Synergistic Models of Electron Emission and Transport Measurements of Disordered SiO2

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**Recommended Citation**

Dennison, JR; Gillespie, Jodie Corbridge; Andersen, Allen; Jensen, Amberly Evans; Wilson, Gregory; Dekany, Justin; Sim, Alec M.; and Hoffmann, Ryan, "Synergistic Models of Electron Emission and Transport Measurements of Disordered SiO2" (2016). 14th Spacecraft Charging Technology Conference. *Posters*. Paper 33. [https://digitalcommons.usu.edu/mp_post/33](https://digitalcommons.usu.edu/mp_post/33)

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Synergistic Models of Electron Emission and Transport Measurements of Disordered SiO₂

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Introduction

A critical component in the prediction and mitigation of spacecraft charging issues is an accurate model of the charging, transport and electron emission properties of a broad array of materials used in the construction of spacecraft. The increased sensitivity, longer-duration missions, and ventures into more demanding environments only serve to heighten this need. One important way for the spacecraft charging community to address this issue is to expand the role of more fundamental materials physics. This includes the development of unifying theoretical models of the charge transport equations based on the creation, distribution, and occupancy of defect densities of states. Models of electron emission and transport measurements that emphasize the synergistic relation between fitting parameters for diverse measurements—for example, defect energies or distributions and transition rates from one state to another—can also lead to a better understanding of materials and facilitate solutions to spacecraft charging.

We present a materials science perspective, with results of many different measurements on similar samples of a single common insulating spacecraft base material, disordered silicon dioxide. Measurements include time, field, and temperature-dependent: conductivity, radiative emission yields and spectra, surface voltage, and decay, cathodoluminescence, electrostatic discharge, endurance time, and optical transmission. We emphasize the emerging—though as yet incomplete—band structure and defect density of states model of disordered silicon dioxide that can be pieced together and cross checked through careful consideration of the diverse results. We also discuss how developing such models for common spacecraft materials lead to new models to predict behavior outside of measured parameters as well as predicting behavior in future useful materials.

Conductivity vs Time

Conductivity vs Temperature

Surface Voltage Charging and Discharging

Surface Voltage Relates to “Intrinsic” Electron Yield

Conclusions

A Materials Physics Approach to the Problem

To address dynamic materials issues in spacecraft charging:

- Myriad spacecraft materials
- New, evolving materials
- Many materials properties
- Wide range of environmental conditions
- Evolving materials properties
- Feed back, with changes in materials properties affecting changes of environment

Requirements:

- Conscious awareness of dynamic nature of materials properties can be used with available modeling tools to forecast and mitigate many potential spacecraft charging problems
- For dynamic materials issues in spacecraft charging, as with other materials physics problems, synthesis of results from different studies and techniques, and development of new theoretical models allows extension of measurements made over limited ranges of environmental parameters to make predictions for broader ranges encountered in space.

Measurements with many methods:

- Complete set of dynamic transport equations...written in terms of spatial and energy distribution of electron trap states