Diverse Light Emissions from Epoxy Due to Energetic Electron Bombardment

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# Abstract

Dielectric materials subjected to energetic electron fluxes can emit light in several forms. We have observed three different types of emissions: (i) short duration (<1 ms), high-intensity electrostatic discharge (ESD) or “arc” events; (ii) intermediate-duration, high-intensity events which begin with a bright arc; followed by an exponential decay of intensity (<10 to 100 sec decay constant); termed “flares”; and (iii) long-duration, low-intensity emission, or cathodoluminescence. That continues as long as the electron flux is on. These events were studied for bulk samples of bisphenol/amine epoxy, using an electron gun with varying current densities (0.3 to 5 nA/cm²) and energies (12 to 40 keV) in a 0.1 micron vacuum chamber. Light emitted from the sample was measured with high-sensitivity visible and near-infrared video cameras. We present results of the spatial and temporal extent for each type of event. We also discuss how absolute spectral radiance and rates for each type of these events are dependent on incident electron current density, energy, and power density and beam uniformity. Applications of this research to spacecraft charging and light emissions are discussed.

# Results

Three types of photon emission were studied for bisphenol/ammine epoxy. Studies were conducted for 36 epoxy dots of ~1 mm diameter. Some epoxy dots were more active than others. A key objective of the study was to understand the variability of the magnitudes of these light emissions and their rates.

## Cathodoluminescence

The intensity of cathodoluminescence for a given incident electron energy and current was approximately constant, as long as the beam was on. For the low current densities used in these tests, the relation between current density and spectral radiance is linear. To compare spectral radiance vs energy, we scaled intensity to a constant current density of 10 nA/cm², approximately equal to the current in typical space weather storm conditions. Scaled spectral radiance was plotted vs. electron energies showed a linear relation, that is intensity scaled with incident power density (current density times beam energy).

To gauge the severity of epoxy cathodoluminescence during a typical storm, the scaled spectral radiance is compared to the faint background glow or zodiacal background. Our results show that a patch of epoxy in the direct optical path of a telescope is 3X to 10X brighter than this zodiacal background.

## Flares

Flares were manually counted for each epoxy dot spectral radiance vs time graph after smoothing. Flare rates are shown in Table 1. Flares were defined as a sudden jump in intensity with a return toward baseline levels over 10-100 sec. Flares were identified at ~10 nA/cm², approximately equal to the current in typical space weather storm conditions. For electron fluxes and energies similar to the space environment bisphenol/amine epoxy produced photon emissions larger than the contamination from the zodiacal background. The cathodoluminescence of this sample exhibited a linear correlation to electron energy. It was also found that the rate at which flares occurred was related linearly to the incident electron energies at a constant electron flux.

# Experimental Methods

Data were collected by Justin Dekany (USU), Chuck Bowers (NASA/GSFC), and Todd Schneider (NASA/MSFC) at MSFC.

- **Sample Preparation**: Sample was mounted inside a vacuum chamber, which was cooled to ~120 K.
- **Electron beam**: Electron beams of known energy (12-40 keV) and flux density (<5 nA/cm²) were used to bombard the sample.
- **Current density**: Current density from the sample was monitored with electrometers.
- **Scanning electron microscopy (SEM)**: SEM images were analyzed by a MATLAB program to determine average intensity per pixel for sample and background regions.
- **Camera**: Background signals were subtracted.
- **Data analysis**: Data were multiplied by a calibration factor to obtain the absolute spectral radiance for each sample (epoxy dot area).

# Conclusion

Three types of photon emission were observed for bisphenol/ammine epoxy: arcs, flares, and cathodoluminescence. A large range of sample activities was observed possibly because of variations of size, shape, placement, contaminants, and electron beam profile. For electron fluxes and energies similar to the space environment bisphenol/amine epoxy produced photon emissions larger than the contamination from the zodiacal background. The cathodoluminescence of this sample exhibited a linear correlation to electron energy. It was also found that the rate at which flares occurred was related linearly to the incident electron energies at a constant electron flux.

# References