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Diverse Electron-induced Optical Emissions from Space Observatory Materials at Low Temperatures

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Abstract

We review laboratory electron irradiation experiments conducted to investigate the diverse electron-induced optical and electrical signatures observed in tests of various space observatory materials at low temperature. Measurements were conducted in an ultrahigh vacuum electron emission test chamber from <40-290 K, using <3-25 keV monoenergetic beams with <0.1-100 nA/cm^2 flux densities to deposit electrons near the surface. Various experiments measured electron-induced absolute photon emission yields and photon emission spectra, arcing rates and location, transport and displacement currents to a rear grounded electrode, and absolute electron emission yields. Numerous arcing events (particularly at lower temperatures) were observed, consistent with enhanced charge accumulation due to lower conductivities at low temperature. Three types of light emission were also observed: (i) short duration (<1 s) arcing resulting from electrostatic discharge, (ii) long duration cathodoluminescence that turned on and off with the electron beam, and (iii) intermediate duration (~100 s) glow—termed "flares"—that dissipated exponentially with time after infrequent and rapid onset. We discuss how the electron currents and arcing—as well as light emission absolute intensity and frequency—depend on electron beam energy, power, and flux, temperature, and thickness. The different bulk and composite insulating materials studied (fused silica thin films, M55J and T300 carbon-epoxy composites, and macroscopically-conductive carbon-loaded polyimide or Black Kapton^{TM}) provide examples of thin, thick, and multi-thickness dielectrics that can be modeled with the same simple approach to predict the dependence of light emission that might be encountered in space applications on nanoscale structure.