SIMULATION STUDIES OF DIELLECTRIC BARRIER BASED MICRO HOLLOW CATHODE DISCHARGE

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Abstract

Dielectric barrier discharge (DBD) is an atmospheric pressure non-thermal and non-equilibrium plasma having the advantage of low electrode erosion at high pressures but have low plasma density [1]. Hollow cathode discharges (HCD), on the other hand, are discharges with higher plasma density due to cathode fall and negative glow confined in a hollow cathode cavity but suffer from electrode erosion at atmospheric pressures [2]. The radius of hollow cavity in these devices is around the cathode fall width such that the entire cavity is occupied by the cathode fall and small negative region between opposite cathode falls. A 2D finite element model of DBD based micro scaled hollow cathode discharge is developed and simulated using COMSOL to understand the discharge analysis of such microscale plasmas [3]. The geometry incorporates a hollow cathode cavity of diameter 500 μm with unity aspect ratio and a coaxially protruding cylindrical anode having diameter 250 μm and 50 μm height inside HC structure. The discharge is produced by varying voltage at 25 kHz frequency from 100-300 Volts and by varying frequency from 25-250kHz at 200 V applied voltage in HC system in a glass ensemble. A 1 μm thick silicon dioxide (dielectric constant of 4.2) dielectric layer is considered on inside walls of hollow cavity. This thin layer of silicon dioxide acts as barrier to current and prevents the transition to an arc discharge. Argon gas environment is used for this model at atmospheric pressure.

Due to impressed anode in HC structure, three regions become significant, a low gap region between anode and cathode, inter cathode region between opposing cathode walls and third is anode bulk region between the HC plasma and anode. The discharge ignites from first region due to low gap distance between anode and cathode and then migrates to the Inter-cathode region. This is evident from the analysis of the migratory electron flux and the fact that no considerable ionization takes place in the HC region during this phase. After ignition phase electrons migrate following an axial electric field and hollow cathode effect is initiated in second hollow cathode phase where fast electrons show pendulum effect thereby enhancing ionization and exciting gas particles. Here, bulk electrons are trapped in self consistent electric field and due to fast electron ionization hot intermediate electrons arises and they carry the electron current in negative glow. In HC region, when the electron generation rate is higher than electron absorption rate in the anode bulk region, the hollow cathode effect is sustained throughout the applied voltage. It is inferred that electron density increases but the discharge moves outside the cavity at the same time with increase in frequency. The discharge remains confined inside hollow cavity at higher voltages and lower frequencies with electron density in order of 10^{16} m^{-3}-10^{18} m^{-3}.

References:

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