§24. Radiation Effects of Organic Electric Insulating Materials

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The knowledge of radiation-induced degradation of polymeric materials is one of the most important factors for designing and establishing the nuclear-fusion power facilities, because polymeric materials are generally sensitive to radiation and key-technologies for soundness maintenance of system. However, most of neutron-irradiation effects of polymer, especially effects of fusion neutron, have not been clarified. In this study, we are aimed at obtaining and arranging the necessary information concerning the radiation-induced degradation of the polymeric insulating materials for the soundness evaluation of the nuclear fusion system. To be concrete, we planned to re-arrange the data from literature and our former raw-data, and planned experimental studies on the effects of the γ-irradiation where dosimetry was almost established.

Composite material consisting of the cyanate ester resin is regarded as superior candidate as an insulator for nuclear fusion reactors [1]. Therefore, in this fiscal year, we aimed at re-evaluating the radiation resistance of the cyanate-ester-system composite materials and investigating the mechanisms. Two kinds of cyanate ester raw materials, CTD-403 and Aro Cy L10 were obtained from Composite Technology Development, Inc and Huntsman Advanced Materials co. ltd., respectively. Bisphenol A-type jER® 828 and curing agents (D-230, D-400) were purchased from Japan Epoxy Resins co. ltd. and Mitsui Fine Chemicals Inc., respectively. A jig for manufacturing hardening resin that kept laminating structure with the glass-fiber cloth and polyimide film was specially produced. Trial preparation of the GFRPs has been done by vacuum impregnation and under conditions of combination ratio of raw materials and temperature-history that were already reported. Obtained GFRPs have been irradiated with neutron from JRR-3 at JAEA and then they will be examined with bending strength. Cured resin without polyimide film and glass fiber cloth was spectroscopically examined.

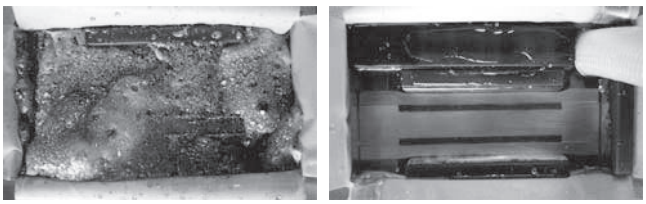

Fig. 1 Cured cyanate ester resin (left) and cured bisphenol A-type resin (right).

Figure 1 shows the apparent condition of cured resin. Bisphenol A-type epoxy resin could be cured without any problems under conditions reported and established by elsewhere. On the other hand, in the case of cyanate ester resin, a trace of intense foaming was observed. The observed intense foaming phenomenon was considered to be due to over-heating during elevated temperature process by sample itself. The curing reaction of resin, especially cyanate ester system, is exothermic. Therefore temperature in a sample must become too high and out of control by the heat generated by sample. Hence, curing reaction was promoted more and more by an abnormal temperature rise. As a result, it is thought that the vicious circle that a temperature rise happens was caused. By the present, we have set extremely low rate of temperature rise than the past as shown in **Table 1**, and the above-mentioned problem of the foaming was considerably reduced (**Fig. 2**). Thus, the unprecedented knowledge can be obtained that careful, slow and mild temperature control is one of the important key-technology during vacuum impregnation and curing process of cyanate ester system to realize magnet systems for ITER.

Table 1 Improved curing conditions

CTD-403	jER® 828
10 h from R.T. to 373 K	1 hour from R.T. to 353 K
16 h hold at 373 K	2 h hold at 353 K
10 h from 373 to 423 K	1 h from 353 to 398 K
4 h hold at 423 K	3 h hold at 398 K
5 h from 423 to 323 K	5 h from 398 to 323 K
> 2 h cooling	> 2h cooling

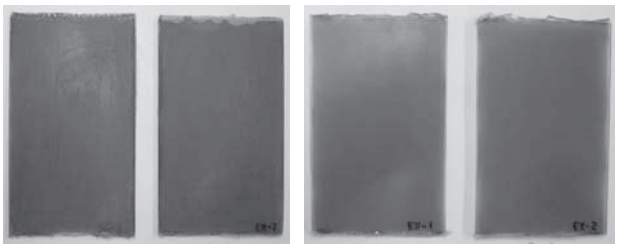

Fig.2 Cured GFRPs prepared by improved procedure, cyanate ester system (left), and bisphenol A-type system (right).

Next, we trially examined FT-IR/ATR spectroscopy of cured resins that include neither glass fiber nor polyimide film. Although the cured resins were cut and well-polished, no considerable spectra were obtained since cured resin was hard and interface adherence with the ATR crystal was bad. Therefore, we have not yet succeeded in the evaluation of the spectral change along with the irradiation.

In the next fiscal year, we are planning to prepare the cured resins and cured GFRPs based on the know-how of resin-curing method provided in this year. And we are also planning to start the γ-irradiation examination of cured resins. Not spectrophotometric properties but mechanical properties such as viscoelasticity will be measured for materials evaluation.

1) K. Bittner-Rohrhofer *et al.*, Fusion Eng. Des. **66-68**, 1209 (2003); R Prokopec *et al.,* J. Phys.: Conf. Ser. **43**, 739-743 (2006).