§6. Development of High Temperature Superconducting Current Feeders in NIFS (3) HTS Current Feedthrough from 4.4 K to 1.8 K

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1. Introduction

In the phase II experiment of the Large Helical Device (LHD) of the National Institute for Fusion Science (NIFS), it is planned to increase a plasma central field from 3 T to 4 T by cooling the helical coils from 4.4 K to 1.8 K using pressurized superfluid helium (He II) instead of the normal liquid helium (He I). The high-purity aluminum stabilizer of the helical coil conductor has high thermal conductivity (~20 kW/m·K). The heat leak from He I to the He II environment through the aluminum-stabilized superconductor can be reduced significantly by using HTS (~0.2 W/m·K) current feedthrough. The development is being carried out as a domestic collaboration with universities and laboratories centering on Kyushu University.

2. Prototype YBCO Current Feedthrough

An HTS current feedthrough from 4.4 K to 1.8 K with high current capacity and low heat leak is required for the helical coils of LHD in the phase II experiment. The helical coils cooled with He II (1.8 K) and the superconducting bus lines cooled with two-phase helium (4.4 K) are connected in the LHD cryostat where the maximum stray field is about 1 T. An $YBa_2Cu_3O_X$ (YBCO) bulk fabricated by the modified quench and melt growth (QMG) process is selected as a promising critical current density under the magnetic field and low thermal conductivity.

As a preliminary experiment to study the feasibility of YBCO bulk for a HTS current feedthrough, high current transport tests were conducted in NIFS together with Kyushu University. "H" shaped samples with 40 mm wide, 50 mm long and 7 mm thick were cut from the disk-shaped YBCO bulk 65 mm in diameter and 15 mm thick. Both sides of "H" shaped sample were soldered to copper electrodes. The cross section of the "H" sample straight part "-" is 7 mm × 7 mm. We succeeded in dc operation a high current transport of this sample up to 25 kA at 4.2 K.

According to the results, we decided to construct a 20 kA prototype HTS current feedthrough with YBCO bulk made by QMG process. The prototype HTS current feedthrough was designed for the large He II cryostat in the cryogenic laboratory of NIFS. Because the straight section of "H" shaped bulk should pass through the thick λ-plate of the cryostat, the geometrical dimensions of the bulk must be larger than the preliminary test sample. Therefore, we have investigated a fabrication process of the high quality YBCO bulk and have succeeded to obtain a bulk conductor 60 mm wide, 140 mm long and 10 mm thick from the material manufactured with a "H" shape as shown in Fig. 1.

Fig. 2 shows the assembled prototype HTS current feedthrough. A pair of the bulk conductors was imbedded in a GFRP center plug of the λ-plate. We have tested three types of prototype HTS current feedthroughs. Two of them were tested in the large He II cryostat and one was tested in the conductor test cryostat with normal liquid helium. During the cool down of feedthrough, the HTS conductors showed a transition to superconducting state. However, in the dc transport current tests, normal voltages were observed for current less than 2 kA. These degradations may be due to a mechanical damage in the HTS bulk during the manufacturing process, the assembling process or the cooling process. The above problems occurred in connection with the increase of the bulk size. We are trying to establish a method to detect a defect in the bulk before assembling it. We are also considering mechanical reinforcement of the bulk. After that, we will try again to test a new type of YBCO current feedthrough.

3. Summary

A 20 kA prototype YBCO current feedthrough from 4.4 K to 1.8 K was designed and tested in the large He II cryostat. During the dc transport current tests, normal voltages were observed for current less than 2 kA due to a mechanical damage in the HTS bulk. It is important to establish a method to detect a defect in the bulk before assembling it.

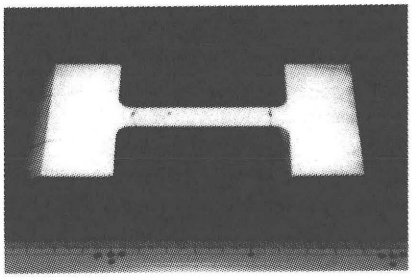

Fig. 1. "H" shaped YBCO bulk conductor (60 mm wide, 140 mm long and 10 mm thick) for the prototype HTS current feedthrough.

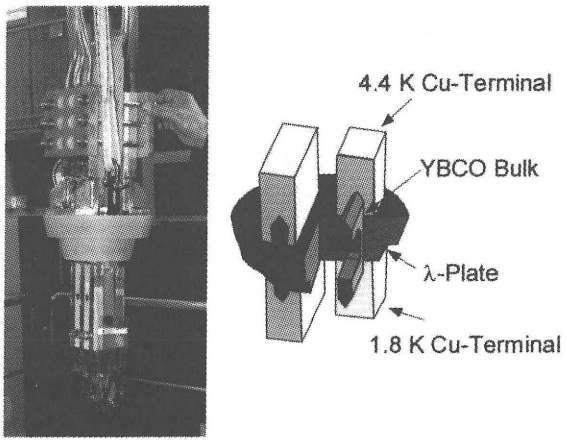

Fig. 2. Assembled prototype HTS current feedthrough..

Reference

1) Mito, T. et al., "Development of High Temperature Superconducting Current Feeders for a Large-scale Superconducting Experimental Fusion System", IEEE Trans. Applied Superconductivity, Vol.11, No. 1 (2001) pp. 2611-2614.