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

Takeuchi, T. (NIMS), Nishijima, S. (Osaka Univ.), Nishijima, G., Shikama, T. (Tohoku Univ.), Nishimura, A.

The effects of neutron irradiation on superconducting wires have been investigated. The neutron irradiation tests were carried out at JRR-3 and FNS in JAEA and the superconducting properties were evaluated after neutron irradiation at High Field Laboratory for Superconducting Materials (HFLSM) in Institute for Metal Research (IMR), Tohoku University. In this year, measurements of critical current ($I_c$) and critical magnetic field ($B_{c2}$) were performed successfully for the first time in this investigation.

The tested superconducting wires were NbTi, $Nb_3Sn$ and $Nb_3Al$. The NbTi and $Nb_3Sn$ wires were provided by Furukawa Electric Co., Ltd. and the $Nb_3Al$ wire was fabricated by NIMS. The diameters of these wires were 0.824 mm, 0.7 mm and 0.75 mm, respectively. The sample length was about 35 mm and $I_c$ and $B_{c2}$ were evaluated with 28 T hybrid magnet at HFLSM in Tohoku university by four-probe method.

Before neutron irradiation, the $I_c$ and $B_{c2}$ were measured at HFLSM and then sent to JRR-3 or FNS. The maximum sample current was limited to 200 A because of the capacity of the power supply for the sample. When the Bc2 was evaluated, the sample was set in liquid helium and the current of 100 mA was put in and then the magnetic field was swept at the rate of 0.053 T/s between 20 T and 27 (26) T.

At FNS, the cold target system has been installed. The cold stage temperature was kept at 4.5 K and the irradiation was carried out keeping the sample at 4.5 K. At the same time, the samples were attached on the cryostat surface at room temperature. Since the cold stage was far from the D-T neutron source, the neutron fluence was less than that on the cryostat surface. The neutron fluence at the cold stage and the cryostat surface was 3.52 x $10^{20}$ n/m$^2$ and 1.78 x $10^{21}$ n/m$^2$, respectively. The irradiation was carried out in 2005 and 2007 at FNS. The residual radioactivity was less than 100 kBq of 60Co which is the maximum amount taken out of the radioactive control area in Katahira campus.

The some of the test results of $B_{c2}$ measurements of $Nb_3Sn$ wire are shown in Fig. 1. The data sets were shifted by 4 μV/cm or 8 μV/cm from the zero-axis to overlap three sets of data. The $B_{c2}$ was determined from the cross point of the resistive line and zero-axis. The estimated $B_{c2}$ was 25.4 T, 25.3 T and 25.2 T for non-irradiated wire, 3.52 x $10^{20}$ n/m$^2$ irradiated wire and 1.78 x $10^{21}$ n/m$^2$ irradiated wire, respectively. +/-0.1 T will be scatter of the measurement, it would be concluded that there is no clear change in $B_{c2}$ after neutron irradiation. However, the upper resistivity ($\rho_n$) in fields increased clearly after 1.78 x $10^{21}$ n/m$^2$ irradiation. Since the resistivity of copper, which is a stabilizer of the wire, is also increased by the irradiation, the change in $\rho_n$ will be related to the change in the copper resistivity. $T_c$ of the irradiated sample will be measured in 2009, and a more precise test procedure to determine $B_{c2}$ will be adopted which is under consideration.

Figure 2 shows the results of $I_c$ measurements against the magnetic field. NbTi and $Nb_3Al$ wires did not show the clear changes. In the case of 1.78 x $10^{21}$ n/m$^2$ irradiation of $Nb_3Sn$ wire, $I_c$ increased remarkably and became about 1.4 times larger at 13 T. This increment is confirmed with two samples. 3.50 x $10^{20}$ n/m$^2$ irradiation at 4.5 K also shows a little increase of $I_c$. However, as mentioned above, $B_{c2}$ did not change clearly. The details will be discussed in 2009.

To increase the sample current, a new sample holder was installed with the capacity of 500 A. In the new sample holder, a copper wire was prepared in parallel with the superconducting sample to avoid the melt-away when the sample would become resistive. The critical current tests will be carried out in 2009.

The samples irradiated at JRR-3 are kept at Hot Lab in Oarai center of IMR and waiting for the decay. The measurement at the end of May, 2009, shows that the residual radioactivity is 3 kBq of 182Ta. After registration process of 182Ta in Tohoku University, the sample will be transferred to Katahira campus of IMR, Sendai, and the superconducting properties will be evaluated.

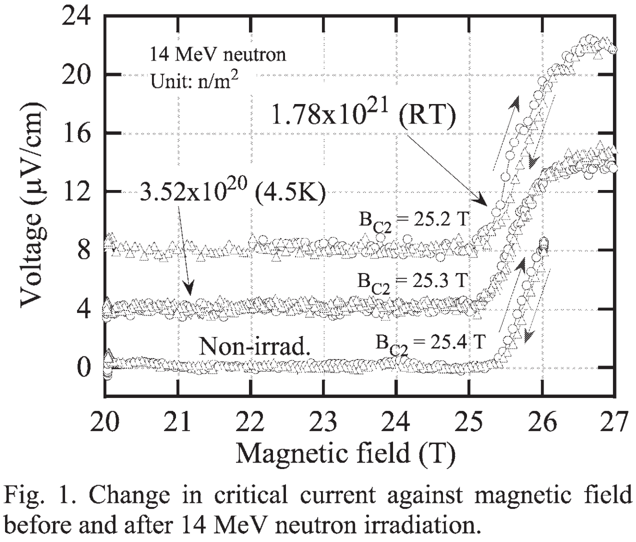


Fig. 1. Change in critical current against magnetic field before and after 14 MeV neutron irradiation.

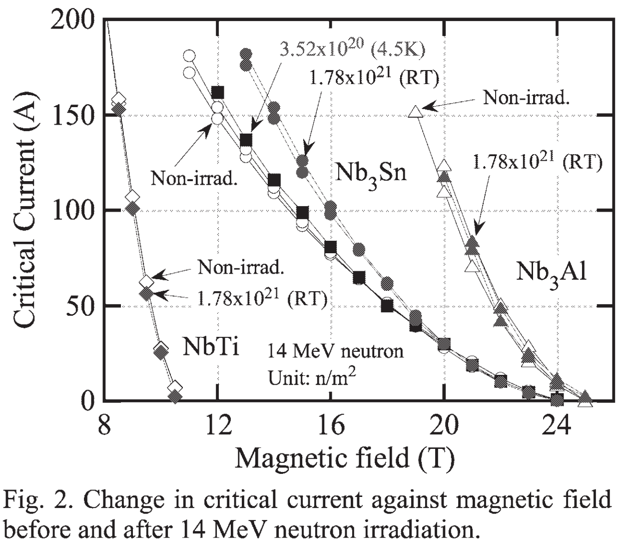


Fig. 2. Change in critical current against magnetic field before and after 14 MeV neutron irradiation.