Spectral investigations on coaxial double transparent cathode discharges

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Transparent cathode discharges have been investigated in a double cathode coaxial cylindrical system. Two gridded cylinders (mesh size 1,2 x 1,2 mm, wire Ø 0,6 mm) cylinders with 3 and 6 cm diameter, respectively, and 10 cm length each, have been negatively biased in a background gas pressure of p = 10–4 mbar. Argon has been used as background gas. Optimal conditions for the discharge have been established for pressures between $p = 10^{-2} - 1{,}8 \cdot 10^{-1}$ mbar for discharge voltages between V = –300 V and –500 V. Plasma space charge structures appear inside and around the cylinders as shown in Fig. 1. Spectral measurements of the optical emission have been performed to obtain the discharge geometries and profiles of the excited and ionized gas particles. As in previous research our research groups [1-4], a well-defined luminous plasma double layer has been observed surrounding a plasma fireball, tangent to a less luminous space charged formation inside the inner cylinder. Spectroscopic data were used to estimate the axial profiles of electron excitation temperature and density. A peak has been observed at the end of the cylinders, both for temperature and density. Multiple plasma space charge formations are observed. The cathode system is investigated in order to understand basic physical processes responsible for its ignition and behaviour.

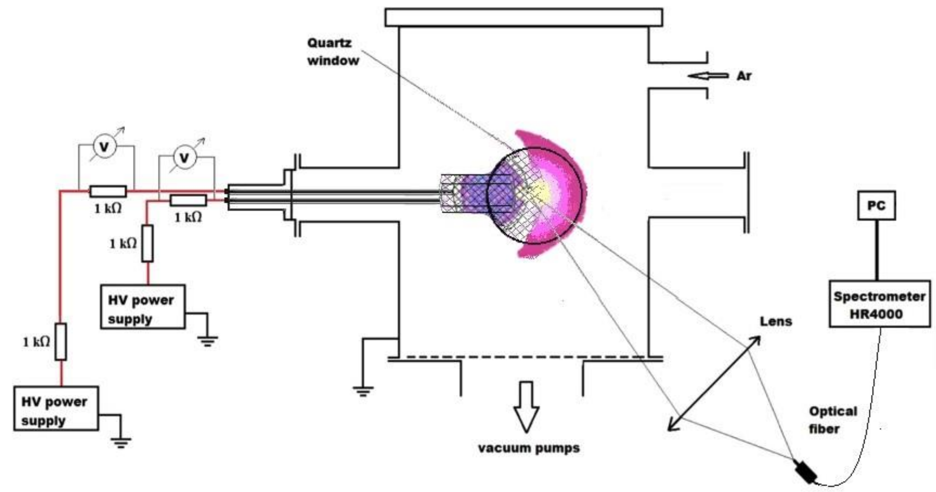

Fig. 1. Schematic of the experimental setup

Experiments were carried out in a grounded small stainless steel cylindrical chamber of 92 cm length and 53,5 cm diameter. The two cylinders (closed at their left) are simultaneously biased in Argon at a pressure between p = 1,2 and 1,6·10−1 mbar, at several negative bias configurations. An Ocean Optics HR400 spectrometer has been used in order to record the emission spectra of the plasma. One mm3 of the plasma volume was focused through a lens onto an optic fiber. Axial profiles of the electron temperature and density were taken throughout the discharge. Several bias configurations have been investigated where different discharge regimes have been observed (see Fig. 2).

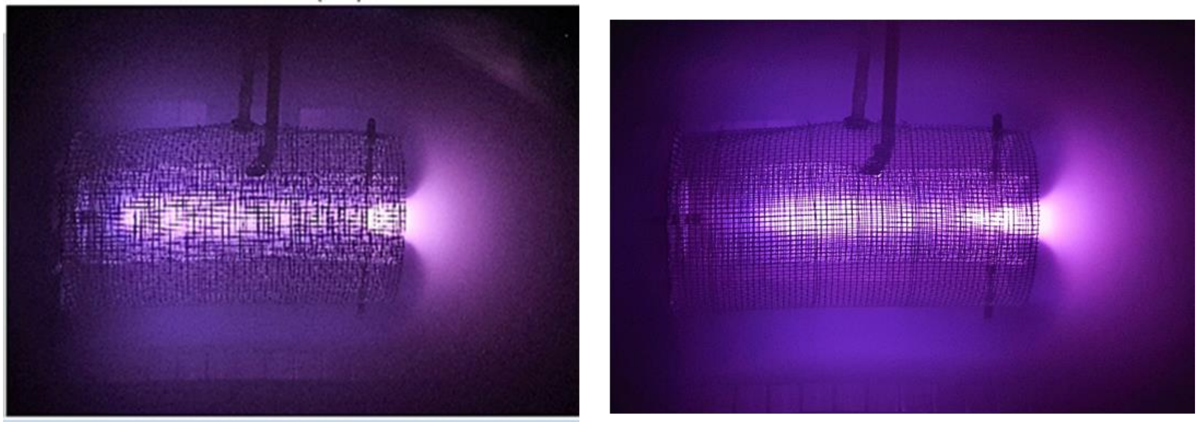

Fig. 2. Double hollow grid discharges at $1{,}2\cdot10^{-2}$ mbar, $V_{ext} - V_{int}$ = (a) -100V – -275V, (b) -150V – -268V.

Optical emission spectroscopy is used in order to calculate the electron temperature Te and electron density ne in Local Thermodynamic Equilibrium (LTE) conditions. Te is assumed equal to the excitation and the plasma temperatures and is determined from the intensity ratio of several spectral lines belonging to the same ionization stage. Thus, accurate temperature values are obtained by extracting the average excited temperature from the Boltzmann plot slope eq. (1). The temporal electronic density profiles have been calculated using relative intensities of the neutral atomic lines and singly charged ionic lines according to the Saha-Eggert eq. (2).

$$I_{ki} = N_0 \frac{1}{4\pi} \frac{hc}{Z(T)} \frac{A_{ki}}{\lambda} g_k \exp\left(-\frac{E_k}{kT_e}\right) \qquad (1)$$

$$n_e = \frac{2g^+ A^+ \lambda^* I^*}{g^* A^* \lambda^+ I^+} \frac{(2\pi m_e k T_e)^{\frac{3}{2}}}{h^3} \exp\left(-\frac{E^+ - E^* + E_i}{kT_e}\right) \qquad (2)$$

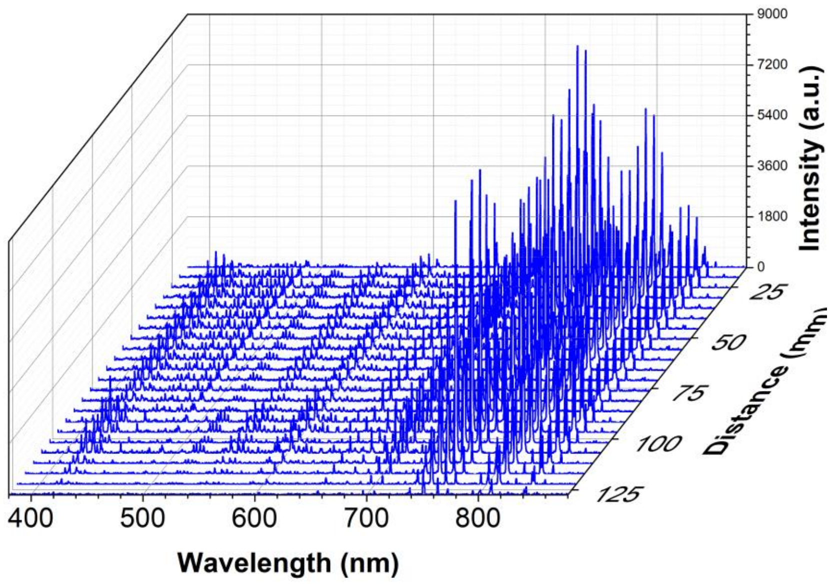

Fig. 3. Axial distribution of the plasma optical emission spectra

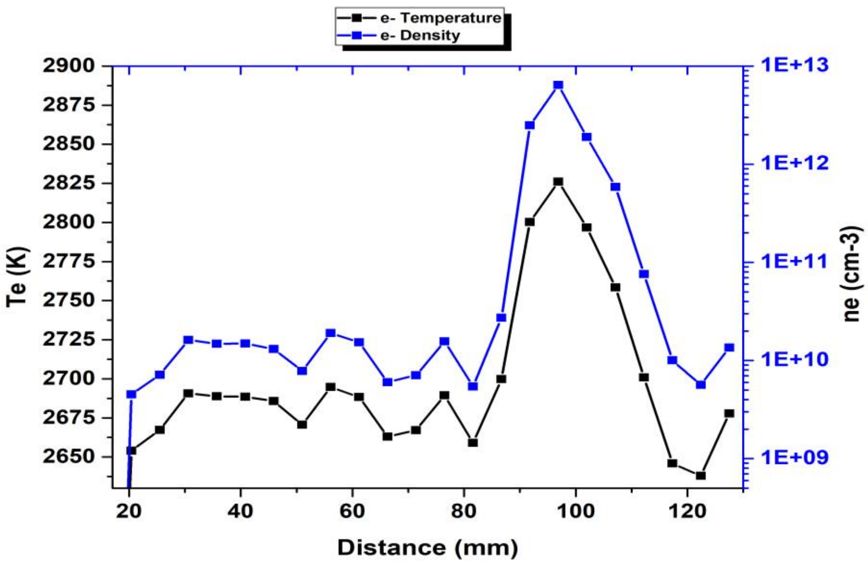

Fig. 4. Axial distribution of electron temperature and density when Vint = -275 V and Vext = -100 V (0 mm corresponds to the closed beginning of the exterior cylinder, 100 mm corresponds with the opened end of the exterior cylinder).

Future experiments involve polarizing different shapes of electrodes – in this case a Möbius band shape – and observe how plasma follows (or not) the shape of the electrode. In Fig. 5.a first we ignited the plasma discharge with a high potential, then we lowered the potential to a minimum, so the plasma fluxes were observable; in Fig. 5b the potential was left high, the plasma followed the shape of the electrode. The challenge will be representing the data with the distance (axis of a virtual unwrapping of the Möbius electrode).

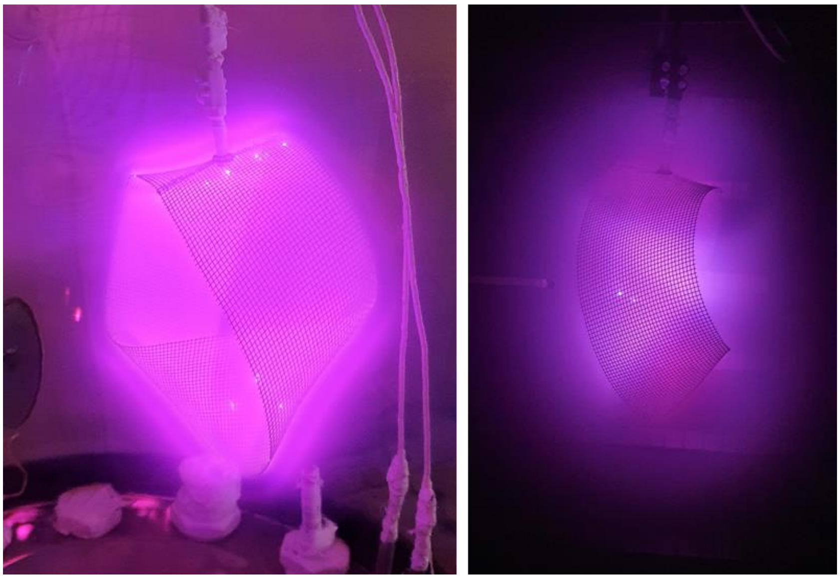

Fig. 5. Plasma discharges with a Möbius electrode. (a) UAIC – Bell shape vacuum chamber, anode at right, (b) UIBK – anode is the chamber

Other experiments will involve ordinary shapes in a dynamic electrode (rotating electrode, high number of rotations per minute). A dynamic electrode raises the problem of acquiring data by a (static) probe, however acquiring optical spectroscopy is still possible, the issue will be with choosing a proper reference.

Conclusion

Measurements were performed in a wide range of bias configurations at several background pressures. First the primary discharge is ignited between the inner grid and the walls of the chamber, while the outer grid provides a supplementary acceleration for the electron beam. The volume of the discharge as well as the accelerating double layer's position are visibly affected by both the bias configuration and background pressure. Complex space charge structures can be observed from the optic axial distribution profiles of the plasma parameters, beginning with the position of the interior grid up to several cm behind the outer grid, caused by the local constraints in the electric field induced by the presence of the holes. Peak values for both electron temperature and density have been established.

References

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