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The effect of seed orientation and separation on the field trapping properties of multi-seeded, melt processed Y–Ba–Cu–O

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Abstract

The size of large, individual bulk Y–Ba–Cu–O (YBCO) grains fabricated by top seeded melt growth (TSMG) determines fundamentally both the sample growth time and the homogeneity of microstructure more distant from the seed. Multiple seeds have been used in the TSMG process with their *ab* planes aligned to provide controlled multiple nucleation sites to promote grain orientation and improve the bulk microstructure. This study reports the influence of the angle of intersection of *ab* plane growth sector boundaries on trapped field and compares the results with those obtained for samples fabricated from perfectly-aligned seeds. The trapped field profiles on the surface of YBCO multi-seeded samples were measured using scanning Hall probe apparatus, and their microstructure investigated using high-resolution optical microscopy. It was observed that the homogeneity of adjacent, multi-seeded grains is related to the angle between the intersecting *ab* planes, with larger angles of mis-orientation producing significant minima in the trapped field profile. This suggests that the grain boundaries form weak links to the flow of current in multi-seeded samples. A single inverted parabolic flux profile, on the other hand, was observed for large grains fabricated from perfectly-aligned seeds. This preliminary study demonstrates the feasibility of fabricating strongly-coupled multiple grains by a multi-seeding technique and identifies seed alignment as a key parameter in achieving this processing aim.

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Keywords: YBCO; TSMG; Multi-seeding; Grain boundary

1. Introduction

The size of large, individual bulk Y–Ba–Cu–O (YBCO) grains fabricated by top seeded melt growth (TSMG) determines fundamentally both the sample growth time and the homogeneity of the bulk microstructure more distant from the seed. The use of multiple seeds in the TSMG process, however, can provide multiple grain nucleation sites for the fabrication of larger samples, which are required for many potential, high field industrial applications. Alignment of the *ab* planes in these separate nucleation processes can result theoretically in the formation of a single grain (i.e. without the presence of a grain boundary where the individual grains meet) [1]. Any mis-alignment of *ab* planes, however, presents a significant barrier to current flow within the grain and therefore reduces the field trapping ability of the sample. The aim of this study was to investigate how the angle of incidence of aligned *ab* planes affects the trapped field profile of large grain, multi-seeded bulk YBCO samples.

Experiments were performed at ATI, Vienna to investigate the effects of angle of incidence between the *ab* plane growth sectors of multi-seeded samples on the macroscopic

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trapped field. A study of the effects of distance between aligned seeds and the number of seeds used was performed at the IRC in Superconductivity, Cambridge. The grain microstructure was observed using high-resolution optical microscopy.

It has been reported that the magnitude of the trapped field at the position of the join of multi-seeded YBCO grains varies inversely with the separation of the seeds and exhibits a minimum at this point [2]. The inter-seed distance is negligible, for example, for the case of touching seed crystals, which subsequently form a single nucleation site [3,4]. The effect of seed separation and orientation on the position and magnitude of the peak trapped field was investigated in this study for multi-seeded melt processed samples.

2. Experimental

Multi-seeded, bulk YBCO samples were fabricated at the IRC in Superconductivity. Samples A and B were fabricated with two seeds positioned with a low angle of misalignment. Three further samples were grown from single seeds of rod-like geometry with slots of various widths cut into their bottom surface (i.e. parallel to the *c*-axis of the seed) to produce a bridge in order to simulate the multi-seeding process, as shown in Fig. 1(a). Of these, samples 1 and 2 were grown from two-leg seed (i.e. with a single cut in the seed surface), and sample 3 was grown from a five-leg seed (i.e. four cuts were made in the surface of the seed to define five separate points of seed contact with the surface of the precursor pellet). Fig. 1(b) shows the top surface of a sample following removal of a two leg, bridge-like seed. The distance between each point of contact of the seed with the pellet surface is determined by the width of the slot. A summary of the seeding geometries investigated is given in Table 1. The angle between the two *ab* plane growth sectors was estimated by eye under a low power optical microscope from the difference in angle between individual growth facet lines of the multi-seeded samples. The trapped magnetic field profile at the sample surface was measured using two different Hall probe flux-scanning arrangements. In the first, the Hall probe was positioned 0.2 mm above the sample surface, which was zero field cooled (ZFC), followed by the application of a field of 1.5 T. The second system involved field cooling (FC) the samples in 500 mT, removal of the field and scanning the Hall probe over the pellet at a distance of 1.0 mm above the sample surface. Each sample was polished flat and the field profile measured prior to the magnetisation process in each case. The main differences between the two characterisation techniques (most significantly the distance between sample and Hall probe) did not limit the ability to interpret the data, which was based on the shape of the trapped field profile, rather than its magnitude.

Finally, successive layers of thickness 0.5 mm were ground away from the top surface of sample A and the flux profile re-measured in order to investigate the variation of trapped field with thickness of the multi-seeded sample (i.e. parallel to the *c*-axis and perpendicular to the *ab* plane).

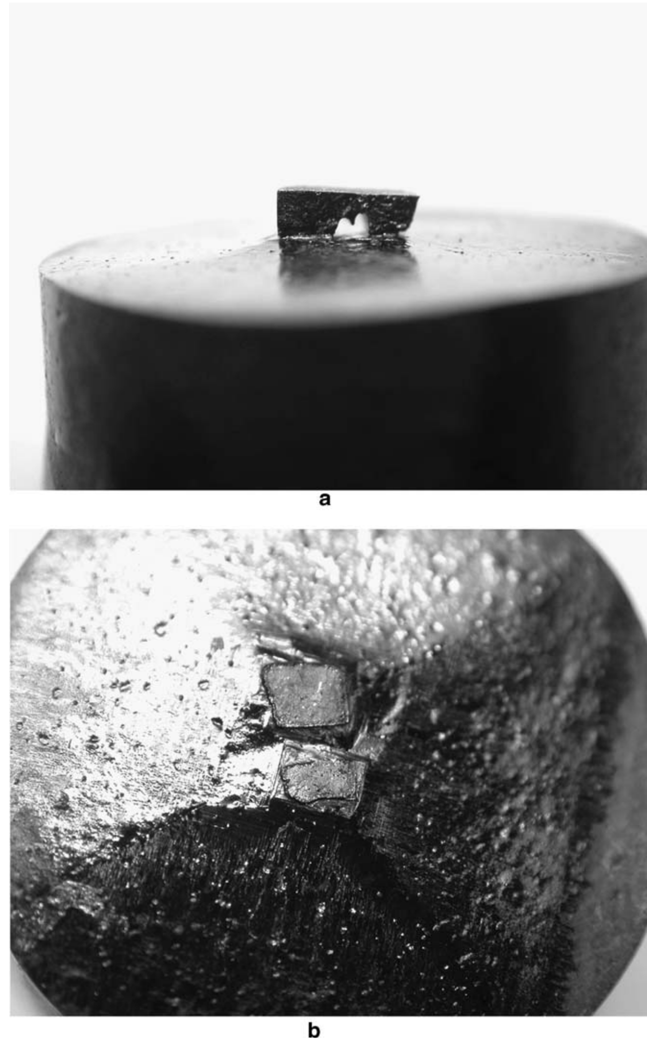

Fig. 1. A multi-seeded YBCO sample grown from a large seed cut into a bridge-like geometry to simulate two perfectly-aligned seed crystals viewed (a) as-grown from the side and (b) from the top following removal of the seed.

Table 1
Multi-seeded samples

Sample designation	Number of seeds	Mismatch angle (deg)	Seed separation (mm)	Measured at
A	2	5	–	ATI
B	2	15	–	ATI
1	2	0	0.436	IRC
2	2	0	0.991	IRC
3	5	0	0.38 (average)	IRC

3. Results and discussion

Samples A and B with low angle *ab* plane alignment exhibited quite different trapped field profiles, as shown in Fig. 2. Both Hall probe scans show the presence of multiple peaks, and two grains are clearly visible in each case.