FABRICATION AND CHARACTERIZATION OF CERAMIC DIELECTRIC HIGH GRADIENT INSULATOR

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The breakdown voltage of high-voltage insulators in vacuum is lower than in air due to surface breakdown failure. In this failure mode, electrons originating at the cathode-dielectric-vacuum triple junction strike the insulator surface causing secondary electrons emission. The positive charge formed on the surface amplifies the number of secondary electrons emission giving rise to an electron avalanche resulting with a catastrophic failure of the device. One approach to overcome this failure is substitution of the dielectric insulator by a periodic metal-dielectric structure known as High Gradient Insulator (HGI). This periodic structure changes the sign of the electric field component perpendicular to the insulator surface. As a result, the incident electrons are shifted from the insulator surface, thus inhibiting the emission of secondary electrons and preventing the electron avalanche. However, the HGI structures suffer from local breakdown damages and metal evaporation from metallic layers onto the dielectric layers, creating short circuit pathways. In addition, the manufacturing of metallic-ceramic HGI has technological challenges.

In this work, we suggest an alternative concept to the HGI structure, where we replace the metallic layers with ceramic layers that have a high dielectric constant. The proposed structure is denoted DHGI (Dielectric HGI). Simulations showed that this structure can alter the electric field around the insulator similarly to the HGI. The alumina insulator and the DHGI layer used herein must be fully dense to maintain high vacuum ($P \leq 10^{-6}$ Torr). We used spark plasma sintering (SPS) to produce high-quality, dense, multilayered composites with controlled layer configuration and thickness. To reduce the stresses between the layers and increase their compatibility, the DHGI layers consisted of alumina with 8wt.% addition of a colossal dielectric coefficient material TiO_2 co-doped Al and Nb (TANO, $\varepsilon \sim 10^4$). We demonstrate the fabrication of a prototype sample composed of two layers. This poster focuses on the microstructural and phase analysis of this prototype sample. It is shown that during sintering, unique intermediate layers formed at the interface between the two original layers. We found that the grain size decreases gradually across the interface. Moreover, the DHGI prototype was found to have superior breakdown performance compared to a conventional reference pure alumina insulator.

Figure 1 – Images of the bi-layer DHGI sintered by SPS; A) Top view, B) Side view and C) schematic illustration.

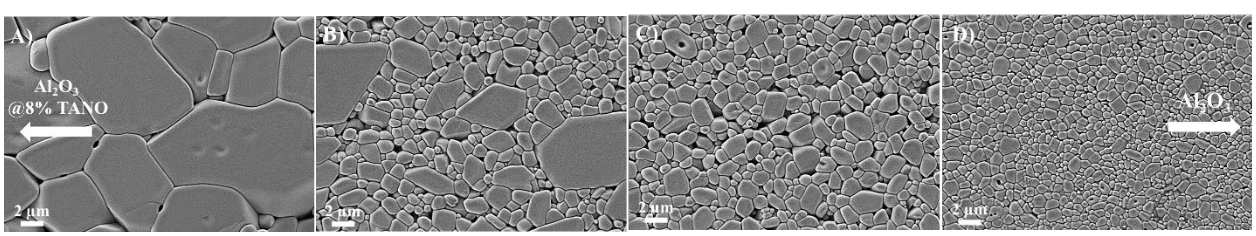

Figure 2 – SEM images of the gradually decreasing alumina grains in the L2-L3 layers between the Al_2O_3@TANO and pure Al_2O_3 layers.