§22. Radiation Effects of Organic Electric Insulation Materials

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i) Introduction

An electrical insulation material for superconducting magnets of a nuclear fusion reactor is the most radiation-sensitive among the magnet materials, and it is important to avoid the degradation of safety and durability of the reactor system. A number of studies on irradiation-induced changes in mechanical properties of polymers have been made[1)2)], whereas the relationship between deterioration of mechanical properties and change in molecular structure is still not clear. The superconducting magnet design for the nuclear fusion reactor requires the study on irradiation effect of neutron, especially fusion neutron.

In this study, the effect of gamma-ray which is secondary emitted by radio-activated materials was investigated as a fundamental study of irradiation effect on the polymer insulation materials.

ii) Experiment

Glass transition temperature, Tg, was determined by means of DSC (Differential Scanning Calorimetry) to examine the structural change by cross-linking or scission in irradiated polymer. DSC measurement was conducted for epoxy resin from room temperature to 473 K at the increasing rate of 10 K/min. The samples were prepared with bisphenol-A type base resin, Epikote828®, polyether-type hardner, Jeffamine® D230 and D400. Fig.1 shows the chemical structures of starting materials of epoxy resin.

In the operating environment for ITER, the irradiation durability against ca. 10^{22}n/m^2 of neutron fluence is required. On the basis of the data, the samples were irradiated up to 10 MGy under which energy deposition is almost equivalent to above environment. The samples were irradiated with 60-Co source under air atmosphere and room temperature.

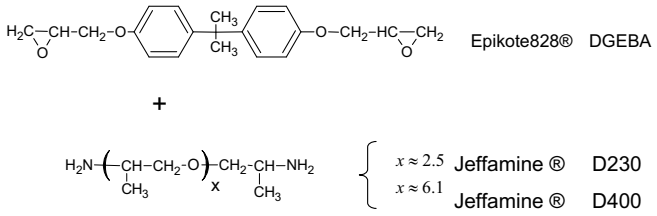

Fig.1 Chemical structures of DGEBA, D230 and D400.

iii) Result and discussion

Fig. 2 shows the DSC curves of the samples with and without irradiation under nitrogen atmosphere. From DSC curves of Fig. 2, Tg was determined by analyzing the curves by detecting the shift of baseline, and was plotted against absorbed dose as shown in Fig. 3. Tg of the sample prepared with D230 was higher than that of D400, and the reason is considered to be longer molecular chain of D230 compared with that of D400. Fig. 3 shows that Tg decreases with increase in the absorbed dose for both D230 and D400. This suggests that the epoxy resin hardened with polyether-type hardener is radiation degradable polymer, whose main chain is easy to undergo scission by high-dose gamma-ray irradiation.

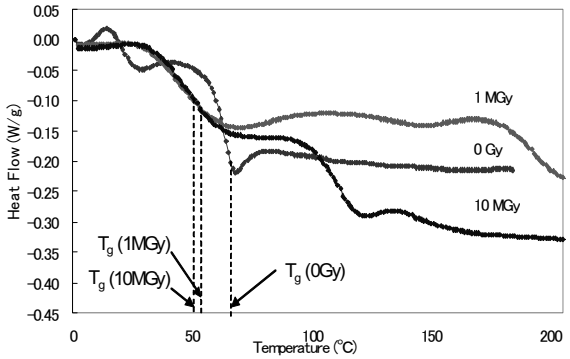

Fig. 2 DSC curves for Epikote828+D230.

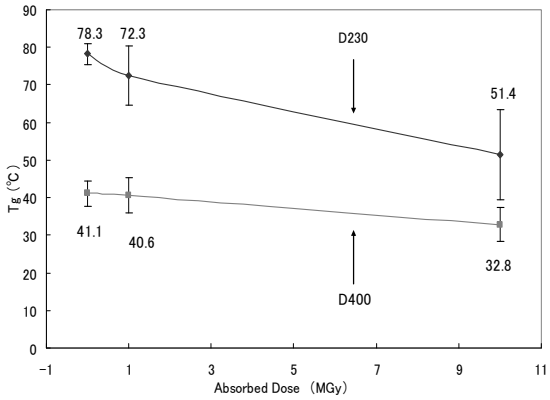

Fig. 3 Change in grass transition temperature (Tg) as a function of absorbed dose.

iv) Conclusion

From these results, it was shown that the molecular structure of epoxy resin, synthesized in this study, undergoes the change in molecular structure which may cause degradation of mechanical properties. It was also shown that the change in molecular structure of polymer insulation materials can be estimated by comparison of glass transition temperature with and without irradiation measured by thermal analysis.

In the near future, temperature dependence of electrical property, dielectric loss tangent, will be measured which is one of the effective method to analyze polymer structure, and be investigated by relating to Tg data for molecular interpretation of irradiation effect of gamma-ray. Based on the information about dose dependence of molecular structure, the molecular design of new polymer insulation materials with high durability against the irradiation under operating environment will be targeted.

1) S. G. Burnay. et al.: Radiat. Phys. Chem. **16** (1979) 389
2) D.P.R. Queiroz. et al.: Radiat. Phys. Chem. **79** (2010) 362