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

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The new large scale fusion devices require a data base on neutron irradiation effect of the fusion magnet, because the devices will generate a lot of high energy neutrons. In order to investigate the mechanisms of the irradiation effect and pile up the data base, neutron irradiation tests have been conducted and post irradiated tests were performed.

The superconducting strands of NbTi, Nb_3Sn and Nb_3Al were prepared for the neutron irradiation [1,2]. The strands were irradiated by 14 NeV neutron at Fusion Neutronics Source (FNS) in JAEA and the post irradiated tests were carried out using 28 T hybrid magnet at High Field Laboratory in Tohoku University.

The results of the critical current measurements after the neutron irradiation are shown in Fig. 1. The Nb_3Sn strand showed that the critical current in the lower field increased remarkably as an increment of the neutron fluence. The border magnetic field (arrows in Fig. 1) where the critical current starts to get away from the non-irradiated critical current curve shifts to the higher magnetic field when the neutron fluence increases. Therefore, the increment of the critical current becomes larger in the lower field comparing with that in the higher field. The results of the critical field measurements under 100 mA showed no clear changes. However, the critical temperature after irradiation to 3.10 x 10^{21} n/m^2 decreased about 0.2 K. as shown in Fig. 2.

The fast neutron knocks on the atoms in the matrix and makes interstitials and vacancies. When the irradiation damage increases with the higher neutron fluence, the magnetic flux pinning force would be strengthened and the critical current would increase in the higher field. At the same time, the A15 crystal structure would be disordered

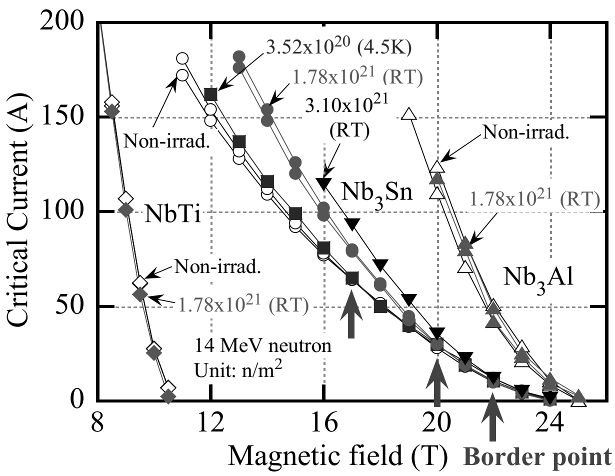

Fig. 1. Change in critical current against magnetic field after 14 MeV neutron irradiation.

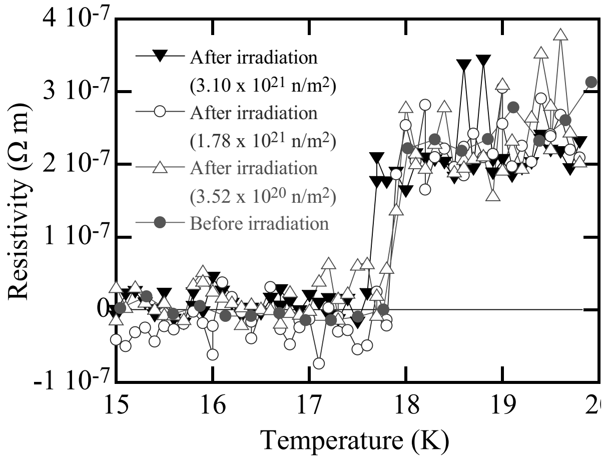

Fig. 2. Critical temperature measurement results after 14 MeV neutron irradiation.

resulting in the decrease of the critical temperature.

Magnetization property was measured after neutron irradiation of 1.0 x 10^{22} n/m^2 at JRR-3. The results are shown in Fig. 3 together with the data of non-irradiated sample. It is clear that the height of hysteresis loop (ΔM) becomes larger after the irradiation. It suggests that the critical current density would be increased by the irradiation. The transport current measurement will be performed with four-probe-method in high magnetic fields. In addition, it is noticed that the hysteresis curve is not plane symmetric and inclined to the horizontal axis a little. Since the strand contains cooper part inside, which shows diamagnetic, the hysteresis curve shows the diamagnetism and is inclined.

The further investigations are ongoing and more interesting and important results will be come out soon.

1) A. Nishimura, T. Takeuchi, S. Nishijima, G. Nishijima, T. Shikama, K. Ochiai, N. Koizumi, Fusion Engineering and Design, 84, 1425–1428 (2009).
2) A. Nishimura, T. Takeuchi, S. Nishijima, K. Ochiai, G. Nishijima, K. Watanabe, and T. Shikama, Advances in Cryogenic Engineering, 56, 255-262 (2010).

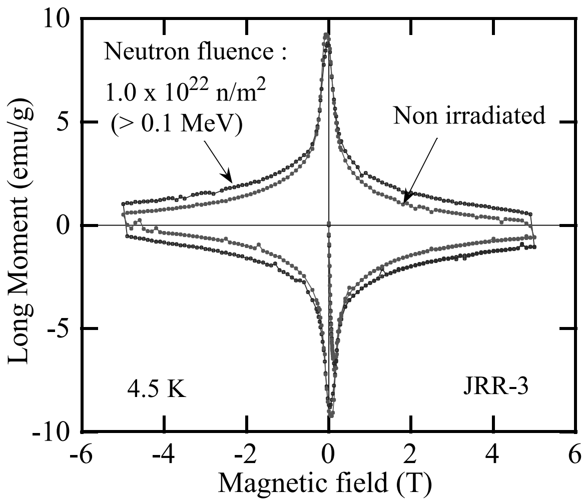

Fig. 3. Results of magnetization measurement comparing non-irradiated sample and irradiated one up to 1.0 x 10^{22} n/m^2 at JRR-3.