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Charging Effects of Multilayered Dielectric Spacecraft Materials: Surface Voltage, Discharge and Arcing

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Electron Energy Dependent Charging Effects of Multilayered Dielectric Materials

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Abstract

In order to investigate the charging of multilayered dielectric materials, pulsed charging experiments were conducted using multilayered dielectrics of an SiO2 based material, consisting of a conductive middle layer and an SiO2 substrate. We measured the conductive layers both grounded and ungrounded. Experiments were conducted in the main USU electron emission laboratory, using wavefunctions determined for observations of low intensity UVS/VIS/NIR glow over a broad range of applied potentials. Figures 1 provide a general schematic of the experimental system used.

The samples were subjected to a pulse of 40 A/cm2 of electron bombardment using a monoenergetic electron beam with beam energies of 100-500 eV/keV an electron energy gun (Utah EK-581) was used, that can deliver a well-characterized, low-flux pulsed beam (1.5-20 A/cm2) with an energy range of 20 eV to 6 keV. The deposited electrons form a uniform beam profile of the sample with a 30% uniformity over an 8-cm diameter beam spot. Beam fluxes were monitored using a channeltron electron beam current monitor and a storage oscilloscope for current measurements and UVS/VIS and IR spectrometers, an X-ray CCD still camera, and a NIR video camera for optical measurements.

Four experiments are conducted as depicted in Fig. 6. The experiments differ in the incident energy and flux, and as we see below, produce dramatically different results. To interpret the experiments, we use both three physical phenomena—the electron range, electron yield and the electron transport (conductivity) of the material—and how they are affected by the experimental conditions.

Theory

Surface Dielectric Deposition—Ungrounded

For a 200 eV monoenergetic electron beam the electron range in disordered SiO2 is approximately 3 nm, as shown in Fig. 2(a), at this depth, the electron flux penetrates into the first layer, but the reach the conductive layer. From the model, the total yield for disordered SiO2 at this energy for a 3 keV monoenergetic electron beam is 39%, which means that the deposited charge is not limited by the deposited charge in the substrate or the conductive layer layer. Thus, we should see a surface-limiting positive net surface potential due to a net deficit of electrons; this agrees with the sign of the measured net surface potential as measured in Fig. 7(a).

Surface Dielectric Deposition—Grounded

For a 200 eV monoenergetic electron beam with a grounded substrate we expect similar behavior for the surface potentials as seen for the ungrounded substrate. Positive surface potentials is observed in Fig. 7(c), as expected.

Conductive Layer Deposition—Ungrounded

For a 5 keV monoenergetic electron beam the electron range in disordered SiO2 is ~500 nm, as shown in Fig. 2(b). This is sufficient for the electrons to penetrate through the surface dielectric and into the conductive layer. The deposited electrons form a uniform beam profile of the sample with a 30% uniformity over an 8-cm diameter beam spot. Beam fluxes were monitored using a channeltron electron beam current monitor and a storage oscilloscope for current measurements and UVS/VIS and IR spectrometers, an X-ray CCD still camera, and a NIR video camera for optical measurements.

Conductive Layer Deposition—Grounded

For a 5 keV monoenergetic electron beam with a grounded conductive layer, we again expect behavior similar to the surface potentials as seen for the ungrounded substrate. Positive surface potentials is observed in Fig. 7(c), as expected.