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§10. Collaboration Network for Investigation on Neutron Irradiation Effect on Superconducting Magnet Materials

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The design researches on a large-scale plasma device with superconducting magnets showed that much neutron would stream out from NBI ports or permeate through shielding blankets, and these neutrons would reach the superconducting magnets and change the materials properties. The neutron irradiation effect on the superconducting magnet materials have been investigated using fission reactors (KUR, BHFBR), 14 MeV neutron source (RTNS-II) and spallation neutron source (IPNS) especially in 1980s and 90s. These pioneer researches showed that superconducting properties, such as the critical current or the critical temperature, would change remarkably. However, there was not a systematic investigation on the neutron irradiation effect. Recently, large-scale plasma experimental devices, of which target is Deuterium – Deuterium reaction or Deuterium – Tritium reaction, are designed and constructed in the world, and the importance of the neutron effect on the superconducting magnet materials increases. In addition, long range scope leading to a fusion reactor has been discussed and a trial road map for realizing commercial fusion reactor has been presented in the fusion community. The commercial fusion reactor will generate 100 or 1000 times much more fusion neutrons than ITER and some of them will reach the superconducting magnets.

Under the recognition of the necessity of neutron irradiation investigation on property changes, an attempt of forming collaboration network among related research fields has been conducted and some important test results were presented. In this report, the status of the network is introduced and some results are presented.

The purpose of this collaboration network is mainly two items. The fist one is to make a database for the large-scale plasma device. The second is to clarify the mechanisms of superconducting property change. The former is strongly related to the application and the latter is academic aspect. To develop new materials for fusion application and a reasonable design process, accumulation of systematic experimental data is important and at the same time the academic consideration must be carried out.

The outline of the working collaboration network is presented in Fig. 1. Core affiliations are NIMS, Osaka University, Tohoku University, and JAEA. The neutron irradiation facilities are FNS and JRR-3 in JAEA and BR2 in Belgium. IMR Ooarai center in Tohoku University play a role of connection center to JRR-3 and BR2. FNS equips a D-T reaction target which generates 14 MeV pure neutron. Also, there is GM refrigeration system keeps the samples at 4.5 K during neutron irradiation. This cryogenic system can provide the critical temperature measurement environment and it can be done even under neutron irradiation.

The target fluence of over 0.1 MeV neutrons was ranged from 10^{20} to 10^{21} n/m^2 in FNS and 10^{20} to 10^{22} n/m^2 in JRR-3 and 10^{22} to 10^{24} n/m^2 in BR2. Around the 10^{24} n/m^2 irradiation, the superconducting materials are expected to be non-superconducting at 4.5 K. The samples irradiated up to 10^{24} n/m^2 will be heat-treated for a certain time at several temperatures and the recovery of superconducting property will be discussed. Through this investigation, metallurgical discussion will be performed and the mechanism of pinning and change in properties would be clarified. At the same time, neutron spectrum effect and neutron irradiation temperature effect will be studied independently.

The samples for neutron irradiation were NbTi, Nb_3Sn, Nb_3Al wires, Bi2223 tapes and electric insulation materials with glass fiber reinforced clothes. The length of superconducting wires was about 35 mm and the critical current, the critical temperature and the critical magnetic field were measured before and after irradiation in some samples. The insulation materials has a matrix of an epoxy resin, and (cyanate ester + epoxy) blended resin. The configuration of the sample was 15 mm^L x 10 mm^W x 2.5 mm^t. The interlaminar shear strength was evaluated with the short beam method at room temperature and 77 K. The test results of GFRP with (cyanate ester + epoxy) blended resin is shown in Fig. 2.

The collaboration network for the investigation of neutron irradiation effect has been formed and the activity increases. The evaluation process of irradiated samples also established and the very important experimental data are being obtained.

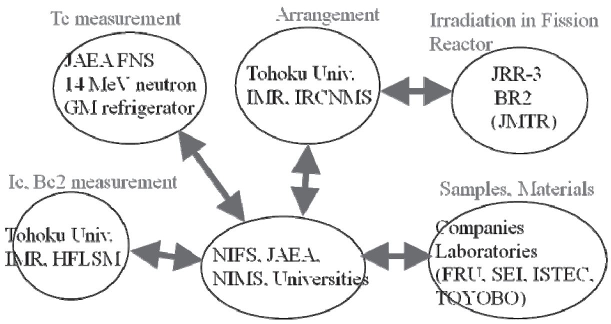

Fig. 1 Collaboration network for investigation on neutron irradiation effect on superconducting magnet matrials.

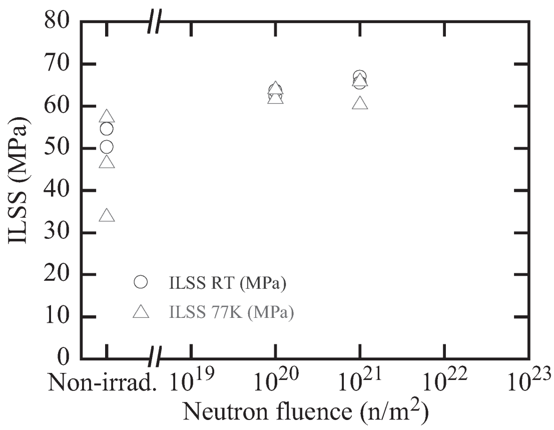

Fig. 2 ILSS against neutron fluence (JRR-3).