§15. Fundamental Study on Application of Magnetic Levitation Using YBCO Bulk Superconductor to Fusion Research

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The possibility of the application of HTS conductor to spherical cryogenic target for laser fusion system has been investigating experimentally and theoretically. A concentric spherical thin shell formed by HTS conductor is required for the cryogenic target and very stable levitation by an active-maglev system composed of HTS conductor and electromagnet is essential to the laser fusion system. Although electromagnetic behaviors of HTS bulks in active-maglev systems have been investigated vigorously, most of the studies are about those of disk-shaped HTS bulks. Maximum levitation force and stability are closely related to supercurrent distribution within HTS bulk and the supercurrent distribution strongly depends on the critical current density and shape of the HTS bulk. The minimum thickness of the concentric spherical shell required for obtaining larger levitation force than the weight would be one of the key parameters in design of spherical cryogenic target. As a first step toward achieving very stable levitation of the spherical cryogenic target, we investigated electromagnetic behaviors of cylindrical HTS samples.

We prepared four cylindrical HTS samples; one Bi2223 sample and three Bi2212 samples prepared by sintering and diffusion processes, respectively. The height of the Bi2223 sample is 19mm and the inner and outer diameters are 10mm and 13mm, respectively. The Bi2212 samples have the different thicknesses of 17mm, 18mm, 19mm and the same inner and outer diameters of 16mm and 19mm, respectively. The sample was cooled from the normal state to superconducting state by liquid nitrogen in the presence of magnetic field generated by a copper electromagnet. The field-cooling currents were 0A, 5A and 10A; the magnetic flux density of the top surface of the electromagnet is 285mT at the operating current of 30A. Levitation force as a function of the operating current was measured by load cell. A schematic drawing of the experimental setup is shown in Fig. 1.

The experimental results of a Bi2223 sample are shown in Fig.2. In Fig.2, the difference of levitation force between "ZFC" (or "FC") and "no sample" corresponds to net levitation force of each sample. In the Bi2223 sample, about 40mN was obtained at the operating current of 30A, while negligible small levitation force in all three Bi2212 samples. The main reason of the negligible small levitation force is the small critical current density of the Bi2212 samples at 77K. In general, levitation force in an active-maglev system increases with the operating current and is almost proportional to the square of the operating current. The net levitation force of the Bi2223 sample, however, increased linearly with the operating current. This difference implies that the whole sample was saturated with supercurrent at a small magnetic field due to thin Bi2223 layer of 150μm and a low critical current density of the sample at 77K. The details of the relationship between levitation force and thickness of HTS layer will be investigated continuously using different types of cylindrical and spherical samples.

As observed in the above experiment, the cylindrical samples with thin superconducting layer could not generate large levitation force. This means that levitation force more than weight of target could not be obtained easily in the target with thin HTS layer. Therefore, field-cooling current and operating current realizing large levitation force and very stable levitation should be as small as possible. We investigated the suitable operating method of electromagnet after field-cooling process using a disk-shaped YBCO bulk with 30mm in diameter and 10mm in thickness. Levitation forces in the following two operating methods are compared each other: 1) increasing operating current after reducing from a field-cooling current to zero; and 2) increasing operating current from a field-cooling current without any reduction. Levitation force with operating current reduction was larger than that without the reduction. Stable levitation, however, was obtained in both cases.

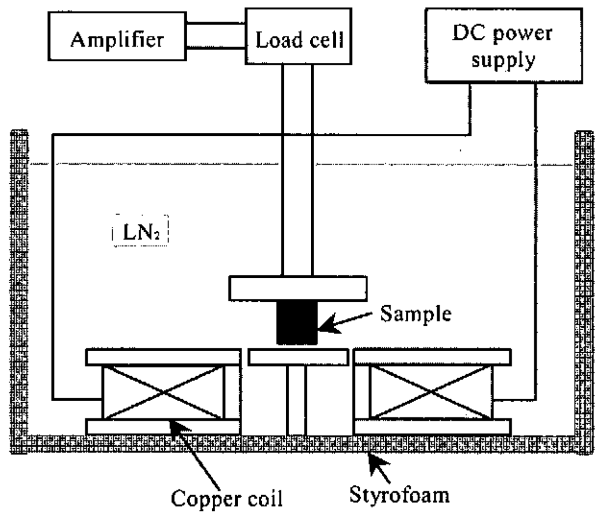

Fig. 1. A schematic drawing of experimental setup for levitation force measurement

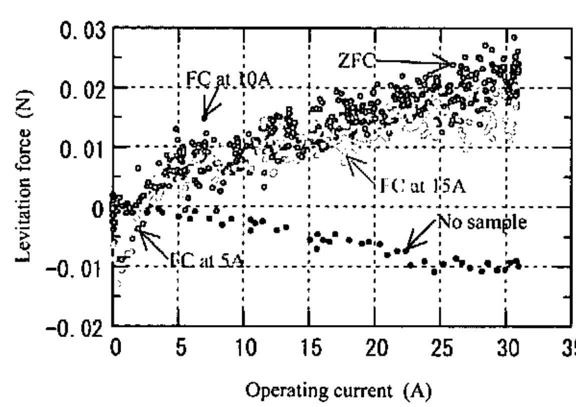

Fig. 2. Experimental results of levitation force in a cylindrical Bi2223 sample