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Defect-Driven Dynamic Model of Electrostatic Discharge and Endurance Time Measurements of Polymeric Spacecraft Materials

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Experimental Chamber

Charge buildup on insulating materials in the space environment can produce long exposure to electric fields, which can lead to Electrostatic Discharge (ESD). Charge buildup is the leading cause of spacecraft failure due to space environment interactions. ESD can be thought of as the point of discharge of a charge already in the material, until breakdown bound in polymeric insulating materials leads to a catastrophic change in electrical conductivity, which can cause the materials to structurally breakdown. Defects produced by radiation, or prolonged exposure to electric fields, significantly alter the endurance time, the time it takes to produce enough defects to generate a current. The literature discusses two competing theories for ESD in insulators, based on generation of either recoverable or irrecoverable defects. Such defects in the polymer chains can be produced by the electric field and result in localized trapped states for conduction. Both mechanisms are characterized by the density of electron traps and the corresponding energy to create such defects. We propose a hybrid model for the aging process that predicts the endurance time as a function of electric field and temperature. The model incorporates both types of defects with an interdependence of the two mechanisms. Measurements of the endurance time dependence on electric fields in the insulating polymer Low Density Polyethylene (LDPE) are fit against this hybrid model. Understanding the electric field dependence of the time to ESD can aid designers in selecting appropriate materials for spacecraft construction and for mitigating destructive processes.

Abstract

Endurance Time Analysis

Tests conducted in the 260±5 MV/m range were dominated by the irreversible breakdown process. Breakdown times observed in this range were on the order of a few hours to several days. Tests conducted in the 235 to 284 MV/m range were dominated by the recoverable pre-breakdown process (Fig. 5a). Breakdown times observed in this range were on the order of minutes to 1 hr.

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References