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A Dual-defect Model of Electrostatic Discharge in Polymeric Dielectrics

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Abstract

Electrostatic discharge (ESD) is a serious concern for spacecraft, high voltage power transmission, and other applications. A parallel plate capacitor geometry under high vacuum was used to apply increasing voltages across insulating samples until ESD breakdown and to apply sub-critical fields and observe time-to-breakdown. Transient arcing was frequently observed prior to complete ESD breakdown in both cases. Results are presented for two prototypical polymeric materials, low density polyethylene (LDPE) and polyimide (PI or Kapton HN™) in terms of both statistical and physics-based models.

Many electrical aging models are described by defect creation within the material from bond stress due to local and applied electric fields and by the Gibbs free energy, bond destruction energy, or cohesion energy associated with creation of these defects. A first order approximation is presented to develop an extended dynamic temperature- and ramp rate-dependent ESD model with both repairable and irreparable defect mechanisms. Repairable defects such as bond bending have energies less than or comparable to thermal energies, so that they can be readily repaired through thermal annealing; irreparable defects such as bond breaking have higher energies. The field at which pre-breakdown arcing begins was compared to the onset field for ESD for each material studied. We present evidence that these two threshold fields are the same. Therefore, the important parameter to consider in design may not be the maximum field for breakdown, as much as the defect structure and the field where pre-breakdown arcing begins in a material.

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