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Influence of thermal treatment on electrical and physical properties of coated ceramics

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ABSTRACT :

Technical dielectric materials and ceramics are used in many different high technology industrial areas and especially for spacecraft applications. On satellites, these materials are subjected to extreme conditions due to the space plasma environment. To survive, these ceramic insulators must have exceptional electrical and thermal properties. Boron Nitride (BN) and Aluminum Oxide (Al_2O_3) are used in particular because they combine good electrical insulation and high thermal conductivity. However, BN and Al_2O_3 used in spacecraft interiors are exposed to critical radiation demands, where these insulators are irradiated by electrons with high energies and flux. Charged particles are trapped in the ceramics, producing high electric fields. Subsequently, internal disturbances and electrical breakdowns can occur. Over time, these phenomena may cause degradation or failure of various components and embedded systems.

Consequently, this study endeavors to understand the physical mechanisms which occur in these ceramics materials under electron irradiation. These dielectrics materials have been characterized at ONERA Toulouse (DESP) in the CEDRE (Chambre d'Etude De Revêtement Electrisés) irradiation chamber. A parametric study was performed to assess the influence of incident energy and flux, temperature, coatings, annealing, and ionizing dose on the charging and relaxation kinetics of BN and Al_2O_3. Surface and thermal treatments were found to limit BN's charging. Dedicated treatments enhanced charge transport. To identify the effect of thermal annealing on electrical behavior in these materials, a thorough study of electron trapping processes was performed using cathodoluminescence in the Electron Emission Test facility at Utah State University. These tests explored differences in the nature and density of defect states. Together, these investigations determined correlations between chemical, structural and physical properties for each insulator's configurations. Further, we observed degradation of coatings and an evolution of the concentration of their chemical defects. Contamination and ageing effects were identified on the rough material surfaces of ceramics exposed under a critical electron flux. Therefore, treatments applied to optimize electrical properties were found to be ineffective, especially for long-term charging mitigation.

We will discuss these results and compare them for each ceramic configuration. The goal of this investigation is to understand the predominant physical mechanisms and main structural and chemical differences between these ceramic configurations in order to perform an exhaustive correlation between the properties. In future studies, we propose to define a defect-based model which can be used to optimize a material to limit both its charging and degradation over the time.