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New method for introducing nanometer flux pinning centers into single domain YBCO bulk superconductors

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ABSTRACT

Single domain YBCO superconductors with different additions of Bi_2O_3 have been fabricated by top seeded infiltration and growth process (TSIG). The effect of Bi_2O_3 additions on the growth morphology, microstructure and levitation force of the YBCO bulk superconductor has been investigated. The results indicate that single domain YBCO superconductors can be fabricated with the additions of Bi_2O_3 less than 2 wt%; Bi_2O_3 can be reacted with Y_2BaCuO_5 and liquid phase and finally form $Y_2Ba_4CuBiO_x$(YBi2411) nanoscale particles; the size of the YBi2411 particles is about 100 nm, which can act as effective flux pinning centers. It is also found that the levitation force of single domain YBCO bulks is increasing from 13 N to 34 N and decreasing to 11 N with the increasing of Bi_2O_3 addition from 0.1 wt% to 0.7 wt% and 2 wt%. This result is helpful for us to improve the physical properties of REBCO bulk superconductors.

1. Introduction

The high levitation force, high trapped field and self stabilized levitation of single domain REBCO bulk superconductors makes it possible for various applications such as magnetic bearing [1], flywheel [2], high magnetic field permanent magnets [3], and levitated transportation systems [4–8]. These applications are based on the trapped magnetic field and levitation force of the superconductors, which is closely related with critical current densities (J_c) of the REBCO bulk superconductors. High J_c can be obtained in the samples with strong flux pinning force, this can be realized by introducing effective flux pinning centers to the REBCO bulks superconductors. RE_2BaCuO_5(RE211) particle is one of the most effective flux pinning center for REBCO bulk superconductors, but the particle size is relatively larger, around several to several ten micrometers, and it is difficult to be reduced to less than 1 μm even if Pt is added [9–13]. So, new flux pinning centers of nanometer particles have to be introduced to improve J_c of these materials, because the effective flux pinning force can be realized only when the size of the particles are close to the coherent length ($\xi_{ab} \approx 1$–2 nm for REBCO superconductor). Recently, it is found that nanoscale inclusions $(RE)_2Ba_4CuMO_y$ (where RE = rare earth, and M = Nb, Ta, W, Mo, Zr, Hf, Ag, Sb, Sn, Bi, etc.) has been successfully synthesized and introduced into YBCO bulk superconductor by melt textured growth process (MTG) [14,15], the result shows that the nanoscale $(RE)_2Ba_4CuMO_y$ (REM2411) particle is really an effective flux pinning centers for the YBCO bulk superconductor. We have successfully introduced $Gd_2Ba_4CuNbO_y$ (GdNb2411) particles into single domain GdBCO bulk superconductors the top-seeding melt texture growth process (TSMTG), the particle size is in the range of 100–300 nm, the levitation force has been improved to 170% [16]. In addition, we have also successfully introduced $Y_2Ba_4CuNbO_y$ (YNb2411) particles into single domain YBCO bulk superconductors by the top seeded infiltration and growth process (TSIG), the particle size is in the range of 200–500 nm, the levitation force has been improved to 200% [17].

It is found that all the flux pinning centers are introduced by direct addition of nanometer REM2411 particles, so it is not easy, not economical and time costing for introducing this kind of REM2411 inclusions, because we have to fabricate the REM2411 powder before melt growth process of the REBCO bulk superconductors. In order to reduce the cost and improve the working efficiency, a new method for introducing nanometer flux pinning centers into single domain YBCO bulk superconductors is proposed in this paper.

2. Experimental

The powders of Y_2BaCuO_5 (Y211), $YBa_2Cu_3O_y$ (Y123) and $Ba_3Cu_5O_8$ (Y035) were prepared by solid state reaction process. The solid phase pellets is consisted of well mixed Y211 + x wt% Bi_2O_3 (x = 0.1, 0.3, 0.5, 0.7, 0.9, 2) powders, the liquid phase pellets is consisted of well mixed Y123 + Y035 powders, both of the solid phase pellets and liquid phase pellets were pressed into cylindrical bulks of 20 mm in diameter. Some Y_2O_3 powders were pressed into pellets of ϕ20 mm × 2 mm and used as liquid phase supporters at elevated temperature. The pellets were placed in a configuration

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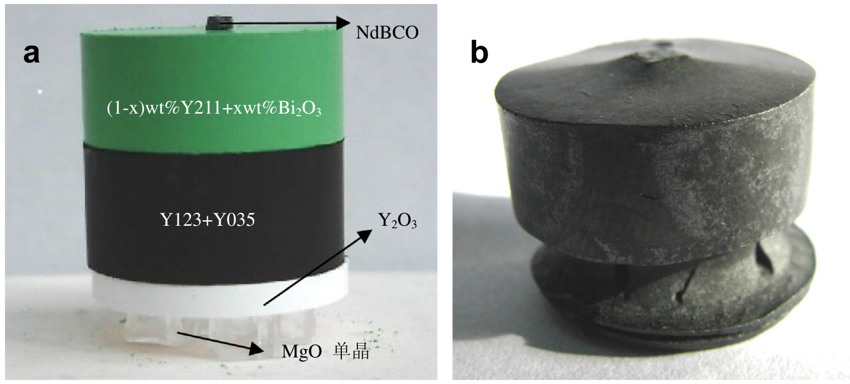

Fig. 1. The morphology of one YBCO bulk sample before and after TSIG process.

as shown in Fig. 1a, then put into a self designed tube furnace with appropriate temperature and temperature gradient distribution which could effectively prevent the random nucleation of YBCO grains at the edges of samples [18]. The samples were heated up to 1045 °C, and held for 2 h for homogeneous melting and the liquid phase infiltration. Then it was decreased to 1020 °C at a rate of 60 °C/h, and further cooled to 970 °C at a rate of less than 0.3 °C/h. Finally, the samples were cooled to room temperature at 120 °C/h. One of the as grown YBCO bulk is shown in Fig. 1b. The as grown samples were annealed in flowing oxygen for 200 h at temperatures ranging from 500 °C to 400 °C. The levitation force of the YBCO bulks was measured with a self designed magnetic levitation force device [19]. The microstructure of the YBCO bulk superconductors was observed and analyzed by a scanning electron microscope (SEM).

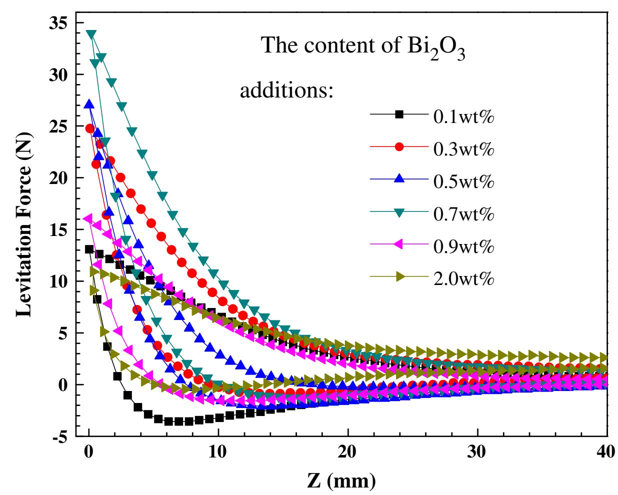

Fig. 3. Levitation force of the samples with the different addition of Bi_2O_3 to Y211.

3. Results and discussion

Fig. 2 is the top view morphology of the YBCO bulk superconductors with different Bi_2O_3 additions. As we can see from this figure, all the samples are nearly of single domain character, this means that single domain YBCO bulk superconductors can be prepared when the Bi_2O_3 additions is less than 2 wt% by TSIG method.

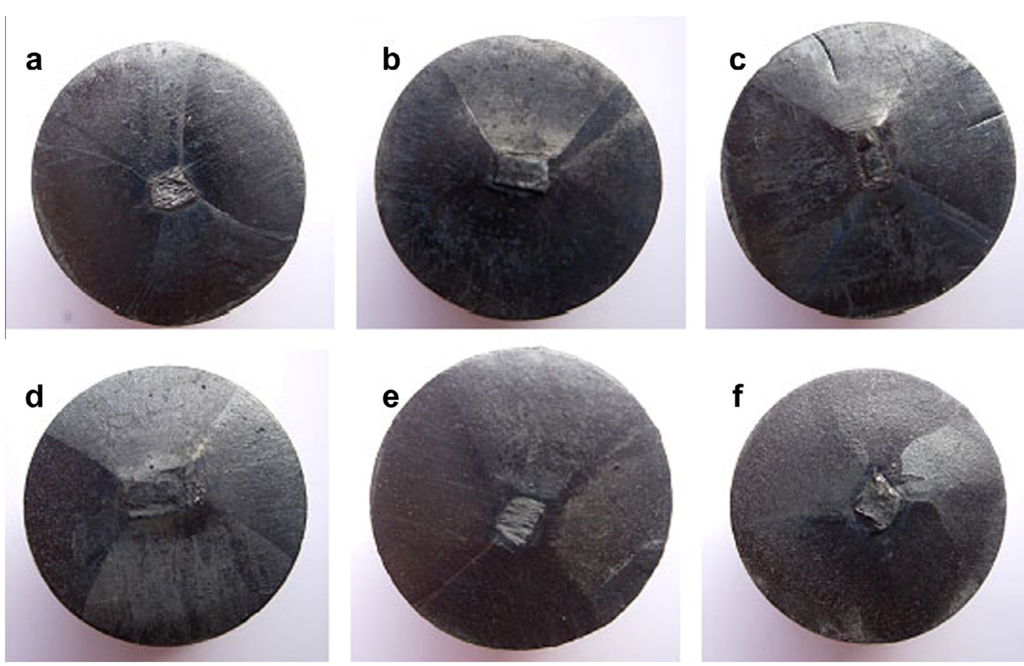

Fig. 2. The morphology of YBCO superconductors with different Bi_2O_3 additions. (a) $x = 0.1$ wt%, (b) $x = 0.3$ wt%, (c) $x = 0.5$ wt%, (d) $x = 0.7$ wt%, (e) $x = 0.9$ wt%, and (f) $x = 2$ wt%.