Modeling the Energy Dependent Cathodoluminescent Intensity of a Carbon Composite Material

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Recommended Citation  
Justin Christensen, Kelby Peterson, Justin Dekany and JR. Dennison, “Modeling the Energy Dependent Cathodoluminescent Intensity of a Carbon Composite Material,” American Physical Society Four Corner Section Meeting, Utah Valley University, Orem, UT, October 17-18, 2014.

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Introduction

Motivation:
- Spacecraft accumulate charge due to ion/electron bombardment in the space-plasma environment. 
- One third of spacecraft anomalies are caused by electrostatic discharge. 
- Highly diversified insulating materials can emit photons under energetic electron bombardment. 
- In space-based observatories, this can cause harmful light contamination. 

What are we looking at?
- Three forms of electron-initiated photon emission have been observed (see Fig. 2).
  - Glow: Cathodoluminescence (termed “glow”) is a continuous light emission with intensity proportional to electron energy and current density.
  - Flares: Longer-duration rise in photon intensity. Began with arc, then intensity exponentially decays (decay constant of ~100 s).
  - Arc: Short (~1 ms) flashes caused by rapid discharges of electrons inside a charged sample.

Study investigates what conditions (incident energy, current, material size) affect the
- Onset of events
- Rates (flares, arcs)
- Intensity
- Saturation effects

Electron Flux:
- Sensors: Monitored current flux density.
- Measurements: In-situ and remote.

Results

Glow:
- For low electron power densities, glow intensity is proportional to the electron power density. (See Fig. 5).
- For high electron power densities (~80 μA/cm²), glow intensity falls off due to saturation. Estimated saturation dose rate is 420 μW/cm² (~30%) (see Fig. 5).
- Statistical analysis of large (36 epoxy dots) sample population reduces error by 6X. 

Flares:
- Observed electron power density threshold below which flares do not occur (30 μA/cm² ~40 μA/cm²) (See Fig. 6(a)).
- Flares have an exponential decay constant (79.4 ± 0.6 s) similar to decay times for initial charging and saturation effects for glow.
- Flares emit light over entire area of epoxy dots (see inset of Fig. 2).

Arcs:
- Arcs are localized (see Fig. 3(a)).
- Analysis of individual epoxy dot data reduces estimates of stray light contamination, lowers arc detection threshold.
- Estimated arc rate (see Fig. 7(a)) is ~2X that from simultaneous analysis of all the epoxy dots.
- No statistically significant correlation over a 1 s interval. 10 mm. No statistically significant correlation over a 1 s interval. 

Analysis

- Xybion camera calibrated absolutely to NIST-calibrated smoke source.
- Minimum observable absolute spectral radiance (light intensity) was ~6 x 10^(-13) W/cm²-nm-sr (or about 1% of zodiacal stray light background) at typical solar wind electron fluxes.
- Analyzed 36 separate epoxy dots (~25 μA/cm²) to minimize measurement uncertainties statistically.
- Matlab® program extracts pixel data from individual video frames from 36 user-defined spatial regions.
- Igor® program calculated average and standard deviation of pixel values for each region of pixel values for each region for successive frames. Removed stray light contamination and converted to absolute spectral radiance.
- Spectral radiance versus time profiles analyzed to determine glow intensity, arc rate and duration, flare rate and rate decay as incident electron energy and current density were varied.

Conclusions

- Statistical analysis of larger sample set reduced uncertainties of glow intensity and arc and flare rates.
- Higher rates of arcs and flares were observed, as statistical analysis of numerous individual epoxy dots lowered the detection threshold, when compared to previous analysis of a single epoxy dot or a cumulative average of all epoxy dots.
- Analysis of individual epoxy dot profiles made saturation effects more discernable.
- Arcs were identified as localized phenomena, in contrast to glow and flares evident over full epoxy dot surfaces.
- For bisphenol/amine epoxy, the best estimates for these measured material properties are:
  - Glow: 1.98 ± 0.04 10^-9 [W/cm²-nm-sr per μA/cm²]
  - Flare Rate: 0.070 ± 0.025 Flares/(hr/μA/cm²)
  - Power Law: 10^-9 [W/cm²-nm-sr per μA/cm²] Saturation/Desaturation time constants (~12 ± 1 s)
  - Flare decay constant = 79.4 ± 0.6 s

Application and Future Work

- This type of analysis is critical when designing and building space-based observatories due to their sensitivity to stray light contamination.
- By measuring the spectra of light emitted from a material it is possible to determine what the material is. This could be used to remotely monitor spacecraft.
- Better understanding of arcs might result from ongoing analysis of correlation between emission intensity and electrometer data.
- More accurate materials properties can be obtained by normalizing individual epoxy dot results by area of each dot.

Acknowledgements

Supported through funding from NASA Goddard Space Flight Center

References

2 D. Leach and M.B. Alexander, "Failures and anomalies attributed to spacecraft charging," NASA Reference