Ph.D. Thesis Title: Effect of Plasma Boundary and Electrode Asymmetry in Planar DC Discharges

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Entry Number: 2014ESZ8092

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ABSTRACT

The work presented in this thesis focuses on the characterization of parallel plate DC discharges with various plasma confining boundaries. In DC discharges, it is standard practice to use a conducting vacuum vessel that is electrically grounded. Since the cathode is also grounded, the conducting chamber works as an extension of the cathode, providing an unlimited auxiliary cathode area relative to the anode. Such a system with a conducting chamber is labelled the Conducting Boundary or CB configuration in this work. To provide alternate boundary conditions to such a scenario, two more boundaries were considered. In one of these, the entire chamber wall along with other conducting surfaces were insulated with mica/glass tubes, *etc.* except the plasma-facing surfaces of electrodes. Such a system was termed the Large Volume Insulating Boundary (LVIB) configuration. One sees immediately that the latter configuration limits the cathode area severely. In effect, plasma in the entire chamber is driven by the planar anode and cathode only. To provide an alternative to the LVIB system in terms of volume, another insulated boundary system, the Small Volume Insulating Boundary (SVIB) system was configured, in which the electrodes are enclosed in a glass tube with mica sheets used for blocking from the top and bottom. It was observed that the discharge shows completely distinct

behaviour with these two different boundaries (conducting and insulating). A relatively much higher discharge voltage is required to maintain the discharge in LVIB/SVIB than CB configuration. In addition to these, a leaky boundary was also created by introducing an annular gap in SVIB, which provides a new configuration termed the Leaky Boundary (LB) system in this work. LB discharges have exhibited several interesting nonlinear properties like Negative Differential Resistance (NDR), and hysteresis in their $V-I$ characteristics, anode glows that exhibit features like splitting into multiple blobs, spontaneous rotation of blobs, etc. Physically and electrically, LB discharges are found either to operate in the SVIB mode or the CB mode, depending on the ratio of the Debye length (at the gap) to the gap width. If this ratio is greater than unity, the plasma produced in the glass tube is unable to escape into the outer conducting chamber and the LB discharge behaves predominantly as an SVIB discharge with almost matching $V-I$ characteristics. On the other hand, as the plasma density rises with increasing discharge current, a point is reached when the ratio of the Debye length to the gap width falls below unity and the plasma escapes into the outer conducting chamber. In the latter case, the $V-I$ characteristics of the LB discharge mimics that of the CB discharge. It is during the switch from the SVIB to CB regime of operation that the NDR mentioned above is observed.

A considerable portion of the investigations in this work pertains to anode glows. It is well known that the glow arises on account of electrons present in the anode sheath exciting the gas atoms as they are accelerated towards the anode. Now, the standard anode sheath is an electron-ion (e-i) sheath comprised of an ion layer (at the sheath edge) followed by a layer of electrons adjacent to the anode. (The presence of the ion layer depresses the potential within the sheath that helps push excess electrons back into the plasma.) However, in the present work, it was found the standard e-i sheath may be replaced by a pure ion sheath. Such types of sheaths are found in SVIB discharges, where electrons arriving at the anode in large numbers need to be heavily restricted (to match the discharge current). It turns out that it is possible to reverse this situation by *reducing the size of the anode drastically in comparison to that of the cathode* (labelled highly asymmetric case), so that *electron collection by the anode becomes highly inefficient* and the anode sheath has to revert back to the standard e-i sheath where anode glows are possible. It is possible to operate highly asymmetric LB discharges over a large range of discharge currents so that anode sheath is an e-i sheath that supports anode glows that exhibit various interesting features like splitting into twin or multiple blobs, fluctuations in their size, and intensities, rotations, *etc*. It is possible that the splitting into multiple anode blobs is indicative of the existence of constricted current channels while the periodic rotation of the blobs within a specific current regime could be associated with a current-driven instability.

To summarize, the work undertaken in this thesis provides a systematic study of all the different discharge configurations (CB, LVIB, SVIB, and the LB) to determine their characteristic features and identify the various discharge regimes of operation that help the build-up to further interesting studies on anode sheaths / glows, mode switches, *etc*. Some of these features have been investigated in considerable detail.