§21. Neutron Irradiation Effect on Superconductivities of Nb_3Sn and Nb_3Al Strands

Nishimura, A.,
Takeuchi, T. (NIMS), Nishijima, S. (Osaka Univ.),
Ochiai, K. (JAEA), Watanabe, K., Shikama, T.
(Tohoku Univ.)

To obtain fusion energy, deuterium-tritium reaction will be realized in a fusion reactor. Fusion reactor will generate a lot of 14 MeV neutrons and the kinetic energy will be taken out by catching the flying neutrons. Since the energy is quite large, some neutrons will penetrate a blanket and a vacuum vessel, and reach superconducting magnets. To investigate the change in superconducting properties by the neutron irradiation, the collaboration network has been established among universities, national institutes and companies [1]. The data are gradually piled up and some important tendencies have been clarified recently.

The superconducting samples were supplied by Furukawa Electric Co. Ltd for Nb_3Sn and NIMS for Nb_3Al, and 14 MeV neutron irradiation was carried out at FNS in JAEA. After the irradiation, the samples were sent to HFLSM, IMR in Tohoku University and the critical current and the critical magnetic field were measured using 28 T hybrid magnet [2].

Figure 1 shows the relation between the critical current (I_C) and magnetic field (B). In the case of Nb_3Sn strand, the increase of I_C is significant in the lower magnetic field, but no increase is observed in the higher magnetic field. The border point, where the I_C gets away from the non-irradiated I_C-B curve, is shifted to the higher magnetic field as an increase of the neutron fluence. It suggests that the change in I_C would be caused by flux pinning. In the case of Nb_3Al and NbTi strand, there is no clear change in I_C as far as the irradiation has been done.

The change in I_C is summarized as a function of neutron fluence as shown in Fig. 2 [3-5]. Since the change in I_C depends on the magnetic field as show in Fig. 1, the I_C/I_{C0} varies among the data sets. General trends are increase of I_C once and then decrease of I_C as an increase of neutron fluence. The present data are also plotted on the same trend line. There is clear difference in I_C/I_{C0} properties depending on the strands. It suggests that the fabrication process of Nb_3Sn strand will affect on the irradiation effects.

Figure 3 shows an image of strengthening mechanism of a quantized flux. In the case of Nb_3Sn strand, a magnetic flux is quantized like a thin string and pinned at inclusions or oxides. The pinning force is strongly related to I_C, and I_C becomes very high when the pinning force is strong. Since the neutron irradiation generates interstitials and vacancies by knock-on effect, the pinning force will be strengthened when the irradiation damage is created on or near the quantized flux. The details of the mechanisms are under investigation and will be clarified in the near future.

1) A. Nishimura, Y. Hishinuma, T. Tanaka, T. Muroga, S. Nishijima, Y. Shindo, T. Takeuchi, K. Ochiai, T. Nishitani, and K. Okuno, Fusion Engineering & Design, 75-79, 173 (2005).
2) A. Nishimura, T. Takeuchi, S. Nishijima, K. Ochiai, G. Nishijima, K. Watanabe, and T. Shikama, Advances in Cryogenic Engineering, 56, 255 (2010).
3) H. Weber, Advances in Cryogenic Engineering, 32, 853 (1986).
4) M. W. Guainan, P. A. Hahn, and T. Okada, Summary Report on RTNS-II Collaboration Research, UCID 21298 (1988).
5) T. Kuroda, K. Katagiri, H. Kodaka, M. Yuyama, H. Wada, K. Inoue, and T. Okada, Atom. Energy Soc. Japan, 37, 652 (1995) (in Japanese).

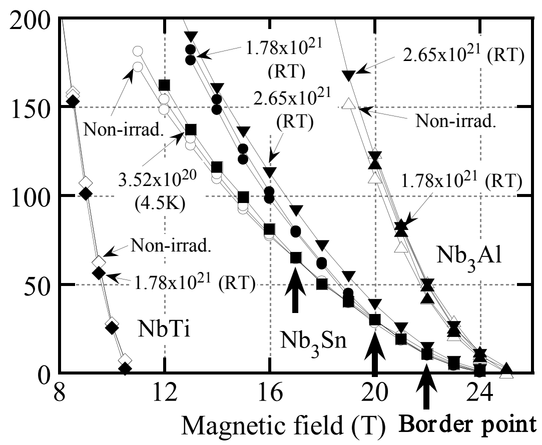

Fig. 1. Results of Ic measurement of non-irradiate and irradiated strands of NbTi, Nb_3Sn and Nb_3Al.

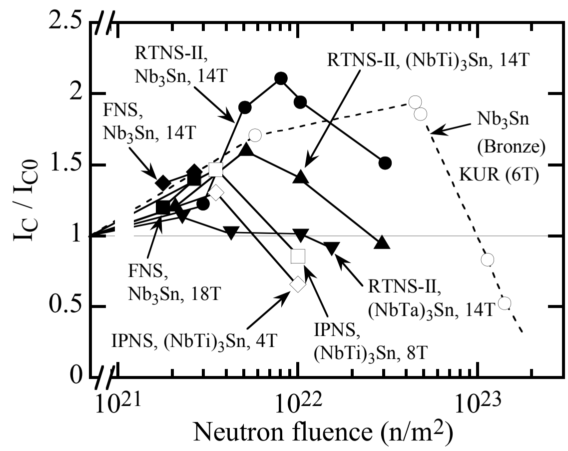

Fig. 2. Change in the critical current by the neutron irradiation.

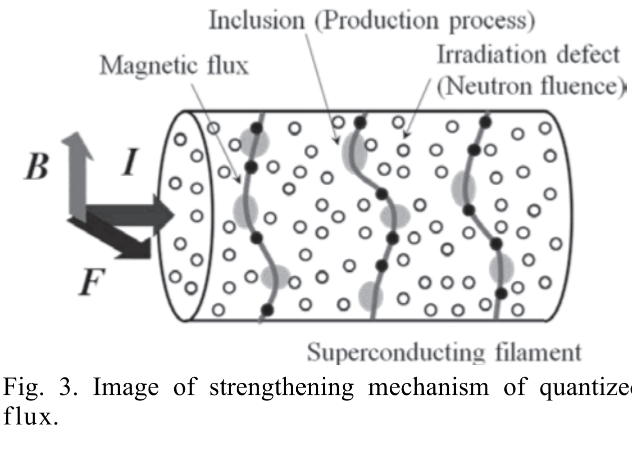

Fig. 3. Image of strengthening mechanism of quantized flux.