Spectral investigation on two spherical cathode discharges

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Introduction

Cathode discharges in Argon were investigated, using mainly emission spectroscopy. The cathodes were either concentric hollow spheres or cylinders of stainless-steel mesh [1-3], allowing better observation of the processes inside the electrodes. However, irregular chaotic discharges between cathodes and the vacuum chamber walls were detrimental of these cathode systems. Better resolution for the spectra is achieved in this study with two larger cathodes not made of grids but with smooth surfaces.

Experimental setup

Cathodic discharges were analysed in a system consisting of two hollow polished stainless-steel spheres with radii of 4,8 cm each (wall thickness 1 mm), placed at 5 cm distance from each other (surface to surface). The experiments were conducted in a grounded cylindrical stainless-steel chamber of 92 cm length and 53,5 cm diameter. Both spheres were simultaneously biased negatively in Argon at a pressure between $p = 7$ and $8{\cdot}10^{-2}$ mbar. The best conditions for the discharge were found for voltages around $V = -400$ V for both spheres. The experimental setup is shown in Fig. 1(a). The spatial structure of the plasma discharge appearing around the spheres is indicated schematically.

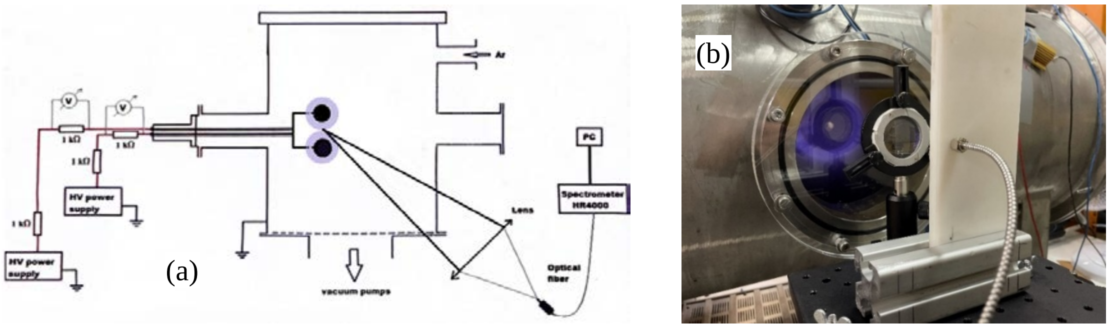

Fig. 1. (a) Schematic of the experimental setup. (b) Installation for emission spectroscopy.

Fig. 1(a) also shows the arrangement for recording emission spectra using an Ocean Optics HR4000 spectrometer. The emission was measured from a point located at mid distance between the spheres. Focusing through a lens onto an optical fiber, the emission of a cubic plasma volume of approx. 7,8 cm^3 could be registered, with the aim to derive the plasma's spectral diagram during discharges (Fig. 1(b)).

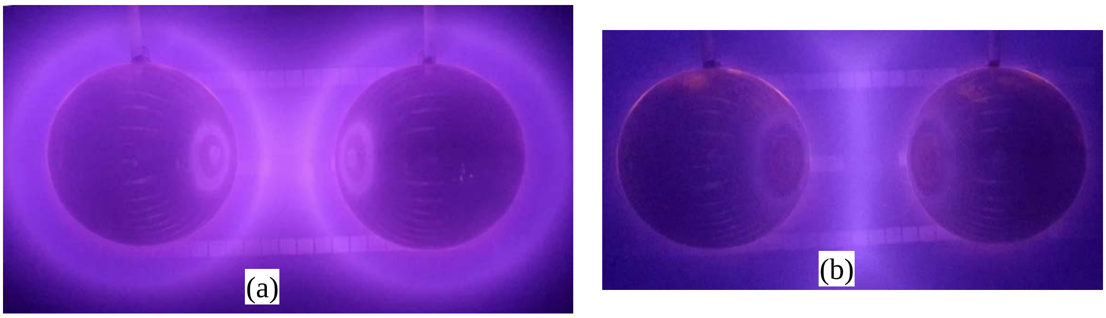

Fig. 2(a) The two discharges without visible interference between the spheres, (b) with visible intersection of space charge sheaths surrounding the spheres.

Experimental results

Various spatial structures were observed around the spheres (see Fig. 2). The best conditions for discharge were found at a voltage of V = –390 V for both spheres with a current of 13 mA in both circuits, at Ar pressure $p = 7{,}8{\cdot}10^{-2}$ mbar. Spectral measurements of the optical emission enabled the generation of the plasma's spectral diagram. The spectroscopic data were used to determine the electronic temperature of the plasma (~ 5479 K) at the midpoint between the spheres with eq.(1) and (2).

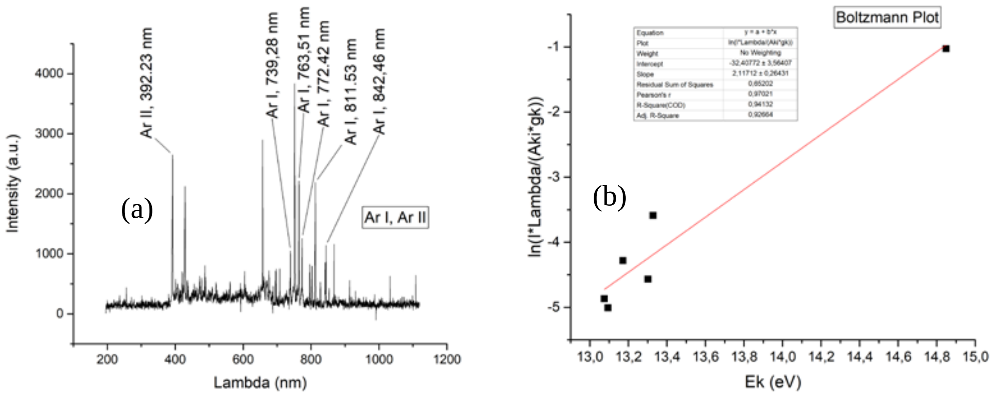

Fig. 3(a) Ar I, II lines spectrum of plasma, (b) Boltzmann plot for derivation of temperature.

Electron temperature from Boltzmann plot slope eq. (1):

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

Electron density from Saha Eggert equation eq. (2):

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

I_{ki} – Intensity of line for an electronic transition between k and i
$g_k A_{ki}$ (s^{-1}) – Transition probability
λ (nm) – Wave length
$Z(T)$ – Partition function
$E_{i,k}$ (cm^{-1}) – Energy of lower and upper level, respectively
$k_B T_e$ (J)– Thermal energy
n_e (cm^{-3}) – Electronic density
+,* - refers to ion, neutral species
m_e (kg) – mass of electron
N_0 – Total concentration of atoms

Conclusion

These findings are useful for understanding the fundamental physical processes responsible for the ignition and behaviour of cathode systems. Future experiments will create spatial electronic temperature and density maps for experimental conditions as previously stated. Also experiments with modified spheres are planned by making opposing 1 cm diameter holes in the sphere along their horizontal axis and the formation of ion beams from the spheres and their interactions will be investigated.

References

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