§21. 14MeV-Neutron Beam Induced Change in Characteristics of Materials for Superconducting Magnets under 4.5 K

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Accumulation of a quantitative database of performance deterioration and recovery of superconducting coil system elements adopted in a nuclear fusion device in the next generation by irradiation of 14MeV neutron under cryogenic temperature are important. In this study, we aimed at clarifying a characteristic of 14MeV neutron irradiation effects from mechanism and enabling feedback for a design of superconducting coil system materials for fusion reactors in the next generation.

The 14MeV neutron irradiation experiments were performed by using a 14MeV neutron generator (FNS) installed in JAEA. The 5 kinds of samples, (i) the tough pace copper wire, (ii) the oxygen-free copper wire, (iii) the Nb_3Al wire rod flash-heated and rapid cooled (RHQ), (iv) the Nb_3Al wire rod annealed after RHQ, and (v) the Nb_3Sn wire rod, were consecutively maintained at 4.5 K using compact-type refrigerating machine during irradiation. In the region at an ambient temperature, different types of polystyrene with different molecular weight, glass-fiber reinforced plastic (GFRP), and a MgB_2 trial manufacture wire rod were arranged. From consideration to a security aspect of treating work after irradiation, the structural material of vacuum chamber was changed from SUS-304, which has been used in the last year, to aluminum alloy in order to reduce the influence of γ-rays.

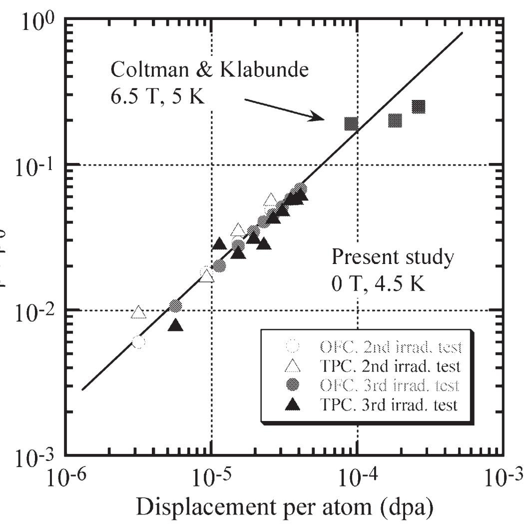

Figure 1 The resistance of copper irradiated with neutron at a cryogenic temperature. OFC: oxygen-free copper, TPC: the tough pace copper.

Some important results were obtained this year. The resistance of copper was increased with increase of a neutron irradiation dose by cryogenic temperature irradiation. **Figure 1** shows this results in which the irradiation dose was converted to dpa in order to compare with data by nuclear reactor irradiation in the literatures. In cases of fission neutron and 14MeV neutron irradiations, 3.06×10^{-7} dpa / 1.00×10^{19} n/m^2 and 3.67×10^{-6} dpa / 1.00×10^{19} n/m^2 were used, respectively. It was suggested that increase in resistance of copper irradiated with neutron was caused by growth of a defect cluster.

The interlaminar shear strength of GFRP was measured after 14 MeV neutron irradiation at a room temperature. For comparison, the interlaminar shear strength of γ-irradiated sample was also measured. The decomposition or chain scission effect by neutron irradiation was lower than that by γ-irradiation. However, a boron compound is included in glass fiber, and influence of deterioration in a glass / resin interface due to n, α reaction by ^{10}B is large. Because LET of the formed α particle is high, α particle gives energy highly in glass fiber / resin interface, and extremely reduces adhesive property between fiber and resin. This is supported from an observation of FRP sample section after shear strength testing.

In order to clarify the degree of side-effects of induced γ-rays affecting the observed characteristics, the contribution rate of γ-rays for an absorbed dose was calculated by Monte Carlo simulation. As a result, the influence of γ-rays from SUS304 steel was less than 1/20 among total absorbed doses. Therefore, almost whole of observed change was suggested to be due to 14 MeV neutron. For example, crosslinking and main chain scission simultaneously undergoes in the case of 14 MeV neutron irradiation of single dispersion polystyrene at room temperature, which was concluded by the experiments in the last year. Such an observed change is also due to not γ-rays but 14 MeV neutron. Furthermore, a similar result was obtained in the experiments in this year; aluminum alloy with a little influence of γ-rays was used in the supporting material. In addition, molecular weight distribution was broadened, that was different from the formation of new peak by a neutron irradiation, in the case of ^{60}Co γ-irradiation experiments. The reason why only 14 MeV neutron irradiation generates the new peak in molecular weight distribution is under consideration. Some of possible mechanisms are as following. Recoiled proton, recoiled carbon atom and α particle formed *via* n, 3α nuclear reaction have high LET. Such particles with high LET induce the track-structured energy transfer distribution like a heavy ion beam irradiation. Thus heterogeneous crosslinking and/or chain scission reaction undergoes. Crosslinking and main chain scission are not caused outside track structure.

The experimental studies have been performed about a performance change by 14MeV neutron irradiation of a superconducting coil system element adopted in a fusion device in the next generation. It was found that new indexes not only fluence but also dpa was necessary in the dosimetry of 14 MeV neutron. In addition, in GFRP, the consideration of effect of α particle from boron included in glass fiber. The heterogeneousness of an energy transfer, such as track structure in the heavy ion beam irradiation, can be important in the 14 MeV neutron irradiation effect on the polymeric materials.