§20. Neutron and Gamma Ray Irradiation Effect on Interlaminar Shear Strength of Electric Insulation Composite for Fusion Device

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Superconducting magnets for fusion will be irradiated by streamed and penetrated neutrons and be activated. Electric resistance of the stabilizer in superconducting conductor such as high purity copper or aluminum increases rapidly by neutron irradiation of 10^{19} to 10^{20} n/m^2 and the thermal conductivity decreases significantly. In case of ITER, the design values of neutron fluence and gamma ray dose are 1.0 x 10^{22} n/m^2 and 10 MGy, respectively. Some of the activated materials will emit gamma ray and the whole magnet will be irradiated. Therefore, the electric insulation composites will be irradiated by the neutron and the gamma ray and a new organic resin with high resistance against neutron and gamma ray has been developed especially for ITER superconducting magnet system.

Many pioneer investigations and trial fabrications were carried out and it was confirmed that cyanate ester has an excellent resistance against the irradiation. Since the longer pot life of the resin is preferable, the cyanate ester will be blended with epoxy at the weight ratio of 40/60.

Using 11 sheets of glass cloth and 10 sheets of polyimide film, an interlamination structure was composed, and impregnation with the blended resin was carried out. Samples with the size of 10 mm^W x 15 mm^L x 2.5 mm^t were machined out of the composite plate and irradiated by fission neutron to 1.0x10^{21} and 1.0x10^{22} n/m^2 (> 0.1 MeV) at JRR-3 in JAEA. The irradiation temperature was around 100 C. After the irradiation, the samples were tested under 3 point bending in liquid nitrogen as shown in Fig. 1. The support span was 12.5 mm and the travelling speed of the loading head was 0.75 mm/min.

To combine the glass cloth and the polyimide film, a certain resin or an adhesive will be used. Four types of the glass cloth/polyimide film combination with a different resin were prepared and the interlaminar shear strength (ILSS) at 77 K was investigated. The results are shown in Fig. 2. It must be noted that there is no clear difference among four trial composites. Irradiation of 1.0x10^{21} n/m^2 does not damage the composites but the 1.0x10^{22} n/m^2 irradiation seems to reduce the ILSS. However, the dose of about 500 MGy was irradiated during the neutron irradiation of 1.0x10^{22} n/m^2 at JRR-3. Fig. 3 shows the relation between the ILSS and the dose of some trial composites with the blended resin reported in 2011. In case of the 1.0x10^{22} n/m^2 irradiation, all samples showed the lower ILSS and the heavy gamma ray irradiation reduces the ILSS except for the composite with 100% cyanate ester.

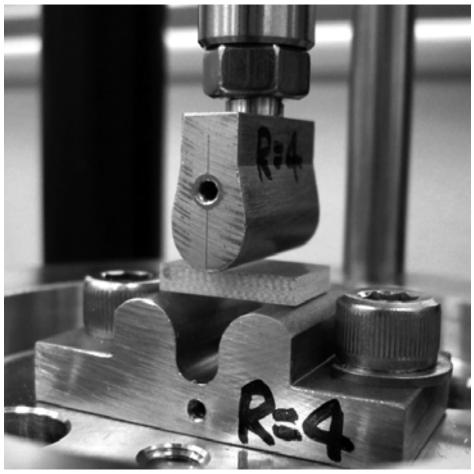

Fig. 1. Test apparatus of interlaminar shear strength of electric insulation composite. 11 sheets of glass cloth and 10 sheets of polyimede film were interlaminated. 3-point bending test was carried out in liquid nitrogen.

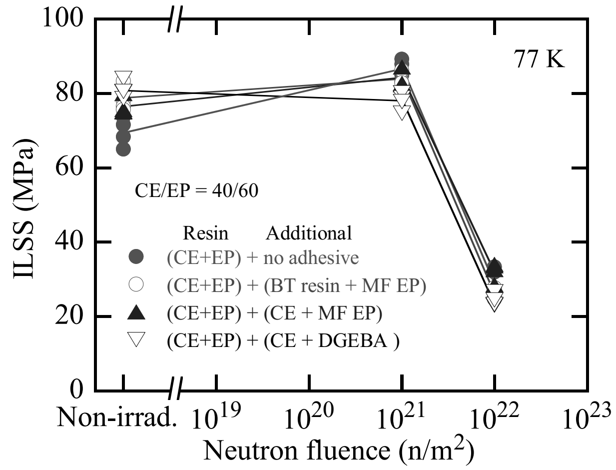

Fig. 2. Relation between interlaminar shear strength at 77 K and neutron fluence of trial composites. Ratio of cyanate ester/epoxy was 40/60. All composites showed the same ILSS property and ILSS dropped after 10^{22} n/m^2 irradiation.

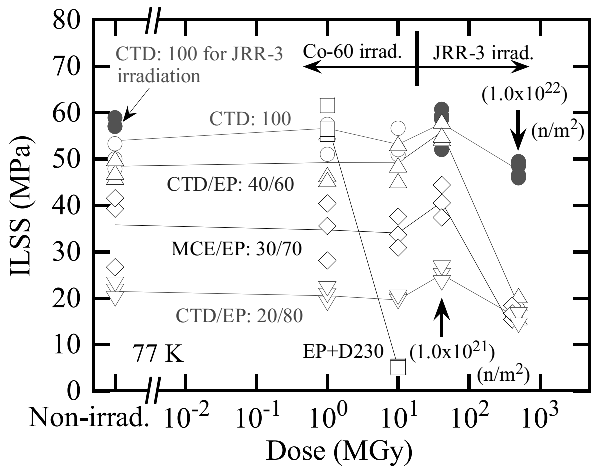

Fig. 3. Relation between interlaminar shear strength at 77 K and dose of gamma ray reported in 2011. During neutron irradiation at JRR-3, gamma ray irradiation undergoes at the same time.