E-beam 조사하에서 유리의 전하 측정

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Charge Accumulation in Glass under E-beam irradiation

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Abstract : Charging of spacecraft occurs in plasma and radiation environment. Especially, we focused on an accident caused by internal charging in a glass material that was used as the cover plate of solar panel array, and tried to measure the charge distribution in glass materials under electron beam irradiation by using a PEA (Pulsed Electro-Acoustic method) system. In the case of a quartz glass (pure SiO_2), no charge accumulation was observed either during or after the electron beam irradiation. On the contrary, positive charge accumulation was observed in glass samples containing metal-oxide components. It is found that the polarity of the observed charges depends on the contents of the impurities. To identify which impurity dominates the polarity of the accumulated charge, we measured charge distributions in several glass materials containing various metal-oxide components and calculated the trap energy depths from the charge decay characteristics of all glass samples.

Key Words : Space charge formation, E-beam irradiation, Spacecraft, Plasma

1. Introduction

Space charging by radioactive rays can be classified as surface charging and internal charging. Surface charging is the phenomena of charging the surface of thermo-control material used at the surface of the satellites by plasma with energy lower than 10k eV, while internal charging is the phenomena that high-energy electrons or protons penetrate into materials and accumulate to form internal charges.[1]

In this study, high-energy electrons from an electron-beam accelerator are used to simulate space environment and to radiate glass materials. Characteristics of charge accumulation and decay during and after the electron-beam irradiation are measured by using the PEA method. It is the aim of this paper to evaluate trap energy depths for accumulated charges from the charge decay characteristic and to investigate the behavior of charges in glass materials.

2. Experiment

Table 1 shows the chemical component of glass samples used in this experiment. The basic component of these glass samples is SiO_2. Alumina Al_2O_3 is added to improve their electric property, while metal-oxide compounds such as oxide calcium CaO, oxide sodium Na_2O and oxide magnesium MgO are added to decrease their melting points and improve their characteristic of dielectric, mechanical stress and so on. The size of the samples is 3.0cm x 3.0cm and their thickness is about 1.0 mm. Both surfaces of the samples are evaporated with aluminum electrodes.

Table 1. Chemical component of glass materials and relative dielectric constant

	Chemical Composition (%)								Relative dielectric constant ε_r
Sample	SiO_2	Al_2O_3	CaO	MgO	Na_2O	B_2O_3	Fe_2O_3	Zr_2O_4	
Quartz glass	99.99	-	-	-	-	-	-	-	4.2
NE-Glass	52~56	12~16	0~10	0~5	0~1	15~20	-	-	5.1
T-Glass	65	23	<0.01	11	<0.1	<0.01	0.1	<0.1	5.8
E-Glass	52~56	12~16	15~25	0~6	0~1	8~13	-	-	6.4
C-Glass	60~65	2~6	15~20		8~12	2~7	-	-	7.5

3. Result and Discussion

Figure 1 shows the space charge distribution in T-glass. Negative charges which were irradiated as electron beam were observed in the bulk. The similar measurement result was obtained in NE-glass. Figure 2 shows the space charge distribution in E-glass. Positive charges were observed in the bulk of sample, though negative charge particles were irradiated to the samples. The similar measurement result was obtained in the bulk of C-glass.

The time-dependent characteristics of charge accumulation and decay processes in four glass materials during and after electron beam irradiation are summarized in Figure 3. The vertical axis represents the total amount of charges accumulated in these glass materials that are calculated from the measured space charge distributions using PEA method. It is observed that negative charges accumulated in T-glass and NE-glass, while positive charges accumulated in C-glass and T-glass, and that the amounts of these accumulated charges become saturated after 3 minutes' irradiation. The amounts of negative charges were 7 times larger than that of positive charges.

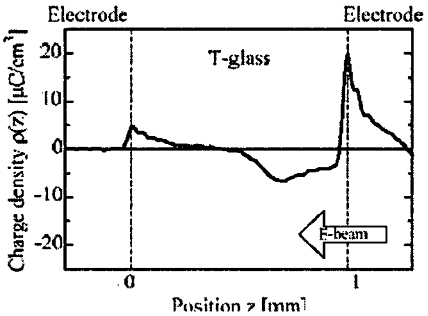

Fig. 1. Negative charge accumulation in T-glass irradiated electron beam.

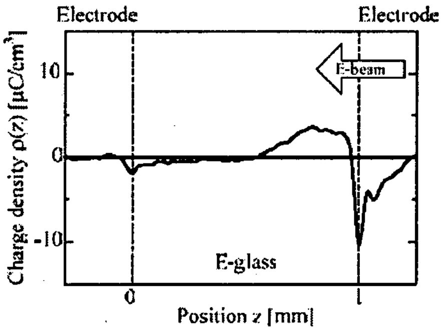

Fig. 2. Positive charge accumulation in E-glass irradiated electron beam.

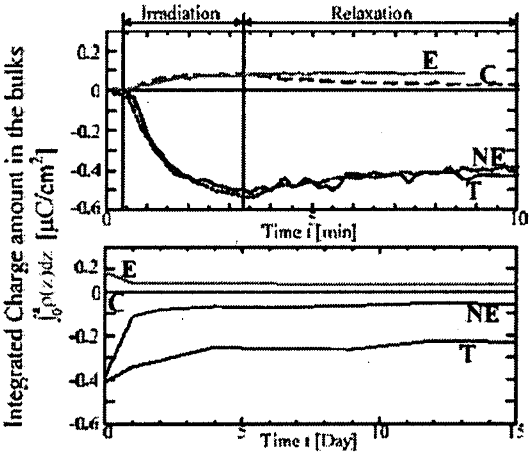

Fig. 3. Comparison between the time dependence of the charge accumulation and decay process in glass samples during and immediately after electron beam irradiation.

Because the glass materials that were used in this study contain alumina and other metal-oxide components, the experimental results show that the characteristics of charge accumulation and decay and the polarity of the accumulated charges depend on their component. It is considered that the characteristic of charge accumulation in these glass materials depends on the trap energy depth of charges that were accumulated by their component, and thus their trap energy depths are calculated from the charge decay characteristic. The trap energy was calculated using the equation (1).

$$\kappa(z) = \rho(z,0)\,\mu_o \exp\left(-\frac{q\phi}{kT}\right) \qquad (1)$$

κ(z) is a conductivity at each position of bulks was calculated from charge decay characteristic form PEA results. ρ(z,0) is a measurement results of charge accumulation at each position of samples. μ0 is intrinsic mobility is measured by the time-of-flight method. Because trap energy ϕ is included in Boltzmann function, ϕ can be calculated.

4. Conclusion

To study the charging phenomena in glass materials, the characteristics of charge accumulation and decay processes in various glass materials under high-energy electron beam irradiation were investigated. The findings can be summarized as follows.

1) No charge was observed to accumulate in quartz glass under electron beam irradiation. Because no trap center formed by impurities exists, the irradiated electrons extinguish toward the grounded electrodes through the conduction band.
2) Similar to the case of polymeric materials, negative charges accumulated glass materials that contained a larger amount of alumina. The alumina became the trap centers for capturing electrons and the irradiated electrons are captured to form the negative.

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References

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