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Cathodoluminescence study on silica glass under electron irradiation

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Electrostatic discharges in the solar panels on geosynchronous spacecrafts are a suspected cause of their anomalous operation. The accidents involving the electrostatic discharge in the space environment must be deeply related with an interaction between dielectric materials and high-energy charged particles. The high energy particles include electrons and protons abundant in the space environment, which are produced by unexpected solar flares. However, the detailed mechanism of the damage on the solar panels by the incident high-energy particles has not been well understood. Solar battery array comprises of the cover glass which is a typical insulator, inter connector which is conductor, and solar battery which is semiconductor. Since the inter-connector is exposed to the outer space, the inter connector is expected to be negatively biased against the plasma, while the cover glass keeps almost the same potential. Therefore, electric discharge can occur at the triple junction of the plasma, cover glass, and inter connector by a localized high electric field. Furthermore, the electric discharge absorbs charges from the insulators charged by the exposure to the energetic particles by sub-storm and they can grow into sustained or sometimes damaging arc. This phenomenon can lead to the power loss or permanent damage of the solar battery on a spacecraft.

Generally, valence electrons of insulators such as glass are excited by the incident high-energy particles from the ground state to the conduction band. This leads to the formation of electron-hole (e-h) pairs, or weakly bound e-h pairs, so-called excitons. When the recombination of the e-h pairs or the excitons is accompanied by emission of photons, a luminescence phenomenon can be observed. In particular, the luminescence phenomenon induced by electron beam irradiation is called cathodoluminescence (CL).

When the positive or negative charges created by the electron beam irradiation are trapped at the site of defects or impurities, the change in CL intensity is expected due to the decreased numbers of the recombination of e-h pairs or excitons. Also, induced defects in insulators by the incident high-energy electrons can act as trapping sites for the charges. Therefore, useful information on the deterioration mechanisms of the insulators including charging phenomena under extreme environments like the outer space can be gained through the CL measurements.

In this paper, we studied electron beam irradiation effects on silica glass for better understanding of the charging phenomena. We evaluated irradiation effects by a keV-order electron beam through the measurements of CL spectra and their time response for various types of silica glass with different concentrations of impurities.

We studied electron-beam irradiation effects on various glass including thermal oxide films, silica, and silicate glasses. We observed intrinsic luminescence band due to the radiative recombination of self-trapped excitons in silica glass at 460 nm by the CL measurements. The luminescence bands due to impurities were observed at 300-400 nm and 650 nm. The time response of the CL comprises increase and decay components, where the recombination of the self-trapped excitons is affected by the presence of impurities and by electron-beam-induced defects. In addition, the intermittent emission of light by an electric discharge was observed for less-pure silica. By the CL measurements, we can monitor the emission of e-h pairs or excitons involving trapping and detrapping processes of electrons and holes in glasses under electron-beam irradiation. Further study on the CL on insulators such as silica-based glass gives insight into the charging effects of insulators used in spacecrafts.