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Space charge configuration formed in weakly magnetized diffusion plasma

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On a positively biased electrode immersed in weekly magnetized plasma a complex space charge configuration is formed, known as fire-rod. This fire-rod consists of a positive nucleus (ion enriched plasma) bordered by an electric double layer (DL). We investigated this structure with one side emissive probe using argon as working gas. The measurements were made in pulsed regime and the probe characteristics were recorded at different times after the application of the step voltage and at different distances from the plasma source. After a few microseconds we observed a change in the characteristic shape comparative with those obtained in continuous regime. From probe characteristics we extract the electron energy distribution function (EEDF). Inside the fire-rod two groups of electrons with different temperatures and energies were observed. The plasma parameters were studied in different experimental conditions (gas pressure, plasma density, potential of the electrode, etc.), at different distance from electrode, inside and outside of the fire-rod. The obtained results give a broad picture about the elementary processes at the origin of the appearance and dynamics of a CSCC in magnetised plasma.

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1. Introduction

By applying a positive potential on an electrode immersed in a weakly magnetized diffusion plasma, a complex space charge structure (CSCS) as an intense luminous fire-rod appears [1,2]. The emissive probe measurements prove that this CSCS consists of a positive nucleus (ion enriched plasma) surrounded by an electric double layer (DL) [1]. The appearance of such a structure is determined by the electron-neutral impact excitations and ionizations [3], which appear because of the electron acceleration towards the electrode. The geometric shape of the structure (fire-rod) is imposed by the geometry of the magnetic field (perpendicular to the electrode).

Recently, based on a scenario of self-organization suggested by plasma experiments we explained the metastable complex space charge configurations [4].

We present here a broad investigation of the appearance of such a CSCS by using Langmuir probes, as well as emissive probes. Measurements were made in pulsed regime and the electron energy distribution function (EEDF) was recorded at different times after the application of the step voltage on the electrode.

2. Experimental results and discussion

Fig. 1 shows the experimental setup [5], which is a linear magnetized plasma device, 1.5 m long and 17 cm in diameter. The electrode immersed in plasma was a tantalum disk with 2 cm in diameter. A step voltage signal, 100 μs, was applied on this electrode by using a very fast field effect transistor switch. The switch was turned on and off by rectangular voltage pulses from the signal generator. These pulses are also used for triggering the digital oscilloscope and a boxcar average. Signals from the probe are sampled and averaged by the boxcar integrator. Output signals from the boxcar are digitized and stored into the computer for later analysis.

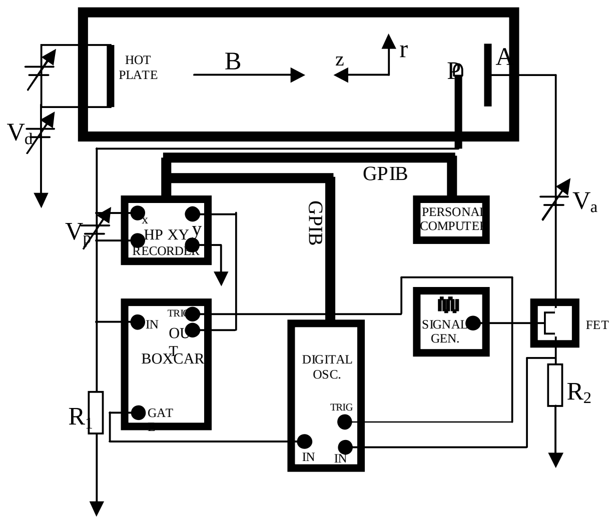

Fig. 1. Experimental setup.

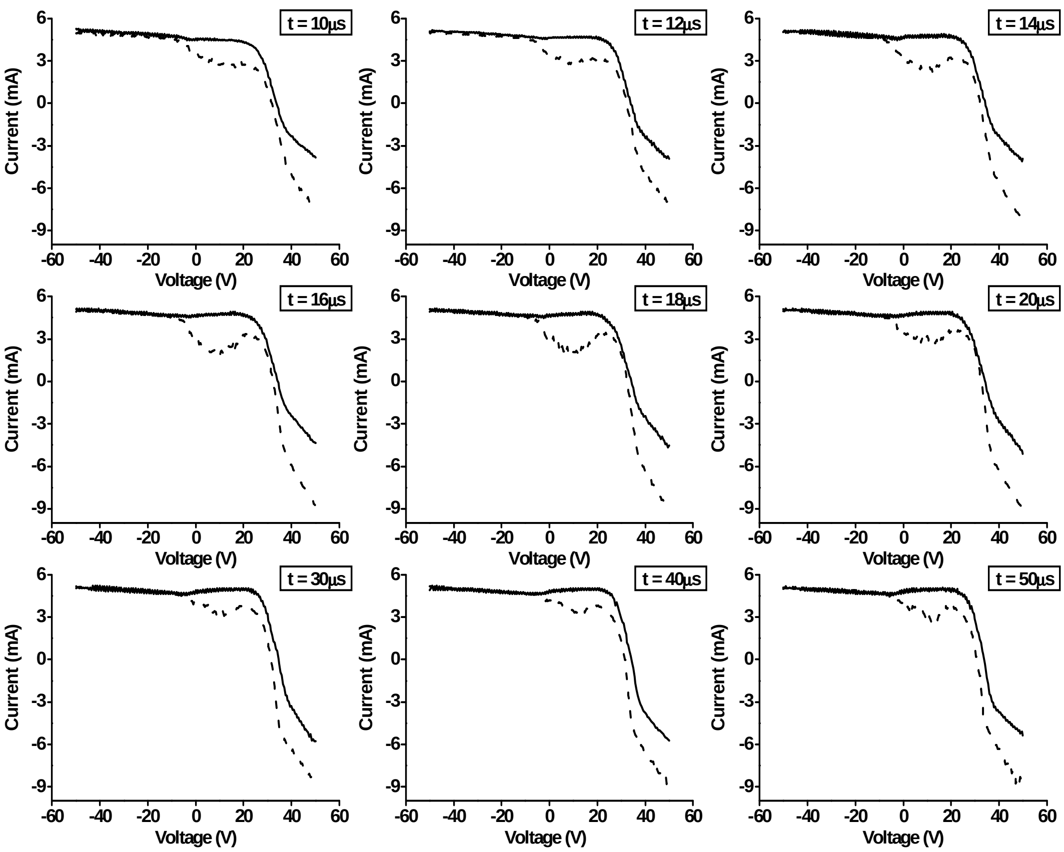

Fig. 2. Current-voltage characteristics of the hot probe, with both orientations of the probe (Solid line correspond to the orientation of the probe toward the electrode, while the dashed line correspond to the orientation of the probe away from the electrode).

Plasma is produced by an electrical discharge between the direct current heated tungsten filaments and the vessel wall, and diffuses toward the electrode. Primary electrons are accelerated by a discharge voltage V_d = 50 V, the discharge current being I_d = 400 mA. The argon pressure was $p = 3\times10^{-4}$ mbar and the magnetic field B = 0.02 T. A one-side emissive probe, protected by a mica shield, was used in order to record current-voltage characteristics, being heated by a current I_h = 3.5 A. The measurements were made with different orientations of the probe: toward and away from the electrode.

The current-voltage characteristics of the probe were recorded at different times after applying the pulse signal on the electrode. For an orientation of the hot probe toward the electrode, an additional positive current was obtained, approximately after 10 μs, in good agreement with the results obtained by Gyergyek *et al.* [6]. For the orientation of the hot probe away from electrode, a gap in the ionic part of current-voltage characteristic was observed. These results are shown in Fig. 2.

Fig. 3 shows the first derivatives of the cold probe characteristics, which are proportional with the electron energy distribution functions [6]. The probe was inserted inside the fire-rod, on its axis, 0.35 cm behind of their frontal part, the voltage on the electrode being V_a = 40 V. One observes that, immediately after the pulse onset, a fast electrons group appears in the EEDF. These electrons are those accelerated in the voltage across the double layer. Once the fire-rod is fully developed (after about 16 μs) this fast electron group becomes dominant in the EEDF. The slow electron group disappears from the EEDF, being accelerated at high energy. These fast electrons produce electron-neutral impact ionizations, creating, in this way the charged particle needed for the fire-rod self-consistence.

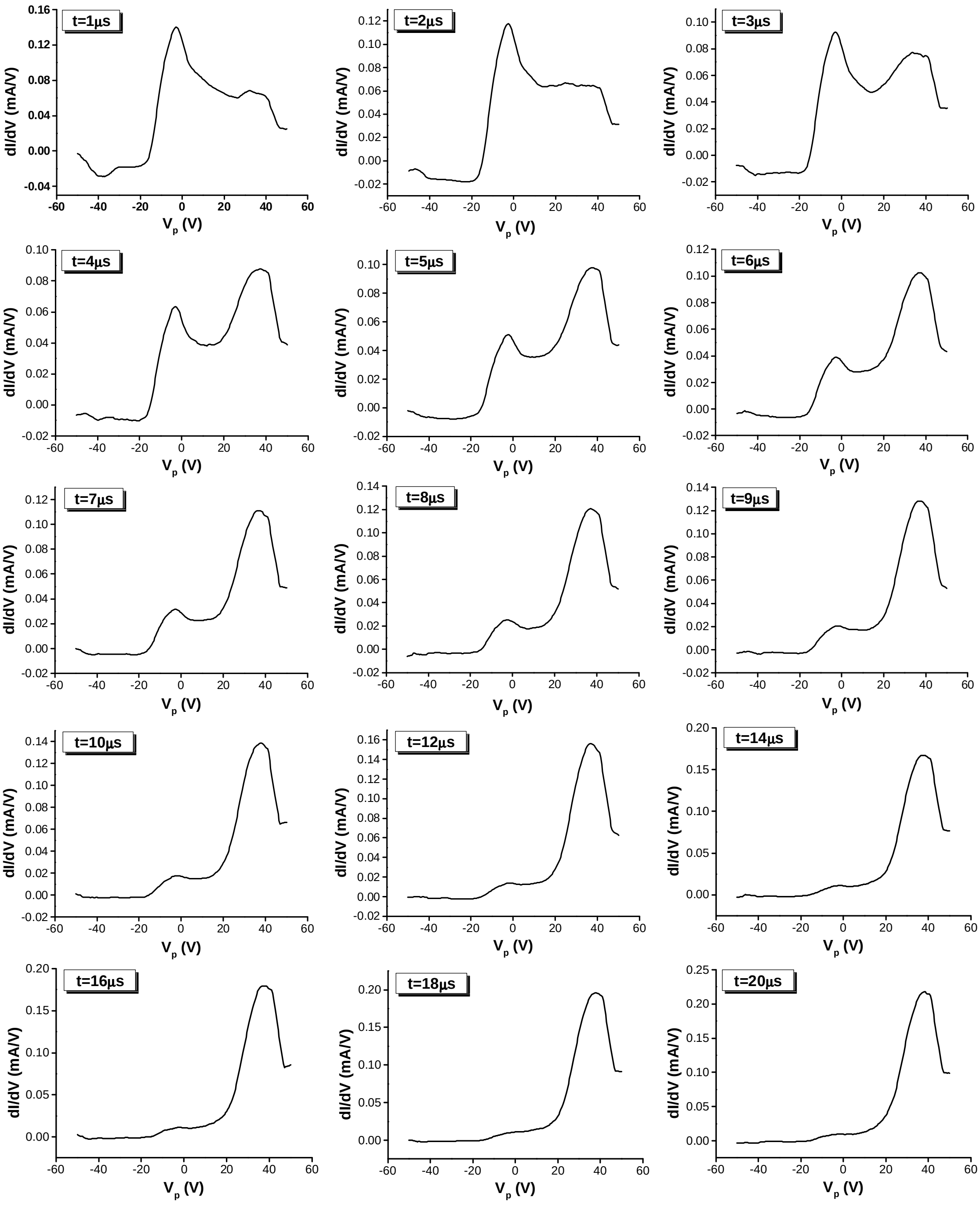

Fig. 3. Electron energy distribution functions obtained from the current-voltage characteristics of the Langmuir probe.

3. Conclusions

Cold and emissive probe measurements were used to investigate a complex space charge structure in weakly magnetized plasma in form of a fire rod, which appears in front of a positively biased electrode. The results prove the essential role of the double layer in maintaining the fire-rod self-consistence by accelerating the electrons from the surrounding plasma.

Acknowledgements

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