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Effects of mechanical pre-stress on the dielectric strength of alumina Al2O3

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The high voltage IGBT (HVIGBT) power modules are used in railways applications to build power converters. Ceramics are used in such modules because of their high electrical insulation properties even at high temperatures, coupled with high thermal conductivity.Dielectrics fail electrically when a breakdown occurs, which leads to a formation of an electrically conductive channel through the insulator. Dielectric breakdown is scarcely understood for ceramics and alumina is one of the main ceramics used.The aim of this study is to shine a new light on the understanding of this phenomena. We have focused on the effect of a mechanical pre-stress on the dielectric breakdown voltages using polycrystalline alumina substrates.Numerous works have pointed out that the dielectric breakdown of ceramics could be strongly related to their mechanical properties. More precisely, mechanical cracks already existing in ceramics would be able to grow under the electric field. The effect of the electric field's application on the cracks propagation has been previously studied either under high electric field or under moderate field. This would lead to the propagation of the cracks until the full dielectric breakdown occurs. In order to support such hypothesis, a mechanical pre-stress have been applied to commercial alumina substrates. Mechanical stresses, ranging from 20 to 140 N and using a 3-point bending test, were applied in order to increase the length of the pre-existing cracks. Then, the dielectric strength has been measured using 50Hz HV for these samples and compared to non-pressed ones.
The evolution of the dielectric strength has been correlated with the cracks evolution during the pre-stress. This shows the contribution of the mechanical properties to the dielectric breakdown phenomena in alumina.It can be concluded that the dielectric breakdown decreases when the mechanical pre-stress increases.

Keywords: Ceramic materials, High voltage power modules, Alumina, Dielectric strength, Mechanical pre-stress

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