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Douglas Ball

Alec Sim
Utah State University & Irving Valley College

JR Dennison
Utah State University

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An electron-photon duel: cathodoluminescence in disordered polymeric materials

Doug Ball
[Mentors: Alec Sim and J.R. Dennison]

Materials Physics Group
Physics Department
Utah State University

Abstract

Sensitive optical instruments and telescopes constructed of polymeric highly disordered insulating materials (HDIM) for use in the space environment are subject to the charging induced by plasma surroundings, which can result in harmful emission of light and charge from HDIM. Recent tests have demonstrated electron induced luminescence of insulating polymeric materials using a high energy electron beam. This behavior, known as cathodoluminescence, results from incident beam electrons exciting electrons in the material from the valence band into extended energy states in the conduction band, which subsequently transition back to either the valence band or a distribution of trap states within the band gap and emit light. The time-dependent interplay between two competing electron decay mechanisms— cathodoluminescence and radiation enhanced conductivity—has been studied in epoxy resin, an HDIM. This study compares evolution of the relative amplitudes of the photon emission and the electric current signatures from the material samples as: (i) space charge accumulates in the HDIM due to the incident electron beam and (ii) before and after electrostatic discharges. Measurements were made at temperatures from ~100 K to ~300 K at various incident electron energies and current densities while the samples were in ultra high vacuum. The complex time dependent behavior observed is described in terms of a microscopic band theory based-model. Electron transport and luminescence provide two competing decay modes for these excited electrons. Thus, the simultaneous measurement of luminescence intensity and electron current can provide information about the spatial and energetic distributions of the trapped charges in the HDIM, their transition rates, and the interaction of electrons within the material. Such knowledge is critical in constructing materials used on space telescopes that can withstand the harsh space environment without impeding the telescope's mission.