§77. Irradiation Effect on Superconducting Magnet Materials for Fusion

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To carry out superconducting performance tests of irradiated samples, high magnetic field must be prepared in radiation control area. A proposal on installation of a superconducting magnet with a variable temperature insert was submitted to Ministry of Education, Culture, Sports, Science and Technology (MEXT) in a frame work of Nuclear Basic Infrastructure Strategic Study Initiative. The proposal was accepted and approved by MEXT, and the design and fabrication activities started in 2008.

The project had three parts; (1) cryogenic and high magnetic field test facilities, (2) development of test procedure in a hot lab, and (3) irradiation effect on materials properties. The main facility or the system of each part was 15.5 T superconducting magnet for (1), an instrumentation system for (2), and a variable temperature insert (VTI) and a shield structure for (3).

The superconducting magnet installed is a so-called dry magnet working without liquid helium or liquid nitrogen. Gifford–McMahon (GM) refrigeration with an air cooled compressor is equipped and the magnet generates 15.5 T as the maximum magnetic field in a 52 mm RT bore. The magnet system requires only the electric power and the coolant treatment is not necessary. This is good for management of the radiation control area and also for the magnet users. The instrumentation system to measure nano-level volt is installed and precise measurement is possible even in high magnetic field. In addition, a shield structure for the magnetic field is constructed with a carbon steel to reduce the magnetic field leakage. Since the other facilities locate near the magnet area, the leakage field at the center of the shield structure plates is reduced to about 5 gauss.

The VTI is a kind of sample holder and has a capacity of 500 A for a sample current. The sample holder is cooled down by thermal conduction with GM refrigeration and the sample temperature is able to be controlled from 4.5 K to around 20 K for 500 A.

These equipments and facilities have been installed in a hot lab at Oarai center of Tohoku University. Figure 1 shows the shield structure and the control system. The compressors are located in the neighboring room and connected with the magnet by high pressure flexible hoses. The control system consists of amplifiers and a computer. The control computer is connected with another computer locates in non-radiation control area by a dedicated internet line. The users are able to change the test conditions from non-radiation room once an irradiated sample is set up. Figure 2 shows a picture of the inside of the shield structure. The 15.5 T superconducting magnet is placed and the VTI is set up on the magnet.

Some Nb_3Sn strands have been irradiated at JRR-3 and BR2 in Belgium up to 10^{24} n/m^2 of over 0.1 MeV neutron. These samples will be tested with the new facility and very important data on the critical current, the critical magnetic field and the critical temperature will be obtained. Based on these results, a new theory on the mechanisms of irradiation effect is anticipated. The facility will be opened to the world and foreign researchers will come together.

Fig. 1. Magnetic field shield structure (back) and control and data acquisition system (this side).

Fig. 2. 15.5 T superconducting magnet (lower) and variable temperature insert (upper) in magnetic field shield structure.