29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. ***26B****, P-2.035 (2002)*

Quasistatic and Dynamic Properties of an Alternating Current Driven Double Layer

D. Alexandroaei

Department of Plasma Physics, "Al.I.Cuza" University, Iasi, Romania
E-mail: d.alex@uaic.ro

Introduction

It is now well known that the space charge double layers (DLs) are relevant in usual plasma devices, in space plasma or in the plasma confinement in fusion devices [1]. Having a nonlinear phenomenology through their dynamics DLs are of great interest also, in many modern problems of theoretical plasma physics and through analogy, with other fields of physics or other sciences [1]. Acting as storing and releasing energy elements, the DLs have a proper dynamics and are connected with certain instabilities observed as ordered or disordered space – temporal structures in many plasma devices. Coherent or noncoherent space-temporal behaviors of the DL are observed for certain internal plasma conditions. The global evolution of a DL-containing-plasma system is the result of the mutual influence of two or more DLs coupled by the current flowing through them. The temporal variations of this current are correlated with the space-temporal variations of the parameters of the above plasma. The potential difference across DL is generally maintained by external electric sources which continuously bias (one versus the other) the two plasma regions between which the DL appears. The situation seems to become more complex if the external driving sources provide alternating current bias. In this case the DL is formed alternately in opposite positions. In certain conditions the two successively formed DLs persists and remain "superposed" resulting complicated DL dynamics. However, in this case, as it was shown in [2,3] there are possible quasi-stationary states for this DL. This paper reveals some new experimental results on the quasistatic and dynamic properties of the alternating current (ac) driven DLs.

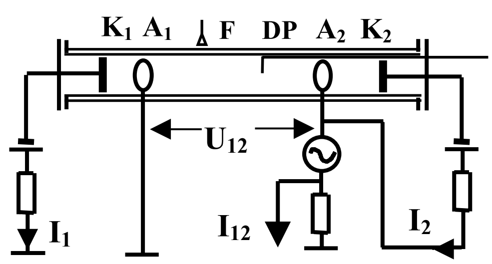

Fig.1 The experimental set-up: K_1, K_2 - plane cathodes, A_1, A_2 - anodes; F- photomultiplier, DP - double probe.

Experimental set-up, results and discussions

The experimental device (fig.1) is detailed described in [4]. The DL structure is formed in the A_1A_2 contact region between the two negative glow plasmas (of the two independent K_1A_1 and K_2A_2 short glow discharges in adjacent positions) which are external dc or ac biased one versus to the other by an external power supply. Conventional plasma diagnostic methods combined in time-resolved measurement procedures were used to study the dynamics of a such discharge DL. It was shown [4] that for a dc biasing U_{12} potential greater than (and

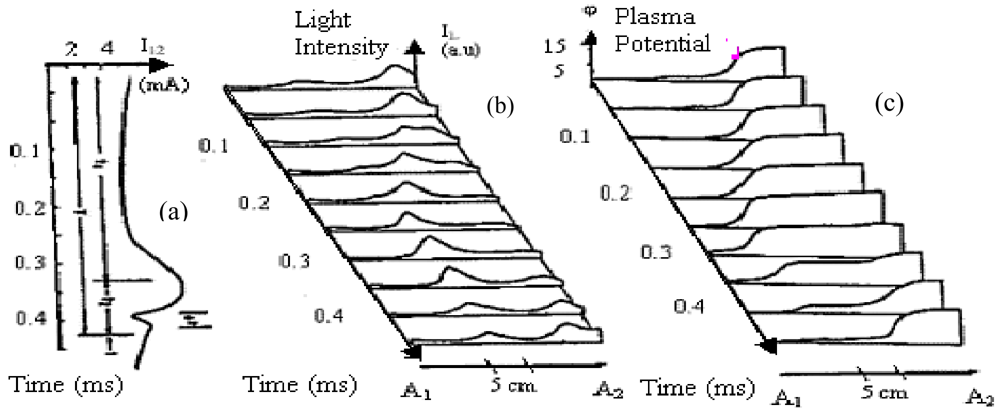

Fig.2 - Time dependence of the I_{12} current (a), time-resolved I_L light intensity (b) and φ plasma potential (c) distributions along the $A_1 A_2$ DL forming region; P=0.06 Torr, I_1= 9mA, I_2=0mA

around) the ionization potential for the working gas coherent oscillations of the I_{12} current (flowing through the DL forming region) and the plasma parameters (in the same region) are observed. Different time-sequences (during DL dynamics) are in connection with experimental parameters which are correlated with external circuit elements and elementary processes taking place in the plasma in which DL is formed [4]. Time-resolved light intensity I_L - taken as plasma density - (b) and plasma potential φ (c) distributions taken at every 50 μs, correlated with the temporal variations of I_{12} current (a), are presented in Fig. 2. After this coherent oscillation regime, for greater values of the U_{12}, (taken as a control parameter), different behaviors of the DL can be observed. Following a period doubling route a chaotic behavior of DL is observed [6,7].

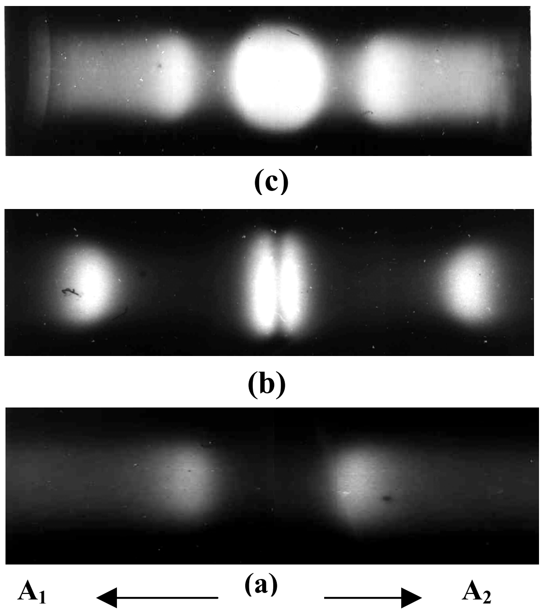

Fig.3 Visual aspect of an alternating current driven double layer. P = 0.06 Torr Argon
a) U_{12} = 10V; b) U_{12} = 18V ; c) U_{12} = 30 V.

For an alternating biasing $\tilde{U}_{12}$ voltage the DL is alternately formed in "opposite" positions. Visual aspects, for different values of the frequency f_{12} and the amplitude of the U_{12} ac biasing voltage, are shown in fig.3. Families of dynamic $U_{12} - I_{12}$ volt-amperic characteristics for different values of the frequency and the amplitude of the U_{12} ac biasing voltage reveal different situations of the dynamics of this kind of DL as it is shown in fig.4 for two values of the gas pressure. The shape of the characteristics reflects the plasma properties in the DL forming region. The DL is formed

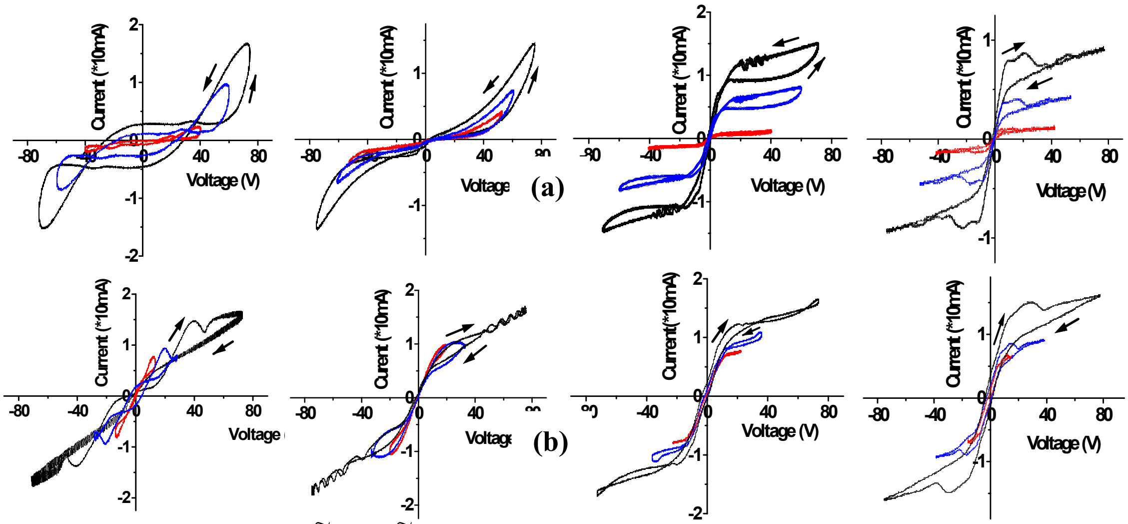

Fig.4 Families of dynamic $\tilde{U}_{12} - \tilde{I}_{12}$ volt-amperic characteristics for different amplitudes of the U_{12} ac biasing voltage and four different values of the frequency (f_{12} equal with 20Hz, 200Hz, 2kHz and 20kHz from left to right). The arrows give time sense. **a**) P = 0.07 Torr ; **b**) P = 0.05 Torr

alternately in the opposite senses in the A_1A_2 region but for values of the $\tilde{U}_{12}$ amplitudes which permit the appearance of the ionizing processes new effects are expected to happen like with dc biasing - see fig. 2 (where it is possible to see the time constants of the DL dynamics). Now, the DL has a proper dynamics [5] which is superposed on those due to the changing ac $\tilde{U}_{12}$ sense. The situation becomes more complicated, in the ac biasing case, when the "decay" of plasma electric charges in the A_1A_2 region is greater than the period of the U_{12} ac biasing voltage. Information about this phenomenology (including observations of the degree of modulation of the corresponding signals) are obtained using an usual plasma probe or (which is easier) a movable photomultiplier F (fig. 1). It is possible to see that, depending on the frequency and the value of the amplitude of the ac biasing potential, the DLs corresponding

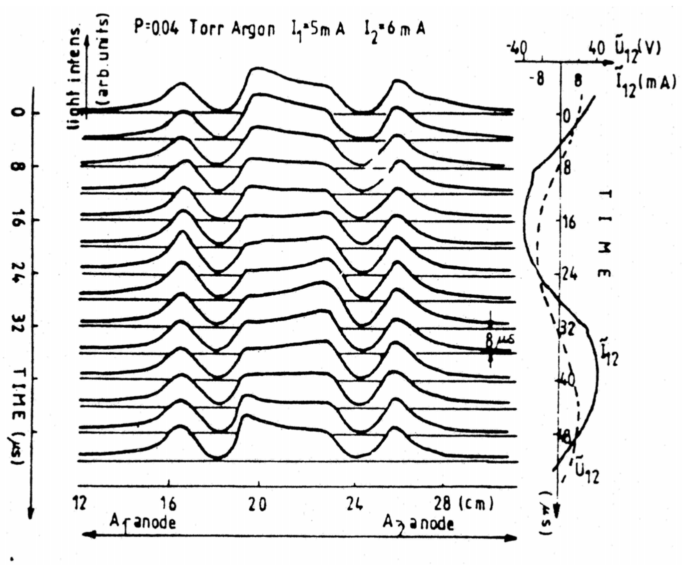

Fig.5 Light-intensity axial distributions along the A_1A_2 region at every 8μs showing a space-time evolution picture of a quasistationary ac driven DL.

to each alternance can "remain superposed", one on the other, resulting quasistationary DL-spatial-well-delimited-plasma structures. The case is shown in fig.5 where, using time-resolved measurements, the space-time evolution of the axial local light intensity in the A_1A_2 region is plotted in correlation with the temporal evolution of the $\tilde{U}_{12}$ ac biasing potential and the $\tilde{I}_{12}$ current. The picture has been drowning up for successive "instantaneous" axial light intensity distributions taken at every 8 μs. The observed quasistationary DL well-delimited-spatial plasma formation, which is similar to the plasmoids from the HF discharges [8], is confirmed by the electric field and the potential distributions along the A_1A_2 region (fig.6) obtained using a movable double probe DP. The electric field is taken, with a good approximation, as the ratio between the potential difference of the two axial-aligned probes of the DP and distance between them.

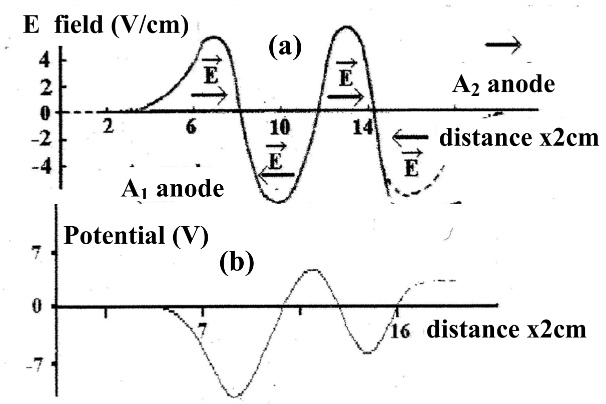

Fig.6 Time-averaged axial distribution of the electric field (a) and the corresponding distribution (b) of the potential along the A_1A_2 region.

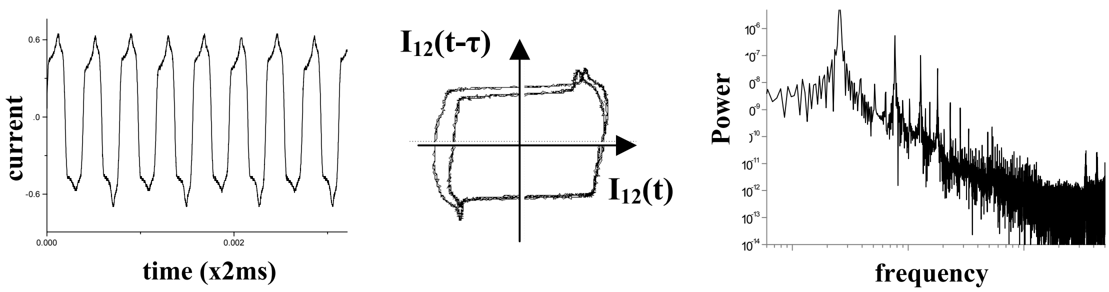

Fig.7 Temporal evolution, phase-space diagram and a power spectrum of the I_{12} current.

The potential distribution was obtained by integrating of the electric field one.

Using computer data recording and processing of signals in fig.7 aspects of nonlinear dynamics of the ac-driven-DLs, as the doubling period phenomenon and the tendency to pass in a chaotic state, are presented.

References

1. R. SCHRITTWIESER editor, *Proceedings of Int. Symp. on Double Layers and Other Nonlinear Potential Structures in Plasmas*, Innsbruck, Austria, Word Scientific, Singapore, (1992)
2. D. ALEXANDROAEI, M. SANDULOVICIU, *Proc. of Intern. Conf.on Plasma Phys.,* Kiev, URSS, Contr. Paper Volume, vol. II, 294, (1987)
3. C. STAN, C. P. CRISTESCU, D. ALEXANDROAEI, Contrib. Plasma Phys. **42,** 53 (2002)
4. D. ALEXANDROAEI, M. SANDULOVICIU, Phys. Lett. A, 122, 173 (1987)
5. P. BERGE, Y. POMEAU, C. VIDAL, *L'ordre dans le Chaos*, Hermann Edt, Paris, (1984)
6. D. ALEXANDROAEI, M. SANDULOVICIU, Romanian Journ. of Phys., **40**(8-9), 841, (1995)
7. J.TAILLET, Amer.Journ.of Phys.,37, 423, (1969)