§5. Studies on the Mechanical Properties and Fracture Mechanisms of Single Crystal RE High T_c Bulk Superconductors

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Mechanical properties of high T_c RE123 (RE: rare earth elements) single-grain bulk superconductors, which have low thermal conductivity as well as high transport current and trapped field are important for their practical applications such as current leads for large scale devices. We have been studying the tensile and 3-point bending characteristics of RE123 bulks at room and cryogenic temperatures[1]. In this study, compressive mechanical properties and the fracture mechanisms of the bulk were investigated so as to obtain the directions of development of the bulk.

Specimens with the dimensions of 3 x 3 x 8 mm^3 were cut from a $SmBa_2Cu_3O_x$ (Sm211 mol. fraction 16.7%、10wt% Ag addition), Sm123, with the dimensions of 45 mm in diameter and 15 mm in thickness samples such that the longitudinal (loading) directions of them corresponded to the direction of c-axis or perpendicular to the c-axis of the bulk samples. The compressive tests were carried out under the stroke control mode with the crosshead speed of 0.15 mm/min by using the 5 kN Shimadzu Autograph testing machine. By measurements through the wire strain gages adhered in the longitudinal and transverse directions adhered on the specimens, the elastic constants were also evaluated.

Elastic constants: As shown in Fig. 1, the initial part of stress-strain curves obtained from the compressive tests at room and 77 K were basically straight, and then some of them clearly deviated into concave to upward or jumped toward the strain axis beyond certain stress levels. They are thought to be resulted from the propagation of pre-existing cracks induced during the processing of the bulk. Due to the closure of the pre-existing cracks perpendicular to the c-axis in the specimens, the Young's modulus at 77K in the c axis direction, 93 GPa, was significantly lower as compared with that perpendicular to it, 150 GPa. Although the former was higher than that at room temperature, 75 GPa, the latter was lower than that at room temperature, 165 GPa. The Poisson's ratio obtained using the measurements on the strains transverse to the specimen are shown in Fig. 2. The anisotropy originated from the closure/opening behaviors of latent micro-crack perpendicular to the c-axis superposed on that intrinsic to crystal structural was clearly observed. This has to be taken into account in the thermal stress analysis.

Compressive strength: The fracture strength at 77K in the c-axis direction, 466 MPa, was higher than that, 368 MPa, in the direction perpendicular to it. This anisotropy can also be comprehended by the existence of the micro-cracks; the reduction of the strength is associated with buckling to be described in the following. These are higher than those at room temperature, 350 and 335 MPa, respectively. These values are utilized as a database for designing current lead made of the bulk. Many of the test pieces loaded in the direction perpendicular to the c-axis fractured into 2 or 3 pieces separating along the cleavage plane. This means the buckling load controls the compressive strength. On the other hand, in the case of loading in the c-axis, they fractured into many small fragments.

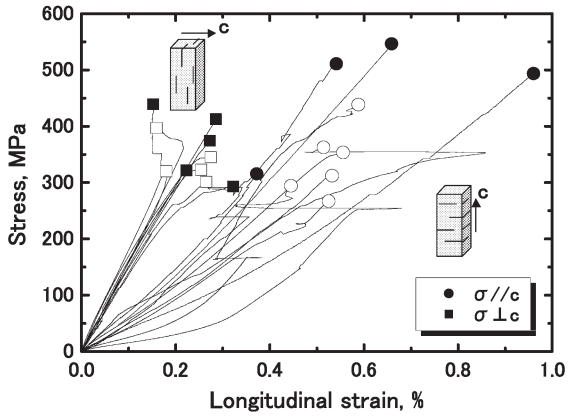

Fig.1 Compressive stress-strain curves of Sm123 bulk. (Open symbols and solid ones denote the fracture points at RT[1] and 77K, respectively)

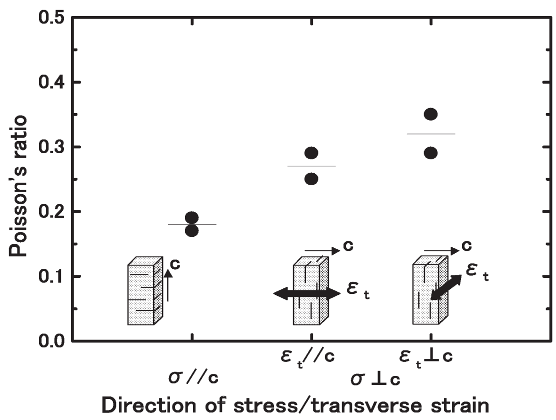

Fig.2 Anisotropy of Poisson's ratio of Sm123 bulk in compression tests (77K)

Reference

1) Katagiri, K., et al. Physica C **412-414,** (2004) 633.