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Trapped Magnetic Field Measurement at 77 K for Multi-grain YBCO Bulk Superconductor

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Abstract – Multi-seeded YBCO superconductors (cylindrical size) 32 mm in diameter were fabricated by top-seeded melt growth (TSMG). Melt-processing was performed using a precursor containing 75 wt % of Y123 and 25 wt % of Y211 with 0.5 wt % of CeO_2. Trapped magnetic field at 77 K of the multi-seeded bulk samples (single grain and two grains) were studied. The maximum trapped field measured at the top and bottom surface of single grain YBCO 32 mm in diameter were as 0.56 and 0.55 T at 77 K, respectively. Trapped field measurements on the top and bottom surfaces of the (100) // (100) aligned samples were measured and as the value of d increases, trapped magnetic field decreases.

Keywords – *Superconductors, Crystal Growth, Magnetic Measurements, Trapped Field, Hall Probe*

I. INTRODUCTION

Since the discovery of high temperature superconductors, many fabrication techniques have been used by scientists. One of the most effective techniques is top-seeded melt growth (TSMG) to fabricate large grain YBCO bulk in some practical applications such as electrical motors, magnetic bearings, generators, flywheel and energy storage devices [1-4]. For the TSMG method, it is important to use a cold-seeding technique in that seed was placed on the top of YBCO pellet. The seed can be NdBaCuO (NdBa2Cu3O7) or SmBaCuO (SmBa2Cu3O7) because the melting point of them is higher than that of YBCO [5].

Many researchers have succeeded lots of work about superconductors in some trapped magnetic field measurements up to now [6-14]. It is known that the trapped magnetic field is dependent on many parameters such as the critical current density, grain orientation, size of the sample and the cooling temperature [8-10]. In the literature, the measurement of the trapped magnetic field between a TSMG single grain YBCO and a permanent magnet (PM) have been worked generally at 77 K using liquid nitrogen by many researchers [8-15].

In recent times, several special methods such as grain boundary joining using filler materials [16], diffusion bonding with pressure [17] and multiseeding [18,19] have been tried to fabricate the sample with larger grain size as well as to reduce processing time. Surrounded by them, the multiple seeding technique was advised as a nominal way that can fabricate the large c-oriented sample in a short time. Kim et al. fabricated a rectangular multi-seeded isothermal-melt-textured (MSIMT) by SmBaCuO seed with (100)/(100) grain junctions and the trapped magnetic field of these samples decreases as d (distance between two seeds) increases from 0 to 20 mm [20] It is also stated that (RE)BCO (where RE=rare earth, Gd or Y) bulk superconductors can trap fields greater than 17 T the longstanding world record field produced by an arrangement of two bulk superconductors of 17.24 T at 29 K [6] was recently exceeded by 17.6 T at 26 K in [7].

For the practical application of the YBCO bulk, we made multi-seeded YBCO samples with (100)/(100) junctions and studied the interaction between superconductor and a permanent magnet. Particularly, trapped magnetic field profiles (3-D maps and 2-D contours) in the superconductor was investigated.

II. MATERIALS AND METHOD

Single grain and multi-seeded YBCO bulk superconductor was fabricated by the Top-Seeded Melt-Growth (TSMG) process in air. Y123 (YBa2Cu3O7) and Y211 (Y2BaCuO6) were prepared using Y2O3, BaCO3 and CuO powders and calcinated at 900 °C for 20 h and 920 °C for 15 h, respectively by solid-state reaction method. 75 wt. % of Y123 and 25 wt. % of Y211 with 0.5 wt. % of CeO2 was mixed. CeO2 powder was added to prevent the grain growth of Y211 phase [21]. Mixture of powders was pressed in a steel mold into the cylindrical pellets of 32 mm in diameter. NdBaCuO seed was used as a seed material for the growth of YBCO grains and YBCO pellet with an arrangement of making (100)/(100) junctions before melt processing of Fig. 1 (a) was placed on the pellet on the calcinated Y211 particles at the center of an electrical box furnace and melt-processed following the heating cycles of Fig. 2 [22]. The c-axis of the NdBaCuO seeds was normal to the top surface of the YBCO compacts. The distance between the two seeds (d) was varied from 0 to 12 mm. Fig. 1 (b) shows that the diameter of multi-seeded YBCO bulk sample reduces to 26 mm after thermal process. Samples were oxygenated in flowing gas at 450 °C for 7 days following TSMG processing to convert the tetragonal Y123 phase to the superconducting orthorhombic phase. Multi-seeded YBCO samples will be hereafter denoted as MS-00 (d = 0 mm), MS-01 (d = 1 mm), MS-04 (d = 4 mm) and MS-12 (d = 12 mm)

Unreacted liquid-rich phase was removed from the base of all samples before the top and bottom surfaces of both samples were polished flat and parallel. The maximum trapped magnetic fields were measured both the top and bottom face of the samples at 77 K following field cooling in an applied magnetic field of 1.4 T. The magnetic field was measured initially using a hand-held Hall sensor positioned 0.5 mm above each sample surface. The full trapped field profiles were then measured at both the top and bottom surfaces using a rotating array of 20 Hall probes at a distance of 1.0 ± 0.5 mm from the surface of each sample [23].

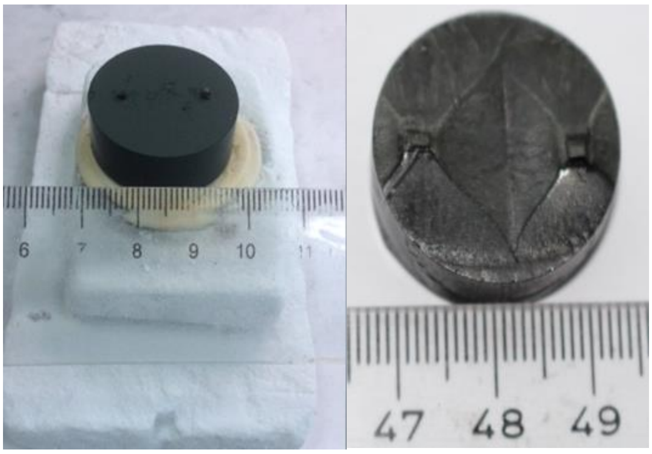

Fig. 1 The view of the top face of multi-seeded YBCO pellet before and after thermal process.

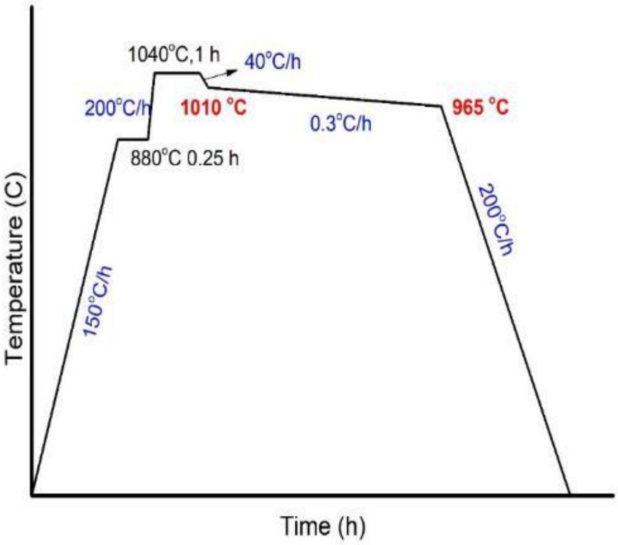

Fig. 2 Heating cycles of the top-seeded melt processing

III. RESULTS AND DISCUSSION

Fig. 3 shows the pictures of the top surface of the multi-seed samples fabricated by TSMG method with various seed distances. It can be seen in all samples that two Y123 matrix were grown at the two seeds and enclosed the whole top surfaces. Owing to the two Y123 grain growth, the (100)//(100) grain junctions were designed at the center region of the top surfaces. The positions of the seeds appear to be progressed considerably from the original positions because of the shrinkage of the YBCO compacts throughout melt textured process. The grain junctions are so slanted marginally from the (100)//(100) junction.

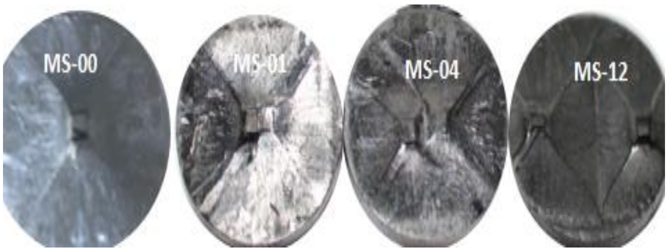

Fig. 3 The view of the top face of multi-seeded YBCO pellets:MS-00, MS-01, MS-04 and MS-12.

Fig. 4 and Fig. 5 shows the trapped magnetic field profiles (3-D maps and 2-D contours) of the top face of MS-00, MS-01, MS-04 and MS-12 samples. The sample with d= 0 mm shows the trapped magnetic field (H) profiles having a hill in the centre region. The H value at the hill is about 0.56 T. The trapped magnetic field profiles (3-D maps) in Fig. 4 with a hill is same that of the MSIMT fabricated sample by using a SmBaCuO seed that indicated a single hill at the center of the sample [20]. MS-01, MS-04 and MS-12 samples show the trapped magnetic field distribution (2-D contours) profiles in Fig. 5 including two hill points at the right and left borders in one separated crystal line at the center. They link to the grain centers of the two grains and the grain connection, respectively.

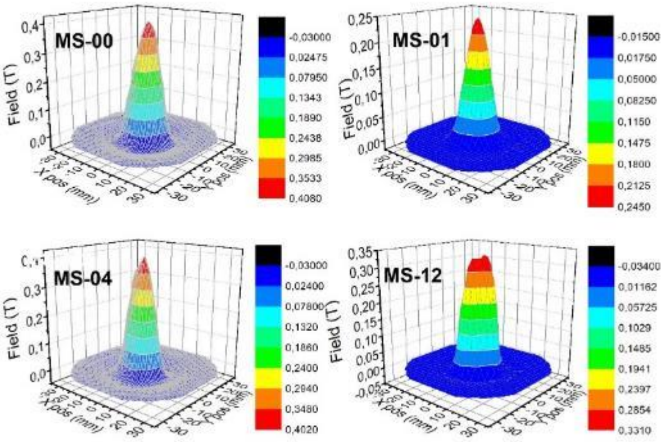

Fig. 3 Trapped magnetic field profiles (3-D maps) for the top face of MS-00, MS-01, MS-04 and MS-12 samples.

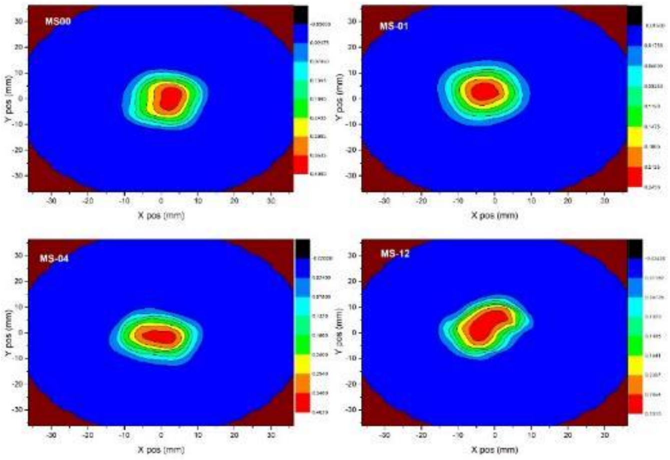

Fig. 4 The trapped magnetic field distributions (2-D contours) for the top face of MS-00, MS-01, MS-04 and MS-12 samples.

Fig. 5 and Fig. 6 indicates the trapped magnetic field profiles (3-D maps and 2-D contours) of the bottom face of MS-00, MS-01, MS-04 and MS-12 samples. It can be clearly observed that the distance between two hills at the right and left sides and one separated crystal line at the center increases. As can be seen in Fig. 5 and Fig. 6, the trapped magnetic field values at the grain junction in the separated crystal line at the center is a function of the d value. When analyzed in Fig. 6, the trapped magnetic field values of MS-01, MS-04 and MS-12 samples decrease swiftly as distance between two seeds increased.

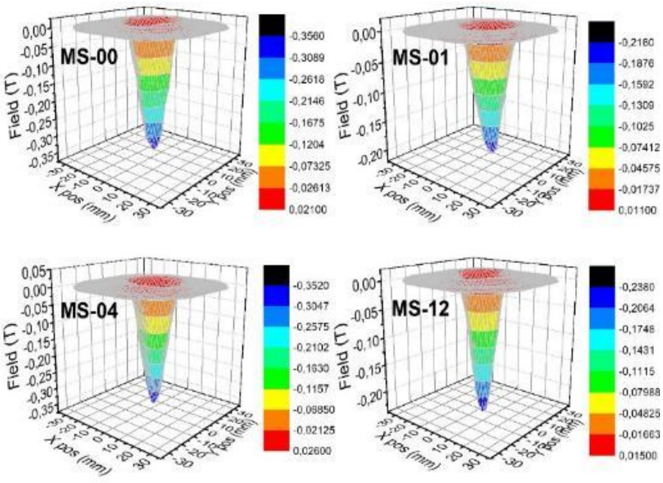

Fig. 5 Trapped magnetic field profiles (3-D maps) for the bottom face of MS-00, MS-01, MS-04 and MS-12 samples.

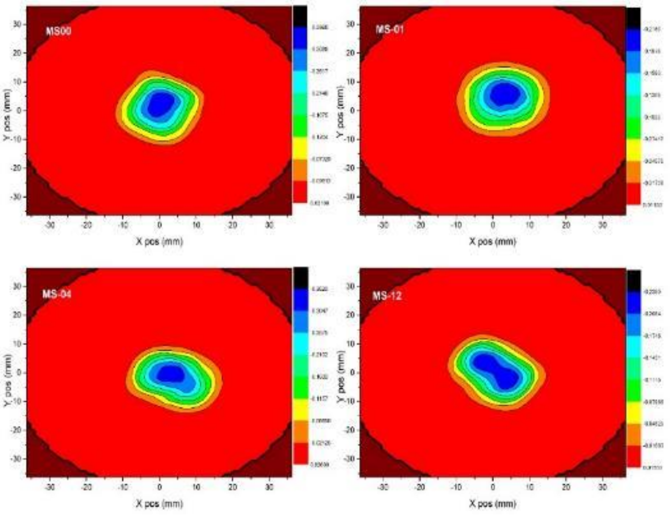

Fig. 6 The trapped magnetic field distributions (2-D contours) for the bottom face of MS-00, MS-01, MS-04 and MS-12 samples.

Our trapped field results plainly indicated that the amount of grain boundary residual phases was varied by the d value control. When the two seeds were placed very closely, no melt phase was seemed. At the smaller d value, there seems be little chance for the melt to be entrapped in the gap space between the two Y123 grains. This is because in the beginning of the growth stage, the two Y123 grains impact each other previous to the melt entrapment. By contrast, much more melt was entrapped in the gap spaces of the samples with higher d value. When d value is higher, it gets a long time for the two growing Y123 grains to impact each other. The melt can easily be entrapped in the long and narrow gap that is made by the growth of the two grains toward the bottom of the compact. [20, 24-26].

IV. CONCLUSION

Multi-seeded YBCO samples were fabricated TSMG method by using Nd123 seed using (100) // (100) aligned two seeds. The magnetic trapped field of these samples with the different seed distances (d) were analysed. The maximum trapped field value decreases as the d increases. The the reduction of trapped field is related with the magnetic properties at the grain junctions because of the existence of the residual melt-forming phases around the grain junctions.

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