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論　文　要　旨
Thesis Abstract

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主論文題名　（Title）

Low-cost Routes and Optimal Processing Conditions for Mass Production of $REBa_2Cu_3O_y$ Bulk Superconductors

内容の要旨　（Abstract）

High temperature bulk $REBa_2Cu_3O_y$ (RE-123/RE: Nd, Eu, Gd, Y, Er) superconductors are attractive for superconducting super-magnet applications since they are able to trap high magnetic fields at liquid nitrogen temperature. Use of liquid nitrogen (boiling point 77.3 K) as a coolant is considerably cheaper than use of liquid helium (4.2 K). To widely explore these special properties, this material has to be fabricated in large amounts, which would also reduce its cost. The operation cost would be considerably reduced if critical temperature (T_c) of the superconductor was well above 77 K, typically above 90 K. In this thesis, two main issues on this superconductor were discussed. First, we focus on the refinement of RE_2BaCuO_5 (RE-211) secondary phase particles by high-energy ultra-sonication in order to improve the material performance and the cost. The second issue is fabrication of a new ternary $(Gd,Y,Er)Ba_2Cu_3O_y$ ((Gd,Y,Er)-123) compound with a considerable critical current density (J_c) and trapped field (TF) performance, produced in air. All RE-123, RE-211 and liquid phase powders used in this study were self-synthesized.

For the effective refinement of RE-211 secondary phase particles to suitable size by ultra-sonication technique, the ultra-sonication conditions had to be optimized. This technique provides an advantage of a contamination-less operation since the samples are not corrupted by any additives. In this technique, the ultra-sonic wave bombarded the Y-211 particles. The frequency and power were fixed constant at 20 Hz and 300 W, respectively, and the bombardment time varied from 0 to 100 min. We also observed that the shape of Y-211 secondary phase particles changed from the sphere-like to irregular shapes after bombarding by the ultra-sonic wave. For the PtO_2 was added to Y-123 for inhibiting grain growth of the Y-211 particles. The optimum time of ultra-sonication was found to be 80 minutes by top-seeded melt growth (TSMG). With 0.5 wt% of PtO_2 addition the J_c value and TF increased twice compared to the standard process, where no ultra-sonic

wave was applied, and no PtO_2 was added.

In the second step, we focused on the composition of the mixed RE-123 compound due to their exceptional superconducting ability because of several defect structures present. The ternary $(Gd_{0.33},Y_{0.33-X},Er_{0.33+X})Ba_2Cu_3O_y$ superconductor named as (Gd,Y,Er)-123 was chosen for this study, with the content factor X varying from 0 to 0.2. For the fabrication of the bulk superconductor, the calcined (Gd,Y,Er)-211 powder was used as a precursor, and the infiltration growth (IG) process was chosen to overcome the inherent problems occurring in TSMG. The values of J_c and TF increased monotonously with the Er increment. The microstructural and chemical analysis showed that the fine secondary phase particles uniformly dispersed in the (Gd,Y,Er)-123 matrix, and were rich in Er. The superconducting properties of ternary (Gd,Y,Er)-123 improved with respect to Y-123. However, the study of the entire bulk superconductor showed a spatial variation of superconducting properties. In the microstructure, a variation in (Gd,Y,Er)-211 particle size was also observed in the as-grown bulk sample.

The ultra-sonication conditions optimized for the ternary bulk (Gd,Y,Er)-123 fabrication process helped to improve superconducting properties of the ternary bulk. The highest J_c and TF values were achieved in $(Gd_{0.33},Y_{0.13},Er_{0.53})Ba_2Cu_3O_y$ sample. The self-field J_c at 77 K increased by 20% compared to that of the standard sample made of calcined (Gd,Y,Er)-211 powder. Moreover, the newly developed mixed RE system exhibited the higher J_c at both low and high magnetic fields. This J_c improvement in a wide range of magnetic fields at liquid nitrogen temperature provides an exceptional advantage for commercial applications.

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