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The Dynamic Interplay Between Spacecraft Charging, Space Environment Interaction and Evolving Materials

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Abstract

While the effects on spacecraft charging from varying environmental conditions and from the selection of different construction materials have been studied extensively, modification of materials properties by the space plasma environment can also have profound effects on spacecraft charging. This presentation focuses on measurement methods and modeling employed to assess the effects of environment-induced material modifications on physical properties relevant to spacecraft charging simulations. It also reviews several specific studies in which environment-induced material modifications have significant impact on predicted spacecraft charging.

Given the increasingly demanding nature of space missions, there is a need to extend our understanding of the dynamic nature of material properties that affect spacecraft charging and to expand our knowledgebase of materials’ responses to specific environmental conditions so that we can more reliably predict the long term response of spacecraft to their environment.

“New Frontiers” from a Materials Perspective

Ferguson’s “New Frontiers in Spacecraft Charging”

Five Cases of Dynamical Change in Materials:

- Contamination and Oxidation
- Surface Modification
- Radiation Effects (and t)
- Temperature Effects (and t)
- Radiation and Temperature Effects

Case Studies I & II—Contamination & Surface Modification

Case I: Evolution of Contamination & Oxidation

Perhaps the most obvious case of dynamical materials properties are found in the contamination of materials by the space environment. Evolution of MSISE-6 samples after 18 months in LEO (shown below).

Instrumentation at USU for study of electron emission and electron transport properties applicable to spacecraft charging (left) USU Electron Emission Test Chamber. (Right) Constant Voltage Resistivity Test Chamber.

Studies of C Contamination Evolution of SE yield as Au contaminated with this disordered C layer. This is an extreme case; Au has very high yield (>1.8 td/sq ft) and C has very low yield (~1 td/sq ft).

Case II: Surface Modification

Surface can be modified in other ways. For example, sputtering or sputtering can roughen a surface. The optical absorption coefficient, κ, changes as a function of wavelength for the range of roughening compound used. Increased absorption indicates that charging is increased through the photoelectric effect.

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Conclusions

- Satellites are complex and require:
  - Complex materials configurations
  - More power
  - Smaller, more sensitive devices
  - More demanding environments

- There are numerous clear examples where accurate dynamic charging models require accurate dynamical materials properties

- It is not sufficient to use static (BOL or EOL) materials properties

- Environment/Materials Modification feedback mechanisms can have numerous new problems

Experimentation

What do you need to know about the materials properties?

- Charge Accumulation
  - Electron yields
  - Ion yields
  - Photovoltaics

- Charge Transport
  - Conductivity
  - RIC
  - Dielectric Constant
  - EDD

- All as functions of materials species, flux, and energy.

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