§36. Change in Properties of Superconducting Magnet Materials by Fission Neutron Irradiation

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The cold target system for 14 MeV neutrons was installed at Fusion Neutronics Source (FNS) in JAEA and pure neutron irradiation tests have been carried out. To investigate the effect of neutron spectrum and to irradiate much more neutron, a fission neutron irradiation was planned and performed at JRR-3 in JAEA. The irradiated materials were superconducting wires (tapes) and electrical insulation materials. The first test of after irradiation was carried out and the critical current was measured by four probe method. In this report, the outline of the fission neutron irradiation test will be summarized.

The samples for neutron irradiation were NbTi, Nb_3Sn, Nb_3Al wires and Bi2223 tapes. The length was about 35 mm and the critical current (Ic) and the critical temperature (Tc) were measured before irradiation. The electric insulation materials reinforced by glass cloth were epoxy resin, and cyanate ester + epoxy blended resin was also prepared. The samples were put in an aluminum capsule and the inside was gas-replaced by helium. The capsule was put in the rabbit capsule which was transferred with compressed water to the right position at JRR-3 fission reactor. The irradiated temperature was around 100 degree in C, and temperature monitor was put in the capsule.

The target fluence of over 0.1 MeV neutrons was ranged from 10^{20} to 10^{22} n/m^2. The irradiation up to 10^{22} n/m^2 requires about 7 days. After irradiation in JRR-3, activated samples were transferred to the hot laboratory in IMR Ooarai center with a special container. The aluminum capsule was disassembled and samples were taken out there.

Bi2223 tapes were soaked in liquid nitrogen and the critical current was measured under self-magnetic field by four probe method using a 100 A power supply. The results are shown in Fig. 1. Two kinds of samples (AC78 and AC78S) were prepared and neutron irradiated up to 10^{20} and 10^{21} n/m^2. As far as the data obtained, no clear effect of neutron irradiation was observed. Since there is a report to present that the change in the critical current of Bi2223 depends on temperature and bias magnetic field [1]. Therefore, further investigation will be performed in 2008.

The critical current and critical magnetic field (B_{C2}) measurements of irradiated Nb_3Sn wire were carried out at 4.2 K using the hybrid magnet at IMR in Tohoku University. The irradiated samples at FNS in JAEA by 14 MeV neutrons were transferred to Laboratory of α-Ray Emitters at IMR in Katahira campus, Sendai, and mounted on the sample holder for the 28 T hybrid magnet in a radiation controlled area. A special cup was attached to the sample holder to avoid the scattering of the melted metal particles when the wire should be melted away by over current during Ic measurement. Also, a special filter was inserted in the recovery line of the helium gas to remove activated materials when unexpected trouble should happen.

The results are presented in Fig. 2. By neutron irradiation of 1.78 x 10^{21} n/m^2, the critical current increased in about 1.4 times. The evaluated B_{C2} of non-irradiated and irradiated samples were about 25.3 T and 25.5 T. Since some error was considered in the B_{C2} measurement, one can conclude that there is no clear increase of B_{C2} by irradiation. From the result, the following issues will be delivered. (1) The increase of Ic depends on the magnetic field. (2) B_{C2} would not increase. At least before irradiation the grain boundary has been believed to act as a major pinning center that suppresses the quantized flux (fluxoid) motion against the Lorentz force and thus enables large critical current densities in high magnetic fields. The increase of the Ic after irradiation suggests that the irradiation defects would play like additional pinning centers and increase the Ic. However, the irradiation defects would not change the crystalline parameters such as atomic distance. Therefore the B_{C2} would not increase clearly. The effect of neutron spectrum and nuclear transformation will be investigated near future.

Regarding the electric insulation materials, an interlaminar shear strength (ILSS) test was performed at 77 K and room temperature. The cyanate ester (40%) + epoxy (60%) blended GFRP showed no degradation of ILSS by the 10^{21} n/m^2 fission neutron irradiation and kept over 60 MPa of ILSS at both 77 K and room temperature. The effect of blended percentage and laminate structure would be discussed in 2008.

[1] S. Tonies, et al., Applied Physics Letters, Vol. 78 (2001)

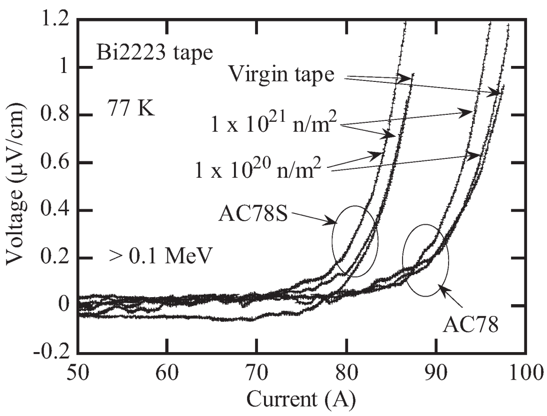

Fig. 1 Voltage - current diagram of Bi2223 tapes.

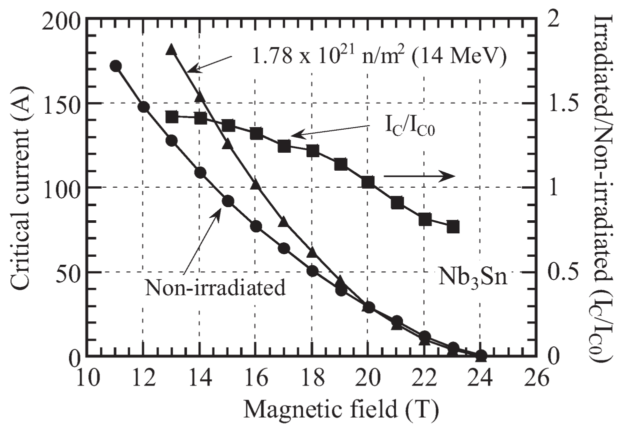

Fig. 2 Critical current of irradiated Nb_3Sn wire.