§11. Study on the Irradiation Effect of Organic Insulation Materials for the Superconducting Magnet

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Among the constituent materials of the superconducting fusion magnet, the organic insulation materials are the most radiosensitive materials which are concerned to degrade by exposure to radiation. It is important to evaluate the irradiation effect of the insulation materials and improve the radiation durability for safety and durability of the reactor system. In order to improve the radiation-durability of the organic insulation materials, cyanate ester (CE) / epoxy (EP) mixed resin was used and the radiation effects on the resins with different percentages of cyanate ester in the mixed resin were investigated[1].

In the actual use in the fusion magnet, Insulation materials are fabricated by impregnating the polymeric material into the stacks of alternating layers of polyimide films and glass cloth, whereas few studies are reported about the irradiation effect on the resin-glass cloth and the resin-polyimide film boundary. In this study, we focused attention on the influence on the interfacial properties on the irradiation effect of the organic insulation materials.

E-glass cloth with and without silane treatment were used. The mixture of the epoxy resin (Epikote® 828, Mitsubishi Chemical Co.) and the hardener (Jeffamine® D230, Huntsman Co.), or 4:6 mixture of cyanate ester (AROCY®35000 CH, Huntsman Co.) and cyanate ester was impregnated to the laminated glass clothes under vacuum at 40 °C. The Glass Fiber Reinforced Plastic (GFRP) was fabricated by hardening under the suitable condition. The GFRP was irradiated by gamma-ray up to 10 MGy by 42 kGy/h in dose rate. After the irradiation, interlaminar shear strength (ILSS) test under liquid nitrogen temperature and the observation of fracture cross section were performed.

Fig. 1 shows the results of ILSS test of the specimens of epoxy resin. Without irradiation, ILSS was almost the same for the specimens with and without surface treatment. After 5 MGy irradiation, ILSS decreased for both specimens, but was a little larger in silane-treated GFRP than non-treated GFRP. After 10 MGy irradiation, ILSS became much lower regardless of surface treatment, and cohesive failure of resin layer was observed by the microscopic observation of fracture cross section. It shows that the interlaminar shear failure occurred in the resin layer.

Fig. 2 shows ILSS of GFRP fabricated with CE/EP mixed resin and the glass cloths with and without surface treatment. ILSS was larger in silane-treated GFRP than that of non-treated one. The decrease in ILSS and change in fracture cross section was never observed after irradiation. In addition, ILSS of silane-treated GFRP was larger than that of the non-treated one, even after 10 MGy irradiation.

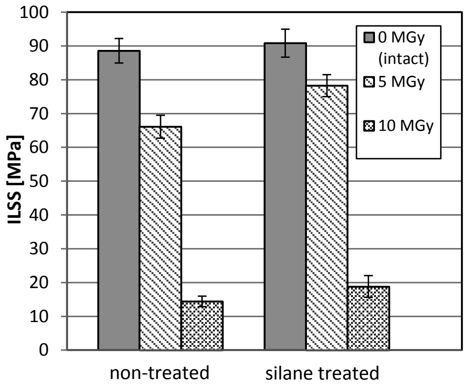

Fig. 1 ILSS of epoxy GFRP using E-glass with and without silane treatment in each absorbed dose.

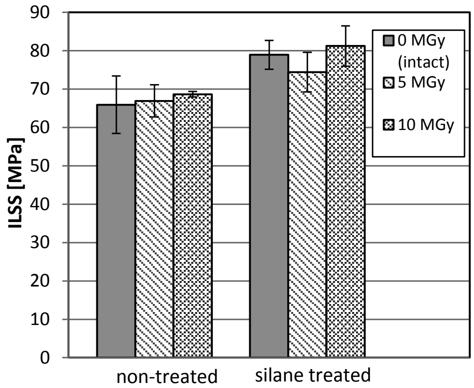

Fig. 2 ILSS of CE/EP mixed GFRP using E-glass with and without silane treatment in each absorbed dose.

It indicates that the silane-coated layer on the glass surface has high radiation resistance, and the degradation of resin-glass cloth interface caused by degradation of resin.

From these results, the following prospection is possible. In the non-irradiated epoxy GFRP, the interfacial breaking strength is larger than the cohesive breaking strength, which causes a crack in the resin layer followed by main body breaking. It is considered that both the resin and interface degrades by 5 MGy irradiation, and then the significant denaturalization occurred in the resin layer by 10 MGy irradiation. The microscopic observation of fracture cross section also supported the conception. Thus, the effect of the silane treatment was hardly observed.

In CE/EP mixed resin, on the other hand, the interfacial breaking strength is smaller than the cohesive one. This causes the interfacial failure which clearly shows the effect of surface treatment in the non-irradiated samples. In addition, both the interfacial and cohesive breaking strength hardly decreases by the irradiation in the mixed resin, which is supposed to cause the interfacial failure, regardless of the absorbed dose.

1) Prokopec, R. et al.: Fusion Engineering and Design **82** (2007) 1508.