§8. Study on Improvement of the Mechanical Properties of HTS Bulks by Reducing Pores

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Improvements of the mechanical properties of rare-earth based high-temperature superconducting (HTS) bulks are indispensable for the development of HTS current leads for magnetically confined fusion reactors. While conventional HTS bulks fabricated in air or under low O_2 pressure have pores which cause degradation of the mechanical properties, HTS bulks fabricated by heating a precursor in O_2 atmosphere have few pores. It is thought that fracture surface observations will be informative for improvements of the mechanical properties of HTS bulks. In the present study, the mechanical properties of low porosity HTS bulks, together with those of porous HTS bulks, were evaluated and fracture surfaces were observed.

The mechanical properties of $DyBa_2Cu_3O_x$ (Dy123) bulk samples were evaluated through three-point bending tests of specimens cut from the bulk samples. Precursors of the bulk samples were heated in air or O_2 atmosphere up to 1423 K, kept at that temperature for 1 h and then cooled down to 1313 K. After that, one Nd based seed crystal was placed on the top of them in air and they were gradually cooled down. Bending test specimens were cut from the melt-grown bulk samples. The dimensions of the specimens were 2.8 x 2.1 x 24 mm^3. Oxygen annealing, which is indispensable for the excellent superconducting properties of HTS bulks, was conducted at 723 K for 100 h for nearly half of the bending test specimens. Bending load was applied in the 2.1 mm direction at 0.1 mm/min by means of INSTRON 4464 testing machine. Loading span was 21 mm. Fracture surfaces were observed by using a scanning electron microscope equipped with an energy dispersive X-ray spectrometer.

The bending strengths of Dy123 low porosity bulks fabricated by heating a precursor in O_2 atmosphere were superior to those of Dy123 porous bulks fabricated in air. Such an improvement is attributable to the increase of the net cross-sectional area and decrease of defects where the stress concentration occurs.

Photographs of a fracture surface of a non-annealed specimen of a Dy123 porous bulk and those of a non-annealed specimen of a Dy123 low porosity bulk[1)] are shown in Fig. 1. The bending strengths of these porous and low porosity specimens were 63 and 82 MPa, respectively. The bottom of the fracture surfaces corresponds to the tensile side where the fatal crack was initiated. Flow patterns formed by the crack propagations were clearly observed on the fracture surfaces of these non-annealed specimens. The crack initiation site was identified as shown by arrows. A large pore of about 300-400μm in size was observed around the crack initiation site on the fracture surface of the porous bulk. On the other hand, some inclusion was observed around the crack initiation site of the low porosity bulk. It is deduced that the stress concentration occurred due to the mismatch of the stresses induced in the Dy123 matrix and the inclusion. It has been clarified that the inclusion consists mainly of Pt which is commonly added to the precursor to disperse fine secondary phase particles in HTS bulks.

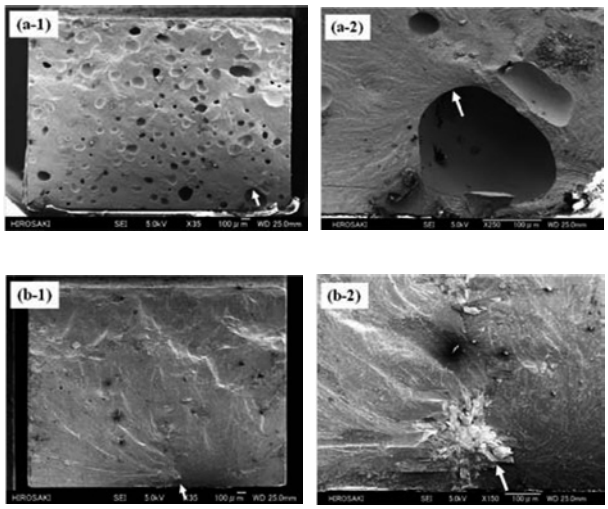

Fig. 1. (a-1) Fracture surface of a non-annealed specimen of a Dy123 porous bulk. (a-2) Magnified view around crack initiation site shown by an arrow in (a-1). (b-1) Fracture surface of a non-annealed specimen of a Dy123 low porosity bulk. (b-2) Magnified view around crack initiation site shown by an arrow in (b-1).

Although it was difficult to identify the crack initiation site on the fracture surfaces of oxygen annealed specimens due to the pre-existing micro-cracks perpendicular to the *c*-axis caused by the phase transformation from tetragonal to orthorhombic during the oxygen annealing, it is expected that suppression of segregation of the Pt inclusion is effective in improving the mechanical properties of low porosity HTS bulks.

1) Murakami, A. et al.: Abst. CSJ Conf. **80** (2009) 93.