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INFLUENCE OF FREQUENCY IN FILAMENTARY AND UNIFORM APD USING THREE-DIMENSIONAL FLUID MODEL

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Introduction:

In recent years, the homogeneous uniform atmospheric pressure discharges have been attracting our attention for their effective use in industrial and biological applications, for instance, semiconductor industry and sterilization of biological samples but the emergence of sudden non-uniform behavior in the breakdown phase still demands a special attention for their practical utilization [1 - 3].

Numerical Simulation Results and Discussion:

In this paper, a close examination of discharge characteristics is performed with three-dimensional fluid model and the conditions under which the uniform and non-uniform discharge plasma regimes are evolved in the breakdown phase.

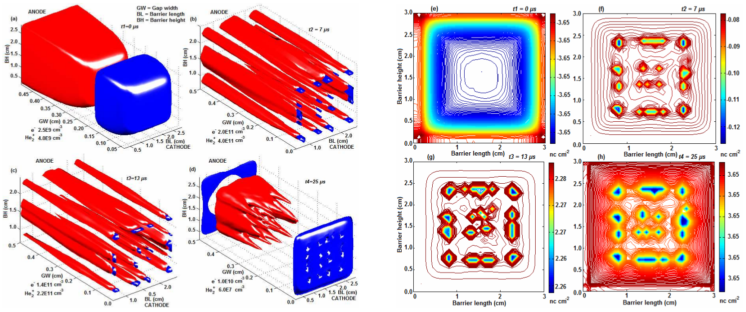

Fig. 1: Electrons and He_2^+ ions density (a - d) and surface charge density (e - h) at 10 kHz and 1.6 kV.

The space and time characteristics of electrons and molecular helium ions density are explored from time t1 = 0 to t4 = 25 μs for a breakdown pulse at 10 kHz, which precisely cover the distinct phases of discharge regimes, such as growth, breakdown, decay and polarity reversal of electric field as illustrated in figure 1 (a - d). The behavior of dielectric barrier surface is elaborated by an analysis of spatio-temporal characteristics of surface charge densities, which provides an evolution of non-uniformities during the breakdown pulse at the similar time instants (t1 - t4) as shown in figure 1 (e - h). The values of surface charge density of dielectric barrier are varied from the negative to nearly zero, when the current density approaches to the higher values during the growth of constricted filamentary discharge plasma and then becomes positive in the afterglow phase of a half cycle as displayed in figure 1 (g, h).

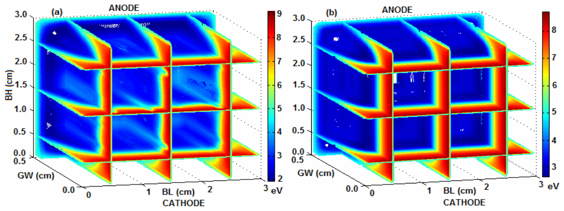

Fig. 2 (a, b): Slice distributions of electron mean temperature at 15 kHz and V_{appl} = 1.6 and 1.45 kV.

The electron temperature is started to reduce from the head of filament near the surface of cathode barrier towards the tail near the anode barrier with a numerical value from ~ 9 to 4 eV.

It is evident from the figure 2 (a) that the existence of filaments intensively persist their dominant influence in the gap. In the absence of overvoltage, the constricted filamentary gradients are vanished and the uniform structure of electron mean temperature is developed near the momentary cathode barrier with the smaller value from ~ 8 to 3 eV as exhibited in fig 2 (b).

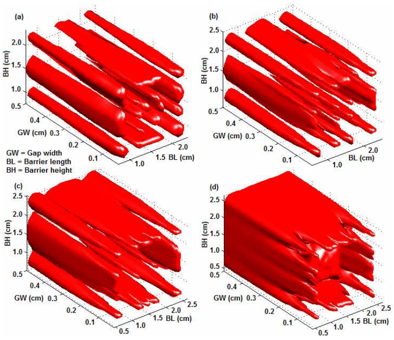

Fig. 3 (a - d): Distribution of electrons in filamentary discharge for 5, 10, 15 and 20 kHz and 1.6 kV.

The effect of driving frequency on the behavior of filamentary atmospheric pressure discharge is illustrated in figure 3 (a - d) by the volumetric distribution of electrons. The size of filaments increases with a rise in driving frequency and ultimately, they are strongly coalesced together from 15 to 20 kHz. The filaments start joining each other with an increase in driving frequency and the spatial gap between them is eradicated approximately at 20 kHz except near the region of cathodic barrier, implying a dynamic role of electrons in this particular region.

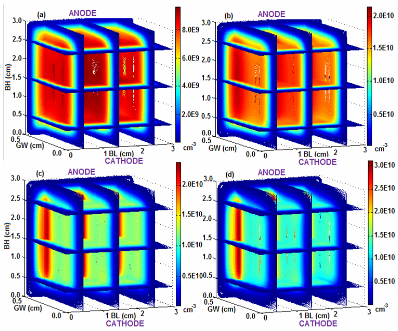

Fig. 4: Slice distributions of electrons density at (a) 30, (b) 50, (c) 70 and (d) 90 kHz and V_{appl}=1.45 kV.

The spatial snaps of electron density are extracted during the half cycle at different frequencies when the discharge current density attains its maximum value. The three-dimensional slice distributions of electrons illustrate that the maximum density is emerged near the cathode fall region at 30 kHz and it shifts near the anodic barrier at 50, 70 and 90 kHz as shown in figure 4 (a - d). A spatial volumetric gradient in the value of electron density is built up near the anodic barrier at 50 kHz, which becomes more intense and squeezed at further higher frequencies as displayed in figure 4 (c, d). These trapped electrons are responsible for the occurrence of residual current density during the polarity reversal of electric field from 50 - 100 kHz. In this frequency regime, the electron density keeps on increasing continuously from 30 to 90 kHz with a numerical value from ~ 8.0×10^{9} to 3.5×10^{10} cm^{-3} and these results are consistent with the previous numerical simulation results [4 - 5].

References

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