§18. 14 MeV Neutron Beam Induced Change in Characteristics of Materials for Superconducting Magnets under 4.5 K

Nishijima, S., Izumi, Y. (Osaka Univ.), Ochiai, K., Konno, C. (JAEA), Takeuchi, T. (NIMS), Nishimura, A., Seo, K., Hishinuma, Y., Muroga, T., Tanaka, T.

Introduction

The neutron energy in a nuclear fusion device has a different spectrum with maximum energy of 14MeV by a place. However, until now, nuclear reactor has been main source of neutron in the field of irradiation effects. Therefore, influence of variety of energy spectrum to change in characteristics of each element has not been clarified. In this report, conventional data were closely explored, and 14MeV neutron irradiation effects of superconducting coil system elements adopted in a nuclear fusion device in the next generation were studied under cryogenic temperature.

Conventional data in precedent studies

Demanded characteristic are different by each element of a magnet. **Figure 1** shows the data of relative change in demanded characteristics of each element ordered by neutron fluence. As shown in this figure, change in electric resistance of copper or aluminum, stabilization materials, are relatively large. However, electric resistance changes with an external magnetic field. Furthermore, considering the conditions in actual use (annealing effect by periodical warming-up), it can be considered that irradiation-induced deterioration of insulator is the largest.

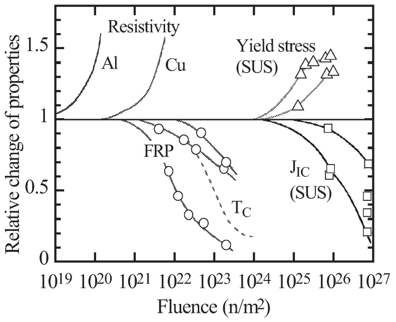

Fig. 1 Neutron-induced deterioration of a superconducting magnet element. Electric resistance, mechanical strength, Tc, and a yield stress and J1c are selected as indexes of properties for stabilization material, insulator (FRP), superconducting material, and SUS, respectively.

Next, **Fig. 2** shows a change in critical temperature (Tc) of superconducting material with irradiation. If materials are the same, deterioration behavior of Tc shows approximately similar tendency. Tc is high so that a long-range regularity is high. Therefore, It is considered that the reason of deterioration of Tc is that a deterioration of long-range regularity is induced by irradiation. Thus, since a radiation-induced deterioration behavior of regularity is approximately same when materials are the same, deterioration of Tc is almost same.

Experimental results of 14MeV neutron irradiation

As well as consideration and discussion of a data from precedent study such as above-mentioned, 14MeV neutron irradiation effects in cryogenic temperature were also studied by using a 14MeV neutron generator (FNS) installed in JAEA.

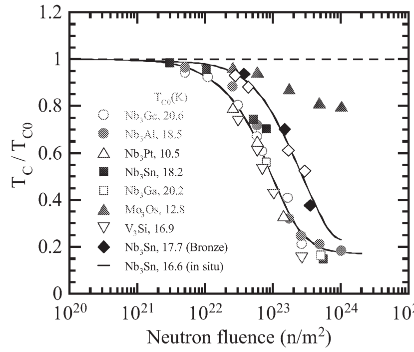

Fig. 2 Degradation behavior of Tc of compound-system superconductor.

Figure 3 shows an radiation-induced change in electric resistance of stabilization materials. Conventionally, fluence has been selected as a horizontal axis. On the other hand, in this case, a horizontal axis indicates displacement per atom (dpa). As shown in this figure, electric resistance linearly increased with dpa. Especially, it can be paid attract attention that increasing behavior of electric resistance could be fitted to same line independently to variation of materials (even if it is OFC or TPC).

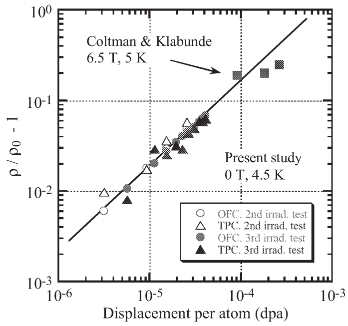

Fig. 3 14MeV neutron irradiation effect on electric resistance.

14MeV neutron irradiation effect of shear strength between the layers of FRP was also studied. As the result, the deterioration of shear strength between the layers was not observed in a dose range up to $4x10^{19}n/m^2$. On the other hand, in the case of γ-irradiation of 10MGy, it was confirmed that the shear strength between the layers of FRP became a zero. With FRP, a conversion coefficient of 2.3 x 10^{15} n/m^2 = 1 Gy is generally used. Using this conversion coefficient, absorbed dose for 2.3 x 10^{15} n/m^2 irradiation can be estimated as 0.017 MGy. Therefore, absorbed dose is very low in the cases of these neutron irradiations. And, this is the reason why no significant degradation of shear strength between the layers of FRP was observed in the case of neutron irradiation. In addition, it could be confirmed that Tc of superconducting wire (Nb3Al) was decreased with increase of neutron fluence.

In conclusion, concerning irradiation effect on components of a superconducting magnet for nuclear fusion reactors, conventional data of precedent studies were rearranged and discussed. In addition, experimental studies on 14MeV neutron irradiation effect were also carried out. It can be in particular thought meaningful that 14MeV neutron irradiation effect was clarified technologically.