전자빔 조사중 유리의 전하축적

조재철[1], 황종선[2]
[1]동신대학교, [2]남도대학

Charge Accumulation in Glass under Electron Beam Irradiation

Jae-Chul Cho[1], Jong-Sun Hwang[2]
[1]Dongshin University, [2]Namdo Provincial College

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.

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, 2]

When the glass plate for covering solar panel array is irradiated by high-energy electrons or protons, these charging particles may penetrate into the insulating glass plate and accumulate to form internal charges. These accumulated charges may possibly cause breakdown to the electrical insulation of the glass material by increasing an internal electrical field. As a result, the internal charging may cause accidents by rapidly lowering down the power supply from the solar panel array. Therefore, direct measurement of the charge distribution accumulated inside glass materials used for solar panel array under the irradiation of high-energy particles is very important for clarifying the origins of the accidents in the satellites and prolonging the lifetime of satellites. 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.

To simulate such a space environment, the electron beam from an electron accelerator was adopted. The condition for radiating electron beam is 500 kV for the acceleration voltage and 150nA/cm2 for the current density. Glass samples were irradiated by the electron beam at room temperature (approximately 20 C) and normal atmosphere. The measurements of space charge distribution were performed every 10 seconds for 3 minutes during the irradiation and for 7 minutes immediately after the irradiation. After that, data during the charge decay process were measured for 15 days after the irradiation.

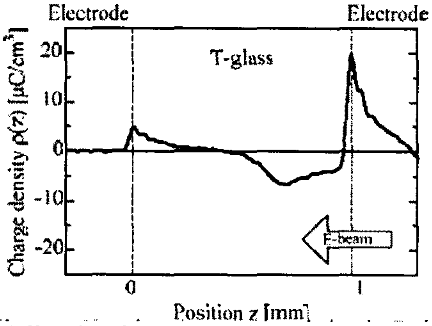
<Table 1> Chemical component of glass materials and relative dielectric constant

	Chemical Composition (%)								Relative dielectric constant ε
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

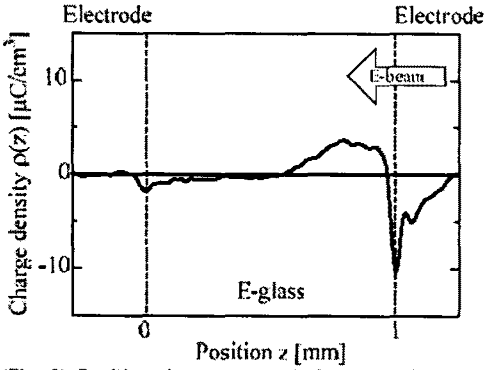
3. Result and Discussion

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.

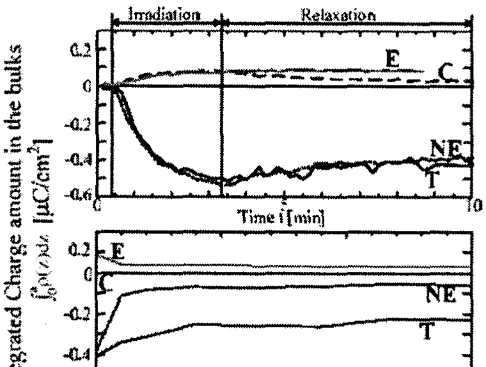
The time-dependent characteristics of charge accumulation and decay processes in four glass materials during and after electron beam irradiation are summarized in Figure 3. The vertical axis represents the total amount of charges accumulated in these glass materials that are calculated from the measured 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.

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. 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.

[Acknowledgement]

This work was finally supported by MOCIE program (I-2006-0-092-01).

[References]

[1] H. C. Koons, J. E. Mazur, R. S. Selesnick, J. B. Blake, J. F. Fennell, J. L. Roeder and P. C. Anderson, "The Impact of the Space Environment on Space Systems", Proceedings of the 6th Spacecraft Charging Technology Conference, Air Force Research Laboratory, pp.7-11, 1998.

[2] H. Miyake, Y. Tanaka, T. Takada and R. Liu, "A New Method for Determination of Trap Energy Depth from PEA Measurement Alone", this papser will be published on Proceedings of ISH2005, Beijing, 2005.