§7. Evaluation of the Mechanical Properties of HTS Single-grain Bulks by Indentation

Murakami, A., Hashimoto, R. (Hirosaki Univ.),
Katagiri, K. (Iwate Univ.),
Iwamoto, A.

Understanding and improvement of the mechanical properties of HTS single-grain bulk materials are indispensable for the development of high performance bulk current leads used for large superconducting devices such as magnetically confined fusion reactor. In this study, the mechanical properties of the bulk materials are investigated in terms of the distribution of pores and the mechanical properties of the matrix evaluated by indentation tests.

Bending test specimens with 2.8 x 2.1 x 24 mm^3 were cut from two Dy123 ($DyBa_2Cu_3O_x$) single-grain bulk samples with 30 or 45 mm in diameter and then annealed at 723 K for 100 h in O_2 atmosphere. Three-point bending tests of the plain and the single-edge V-notched specimens were carried out at room temperature by means of the testing machine INSTRON 4464. The fulcrum span was 21 mm and the crosshead speed was 0.1 mm/min. The longitudinal strain was measured by a 0.2 mm strain gage. Side surfaces of the fractured specimens were polished. Area fraction of pores (porosity) was evaluated on the polished surfaces and then Vickers indentation tests were conducted at room temperature using the hardness tester AKASHI Mvk Type C. Indentation load was 4.9 N.

The relationship between the Young's modulus and the porosity is shown in Fig. 1. The porosity near the top surface of the bulk samples is low and the Young's modulus value is high. Bending strength value is also high. The porosity of the smaller bulk is lower than that of the larger bulk and the mechanical properties of the smaller bulk are excellent. Such a difference in the porosity associated with the location in the bulk sample and the size of the bulk sample is presumably ascribed to that oxygen bubbles generated in the fabrication process are easily released near the surfaces. The Young's modulus values are decreased by the phase transformation from tetragonal to orthorhombic in the oxygen annealing. On the other hand, the bending strength values are slightly increased.

The fracture toughness values evaluated by Vickers indentation tests (IF method) with indenting in the c-axis are shown in Fig. 2, together with the average values obtained by bending tests of single-edge V-notched specimens (SEVNB method). These fracture toughness values were calculated by the equations defined in the JIS-R-1607[1]. The estimated Young's modulus values at 0 % porosity shown in Fig. 1 are used. Cracks initiated from corners of the indentation scar could not be recognized clearly on the annealed specimens because the matrix around the scar was delaminated due to micro-cracks perpendicular to the c-axis induced by the phase transformation. It was assumed that the crack length corresponded to the width of the delaminated area around the scar. The fracture toughness is improved by oxygen annealing, which is similar to the bending strength of the plain specimen. There is no significant difference in the facture toughness of the matrix evaluated by IF method between the two bulk samples.

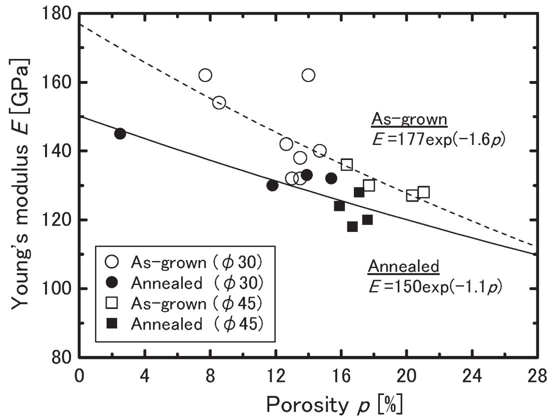

Fig. 1. Relationship between Young's modulus and porosity of as-grown and annealed specimens cut from Dy123 bulks with 30 and 45 mm in diameter.

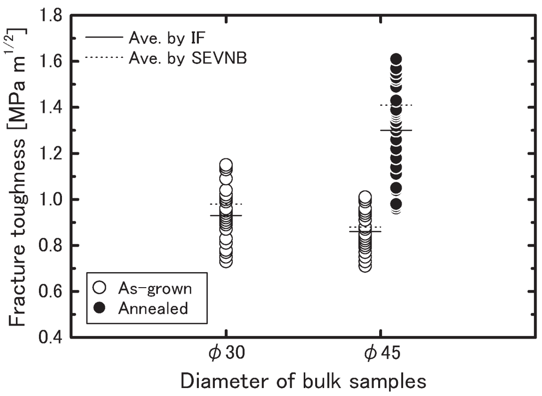

Fig. 2. Fracture toughness evaluated by IF method with indenting in the c-axis.

1) JIS-R-1607: testing methods for fracture toughness of fine ceramics, Japanese Industrial Standard