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

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i) Introduction

The objective of this study is to investigate the radiation damage of electrical insulation materials used in the superconducting magnet, which is the most radiation-sensitive among the materials in the nuclear fusion reactor. In this study, the structure change in a kind of epoxy resin, di-glycidyl ether of bisphenol-A (DGEBA), which is bisphenol-type prepolymer, by gamma-ray irradiation was investigated by positron annihilation lifetime spectroscopy (PALS).

ii) Experiment

The samples were prepared with Epikote828® as bisphenol-A type base resin, and 2 types of polyether-type amines, Jeffamine® D230 and D400 with different molecular weight were used as curing agents. Fig.1 shows the chemical structures of starting materials.

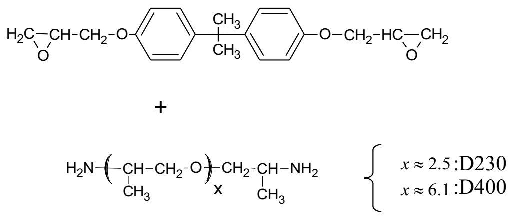

Fig.1 Chemical structures of base resin and curing agents.

In the driving environment ITER, super conducting magnet is required to hold up against neutron over 0.1 MeV with fluence of 10^{22} n/m^2, whose energy transfer is equivalent to 10 MGy of gamma ray. On the basis of the data, the samples were irradiated with 60-Co source up to 10 MGy under air atmosphere and room temperature.

Change in the sample structure before and after irradiation was analyzed by grass transition temperature measured by differential scanning calorimetry (DSC) and lifetime of ortho-positronium (*o*-Ps) obtained by positron annihilation lifetime spectroscopy (PALS).

iii) Result and discussion

In order to examine the degradation process, glass transition temperature (Tg) was measured before and after irradiation at each specimens, by using DSC. Fig.2 shows Tg as a function of gamma-ray absorbed dose for the samples hardened by Jeffamine®D230 and D400. Glass transition temperatures of both the samples decreased with absorbed dose. This suggests that chain scission of epoxy resin network was induced by gamma ray irradiation.

Positron annihilation lifetime spectroscopy (PALS) was applied to all the samples in order to examine change in the free volume by irradiation. Fig.3 shows the lifetime of *o*-Ps, which corresponds to the free volume in the samples. Long lifetime indicates large free volume hole radius. The result shows that the free volume of samples which includes polyether-type amine increased with increase in absorbed dose of gamma ray irradiation. It suggests that the scission of main or side chain by irradiation makes the free volume large.

(a)

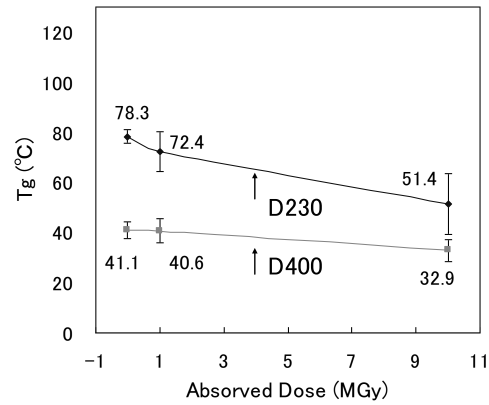

Fig.2 Dependency on absorbed dose of grass transition temperature measured by DSC.

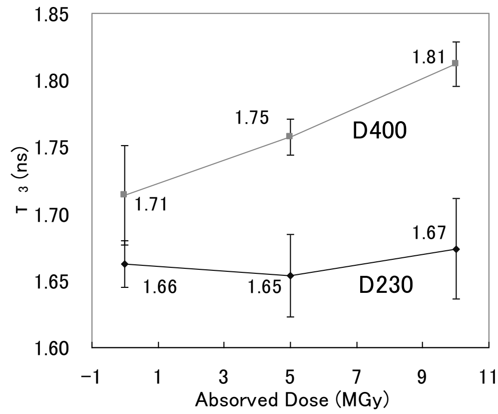

Fig.3 Dependency on absorbed dose of lifetime of o-Ps measured by PALS.

iv) Conclusion

To investigate the radiation damage of electrical insulation materials used in the superconducting magnet, change in grass transition temperature and free volume was investigated. As a result, decrease in grass transition temperature and increase in free volume was observed, which indicates the scission of polymer chain.

Epoxy resin which consists of DGEBA and polyether-type amine is generally used as actual insulation material, whereas resent study suggests that polymeric material including cyanate ester is highly radiation-resistant, which can be applied to insulation material of ITER super conducting magnet. In the future, change in molecular structure through irradiation will be examined using cyanate ester, followed by investigation of relationship between the nanoscopic structure and mechanical properties.