# E-빔 조사된 폴리머의 전하 분포의 축퇴 과정

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# Decay Process of Charge Distribution in E-Beam Irradiated Polymers

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**Abstract** : Decay processes of accumulated charge in e-beam irradiated polymers during elevating temperature are observed using pulsed electro-acoustic measurement system. Since the polymeric materials have many superior properties such as light-weight, good mechanical strength, high flexibility and low cost, they are inevitable materials for spacecrafts. In space environment, however, the polymers sometimes have serious damage by irradiation of high energy charged particles. When the polymers of the spacecraft are irradiated by high energy charged particles, some of injected charges accumulate and remain for long time in the bulk of the polymers. Since the bulk charges sometimes cause the degradation or breakdown of the materials, the investigation of the charging and the decay processes in polymeric materials under change of temperature is important to decide an adequate material for the spacecrafts. By measuring the charge behavior in e-beam irradiated polymer, such as polyimide or polystyrene, it is found that the various accumulation and decay patterns are observed in each material. The results seem to be useful and be helpful to progress in the reliability of the polymers for the spacecraft.

**Key Words** : Decay processes, E-beam irradiated polymers, Elevating temperature

## 1. Introduction

The polymeric materials used for the spacecraft are demanded a stable performance in the environment of temperature change from -120 to 150 oC under irradiation of high energy charged particles. Since there were few methods to observe the charge distributions in the irradiated polymeric materials by charged particle, it had been difficult to analysis about, so-called "internal charge". Therefore, we have been developing the measurement system using pulse electro-acoustic (PEA) method [1] to observe the charge distributions in dielectric materials under charged particle irradiation. Since, the measurement, however, have beencarried out at room temperature, the dependence of the internal charging on temperature change have not been clear yet. Fortunately, we have an experience to measure the charge distribution at high temperature using an originally developed system [2], we have applied the system to observe the decay processes of accumulated charge in the e-beam irradiated polyimide during elevating temperature [3]. Using the system, we can not measure only charge distribution in polymeric materials during elevating temperature, but we can also measure the external current, which is, so-called, thermally stimulated current (TSC), simultaneously. Since the simultaneous measurement of PEA and TSC makes it possible to calculate the conduction current during the decay process, wecan analyze the details of the decay processes [2]. In this report, we have observed the decay processes of accumulated charge in e-beam irradiated polyimide and polystyrene. The polystyrene is said that its performance against the irradiation is superior to the polyimide [3, 4].

## 2. Experimental

Figure 1 shows the PEA system for measurement of the space charge distribution in polymeric materials. Since the space charge distribution is measured by applying the high voltage narrow pulse to the sample, the electrode is connected with a pulse generator. The temperature of the sample is controlled from room temperature to 150 oC using the electric band heater put on upper electrode unit.

The temperature of the sample is measured by a thermocouple inserted into silicon oil in which the sample is immersed. To obtain the space charge distribution in the sample at the high temperature, the piezoelectric transducer of LiNbO3 crystal, which has a stable sensitivity at high temperature [3], is used in the PEA system as a signal detector. In this system, an external circuit current is also measured using the digital electrometer to calculate the conduction current. To obtain all data automatically, the pulse generator, the temperature controller and a digitizing oscilloscope are controlled using a personal computer. Details of measurement principle are described elsewhere [1-2].

The samples used in the experiments are commercially available Polyimide and Polystyrene films with thicknesses of 125 and 250 m, respectively. The e-beam irradiation was carried out with the acceleration energy of 70 keV for 10 or 600 seconds in vacuum at

room temperature. Table1 shows the condition of the e-beam irradiation. The TSC of e-beam irradiated sample was measured in air atmosphere by increasing the temperature under short circuit condition from room temperature to 120 oC at a rate of one oC/min.

## 3. Results and Discusion

Figures 1 shows the space charge and the electric field distributions in e-beam irradiated polyimide and polystyrene films, respectively. We observed the charge decay processes for sample which are irradiated bye-beam for 10 and 600 seconds. So, in those figures, the results obtained from the samples irradiated by e-beam for 10 and 600 seconds are shown with (a) and (b), respectively. The samples were irradiated by e-beam from right side in each figure. As show in Fig. 1 (1-a), the injected electron (peak A) accumulates in the middle of the sample. When the irradiation period becomes longer, we can observe the charge distribution changed obviously. As shown in Fig.1 (1-b), it is not found only the negative charge(peak B), but it is also found the positive charge (peak C). It is assumed that when the irradiation period is longer, the positive charge come appear in the bulk of the polyimide film. The reason why the positive charge appears with longer e-beam irradiation has not been clear yet. It maybe, however, thought that the longer irradiation period makes the possibility of the ionization higher. The electric field distributions are also different between samples irradiated for 10 and 600 s. In polyimide irradiated for 10 s, the maximum electric field in the sample is near irradiated surface of the sample as shown in Fig.1 (2-a). On the other hand, that in the sample irradiated for 600 s, the maximum electric field is located at the middle of the sample. In the case of polystyrene, only negative charge accumulation was observed in the sample irradiated for both 10 and 600 s. The charge and the electric field distribution patterns in this sample are similar to those observed in polyimide as shown in Fig.1 (1-a) and (2-a).

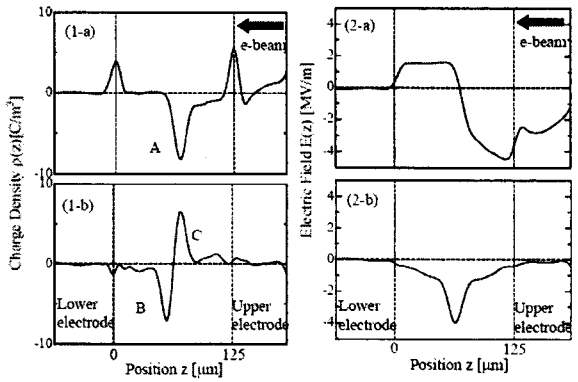


**Fig. 1.** Charge (1) and electric field (2) distributions in e-beam irradiated polyimide film for (a) 10, (b) 600s, respectively.

Fig. 2 shows the TSC curves obtained by measuring the external current during elevating temperature of e-beam irradiated samples. We calculated the conduction currents from those results. Details of the calculation of conduction current are described elsewhere [3].

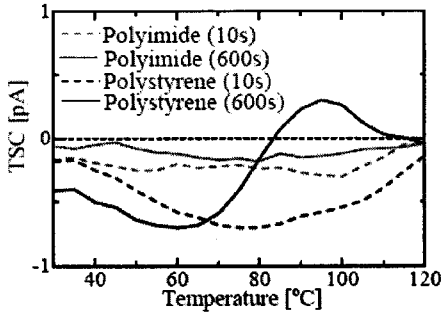


**Fig. 2.** TSC curves obtained by measuring the external current during elevating temperature of e-beam irradiated samples.


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