



In Situ Surface Voltage Measurements of Dielectrics Under Electron Beam Irradiation

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Abstract

New instrumentation has been developed for non-contact, *in situ* measurements of the electron beam-induced surface voltage of non-conductive spacecraft materials in a simulated space environment as a function of time and position. Used in conjunction with the capabilities of an existing ultrahigh vacuum electron emission analysis chamber, the new instrumentation facilitates measurements regarding charge accumulation, bulk resistivity, effects of charge depletion and accumulation on yield measurements, electron induced electrostatic breakdown potentials, radiation induced conductivity effects, and the radial dispersion of surface voltage.

The novel system uses two movable capacitive sensor electrodes that can be swept across the sample using an *in vacuo* stepper motor to measure surface charge distributions on samples *in situ*, using a non-contact method that does not dissipate sample charge. The compact transfer probe positions the electrodes just above the sample, inside an existing hemispherical grid retarding field analyzer used to make electron emission measurements. A large (7 mm) diameter electrode measures a lower surface voltage range (<10 kV) at higher resolution (<1 V); a small (3 mm) diameter electrode measures 1.5 mm resolution spatial profiles of voltage across the sample surface. The response time of the probe and data acquisition system are fast enough to acquire data for lower resistivity materials such as low density polyethylene (LDPE), with a few seconds decay times. The long term stability and drift characterization required to measure at slow rates and take data over several days on materials that have a high resistivity like Kapton necessitated use of LabView computer controlled data acquisition. Design details, calibration and characterization measurements of the system are presented, for a surface voltage range from <1 V to >40 kV, voltage resolution <1 V, and spatial resolution <1.5 mm. Extensive characterization tests with externally biased conductors were performed to calibrate the system and determine the instrument stability, sensitivity, accuracy, range, spatial resolution and temporal response.

Two types of measurements have been made on two prototypical polymeric spacecraft materials, LDPE and polyimide (Kapton HNTM) to illustrate the research capabilities of the new system. First, surface voltage measurements were made using a pulsed electron beam, while periodically measuring the surface voltage. Second, post charging measurements of the surface voltage were conducted, as deposited charge dissipated to a grounded substrate. This process allows for the collection of information about the material's electron yields and bulk resistivity. Theoretical models for sample charging and discharge are presented, based on dynamic bulk charge transport equations developed for electron charge carriers to predict the time, temperature, and electric field dependence of the sample net surface voltage. The model includes electron drift, diffusion, and displacement currents and makes direct ties to the interactions between injected electrons, which are trapped in localized states, and the magnitude and energy dependence of the density of those localized trap states within the gap; the carrier mobility, and the carrier trapping and de-trapping rates are then evaluated using the model. The good agreement is discussed between the fitting parameters of the model and the corresponding physical parameters determined from the literature and measurements by related techniques.