§21. Change in Properties of Superconducting Magnet Materials by 14 MeV Neutron Irradiation under Cryogenic Temperature

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Neutron streaming from NBI ports is expected on the design of ITER and DEMO reactor. To investigate the neutron irradiation effect on the superconducting magnet, a new cryogenic target system was installed at FNS in JAERI. In September of 2004, the first irradiation test was carried out at FNS for three weeks and additional test was performed in March, 2005, for one week.

In this report, the outline of the cryogenic target system is described and some test results are presented.

The fusion neutron source (FNS) in JAERI has a capability to produce 14 MeV neutron at the rate of 3×10^{12} n/s. A new facility to carry out irradiation test at cryogenic temperature was installed in FNS, which consists of a GM refrigerator and a thermo-control system. Temperature of the second stage was controlled at 4.5 K during 14 MeV neutron irradiation. On the cold stage, the following five samples were attached.

1. Tough pitch copper wire (0.28 mm^{ϕ})
2. Oxygen free copper wire (0.299 mm^{ϕ})
3. Nb_3Al wire (As-RHQ. 0.79 mm^{ϕ})
4. Nb_3Al wire (RHQ + annealed. 0.79 mm^{ϕ})
5. Nb_3Sn wire (0.70 mm^{ϕ})

Copper wires were irradiated and change in resistivity was measured. Two Nb_3Al wires were prepared. One was rapid heated and quenched (RHQ). The other was annealed at 1073 K for 10 hours after RHQ. Critical temperature of these wires was 13.8 K for the RHQ sample and 18.3 K for the RHQ + annealed sample. The temperature of the cold stage was measured with Cernox sensor and temperature was kept at 4.5 K. Two Cernox sensors were attached at location of 57 mm far to compare the irradiation damage.

On the top of cryostat, the following samples were attached as shown in Fig. 1.

1. Glass Fiber Reinforced Plastic (GFRP, G10-CR)
2. Polystyrene powder. (Molecular size was selected)
3. TEM samples of Nb_3Sn and NbTi wires.

GFRP samples are three-point tested after irradiation and interlaminar share strength is evaluated. Polystyrene powder, of which molecular size was selected, was irradiated and effect of 14 MeV irradiation was investigated.

The irradiation test was carried out twice in 2004 fiscal year. The first irradiation test was carried out from August 31 to September 17, 2004. Total neutron production was 5.35×10^{17} n/12 days and neutron fluence at the center of the cold stage was 1.47×10^{20} n/m^2. And the second irradiation test was carried out from March 7 to March 11, 2004. Total neutron production was 2.54×10^{17} n/5 days and neutron fluence at the center of the cold stage was 0.70×10^{20} n/m^2. Therefore, the total neutron fluence at the center of the cold stage in 2004 was 2.17×10^{20} n/m^2.

Results of critical temperature (Tc) measurement of Nb_3Al wires are shown in Fig.2. Tc was measured by rising up the temperature of cold head with heater at the rate of 0.1 K/min to 25 K. Tc of RHQ and annealed Nb_3Al wire did not change. (Difference of 0.1 K is considered to be within scatter range.) However, RHQ Nb_3Al wire showed clear degradation of Tc. It is recognized that Tc has strong relation with long range of ordering of A15 structure. Therefore, it is thought that the RHQ and annealed Nb_3Al wire has long range ordering and there may be many bypass lines to detour damaged area. On the other hand, in case of RHQ Nb_3Al wire, the ordering would not expand so widely and damaged area might disturb the superconducting current running, and it results in the decrease of Tc.

Other remarkable results would be as follows: (1) Tc of Nb_3Sn wire did not change after irradiation. (2) Resistivity of copper wires increased, and there is good relation between increment of resistivity and displacement per atom converted from neutron fluence. (3) Cernox sensors could endure the irradiation of at least 9.29×10^{19} n/m^2. (4) When polystyrene powder was irradiated, decomposition and polymerization happened. The molecular size distribution became broader and another peak appeared at the larger molecular region.

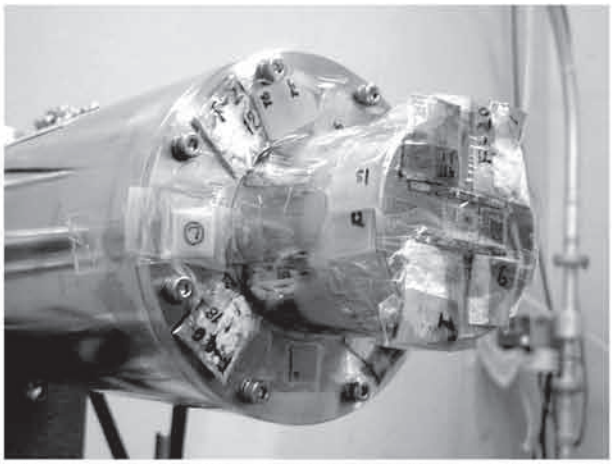

Fig. 1 Set up of samples on cryostat of GM refrigerator. (August 31, 2004)

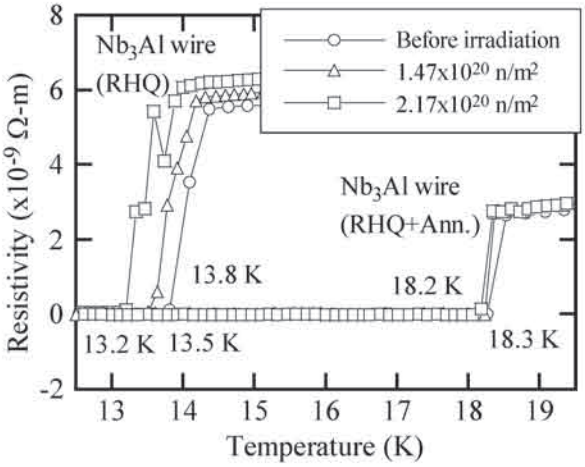

Fig. 2 Change in Tc of Nb_3Al wires before and after neutron irradiation.