WBP1-1

Improved performance of bulk MgB_2 superconductor produced via combination of in-situ and ex-situ method

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In this study, we propose a combination of in-situ method and ex-situ method, which are typical fabrication techniques in bulk MgB_2 superconductor system, to achieve high density as well as improve the critical current density (J_c). The bulk MgB_2 sample was synthesized with varying ex-situ powder (pre-synthesized powder) content such as 0, 10, 15, 20, 25 and 30wt% in conjunction with in-situ method followed by sintering at 775℃ for 3 hours in Ar atmosphere. As a result, it was observed that the filling rate, which represents the index of density, increased by 1% for every 5wt% increase of the ex-situ powder. Among all the samples, the 20wt% ex-situ added sample showed the highest J_c value of 321 kA / cm^2 at 20 K and self-field. Furthermore, it can be observed that all the ex-situ powder-added MgB_2 samples exhibit superiority in J_c values at the high magnetic field when compared with the sample fabricated by the in-situ method alone.

Keywords: in-situ, ex-situ, combination method, critical current density

WBP1-2

Superconducting Properties of Polycrystalline $Ba_{0.6}K_{0.4}Fe_2As_2$ Bulks Fabricated by a Spark Plasma Sintering Method

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Iron-based superconductors are expected to be applied in high magnetic fields, because it has a high superconducting transition temperature T_c and a high upper critical magnetic field H_{c2}. (Ba, K)Fe_2As_2 (T_c = 38 K for the optimal composition) is known to have a small electromagnetic anisotropy compared to the cuprate superconductors, therefore the polycrystalline samples, which were prepared by a powder-in tube [1] or a hot isostatic pressing (HIP) [2] methods, showed the relatively high critical current density. In this study, we attempted to produce the (Ba, K)Fe_2As_2 bulk by a spark plasma sintering (SPS) method and measured the superconducting properties.

Precursor powder of $Ba_{0.6}K_{0.4}Fe_2As_2$ was prepared by heating stoichiometric mixtures of pure Ba, K, Fe and As enclosed in the stainless steel tube under an atmosphere of pure gas argon. The obtained $Ba_{0.6}K_{0.4}Fe_2As_2$ powder was confirmed as the single phase by the powder X-ray diffraction method, and was sintered by the SPS method to produce a disk with a diameter of 10 mm and a thickness of 4 mm.

From the results of DC magnetic susceptibility, the onset of T_c was 35.0 K and the volume fraction of superconduction was 32.8 % at 5 K for the SPS-processed $Ba_{0.6}K_{0.4}Fe_2As_2$ bulks. A somewhat lower T_c suggested that the K substitution for the Ba-site might be incomplete. Thus, the optimization of the sample preparation such as the nominal composition of precursor powder and firing condition is now in progress.

[1] Z. Gao *et al.*, Supercond. Sci. Technol. **30** (2017) 095012.
[2] J D Weiss *et al.,* Supercond. Sci. Technol. **28** (2015) 112001.

Keywords: iron-based superconductors, Ba0.6K0.4Fe2As2, spark plasma sintering method

WBP1-3

Optimization of Sintering Conditions for Synthesizing Dense Magnesium Diboride Bulk Superconductors via Ex-Situ Spark Plasma Sintering Method

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Along with relatively high superconducting transition temperature (T_c), light weight, nontoxic, scalability, and simple synthesis procedures makes MgB_2 superconductors to be one of the promising candidates for accomplishing portable magnetic devices. Bulk superconductors developing for high field magnets, very high critical current density (J_c) values are required. Spark plasma sintering (SPS) is known as rapid synthesis method, suppressing the grain growth, and producing bulk products with high density into compact shapes. Therefore, the method is suitable to synthesize bulk MgB_2 [1, 2]. In this work, we have tried to synthesize bulk MgB_2 via SPS method with several synthesis conditions.
A series of samples were fabricated by varying the pulsed current intensity (350 A – 500 A). As the current intensity increased, MgB_2 decomposed mainly to MgB_4 and MgO. The impurity phase fraction was increased with raise in the pulse intensity while densification was not occurred at lower current and the 400 A was observed to be the best condition. The microstructural characterization reveals that the size of the MgB_2 grain was to be ~200 nm - 500 nm. Compared to the conventional solid-state sintering method, SPS samples own dense microstructures with remarkable grain connectivity. The obtained bulk MgB_2 materials were ~95 % dense as compared to a sintered product which possesses ~60%. The onset of T_c determined by SQUID magnetometry was ~38 K. The J_c of the sample fabricated by applying current of 400 A was exhibiting 220 kA/cm^2 at self-field and 20 K which is superior to the previous reports [1, 2]. Present results revealed that the SPS is a promising way to fabricate dense samples with improved grains connection and better densification of the bulk MgB_2 superconductors, which could be an important variant for magnetic applications. However, optimization of several parameters such as dwell time, applied pressure, doping, etc., can effectively enhance the flux pinning hence the J_c performance.

[1] J. G. Noudem et al., Journal of Applied Physics 116, 163916 (2014).
[2] C. E. J. Dancer et al., Supercond. Sci. Technol. 22, 095003 (2009).

Keywords: MgB2, Spark plasma sintering, Critical current density, Dwell time

WBP1-4

Trapped Field Properties of Pulsed Field Magnetization of MgB_2 Bulk with Ti-doped

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Until now, some research institutes have magnetized MgB_2 by Field Cooled Magnetization (FCM) which is said to be the most efficient, but FCM requires a large device and power consumption is large and the time required for magnetization is long. Therefore, this time we used Pulsed Field Magnetization (PFM) to experiment that can magnetize in a short time and compact. In this research, trapped field characteristics were evaluated by pulse magnetization of MgB_2 prepared by HP method.

Samples used for PFM are shown in Table.1. The sample of this time was prepared by the HP method by changing Ti content. The sample was set on the cold stage and a hall sensor was attached to the surface center of the sample. After that, the inside of the chamber was evacuated and the sample was cooled by setting the freezer to 14K. The pulsed magnetic field was obtained by discharging a pulse current from a capacitor charged in a conductor coil cooled to 77 K with liquid nitrogen.

Fig. 1 shows trapped fields of each bulk. In this experiment, the highest trapped field was BT = 0.73 T of MH104b. Increasing the Ti content did not improve the captured magnetic field.

Table.1 Spec of Bulk

Sample Name	Diameter[mm]	Height[mm]	Mg : B : Ti
MH90-2,3,7	20	3.58	1 : 2 : 0
MH104b	20	3.67	0.975 : 2 : 0.025
MH113a	20	3.5	0.975 : 2 : 0.05
MH117	20	2.7	0.975 : 2 : 0.10

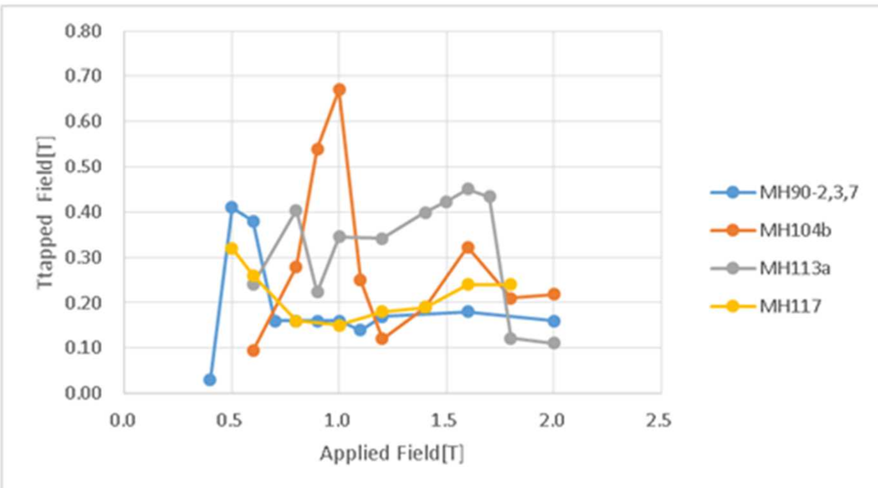

Figure.1 Trapped Field

Keywords: MgB2, Ti-doped, PFM

WBP1-5

Effects of SiC-doping on the trapped field properties of *in-situ* HIP-processed MgB_2 bulks

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MgB_2 bulk magnets have been strengthen by the densification, grain refining, and chemical doping. We found that the Ti-doped MgB_2 bulk fabricated by an *in-situ* hot isostatic pressing (HIP) method offered the high B_T of 3.6 T at 13 K [1]. C-doping is also well known to bring about the pronounced increase of both the critical current density J_c and the irreversibility field, H_{irr} [2]. In this paper, we report on the effects of SiC-doping on the trapped field properties of MgB_2 bulk. The $Mg(B_{1-x}(SiC)_x)_2$ (x=0-0.2) bulks were synthesized at 973-1173 K under gas-Ar pressure of 98 MPa by the *in-situ* HIP method, and then magnetized under 5 T by field-cooled magnetization. The B_T of 2.20 T at 20 K for the pristine bulk was increased to 2.25 T for the x=0.05 bulk and to 2.47 T for the x=0.1 bulk. However, further doping (x=0.2) deteriorated. On the other hand, the highest J_c and H_{irr} at 20 K were obtained for the x=0.05 bulk, and the J_c of x=0.1 bulk was somewhat smaller than that of the pristine bulk. We discuss an origin of the B_T-increase by SiC-doping in conjunction with the J_c properties, the connectivity, and the microstructure observation.

Acknowledgements:
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[1] T. Naito *et al.*, Supercond. Sci. Technol., Vol. 28 (2015) 095009.
[2] S. X. Dou *et al.*, Appl. Phys. Lett. Vol. 81 (2002) 3419.

Keywords: MgB2, trapped field

WBP1-6

Study on the thermal stability of the NdBCO film in inducing the growth of $REBa_2Cu_3O_x$/Ag superconductor bulks

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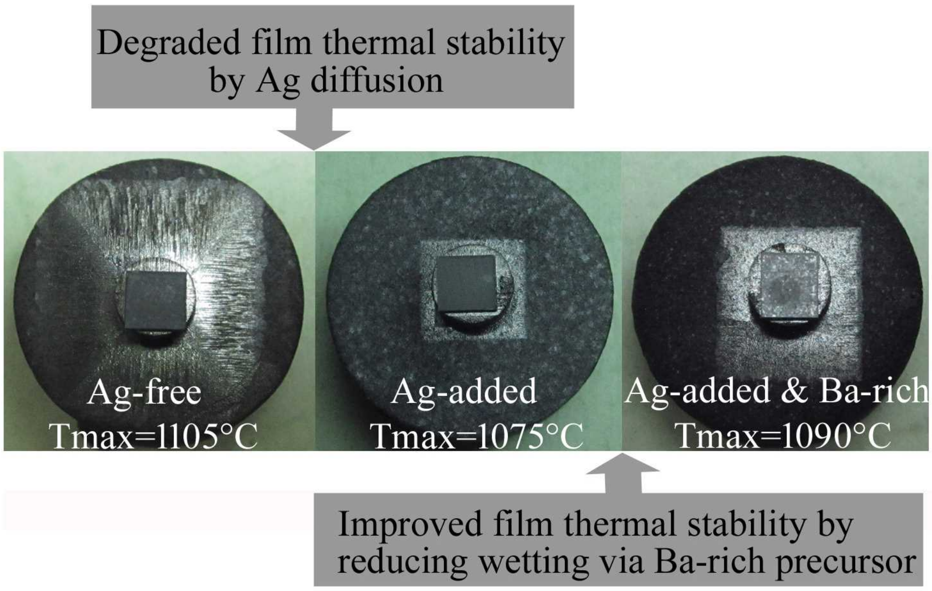
The NdBCO-film is a prominent seed in melt-growth of $REBa_2Cu_3O_x$ (REBCO, RE=rear earth element) cryomagnets because of its extremely high thermal stability, which, however evidently degraded, when Ag was added into NdBCO for improving its brittle nature, leading to fabrication failure. Here we clarified that film thermal stability is caused by high wettability of the Ag-added liquid, governed by precursor composition of REBCO/Ag. We developed a novel film seed/buffer-pellet/main-pellet construction to effectively strengthen film thermal stability via wetting modification by exploiting Ba-rich buffer-pellets, and succeeded in growing high superconductivity NdBCO/Ag bulks. This new conception is broadly applicable for producing all REBCO/Ag cryomagnets.



Graphical Absract: The top view of three kinds of NdBCO grown samples with procedures at their correspondingly tolerable maximum temperature(T_{max}).

Keywords: superconductor, thin film, wetting, thermal stability

WBP1-8

Effect of Carbon Nanotube doping on superconducting properties in Y-Ba-Cu-O Bulk Superconductors

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Melt-processed Y-Ba-Cu-O bulk superconductor can trap strong magnetic field at liquid nitrogen temperature and can act as a strong compact magnet, which is considered to be applicable for magnetic separation device, compact NMR and so on. In order to improve the performance of the field trapping Y-Ba-Cu-O bulk magnet, enhancement in critical current density J_c is required by embedding finely dispersed non-superconducting particles in the superconducting phase as effective pinning centres. Till now, an enormous number of works have been performed to increase in J_c by controlling the size and distribution of Y211 second phase. Recently, we have found that the addition of carbon nanotube (CNT) in the Y-Ba-Cu-O bulk superconductors is effective in increasing J_c. In this report, we have investigated the effects of two kinds of CNT addition on superconducting properties, such as single layer carbon nanotube (SWCNT) and multi-layered carbon nanotube (MWCNT). As a result, J_c value was improved when the SWCNT was employed rather than the case of MWCNT addition. From the microstructural observations, carbon-contained fine phases could be observed by SEM and compositional analyes by EPMA. We will present the distribution of the carbon contained phases and the affect to the superconducting properties (T_c, J_c, *etc*).

Keywords: carbon nanotube, melt-process, pinning centers, critical current density

WBP1-9

Study on superconducting welding method of Gd-Ba-Cu-O Bulk Superconductors for pulsed field magnetization

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We are investigating the effect of welding of Gd-Ba-Cu-O bulk superconductors on the trapped field properties obtained by pulsed field magnetization (PFM). RE-Ba-Cu-O bulk superconductors can trap a strong magnetic field below T_c, therefore, several applications like magnetic separation systems or motors using these strong compact magnets are being considered. The combination of bulk superconductor and the PFM method is one of the promising ways to design a simple superconducting bulk magnet device. However, in case of PFM, it is slightly difficult to trap a high magnetic field due to fast flux movement and heat generation during the PFM process. In order to overcome such a hurdle, we are studying welded bulk superconductors and the effect of an artificial superconducting grain boundary with different pinning and thermal properties compared to superconducting bulk body. There is a chance, by employing the artificial grain boundary by welding method, to enhance the performance of PFM processed magnets. In this paper, a Gd-Ba-Cu-O/Ag cut sample of 30 mm in diameter, taken from a single grain bulk, was split along the (110) plane then welded using Er-Ba-Cu-O/Ag solder. Trapped field distribution has been measured at 40 K after PFM with different applied fields. Finally, we discuss the potential of superconducting welding processes for the PFM.

Keywords: Bulk superconductor, welding process, pulsed field magnetization

WBP1-10

Magnetic Field Uniformity on Magnetic Pole of HTS Bulk Magnet System Attached Iron Plates with Holes

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The abstract is not released, but the poster presentation will be made.

WBP1-11

Pulsed field magnetization of GdBCO bulk using a ring-shaped soft-iron yoke

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We study to improve a trapped field of REBCO bulk excited by pulsed field magnetization (PFM). In PFM, there are some merits such as a magnetizing system is compact and inexpensive, and magnetizing time is short. It is very important to simplify a magnetizing process in order to accelerate a practical use of bulk magnet. Then, we focus on a soft-iron yoke which is used in order to expose the bulk to a large amount of magnetic flux for a long time. In our previous study, trapped field performance was investigated by varying a diameter of disk-shaped yoke. In this paper, we evaluate an influence of a shape of soft-iron yoke on magnetizing characteristic. A ring-shaped yoke with a 64 mm outer diameter, 20 mm inner diameter and 47 mm thick is newly fabricated. PFM experiment using a GdBCO bulk 60 mm in diameter and 20 mm thick is performed by varying an amplitude of applied field and temperature, and these results are compared with that of a disk-shaped yoke.

Keywords: GdBCO bulk, pulsed field magnetization, ring-shaped soft-iron yoke, trapped field