experiments clarified that supply of liquid phase is crucial for growing large grains by IG process. Further, if we utilize the 100% liquid phase or mixture of liquid phase with Gd-123 as liquid source found it quite difficult to growing the large size bulk Gd-123 material. In this presentation, we adapted the IG technique and produced several large size bulk $GdBa_2Cu_3O_y$ samples by means of Er-123+liquid (1:1) as liquid source. Experimental results indicated that single grain bulk Gd-123 samples were produced easily with Er-123+liquid as a liquid source. Magnetization measurements showed a sharp superconducting transition with T_c(onset) around 92.5 K. The trapped field experiments conformed by single grain nature. Further we have cut the large bulk Gd-123 sample in varying positons to understand the uniformity and measured the critical current density at 77 K and compared the microstructure analysis by optical microscope and scanning electron microscope (SEM). The experimental results clearly indicated that the easy production of single grain Gd-123 material by IG process can be understood in terms of a low peritectic temperature of Er-123 with liquid phase source (1:1), which helps to supply the liquid phase to the growth place.

Keywords: infiltration-growth (IG), Gd-123, Critical Currenet Density , SEM

WBP9-4

The effect of cooling rate on critical current density and microstructure of single grain bulk $YBa_2Cu_3O_y$ superconductors grown by IG process

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In the recent years, top-seeded infiltration-growth (IG) process of $YBa_2Cu_3O_y$ (Y-123) had shown crucial and promising strengths as compared to melt growth process. The IG process lucidly clarified that a supply of liquid phase is more than essential for further growing large grains. Further, this experimentation aimed to enhance the performance of bulk YBCO superconducting materials which were processed by IG process. The homemade Yb-123 and Y-211 were utilized in order to produce $YBa_2Cu_3O_y$ samples with the means of Yb-123+liquid (1:1) as a liquid source under a varied cooling rate. Moreover, fabricated employing top seeded infiltration growth process consisted of numerous varied cooling rates of 0.16 $^oC/h$, 0.25 $^oC/h$ and 0.5 $^oC/h$, respectively. In essence, all samples were oxygenated for 300 h with a constant pressure of 300 mL/min. Trapped field experiments clearly indicated that samples with cooling temperature of 0.16 $^oC/h$ produced a double value as compared to samples produced at a cooling rate of 0.5 $^oC/h$. Eventually, all samples with improved trapped field values were systematically investigated for correlation of the following properties of critical current density and microstructure analysis by SEM.

Keywords: IG Process, Yb-123, Critical Current Density, Trapped Field

WBP9-5

Study on the Torque Property of Non-Contact Rotating System Using HTS Bulks and Permanent Magnets

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Non-contact rotating system using magnetic levitation technology doesn't have mechanical friction. Therefore, there are no need to worry about energy loss and maintenance. It is very useful using in vacuum chamber or clean room where dislike generated dust. For these reasons, a lot of researches about non-contact levitation technology using electrostatic force, pressure, ultrasonic wave, air pressure and magnetic force have been conducted. Among them, the technology using magnetic force has the advantages that can generate relatively large levitation force and easy to handle.
The high temperature superconducting bulks which magnetized by field cooling method shows the diamagnetic behavior and pinning effect at the same time. We have been developed non-contact rotating system using ring-shaped HTS bulks (ID 20 mm OD 60 mm and 5 mm height) and ring-shaped permanent magnet. In order to apply to developed the non-contact rotating system as the medical mixer, a torque of 240 N･cm and rotating speed of 10~120 rpm are needed required. From our previous study, we have achieved a sufficient rotating speed of 840 rpm. However, the target torque value of 90 N･cm has not been obtained. Therefore, we have studied about structure optimization of the non-contact rotating system to improve the ability of torque. The detailed experimental results about structure optimization of non-contact rotating system and its torque property will be presented.

Keywords: HTS bulk, non-contact, torque

WBP9-6

Effects of Nanodiamond Addition on Critical Current Density in Y-Ba-Cu-O Bulk Superconductors

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Bulk Y-Ba-Cu-O superconductors have significant potential for engineering applications due to high critical current density (J_c) and high trapped magnetic fields, which is attributed to the presence of pinning centers such as micro-sized Y_2BaCuO_5 (Y211) inclusions. The introduction of nano-sized particles is known to function as more effective pinning centers than micro-sized ones. It has been reported that J_c values were enhanced with the addition of nano-sized particles such as ZrO_2 and $Y_2Ba_4CuMO_y$ (M = Nb, W, etc.) in $YBa_2Cu_3O_x$ (Y123). We have focused on nanocarbon as another candidate of the pinning centers and reported that the addition of carbon nanotube led to the enhancement of J_c in Y-Ba-Cu-O superconductors [1]. Nanodiamond is also expected to improve the flux pinning performance. We then fabricated melt-processed Y-Ba-Cu-O bulk samples with the addition of nanodiamond and investigated J_c and microstructure. SEM observation showed the presence of needle-like particles less than 100 nm in length in the Y123 matrix. J_c exhibited the highest value for the sample with 0.4 wt% nanodiamond addition. These results suggest that nanodiamonds act as effective pinning centers.
[1] K. Inoue, Y. Miyake, M. Miryala, M. Murakami, J. Phys: Conf. Ser. 871 (2017) 012051.

Keywords: Y-Ba-Cu-O bulk superconductors, Nanodiamond, Critical current density

WBP9-7

Basic Design of Electromagnets to Prevent the Overshoots in 3-D Superconducting Actuator

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The electric device applications of a high temperature superconducting (HTS) bulk having stable levitation and suspension properties due to their strong flux pinning force have been proposed and developed. We have been investigating a three-dimensional (3-D) superconducting actuator using HTS bulk to develop the transportation device with non-contact and moves in free space. It is expected that our proposed 3-D superconducting actuator will be useful as a transporter used in a space full of combustible gas and a clean room which manufactures the silicon wafer where dislikes mechanical contact and dust. Proposed actuator consists of the trapped HTS bulk as a mover and two-dimensionally (2-D) arranged electromagnets (EMs) with iron core and copper coil as a stator. The HTS bulk can be moved the 3-D directions and rotates without upper side EMs. The current and the polarity of each EM are individually controlled by the switching power supply.

The four EMs are used as one unit and the diameter of each coil with iron core is 43 mm and the gap length between EMs is 3 mm. The diameter of iron core is 28 mm. From our previous experiments with this stator, we concluded that a more powerful guidance force is needed because the mover overshoots during operation. In order to obtain a large guidance force and stable levitation, it is necessary to increase the strength of magnetic gradient and increase the total number of it. Therefore, we designed one unit of stator with nine EMs. By using this stator, the total number of magnetic gradients to the direction of travel increases from two to six. In our actuator, the GdBCO HTS bulk with 64 mm diameter is used. So one unit is designed to fit within the range of 63 × 63 mm^2. When 8 A is energized, it can generate a magnetic field of about 0.29 T at the maximum. This is almost the same as the previous electromagnet. The dynamic behaviors of the mover in the new stator was experimentally investigated and the obtained results will be presented.

Keywords: actuator, HTS bulk, flux pinning , magnetic levitation

WBP9-8

Trapping Large Magnetic Field by Suppression of Thermomagnetic Instability in Coated Conductor Stacks

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Coated conductors (CCs) of 123-type superconductors with a large critical current density (J_c) have been successfully developed for applications of power transmission and generation of high magnetic fields. However, such CCs can find applications in other purposes. One of them is an alternative method to generate a large magnetic field like bulk materials of high temperature superconductors. However, when one attempts to magnetize such bulk materials, one faces problems of mechanical strength and thermomagnetic instability. In order to solve such problems of the bulk magnet, stacking short segments of CCs has been proposed and a modest field has been successfully trapped [1]. We have also fabricated two stacks of each 130 pieces of GdBCO CCs and trapped 7.92 T at the center of the stacks [2].
In the present study, we aimed at improving the trapped magnetic field by modeling the bulk magnet using GdBCO CCs with better J_c-H characteristics. For that purpose, GdBCO CCs produced by Fujikura were irradiated by 800 MeV Xe with B_Φ=4 T. Two stacks of each 40 pieces of GdBCO CCs were placed next to each other and miniature Hall probes for measuring the trapped field were placed at the center of the stacks. They were cooled down to 4.2 K in a magnetic field of 90 kOe, and the field was reduced to zero at different sweep rates from 100 Oe/s to 1 Oe/sec. In this condition, we have succeeded in trapping 7.95 T at the center of the stacks. However, it was also found that as the sweep rate of the magnetic field was increased, flux jumps occurred and the trapped magnetic field was strongly suppressed.

We also report the evaluation of the local magnetic characterizations of the GdBCO CCs used for trapping magnetic fields, and discuss thermomagnetic instability due to changes in the number of CC stacked and sweep rate of the magnetic field.

[1]A. Patel, K. Filar, V. I. Nizhankovskii, S. C. Hopkins, and B. A. Glowacki, Appl. Phys. Lett. **102**, 102601 (2013).
[2]T. Tamegai, T. Hirai, Y. Sun, and S. Pyon, Physica C **530**, 20 (2016).

Keywords: Cuprate, Coated Conductor, Bulk Magnet, Columner Defects

WBP9-9

Effects of SPS pressure on the mechanical properties of high packing ratio bulk MgB_2 superconductor

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It has been reported that the mechanical properties of bulk MgB_2 superconductor processed by spark plasma sintering (SPS) technique are excellent due to the high packing ratio. However, the conditions of SPS on the mechanical properties of bulk MgB_2 superconductor have not been understood extensively. In this study, bulk MgB_2 samples were processed by SPS under different pressures. Effects of SPS pressure on the mechanical properties were investigated through bending tests for specimens cut from the bulk samples. There was no significant difference in the average Young's modulus value among the bulk samples. The average bending strength values of these bulk samples were also similar to each other. However, the bending strength data of the bulk samples processed under higher pressure scattered widely in comparison with the bulk sample processed under lower pressure. The reason for it is discussed in association with the microstructures of these bulk samples.

Keywords: MgB2, Bulk superconductor, Bending test , Mechanical properties

WBP9-10

MgB_2 bulk superconductors prepared through a powder reaction method using MgB_4 and Mg powders

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MgB_2 bulk superconductors were prepared through a powder reaction method using MgB_4 and Mg powders. The effects of the size and shape of Mg powder on the formation of MgB_2 and and superconducting propertiesof MgB_2 was examined. It was found that the size of the Mg powder did not affect the superconducting transition temperature (T_c) of MgB_2 significantly: T_c of all prepared samples were 37.9-38.3K regardless of the size and shape of Mg powder.The critical current density(J_c) of MgB_2 was, however, dependent on those of Mg powder: the small and spherical Mg power with a size about 20 μm showed the J_c higher than that of large spheical Mg powder or plate-like Mg powder. The use of the small and spherical Mg powder seems to not only accelerate the formation of MgB_2 but also reduce the porosity in MgB_2. In addition to the characterictics of Mg powder, the heat treatment condition for the formation of MgB_2 and the J_c was examined. The optimum heat-treatment condition for obtaining high J_c of this study was 700°C for 2 h. The extended heat treatment at this temperature decreased the J_c owing to the grain growth of MgB_2.

Keywords: MgB2, bulk superconductors, MgB4 , critical current density

WBP9-11

Flux pinning and superconducting properties of MgB_2-diamond nanocomposites

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Since the discovery of superconductivity in MgB_2 with the highest T_c of 40K, a significant progress has been made concerning the development of processing techniques, flux pining, critical current density (J_c), large size MgB_2 bulk growth. To utilize this material for industrial applications, including superconducting super-magnets, a further improvement of critical current density is crucial, especially in sintered bulks. The present investigation focuses on a further performance improvement of disk- shaped bulk MgB_2 superconductors by means of a nanoscopic diamond powder and using a single-step solid-state reaction process. MgB_2 bulks were produced by in-situ solid state reaction in Ar gas using high purity commercial powders of Mg metal and amorphous B mixed in a fixed ratio of Mg:B = 1:2. Further, 0, 0.4, 0.8, 1.2 wt% of nanoscopic diamond powder was added to improve flux pinning performance of the bulk MgB_2 material. All samples were sintered at 800 ^{o}C for 3 hours in Ar atmosphere. As grown bulk samples were characterized utilizing the X-ray diffraction and the microstructure was tested by scanning electron microscopy. The superconducting transition temperature of the MgB_2 with nanoscopic diamond particles, deduced from magnetization measurements, was around 33.6 K. The best sample had the critical current density of 18 kA/cm^2 at 20 K and 4 T.

Keywords: MgB2, Nanodiamond, Critical current density, Microstructure

WBP9-12

High performance bulk FeSe produced by silver addition and ball-milling technique

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The new types of pnictide materials are very interesting for applications where large and homogenous samples are required, especially for superconducting super-magnet applications. Recently, we optimized the processing conditions to obtain high critical current densities (J_c). Furthermore, the mechanical performance is quite important, especially when utilizing these materials for applications as trapped field magnets. In this report, we have produced polycrystalline samples of FeSe with varying contents of silver (0-7 wt.-%) by the solid state reaction method at 850 °C (24 h). The mixing was done in a glove box and pellets of 5 mm diameter were prepared; then the samples were vacuum sealed in quartz tubes. X-ray diffraction results demonstrated that the main phase in all the samples is FeSe. Above 4 wt.-% of silver addition, a minor amount of Ag_2Se phase was observed. All samples showed a superconducting transition around 9 K. Further, the critical current density was improved in the sample with 4 wt.-% of silver. SEM results indicated an enhanced grain connectivity. Our results clearly indicate that ball milling combined with silver additions and an optimum sintering temperature is crucial to obtain good quality, bulk FeSe material for several industrial applications.

Keywords: FeSe, X-ray diffraction, Magnetization measurements, SEM

WBP9-13

High Performance Y123 Superconductor Bulks and Thick Films for Practical Applications

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We will report two aspects work, superconductor *bulks and thick films,* in this presentation. Firstly, the refinement of Y_2BaCuO_5 (Y211) particles is a matter of significant importance in fabricating high performance $YBa_2Cu_3O_{7-d}$ (Y123) superconductor bulks by top-seeded melt-growth (TSMG). we developed a novel TSMG approach in which instead of Y211, modified precursor powders (MPP, Y_2O_3 and $Ba_2Cu_3O_x$) were employed. As a result, massive Y211 nanoparticles were derived from the homogeneous nucleation catastrophe through peritectic solidification of Y_2O_3+Ba_x-Cu_y-OèY211. Correspondingly, superior property of trapped field was achieved from the MPP-processed bulk.
Secondly, different microstructures of high temperature superconductor (HTS) suit for different applications. For instance, *c*-axis orientated Y123 films are appropriate for current transport approach, while *a*-axis oriented films are suitable for device applications. Besides, grain boundaries (GBs) with a special structure are of great potential to improve superconducting performance. Over the years, we have developed several approaches for effective control the supersaturation state in solution with a wide range from ultra-low to high, to reliably prepare various oriented microstructures for more applications.

Keywords: superconductor bulk, Y211 nanoparticles, oriented film, supersaturation