INFLUENCE OF CORONA DISCHARGES ON THE SURFACE CONDITION OF POLYMER INSULATORS: CHARGE INJECTION, TRANSPORT AND TRAPPING PROCESSES IN POLYMER

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The processes of charge trapping and detrapping in insulating materials play a fundamental role in their behavior under intense electric fields, particularly in the presence of corona discharges. These phenomena involve the generation, capture and release of charge carriers, such as electrons and holes, within the dielectric. Under the effect of plasma or a high electric field, free electrons are produced by molecular ionization, while holes appear through the extraction of electrons from molecular bonds [1]. Once generated, these charges can be trapped in localized energy states within the material, classified as deep or shallow traps according to their energy level [2]. Trapped charges modify the local electric field, influence electrical conduction and accelerate material ageing, notably through chemical and physical degradation mechanisms. Trapping can be induced by intense electric fields, high temperatures or interactions with other charge carriers, facilitating charge transport in the material through effects such as the Poole-Frenkel mechanism [3].

To study these mechanisms in composite insulators subjected to corona discharges, a 2D axisymmetric model based on the finite element method was developed using COMSOL Multiphysics®. This model couples the plasma hydrodynamic equations describing the corona discharge with the processes of charge trapping and detrapping in the dielectric. Plasma in air is governed by 12 charged and neutral gas species and nearly 30 chemical reactions in air. The accumulation of charges from the plasma triggers the trapping and detrapping processes in the solid insulating material. Simulations are used to analyze the spatio-temporal evolution of the electric field, electron density and surface potential of the insulator. Initially, the intensity of the corona discharge increases due to the accumulation of charges, before gradually stabilizing. The surface potential of the composite insulator reaches a state of saturation, while its radial gradient decreases under the effect of charge diffusion. Mobile electrons penetrate the dielectric towards the grounded electrode, although many are trapped by holes, limiting charge transport to a shallow depth in the material. In addition, lateral charge migration is observed along the dielectric surface under the influence of surface charges accumulated at the gas-solid interface.

These results shed new light on the mechanisms of charge transport in polymer insulators subjected to corona discharge and high electrical stress and contribute to optimizing their performance and durability in high-voltage applications.

Word count: 378

References

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[3] P. Mainali, P. Wagle, C. McPherson, and D.N McIlroy, Sci 2023, 5, 3.

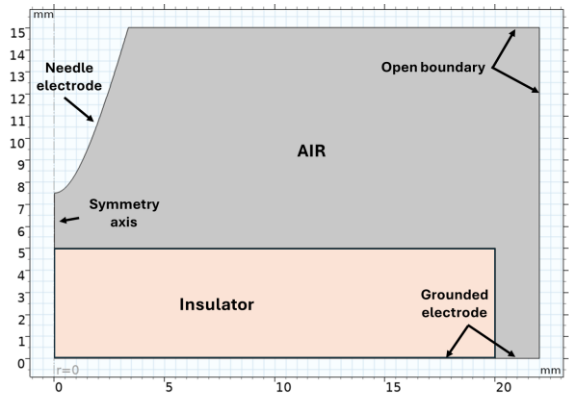

Figure 1. Simulation geometry distribution of the computational domain.

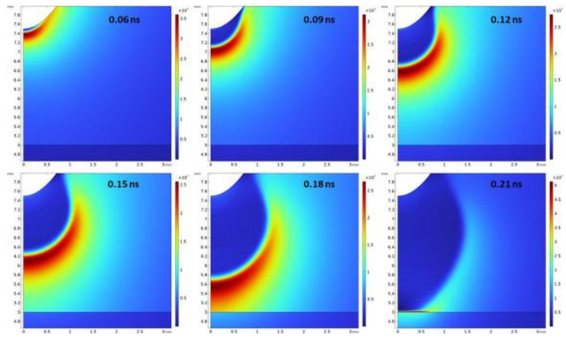

Figure 2. Spatial distribution of the electric field during the development of the streamer in the gas gap.

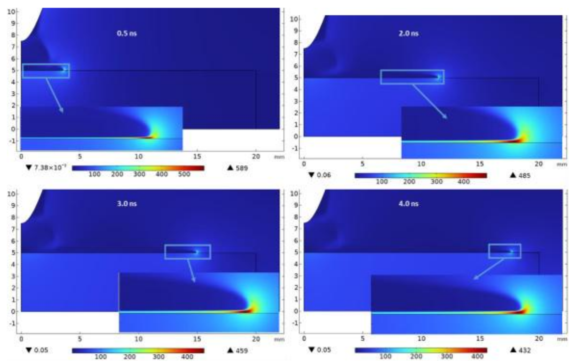

Figure 3. Electric field profiles (kV/cm) at different times along the solid dielectric surface.

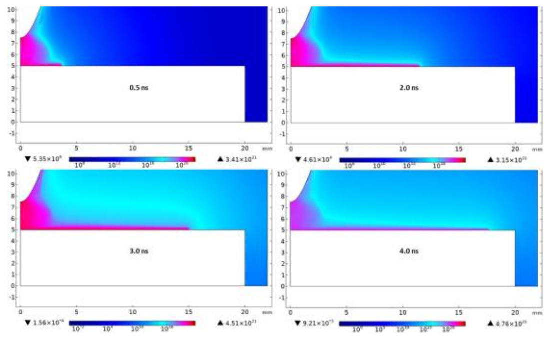

Figure 4. Electron density profiles (m-3) at different times along the solid dielectric surface.

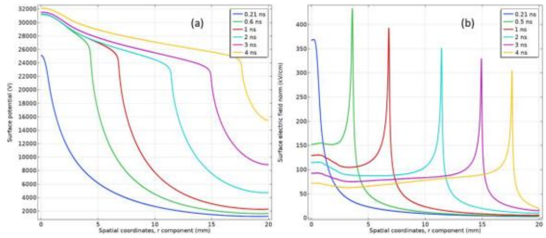

Figure 5. Surface potential distribution (a) and surface electric field distribution (b) along the interface between the gas and the solid dielectric.

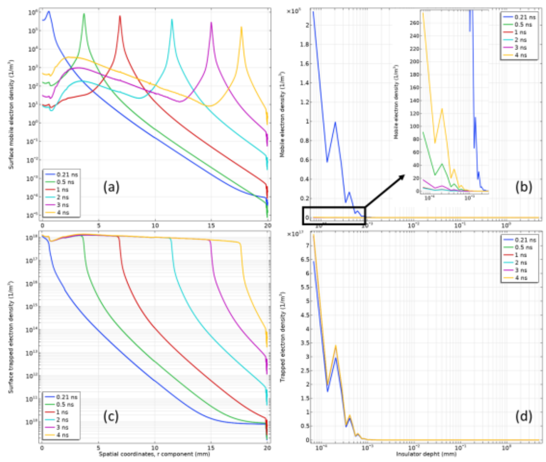

Figure 6. Distributions of the mobile and trapped electron densities along the inner surface of the insulator (a & c) and along the axis of symmetry of the insulator (b & d).