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Recommended Citation

Hoffmann, Ryan Carl; Dennison, JR; Wilson, Greg; and Evans Jensen, Amberly, "The Correlation Between Radiation Induced Conductivity (RIC) and Electron Beam Induced Luminescence in Disordered SiO₂" (2013). 11th IEEE International Conference on Solid Dielectrics. *Presentations*. Paper 25.
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11th IEEE CONFERENCE ON
International Conference on Solid Dielectrics

Bologna, ITALY
June 30-July 4, 2013



***The Correlation Between Radiation Induced Conductivity (RIC) and
Electron Beam Induced Luminescence in Disordered SiO₂***

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Abstract

High energy electron radiation incident on highly disordered insulating materials (HDIM) deposits both charge and energy. Quasielastic collisions of the incident electrons impart energy to the material, which can excite multiple intrinsic electrons from valence band or low level trap states into the extended states of the conduction band. These excited electrons provide a significant conduction mechanism in HDIM under the influence of applied fields, but quickly thermalize to shallow localized trap states just below the conduction band edge that are associated with structural (physical) or compositional (chemical) defects. Electrons in these shallow trap states can: (i) remain in these shallow trap states; (ii) be thermally re-excited into the conduction band, leading to thermally assisted charge transport, termed radiation induced conductivity (RIC); (iii) decay into deep traps well within the band gap, often emitting a photon which is termed cathodoluminescence; or (iv) decay to low level valence band or trap states through radiative or non-radiative processes termed recombination. The occupancy of these states depends on the number of electrons that can potentially populate the states, the number of states that can be populated, and the trapping and retention rates of the states. In turn, these fundamental quantities depend on the material structure and disorder the energetic and spatial densities of states; and the temperature, space charge, electric field, dose rate and dose. Measurements of RIC, cathodoluminescence, surface charge and dissipation currents will be presented for disordered SiO₂ over a range of temperatures, applied field, dose rates and dose. The magnitude of all four of these processes depends primarily on the power deposited in the material, and to a lesser extent on the charge deposited. Obviously, the relative likelihood of these processes are interrelated and fundamentally tied to the densities and occupation of the defect states. Simple theory based on thermally-assisted hopping conductivity and disordered band theory will be used to link these different measurements to the transition mechanisms for electrons in the shallow states. The ability of the simple theories to model the experimental results and to provide information on the trap densities of states will be assessed. This work is intended to provide a fundamental basis for understanding the dependence of electron induced electron excitation and associated decay mechanisms on temperature, applied field, dose rate, dose, and density of trap states in the band gap. Understanding of these mechanisms is of critical importance to spacecraft design and the mitigation of damaging arcing and dielectric charging events.