§78. Study of Radiation Damage of Organic Electric Insulation Material for Fusion Superconducting Magnet

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i) Introduction

The polymeric materials used for the electric insulation are one of the most radiosensitive materials in the superconducting fusion magnet. 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. Recently, cyanate ester was reported to have high radiation durability, but the mechanism has been not clarified nor a guideline to give radiation durability to insulation materials has not been obtained. In this study, interlaminar shear strength (ILSS) of GFRP (Grass fiber reinforced plastic) at 77K was measured to investigate the effect of the change in the molecular structure on the macroscopic mechanical property before and after irradiation.

ii) Experiment

Samples used in this study were Epikote828 (Diglycidyl Ether of Bisphenol-A, DGEBA, Mitsubishi Chemical Corporation) known as representative epoxy resin and cyanate ester (CE) which has an excellent radiation durability.

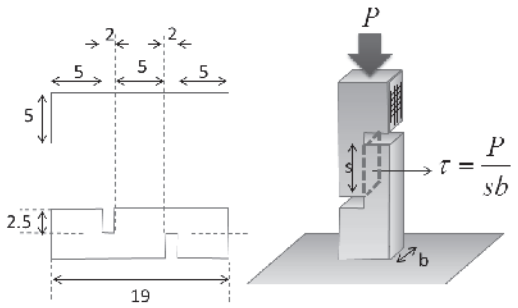

Fig.1 Double-notched specimen

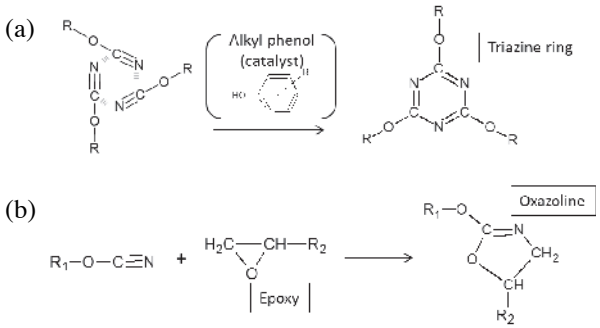

Fig.2 Curing reaction of CE and epoxy resin
((a): cyclotrimerization of cyanate ester,
(b): formation of oxazoline and oxazolidinone)

CTD403 (CTD) recognized as the representative CE was blended with Epikote828 in the weight fractions of 100, 80, 60, 40 and 20 wt.%. The specimen used for ILSS measurement as shown in Fig.1, and the curing reaction of CE and epoxy resin was shown in Fig.2. The samples were irradiated with 60-Co source at dose rate of 11.6 Gy/s under air atmosphere and room temperature. The compression test was performed to measure ILSS at 77K before and after irradiation.

iii) Result and discussion

The results of ILSS tests at 77K of GFRP with CE/epoxy resin after gamma ray irradiation up to 10MGy were shown in Fig.3. CE forms a crosslinked polymer network structure with high crosslink density by trimerization (Fig.2(a)). It is considered that the scission of molecular chain by irradiation does not affect the mechanical properties so much when the absorbed dose is up to 10 MGy and CE content is more than 40 wt.%. ILSS (77 K) of CE 100 wt.% hardly changed even after 10 MGy of irradiation. Moreover, the specimens over 40 wt.% in CE content showed little change after irradiation, which agrees with other previous studies. For this reason, it is concluded that ILSS of GFRP was barely affected by radiation-induced decrease in crosslink density if the sample contains a lot of triazine rings formed by CE.

On the other hand, intact CE/epoxy resin mixture of CE 20 wt.% showed lower ILSS than other ratio mixtures, and irradiated one showed decease in ILSS. GFRP matrix of CE 20 wt.% is considered to have a lot of oxazoline shown in Fig. 2(b) and oxazolidinone, and thus have small number of triazine.

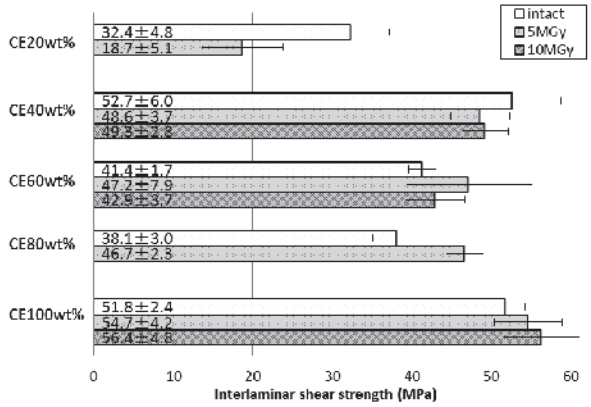

Fig.3 ILSS of CE/Epoxy composites

iv) Conclusion

It was concluded that decrease in crosslink density caused by irradiation up to 10MGy barely affected on the mechanical property when polymeric materials had a certain amount of triazine ring in crosslinked polymer network structure. Consequently, the material with practical resistance to radiation can be synthesized by controlling the additive amount of CE in epoxy resin in consideration of the cost and ease of handling.

In the future, changes in the structure of nano-space due to changes in the crosslink density will investigated by positron annihilation lifetime spectroscopy, and it will correlated with changes in glass transition temperature and mechanical property in order to investigate the mechanism of improvement of radiation resistance by addition of CE.