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Dynamics of nanosecond discharges in air in-contact with water

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The application of a high E-field to a dielectric medium can induce ionization. The breakdown field of air at atmospheric pressure is around 30 kV/cm. If the electron avalanches produce more than ˜10e8 charged species (Meek's criterium), an avalanche may transition to a streamer. The space charge field produced at the streamer head may exceed the breakdown field and supports its propagation in the medium. While the propagation of streamer in air is relatively well-understood, its interaction with solid or liquid surfaces complicates our understanding of the propagation mechanisms. More specifically, the properties of the material in front of the discharge, such as dielectric permittivity (ε_r) and electrical conductivity (σ), strongly influence the discharge dynamics. To investigate the influence of ε_r and σ on the discharge dynamics, we utilized liquids with varying permittivity (ranging from 32 to 80) and conductivity (ranging from 2 to 1000 μS/cm). The discharges were generated using single-shot nanosecond high voltage pulses and characterized both electrically and optically using ICCD images. Streamer propagation across a surface is primarily sustained by surface charging and charge accumulation. Accordingly, a decrease in ε_r accelerates surface charging, leading to more significant radial propagation, while an increase in σ results in the dissipation of surface charge accumulation in air from the ions present in the liquids, leading to reduced radial propagation. On the other hand, a 2D axisymmetric cylindrical fluid model is developed. The model consists of solving the fluid equations for the density of electrons, positive ions, and negative ions. The model is adapted to simulate the various conditions of ε_r and σ of the material in front of the discharge. The emission of the discharge acquired during its propagation is compared to the source term of electron impact avalanches. Such a simulation allows the determination of some fundamental properties that are hardly accessible experimentally such as the spatio-temporal evolution of the species density, the space charge density, and the E-field. The results are further processed to discuss the evolution of the pattern, particularly the disc-to-ring-to-dots transitions.

Keyword-1

nanosecond discharges

Keyword-2

plasma-water interaction

Keyword-3

fluid simulation

Authors: Prof. HAMDAN, Ahmad; HERRMANN, Antoine

Presenter: Prof. HAMDAN, Ahmad

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