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Large bulk Y-Ba-Cu-O superconductors fabricated by multiseeding melt growth methods

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Abstract: We have fabricated the large single domain YBaCuO bulk superconductors by using multiseeding technique combined with composition gradient in the precursor. Obviously, the growth time can be shortened by multiseeding method and the weak links between grain boundaries originated from different seeds can be also overcome with introducing the chemical component gradient and arranging the seeds exactly. For these YBCO disks, only single peak occurs in the distributions of trapped field, and the magnetic levitation force is equal to that of the same size sample fabricated with single seed. Although the arrangement of seeds is similar, the distribution of trapped field still shows four peaks for the sample without composition gradient.

Key words: multiseeding; composition gradient; YBaCuO; trapped field

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1 Introduction

It is known that a top-seeded melt-growth method (TSMG) allows the growth of c-axis oriented REBaCuO bulk superconductors[1]. Large single domain YBCO bulk superconductors exhibit excellent field trapping properties. A single domain sample of 10 cm diameter is now available from TSMG process[2]. However, a processing time is too long due to the low growth rate of Y123 grain in a peritectic melt, and regarded as one of the most significant weak points in general. For example, to prepare a sample of 10 cm size, 500 h is needed as an estimate, and a delicate heat treatment is required since undesirable parasitic nucleation is more likely for larger samples.

In general, joining and multiseeding techniques are the practical ways of enlarging bulk superconductors[3-6]. It, however, is inevitable to lower the superconducting properties of the mother blocks during the joining process with above 950℃. On the other hand, multiseeding method was started in an attempt to make large single domain samples in a short time by using several seeds. Multiseeding has additional advantages as well as a time-saving effect. It does not need any additional post-MTG heat treatment compared with joining process. Additionally, variation in sample shape is possible by arranging the seeds properly. This process, however, has a disadvantage of forming grain boundaries and results in several peaks for the magnetic trapped field distribution.

Recently, a multiseeding seamless bulk technique (MUSLE) can be used for fabricating Dy-Ba-Cu-O

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bulk superconductors that have a single peak in the trapped field distribution[8-9]. It is the basic concept of MUSLE technique that the precursor is composed of the two or more RE-Ba-Cu-O layers with different peritectic temperatures. In this study, we have fabricated the large bulk YBaCuO superconductors by using multiseeding technique. By comparison with conventional multiseeding technique, it is easier to fabricate large single domain 1YBaCuO bulk superconductors by MUSLE.

2 Experimental

$Y_{1.8}Ba_{2.4}Cu_{3.4}O_y$(Y1.8) and $Gd_{1.8}Ba_{2.4}Cu_{3.4}O_y$(Gd1.8) powders were prepared from Y_2O_3(Gd_2O_3), $BaCO_3$ and CuO powders with the ratio of Y (Gd) : Ba : Cu=1.8 : 2.4 : 3.4 by a solid state reaction. In order to refine the 211 phase 0.2%(mass fraction) of Pt powder was added. The sintered powders Y1.8 and Gd1.8 were mixed with a compositional ratio of Y1.8 : Gd1.8=1 : x and $(Y_{1-x}Gd_x)$1.8Ba2.4Cu3.4Oy (YGdBaCuO) were obtained as the material of transitional layer. The decomposition temperature of $(Y_{1-x}Gd_x)_{1.8}Ba_{2.4}Cu_{3.4}O_y$ were measured by differential thermal analysis (DTA) as shown in Fig. 1. It can be seen that the peritectic decomposition temperature (T_p) is 1010℃ for Y123, and 1041℃ for Gd123, moreover, T_p increases monotonously with x increasing.

Well mixed powders were pressed into pellets 46 mm in diameter and 20 mm in thickness with uniaxial mould pressing as seen in Fig. 2. Layer A is the transitional layer of YGdBaCuO composition, and can be divided into several layers, such as A1, A2, etc. Layer B is the matrix of YBaCuO composition.

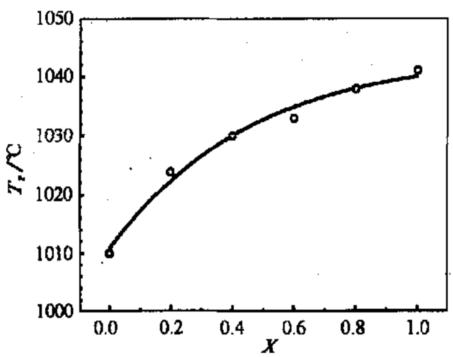

Fig. 1 The decomposition temperature of $(Y_{1-x}Gd_x)_{1.8}Ba_{2.4}Cu_{3.4}O_y$

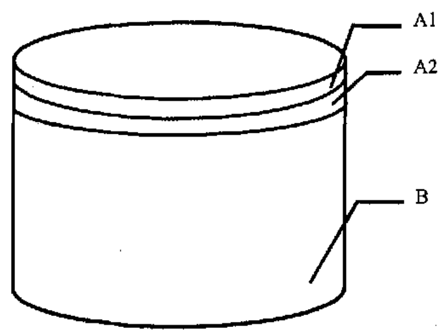

Fig. 2 A schematic diagram of the precursor

SmBaCuO seeds were used to predetermine the orientation of the growing YBCO single grains. One single seed was applied on the top of the cylindrical shaped disks whereas up to four seeds were placed in defined angle correlations on the top of disks. The c-axis of the seeds was perpendicular to the top face of the disks.

The precursor with seeds was placed into a furnace and heated to 1040℃ for 3 h, held for 1 h, cooled down to 1015℃ rapidly, and then slowly cooled down to 980℃ with a rate of 0.4-1℃/h, and finally furnace cooled to room temperature.

The trapped field distributions were measured by scanning a Hall sensor at a gap of 1.5 mm between the Hall sensor and top surface of samples under field cooled condition at 77K.

3 Results and discussion

Fig. 3 shows a photograph for the top surface of the bulk superconductor (30 mm in diameter and 18 mm in thickness) fabricated by single seed Melt-textured-growth method. Obviously, the 123 grain is grown from the seed to form four sectors with 90° included angle each other. The X-ray diffraction results show that the c-axis of every sector is parallel to the symmetrical axis of cylindrical samples, and the misorientation angles of c-axis orientations among the four sectors is lower than 5°. The space distributions of trapped field present single conical peak, and the contour exhibits concentric circles. The maximum magnetic levitation force reaches 110 N at 77 K and 0.5 T.

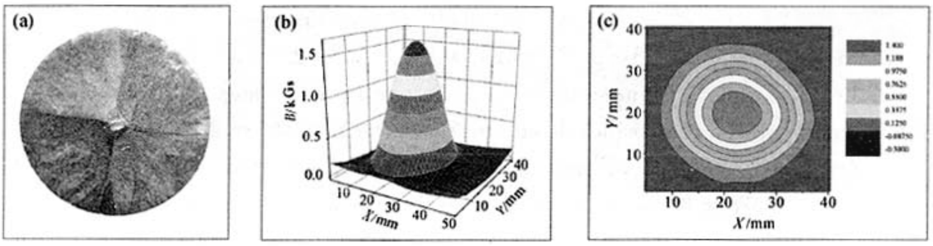

Fig. 3 Photographs and trapped field profile of TSMG-processed sample (30 mm in diameter and 18 mm in thickness) with one seed

(a) — Photographs of the top surface of single grain with one seed; (b) — Space distributions of trapped field; (c) — the contour of trapped field

It is noticed that the arrangement modes of several seeds have significantly influence on the crystalline state and superconducting properties of the entire sample with using multiseeding technique, that is, the seeds have to placed on the top surface of the precursor in defined angle correlations so as to (100)/(100) or (110)/(110) grain junctions formed between the seed crystals. Fig. 4 indicates the top surface profiles of YBCO samples prepared with four seeds having three arrangements. Although every grain grown from single seed has the similar c-axis orientation, the grain boundaries between two proximal grains have significant difference. Fig. 4(a) shows the irregular grain boundaries corresponding to irregular seed arrangement; while (100)/(100)or (010)/(010) and (110)/(110) grain boundaries formed with the regular seed arrangements, as shown in Figs. 4(b) and (c), respectively. The microstructure observed by SEM indicates that the residual phases, such as CuO, were observed at the grain boundary, but the grain boundaries in Figs. 4(b) and (c) are relatively cleaner than that in Fig. 4(a).

Fig. 5 presents photograph and trapped field profile of TSMG-processed sample (40 mm in diameter and 18 mm in thickness) with four seeds. The precursor (in diameter 46 mm) of this sample only consists of layer B (i. e. Y1.8) without layer A (i. e. YGdBaCuO). Four seeds were placed on the top surface with the distance of 20 mm one another, similar to Fig. 4(b). The space distribution of trapped field is approximately single peak, however, in upper part there exist four small peaks. This indicates that the grain boundaries still act as weak links, but superior to that of Fig. 4(a) and joining four similar grains. The measured maximum levitation force is 167 N at 77 K and 0.5 T for this sample, and is lower than that of single domain sample in same dimensions fabricated with single seed (about 220 N).

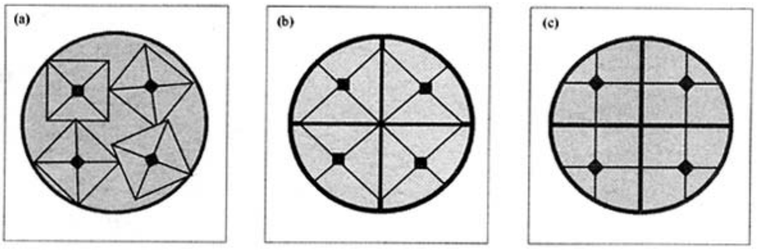

Fig. 4 Schematic diagrams of crystalline morphology of YBCO with various four-seed arrangements
(a)—Irregular boundary; (b)—(100)/(100)or(010)/(010) boundary; (c)—(110)/(110)boundary.

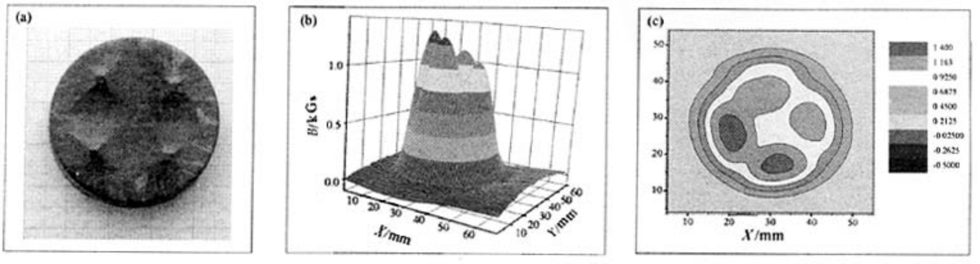

Fig. 5 Photographs and trapped field profile of TSMG-processed sample (40 mm in diameter and 18 mm in thickness) with four seeds and without layer A
(a)—Photographs of the top surface of single grain with four seed; (b)—Space distributions of trapped field; (c)—the contour of trapped field

The precursor, similar to that shown in Fig. 2, was pressed in diameter 35 mm. The upper part consists of $Y_{1.8}Ba_{2.4}Cu_{3.4}O_y$: $Gd_{1.8}Ba_{2.4}Cu_{3.4}O_y$ = 0.8 : 0.2, and the lower part is Y1.8. The distance of four seeds is 20 mm, placed on the top surface similar to Fig. 4(b). After TSMG process, the top surface of the sample is the same as that in Fig. 5(a), has typical (100)/(100) junctions. The distributions of trapped field are shown in Fig. 6, a conical peak and concentric circles, respectively, which is characteristic of a bulk superconductor without weak links and segregation at the grain boundaries orientated by the multiple seeds. The measured maximum levitation force is 106 N, equal to that of single grain sample in the same size prepared with single seed.

The above result is evidence showing that the boundary is well combined magnetically as well as apparently suggests a strong possibility of multiseeding for preparation of large YBCO samples. In addition, the arrangement of seeds is very important. It is necessary to form (100)/(100) or (110)/(110) junctions at grain boundaries and to control the distance of seeds one another. When the distance of seeds is near zero, there is a clear grain boundary for (110)/(110) junction, even if, without transitional layer[10]. However, it is very difficult to arrange the seeds exactly in line with the same orientation. Accordingly, the multiseeding technique combined with composition gradient is effective for fabricating large size single domain YBCO bulk superconductors with a short time.

4 Conclusion

YBaCuO superconducting sample was fabricated by TSMG with a multiseeding technique. By introducing composition gradient in the precursor, the weak links at grain boundaries have been eliminated and the

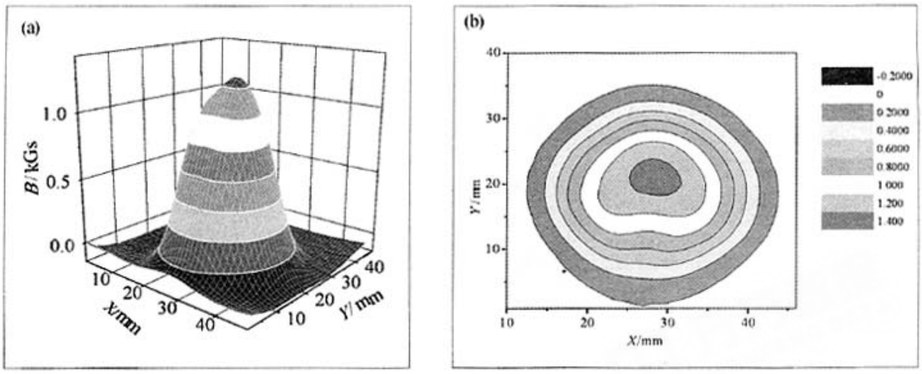

Fig. 6 Trapped field profile of TSMG-processed sample (30mm in diameter and 18mm in thickness) with layer A and four seeds

(a)—Space distributions of trapped field; (b)—the contour of trapped field

bulk sample exhibits the characteristic of a single grain according to the distributions of trapped field. Therefore, it is an effective method to fabricate large size single domain RE-Ba-Cu-O bulk superconductors with a short time by using several seeds and introducing transitional layer. With the increase of sample size, the number of seeds and the transitional layers must be increased.

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