EXPERIMENTAL INVESTIGATION OF A FIREROD IN WEAKLY MAGNETIZED DIFFUSION PLASMA*

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When a positively biased electrode is immersed in plasma, up to a certain value of the applied potential a complex space charge structure develops in front of it. This structure looks like a quasi-spherical intense luminous plasma blob, attached to the surface of the electrode, known as ball of fire or fireball. Emissive probe measurements proved that the structure consists of a positive ion-enriched plasma region, confined by an electrical double layer. When a magnetic field is applied perpendicular to the electrode surface, the spherical structure will along in the direction of the field, taking a rod-like form. Thus, the magnetic field introduces anisotropy in the electron velocity field, the electrons moving towards electrode surface in the perpendicular direction on it. By using different Langmuir probes inside and outside the firerod, we extracted the electron energy distribution function, which emphasize the existence of different groups of electrons. This way, we analyzed the important role of the electron-neutral impact excitations and ionizations in the appearance and dynamics of the firerod in magnetized plasma.

Key words: firerod, double layer, electrons energy distribution function, excitations, ionizations.

INTRODUCTION

By applying a positive potential on an electrode immersed in plasma, a complex space charge structure in form of an intense luminous spherical body appears in front of it, known as anode glow [1] or fireball [2]. Experimental investigations revealed that such a structure consists of a positive core (an ion-enriched plasma) surrounded by a nearly spherical double layer [2–5]. The potential drop across the double layer is almost equal with the ionization potential of the used gas atoms.

When a magnetic field is applied perpendicular to the electrode, the spherical space charge structure passes into a rod-like one [6–10], elongated on the direction of the magnetic field. This new geometry of the structure can be explained by taking account that the electrons move now towards the electrode

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only on the direction of the magnetic field (the Larmor radius is very small) and their excitations and ionizations impacts with the gas atoms play the most important role in the structure appearance and dynamics [3, 6, 10].

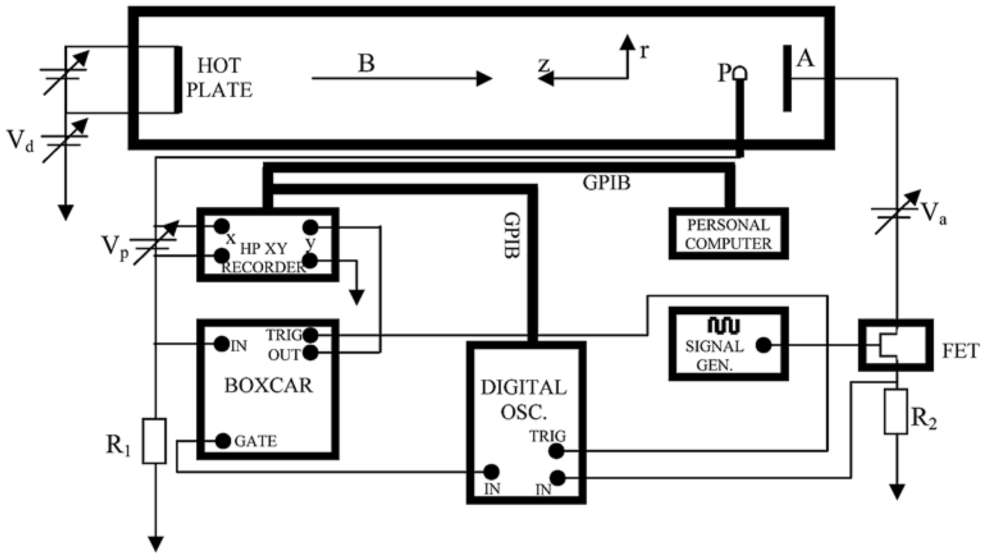

Fig. 1 – Experimental setup.

Here we present a broad investigation of the appearance of such a firerod structure in weakly magnetized diffusion plasma, by using Langmuir and emissive probes. The results emphasize important information on the appearance of the structure, extracted from the electron energy distribution function, recorded at different times after the application of the step voltage (in pulsed regime) on the electrode.

EXPERIMENTAL RESULTS AND DISCUSSION

The experiments were performed in a linear magnetized plasma device [8], shown in Fig. 1. Plasma is produced by an electrical discharge between the heated tungsten filament and the vessel wall, diffusing towards the supplementary electrode (marked by **A** in Fig. 1). The discharge voltage was $V_d = 50$ V, while the discharge current was $I_d = 400$ mA. The used gas was argon, at the pressure $p = 3 \times 10^{-4}$ mbar. The plasma diffuse in a magnetic field $B = 0.02$ T. The electrode immersed in plasma was a tantalum disk with 2 cm 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 a signal generator. These pulses are also used for triggering the digital oscilloscope and a boxcar average system. Signals from the probes are sampled and averaged by the boxcar integrator. Output signals are digitized and stored into a computer for later analysis. A one-side emissive probe, protected by a mica shield, was used, being heated by a current I_p = 3.5 A. The measurements were made with different orientations of the probe: towards and away from the electrode.

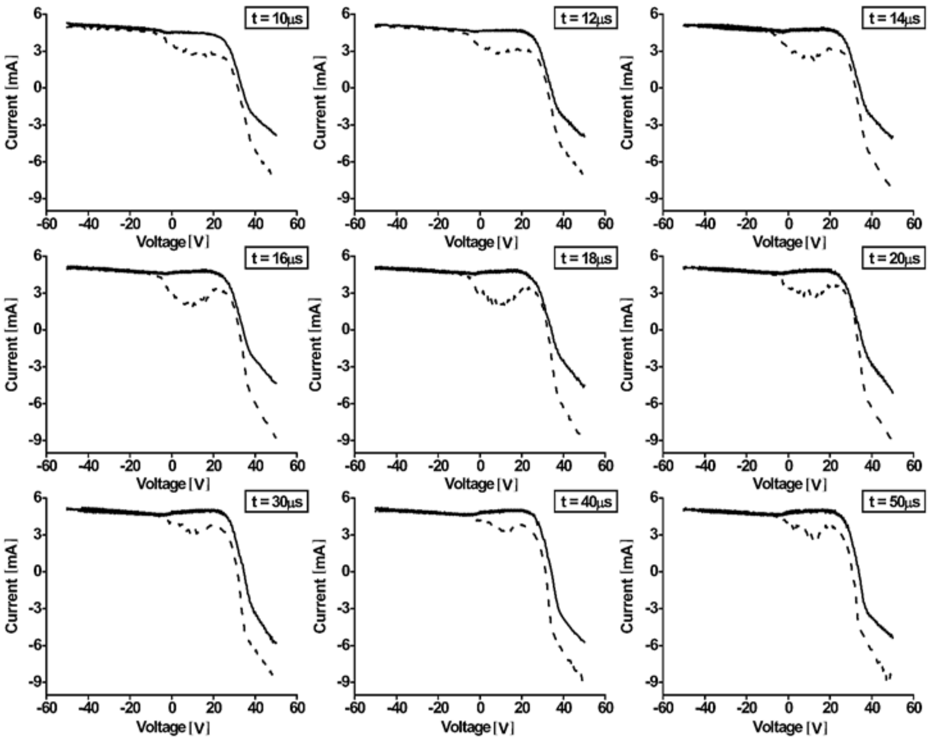

Fig. 2 – Current-voltage characteristics of the hot probe with both orientations of the probe (solid line correspond to the orientation of the probe toward the electrode, while the dashed line correspond to the orientation of the probe away from the electrode).

The current-voltage characteristics of the probe were recorded at different time intervals after the application of the pulse voltage on the electrode. For an orientation of the hot probe towards the electrode, an additional ionic current was obtained, approximately 10 μs after the pulse voltage application, in good agreement with the results obtained by Gyergyek *et al.* [7]. For the orientation of the hot probe away form the electrode, a gap in the ionic part of the current-voltage characteristic is observed. The obtained current-voltage characteristics are shown in Fig. 2.

Fig. 3 shows the first derivatives of the cold probe current-voltage characteristics, which are proportional with the electrons energy distribution functions [7]. This probe was inserted inside the firerod, on its axis, 0.35 cm behind of their frontal part. The voltage applied on the electrode was V_A = 40 V. Immediately after the voltage pulse onset, a fast electrons group appears, being emphasized in the electrons energy distribution function (Fig. 3). These electrons are those accelerated in the voltage across the double layer existing in the front

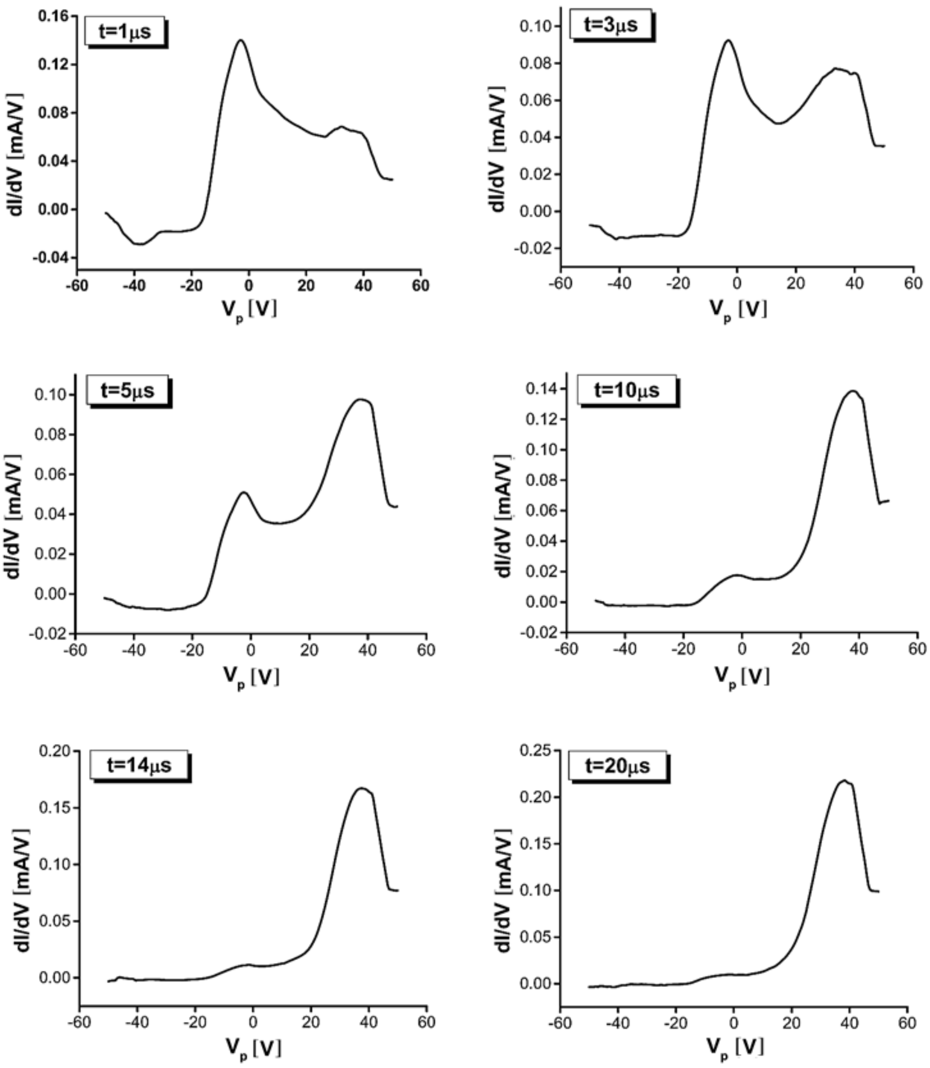

Fig. 3 – Electron energy distribution functions proportional with the first derivatives of the current-voltage characteristics of the Langmuir probe.

of the firerod. 16 μs after the voltage pulse application, when the firerod is fully developed, this fast electrons group becomes dominant in the electrons energy distribution function. The slow electrons group disappears from the electrons energy distribution function, being accelerated to higher energies. These fast electrons produce electron-neutral impact excitations and ionizations, creating, in this way, the charged particle needed for the firerod maintenance.

CONCLUSION

The formation of a complex space charge structure in weakly magnetized plasma in form of a firerod was investigated by means of cold and emissive probes measurements. The results prove that the electrons from plasma are accelerated by the double layers existing in the front of the firerod until energies high enough to produce excitation and ionization electron-neutral impacts, assuring, in this way the preservation of the structure.

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