TWO CHANNELS OF SELF-ORGANIZATION OF IONIZED GASEOUS MEDIA

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Abstract
The appearance is pointed out, experimentally, of a complex electric charge structure, within an ionized gas, relatively homogeneous at first, under the influence of a number of external constraints. Two different mechanisms of self-organization are presented: the former implying, essentially, long-range interactions, and the latter implying, essentially, short-range quantum interactions. The phenomenological scenarios are presented, which underlie the two mechanisms of self-organization, as well as the broader theoretical frame, currently accepted, concerning the generation of complexity in the material media that are far from the state of thermodynamic equilibrium.

Keywords: distribution of electric charge, double layer, self-organization

1. INTRODUCTION

Within the plasmas dissipative structures can be formed through both the long-range forces (the electromagnetic forces), and the short-range interactions (inelastic clashes between the micro-constituents of the system). Macroscopic instabilities (magneto-hydro-dynamic instabilities) can also occur. A phenomen of structuring can be achieved under the influence of the electric field that is applied. When in a plasma is introduced an electrode having a potential that is different from the potential of the respective place, a perturbation of the ionized medium occurs around it. As shown henceforward, according to the value of the potential that is applied, in front of that electrode a simple distribution of electric charge can be developed or not. We assume that the electrode is plane and polarized for a potential smaller than the potential of the place. The equations characterizing the medium before the plate lead to the following equation:

$$\frac{d^2\Phi}{dx^2} = \left(1 - \frac{1}{M^2}\right)\Phi \tag{1}$$

by making the folowing notations:

$$\Phi = -\frac{eV}{kT_e}, \qquad M = \frac{u_0}{c_s} = u_0\left(\frac{m_i}{kT_e}\right)^{1/2}$$

If M>1, equation (1) admits of a monotonously decreasing solution. This condition is called Bhom's criterion (Bohm, 1949). On the basis of this condition it follows that, *in order that a simple layer of spatial charge should form, it is necessary for the kinetic energy the ions possess when entering the layer to be bigger than the thermic energy of the electrons*. We find that, in this case, the appearance of a potential structure is realizable only if a threshold of instability is surpassed, determined by the ratio between the energy of the ions and that of the electrons. The question of the origin of that ion energy is related to the existence of a "pre-layer", where the ions are accelerated (Sanduloviciu and Lizneanu., 2000). In principle, this means that the electric field of the electrode is not completely screened by the positive layer. Also noticeable is the fact that the distribution of the ions and of the electrons around the electrode is monotonous; the appearance of the layer is only the result of the difference in concentration between the two groups of carriers.

As an example of self-organization under the influence of short-range forces is the appearance of the DL in collisional plasmas. According to Sanduloviciu (Sanduloviciu et al, 1999, Oprescu et al, 1997), the generation of the DL is *the spatial separation of the regions where the cross-sections of excitation and ionization, respectively, have the maximal values.*

2. MATERIAL AND METHOD

The basic schema of the experimental is presented in Figure 1. The basic idea in achieving this

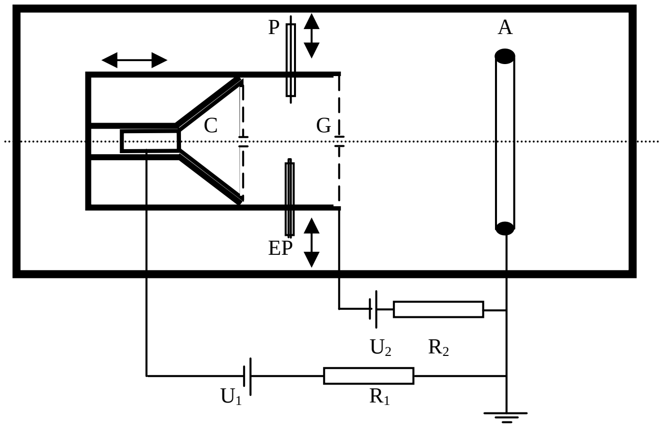

Figure 1. The schema of the experimental device: C–cathode; G–control grid; A–anode; P–simple probe; EP–emissive probe; U_1, U_2–power sources in CC.

device was the following: to create an ionized medium into which an accelerated ion beam should be injected. The choice of such a cathode can be justified as follows: cavitary cathodes – consequences of the double cathode effect – allow a remarkably high efficiency of the gas ionization. In addition, the special geometry of this cathode allows injecting a sufficiently collimated electron beam into the CG spatial region, through the hole bored at the centre of the cathode grid.

In order to diagnose the medium between the two grids, two probes were used: a simple probe, and a thermo-emissive probe. In order to be able to scan the whole spatial range, both the probes and the ensemble made up of the cathode and the grid can move as in Figure 1 (these moves are facilitated by the presence of two slits cut along the axis of the inner glass tube). The experiments were conducted in water vapour at the pressure of $5 \cdot 10^{-2}$ torr.

3. RESULTS AND DISCUSSIONS

The experimental device is similar to a gas triode. The peculiarity of this device lies in the fact that a well collimated electron beam is emitted from within its cathode.

This electron beam, which continuously extends between the two grids, basically behaves like a virtual electrode that is at a negative potential as to the ionized medium around. In the presence of this electrode with a cillindrical geometry, the phenomenon of self-organization of the ionized medium can occur through the appearance of a layer with a positive electric charge (PEL). This can only occur only if the conditions imposed by Bhom's criterion concerning the forming of the spatial electric charge layer are met.

Due to the concentration of the electric field lines towards the central orifice of the control grid, the electrons are accelerated until they can produce phenomena of excitation and ionization of the water molecules. In this manner, according to the phenomenological scenario supported by Sanduloviciu, the phenomenon of self-organization can appear, concretized in the appearance of the double layer.

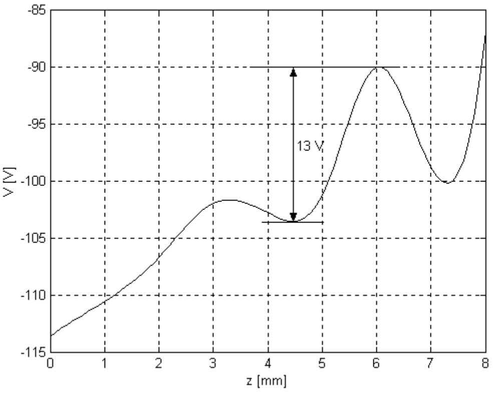

Figure 2 Axial distribution of the electric potential

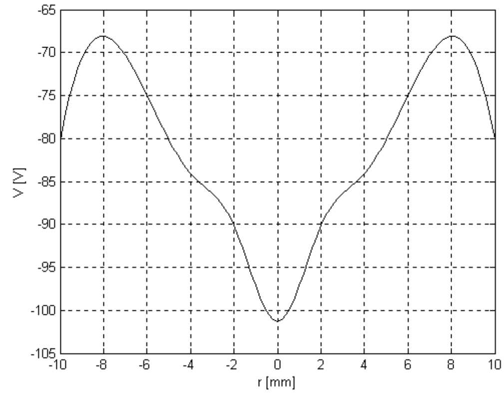

Figure 3. The radial distribution of the electric potential for z=6 mm

In order to be able to evince the appearance of the electric charge distributions, the best method is the diagnosis of the inter-grid medium by means of the probes.Using this method, the axial distribution could be determined (Figure 2), as well as the radial distribution (Figure 3) of the electric potential. From Figure 2 can be noted the existence of the second DL. The region where the negative electric charge layer (the area around the first local minimum) is located, as well as the region of existence of the positive electric charge layer, are clearly evinced. It can be noted that, in between the two regions there exists a potential difference of approximately 13 V, which perfectly agrees with the value of the ionization potential of the water molecules (12,6 V). Beyond this DL a new potential minimum can be seen, which comes from the negative charge existing in the first DL.

In Figure 3 the radial distribution of the electric potential is presented. The existence of a central minimum of potential is found. This minimum corresponds to the presence of the electron beam passing through the device. Around that potential minimum there is the potential maximum, which proves the existence of the positive charge distribution that tends to screen the virtual electrode (in the graph, at r=±8 mm). As the potential difference between the axial area and the regions of positive electric charge is sufficiently great, the central electrons undergo an acceleration in the radial direction leading to the ionization of the gas, where their energy becomes equal to the ionization energy. The existence of this phenomenon is evinced by the presence of the potential tiers around the points r=±3 mm.

4. CONCLUSIONS

In this paper are presented the experimental results concerning the self-organization phenomena appearing inside an ionized medium, which is initially homogeneous, under the influence of an external constraint. Two distinct self-organization mechanisms are revealed: one based on the presence of long-range action forces, and the other essentially based on short-range action forces. The fact is thus confirmed – which has been theoretically predicted – that, irrespective of the type of interaction forces, nature finds ways to use the ordered energy provided from sources outside of the system to generate a number of dissipative structures. The existence is also proved, with arguments, of instability thresholds above which the various types of interactions can conduce to the triggering of the sequence of the microscopic phenomena capable of finally generating complexity.

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