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論　文　要　旨
Thesis Abstract

(yyyy/mm/dd)　　2022 年　3 月　8 日

※報告番号	甲第３０２号	氏　名 (Name)	JOSEPH LONGJI DADIEL

主論文題名　（Title）Study on Fabrication Method of High Performance MgB2 Bulk Superconductor and Improvement of Pulse Magnetization Property

This thesis is focused on the processing techniques of improving the superconducting performance of polycrystalline and high density magnesium diboride (MgB_2) as well as the effective cost of production. This intermetallic material is highly attractive for practical applications because of its excellent and unique features which ranges from it's simple stoichiometry and high critical temperature for a non-oxide superconductor, low density, high upper critical field and strong trapped field among other features for the samples produced in the bulk form. Several techniques have been suggested and researched to improve the density and connectivity, grain sizes with the resulting effect on the critical current density (J_c), to be utilized for practical applications of the bulk such as magnetic resonance imaging (MRI), nuclear magnetic resonance, trapped field magnets, motors and generators, magnetic separations, flywheel storage, levitation, innovative applications such as biomedical. Classically, most of the samples prepared by conventional powder metallurgy leads to low relative densities which affect the final properties of the bulk materials. Different methods have been used for enhancing the grain refinement, connectivity and densifying the material such as high pressure sintering, hot isostatic pressing (HIP), hot compactions, and nonconventional field assisted sintering techniques (FAST) or spark plasma sintering (SPS) process. However, the challenges in the optimization of the microstructures and material density for effective self-field J_c improvement and high trapped field is still at large.

As a remedy to the aforementioned issues, suggested possible methods were used in this thesis to enhance the critical current density and flux pinning of bulk MgB_2 as well as connectivity between grains. In order to improve the bulk superconducting performance, two different perspectives were considered; the material development aspect and the application aspect. In the material aspect of this thesis, the chemical doping technique was initially adopted to improve the flux pinning properties of MgB_2 bulk superconductor material, these techniques were effective for the samples produced at the course of this chapter. Three different techniques were discussed in order to compare the effect of different additives on the superconducting performance of bulk MgB_2 superconductor. The first series was based on nanoscopic diamond powder addition.

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内容の要旨(Abstract)

Optimization of the nanoscopic diamond powder at 775 ^oC sintering temperature for 3 hours played a vital role in improving the flux pinning performance of the bulk MgB_2 material resulting in high self-field J_c at ~300 kA/cm^2 for 0.8 wt.% of nanoscopic diamond addition. To further improve the superconducting performance of the bulk, synthesis of the product by silver (Ag) addition using the same processing technique and conditions was employed. XRD and SEM micrograph analyses indicated AgMg secondary phase as nanoparticles embedded in the MgB_2 matrix in the samples with Ag addition. Optimization was achieved for 4.0 wt.% added Ag which showed improved self-field J_c of 398 kA/cm^2 at 20 K. The study showed Ag addition contributed to formation of more effective pinning medium in bulk MgB_2 and helps to further improve performance of the bulk. Nanodiamond and Silver are very expensive raw materials for bulk MgB_2 synthesis which could further make the final product costlier. To solve this problem, a cost effective technique of ball-milled charcoal powder within the range of 60-100 nm sizes was considered. Doping was done on MgB_2 with resulting optimization at 0.4 % charcoal doping for a superconducting J_c improvement to about 467 kA/cm^2.

In order to achieve high performance by simultaneous structural control and density enhancement of bulk MgB_2 for practical applications, this work suggests synthesis of bulk MgB_2 samples via spark plasma sintering *in-situ* and also utilized *ex-situ* processing by optimizing the sintering temperatures and observing the effects on the bulk density and microstructure. The microstructural characterization by FE-SEM reveals some Mg-O inclusions for the *ex-situ* process, better grain connectivity and the size of the MgB_2 grain was statistically analyzed to be within the range of ~100 to 120 nm. The distribution of the generated impurity phases which occurred due to the effect of our processing condition were studied by transmission electron microscope. The onset of the critical temperature, T_c determined by superconducting quantum interference magnetometer was ~38 K showing slight effect of secondary phases in the sample microstructure. The critical current density, J_c is influenced by the sintering temperature for both *ex-situ* and *in-situ* process exhibiting $J_{c,s}$ of the order ~500 kA/cm^2 at self-field and 20 K.

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The density by SPS *in-situ* is superior to the previous reports by SPS in-situ processing. This work urge that the flux pinning was highly promoted by the interactive contributions of the grain refinements and controlled minor secondary phases towards improving the superconducting performance compared to the bulk MgB_2 synthesized by the conventional methods.

To complement the application aspect of this study, a modified bulk MgB_2 was subjected to trapped field measurements via pulse field magnetization (PFM). Degrading of trapped fields B_T in bulk MgB_2 superconductor due to the occurrences of flux jumps has been a lingering challenge due to the anisotropic thermal property of bulk MgB_2.

This section of the thesis presents the method for characterizing the propagation of the magnetic flux in an artificially drilled MgB_2 bulk superconductor fabricated via spark plasma sintering (SPS) which was achieved by studying the effect of applied fields, B_A on the bulk MgB_2 embedded with low melting alloy of Bi-In-Sn alloy and aluminum rods within the holes. The bulk MgB_2 sample was redesigned to enhance both the thermal properties and to suppress flux jumps during pulse applications. The magnetic flux dissipation, the flux motion, and performance by evaluation of the capture field ratio B_T/B_P were discussed. We achieved 0.7 T trapped field at 1.8 T applied field without flux jumps which is a vital breakthrough for high magnetic field applications. This study helps to solve the flux jump problem in the bulk superconductor resulting from poor heat dissipation. This is an experimental breakthrough that supports existing simulation studies and reports giving way for more prospects for high field applications in the development of bulk MgB_2 superconductors.

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