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Study of a Micro Hollow Cathode Discharge at medium argon gas pressure

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The interest of microplasmas lies in the fact that they can be generated at medium and high pressure with a very low applied voltage or injected power. They have applications in various field such as surface treatment, light sources or sterilization [1,2,3]. Experimental results shown here give information about the structure of the plasma bulk and the sheaths in the microdischarge thanks to the observed radial profiles of atomic and ionic emisssion lines. The electronic density is also inferred from spectroscopic measurements. A theoretical work completes these experimental results.

A microplasma is generated in the 400 µm diameter microhole of a molybdenum-alumina-molybdenum sandwich (MHCD type) at medium pressure (30-200 Torr) in pure argon. This kind of discharge can be operated in an unsteady self-pulsing regime at lower current despite a continuous power supply, or in a steady-state normal regime at higher current [4]. Imaging and emission spectroscopy give indications, during these two regimes, on the electronic density in the microhole and allow the identification of different zones of the micro discharge, in which various excitation mechanisms of atoms are involved. To confirm the experimental interpretations, we use a O-Dimensional transport model to obtain the radial evolution of the particles densities and fluxes, and we also propose a zero dimensional unstationnary model to describe the self-pulsing regime.

The image of the MHCD, viewed from the anode side, is formed on the entrance slit of a 2 m spectrograph working at the third diffraction order of the 1200 g/mm grating. A CCD camera, placed on the exit plane of the spectrograph, captures the horizontally dispersed images at different spectral lines. Consequently, with fully open entrance slit, images of the MHCD observed at different wavelengths are formed at different horizontal positions.

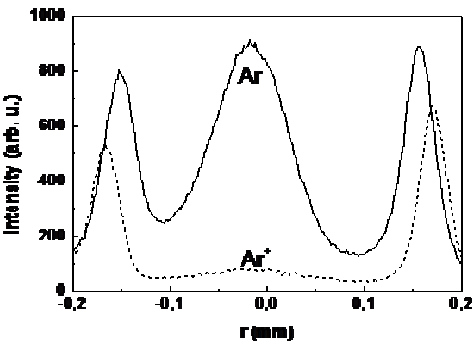

Fig. 1: Radial intensity profiles of Ar (solid) and Ar$^+$ (dashed) lines, in the 400 µm hole, at 200 Torr argon pressure and 1 mA discharge current during the normal regime

We study an atomic line (427.217 nm) and an ionic line (427.752 nm) of argon. During the steady state normal regime, the image of Ar$^+$ line emission has an annular shape with its maximum intensity near the cathode surface, whereas the intensity of Ar line shows, in addition to similar annular emission, a pronounced maximum at the centre of the hole (Fig.1). By comparing the experimental results to a ionizing sheath model, it was shown that the maximum of the annular Ar$^+$ emission was located at the sheath edge [5]. In this case, the emission comes from the direct excitation by electrons accelerated in the sheath.

The maximum of the Ar emission at the centre comes from excited Ar atoms produced by electron-ion recombination. We recover this structure of the emission during the self-pulsing regime near the maximum of the discharge current peak, and then the direct electronic excitation near the edges vanishes faster than the excitation by electron-ion recombination in the centre.

The Stark broadening of the H_β-line at 486.1 nm is used to obtain the electron density in the hole. At 150 Torr and 1 mA mean discharge current, during the normal regime, the value of the electron density is about 2.10^{13}cm^{-3} whereas the maximum reached during the self-pulsing regime is 4.10^{15}cm^{-3}, that is two orders of magnitude higher. This can be explain by the fact that in the self-pulsing regime, the maximum of the discharge current reaches several tens of mA.

To complete these experimental interpretations, a one-dimensional stationnary transport model is used to study the radial evolution of the particles densities (charge particles and metastable atoms) and of the electron temperature during the normal regime. We decompose the study in two regions, separating the cathodic region (facing the electrod) from the positive column in the dielectric part of the sandwich. The equations are solved as an initial value problem, with a given electron density fixed in the centre; for all pressures in Fig.2 we have chosen $n_0=10^{13}\text{cm}^{-3}$ (in practice n_0 has a very weak influence on the profile). With increasing pressure, the Bessel profile of the electron density (characterisitic of an ambipolar diffusion with constant ionization frequency) flattens in the cathodic region because the peak of ionization moves toward the cathode and e-ion recombination rate increases in the centre. Finally, adding the energy balance equation, a zero dimensional unstationnary model is built to study the temporal evolution of the same plasmas parameters. This model confirms that in the self-pulsing regime, the electron density follows the temporal evolution of the discharge current, whose peak value is much higher than the steady-state discharge current, with slightly longer characteristic rise and decay times.

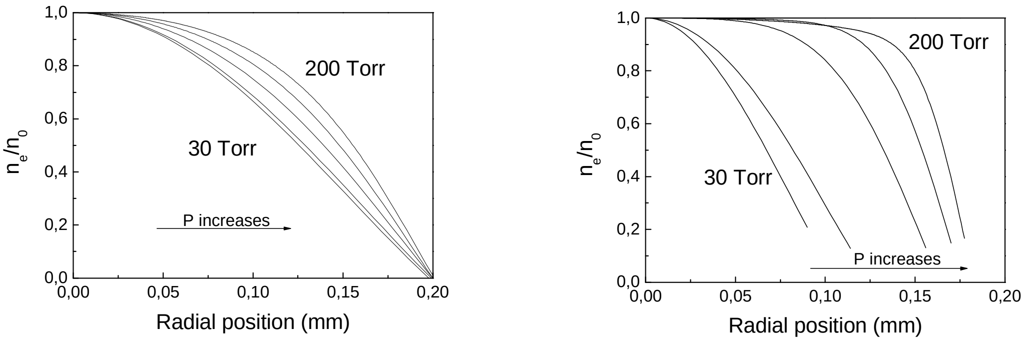

Fig. 2: Simulated radial evolution of the electron density at different pressures (30, 50, 100, 150 and 200 Torr) in the 400 µm diameter MHCD in the positive column (on the left) and in the cathodic region (on the right)

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