§14. Radiation Effects of Organic Electric Insulation Materials

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i) Introduction

Electrical insulation materials used in the superconducting magnet of nuclear fusion reactor are the most radiation-sensitive among the materials used in the reactor, and it is important to avoid the degradation for maintenance of safety and durability of the reactor system. The final aim of this study is molecular design of radiation-resistant polymer insulation materials, and the structure change in epoxy resin by gamma-ray irradiation was investigated. Among epoxy resins, di-glycidyl ether of bisphenol A (DGEBA), which is bisphenol-type prepolymer, was chosen as the base resin of samples in this report, and the effect of chemical structure of curing agents were investigated.

ii) Experiment

The samples were prepared with Epikote828® as bisphenol-A type base resin, and 4 types of amines were used as curing agents: 2 aliphatic amines and 2 polyether-type amines, which include ether binding in their main chain. Ethylene diamine (EDA) and diethylenetriamine (DETA) were used as aliphatic amines, and Jeffamine® D230 and D400 with different molecular weight were used as polyether-type amines.

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. Based on this, the samples were irradiated with 60-Co source under air atmosphere and room temperature.

Change in the sample structure before and after irradiation was analyzed by Fourier transform infrared spectroscopy (FT-IR), and generated radical species were detected by electron spin resonance (ESR) technique.

iii) Result and discussion

Fig.1 shows FT-IR spectra of epoxy resin samples before and after gamma-ray irradiation hardened by Jeffamine®D230. The similar result was also obtained for D400. For the samples of polyether-type amines, a new absorption peak was observed around 1720 cm^{-1}, which indicates formation of C=O bond. On the other hand, change in structure by irradiation was not observed for the samples hardened by EDA and DETA. It indicates that the ether bond is easier to undergo scission by irradiation than C-C bond.

The result of ESR measurement is shown in Fig.2. The microwave absorption intensity was larger for DETA and EDA, compared with D230 and D400. It is considered that the radical species generated in D230 and D400 samples by irradiation immediately cause the ether bond scission, whereas those in EDA and DETA are relatively stable in the room temperature which remains in the polymer chain.

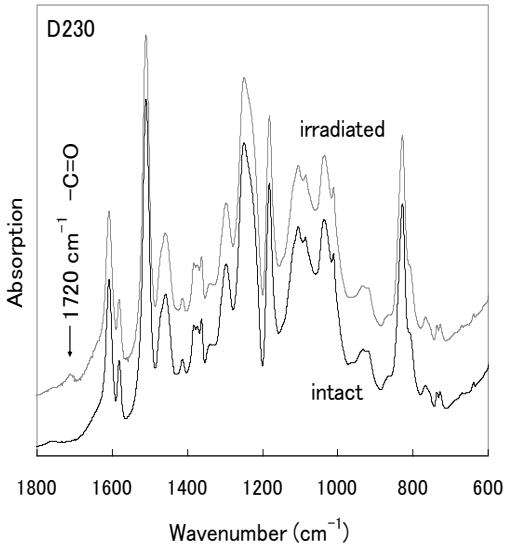

Fig.1 FT-IR spectra of EP resin with D230.

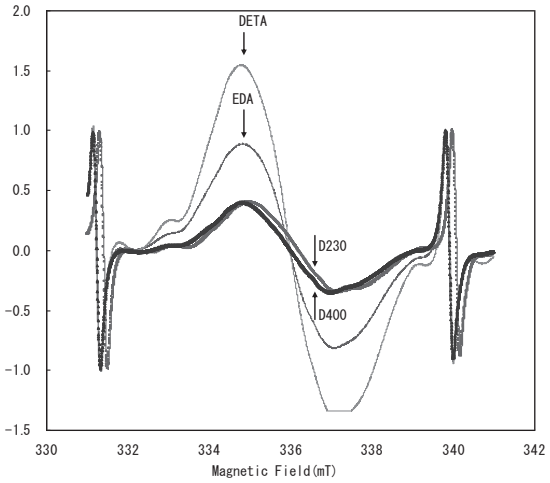

Fig.2 ESR spectra of epoxy resins.

iv) Conclusion

To investigate the effect of chemical structure of curing agents, aliphatic amines and polyether-type amines were used for the hardening of epoxy resin, and the gamma-ray irradiation effect to the samples was investigated by FT-IR and ESR. The results showed that the existence of ether bond in the polymer chain causes chain scission, and that the stability of radical species generated by irradiation is different between the samples of two types of curing agents.

Toward the molecular design of new polymer insulation materials with high durability against the irradiation under operating environment, the relation among the structure change, mechanical and electrical properties will be discussed after data acquisition of mechanical test and electric measurement. In addition, the investigation on temperature dependence of irradiation effect, especially at low temperature, will be required to imitate the operation environment.