# E-빔 조사하에서 유리의 전하축퇴 특성

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# Characteristics of Charge Accumulation in Glass Materials under E-Beam Irradiation

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**Abstract** : Space charge formation in various glass materials under electron beam irradiation was investigated. 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. Furthermore, the dependence of the polarity of accumulated charges on the component of glass materials is discussed by using the models of energy bands.

**Key Words** : Space charge, Glass material, E-beam irradiation, Charging of spacecraft

## 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]

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. Experimentals

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.

## 3. Results and Discussion

**3.1 Positive charge observation in E-glass & C-glass**

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.

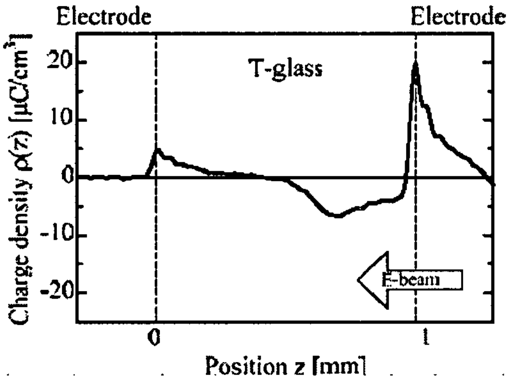


**Fig. 1.** Negative charge accumulation in T-glass irradiated electron beam.

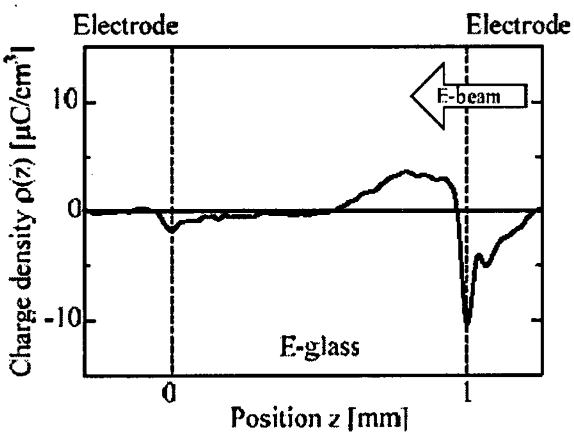


**Fig. 2.** Positive charge accumulation in E-glass irradiated electron beam.

**3.2 Comparison between the charge ccumulation polarity and contained oxide metal components**

Figure 3 shows graphically the components of these glass materials. The negatively charged T-glass and NE-glass are shown on the right side, while the positively charge E-glass and C-glass are shown on the left side. In T-glass and NE-glass, negative charges were accumulated during the irradiation. It contains a large amount of alumina (Al2O3) compared with the containing amount of oxide metal component ($Na_2O$, CaO, MgO). Therefore, the alumina ($Al_2O_3$) is considered to act as the trap center for capturing the injected electrons. In E-glass, positive charges accumulated during the irradiation and decayed relatively slow. Although it contains 16 % alumina ($Al_2O_3$), it also contains more than 24 % metal oxide component (CaO, MgO and $Na_2O$). Therefore, it is speculated that those metal-oxide compounds are the origin for positive charge accumulation.

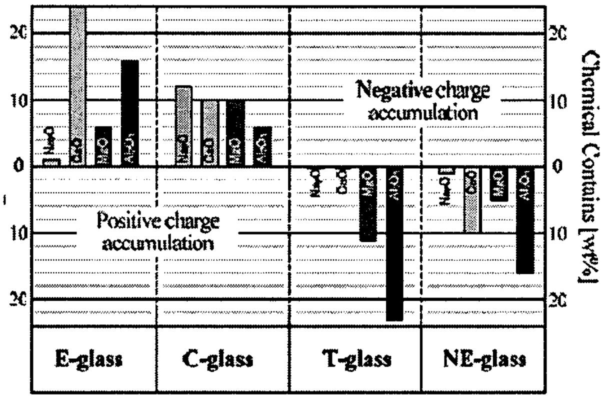


**Fig. 3.** Comparison between the time dependence of the charge accumulation and decay process in glass samples during and immediately after electron beam irradiation and the contained metal components in glass.

## 4. Conclusions

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

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## References

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