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Self-organization of Multiple Double Layers in different Negative Differential Regimes

The ubiquitous development of multiple charged layers and their characteristics has been widely investigated in recent years under varied experimental conditions in hollow cathode discharges due to their wide variety of applications [1], [2]. However, no controlled plasma source could be developed during these earlier studies to investigate the underlying cause of formations of complex charged layers like multiple double layers (MDL) and anode spots. In the present experimental study, a controlled negatively biased grid acting as a secondary plasma source is positioned between a hollow cylindrical mesh cathode and a spherical anode in the vacuum chamber while a low magnetic field is present in it. The present study investigates the impact of the introduction of the biased grid that facilitates the nonlinear dissipation of trapped non-thermal electrons in the plasma column due to its repelling effect, leading to the formation of complex MDL near the anode during different Negative Differential Resistance (NDR) regimes in a DC glow discharge plasma [3]. The NDR typically develops after a controlling grid is introduced and arises when the discharge current shows abrupt jumps in the hysteresis traces [4]. The present study also provides insight into the reorganization of MDL near the anode and the associated sheath-plasma interaction triggering the phenomenon of self-organization during the discharge. The initial sheath formation near the anode occurs due to the insufficient supply of electrons by the negatively biased grid suggesting the entrapment of localized charged particles near the biased grid [1], [4]. This localization of charged particles due to the space charge effect also creates intricate structures near the grid. The initial sheath formations surrounding the anode progressively change into concentric bright spots on the anode when the applied voltage is raised beyond the barrier potential of the biased grid. The potential distribution governs the ongoing developments of many localized complex sheaths following the trapping of charged particles and the production of complex structures in the presence of a negatively biased grid [5]. A set of detailed nonlinear dynamical analyses are done to investigate and confirm the formation of the MDL through the interaction of low-frequency as well as high-frequency [6]. Thus, the resulting sheath dynamics and self-organized phenomenon through successive layer reduction promote the NDR zone in the plasma and its resistance to the associated sheath-plasma instabilities. These self-organized structures or MDL formation are essential for numerous kinds of plasma applications in medical and nanomaterial synthesis.

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