The structural and transport properties of dust formation in plasma of combined RF and DC discharge of gas mixture

M.K. Dosbolayev[1], A.U. Utegenov[1], T.S. Ramazanov[1]

[1] *IETP, al-Farabi Kazakh National University, 71, al-Farabi av., Almaty, 050040, Kazakhstan*

In this paper the results of investigation of the buffer and dusty plasma properties in combined discharge of alternating and direct current are presented. The results of the experiments revealed several features of burning plasma in combined discharge and changes in the properties of dusty plasma, i.e. further increase of the static field in the RF discharge led to a significant change in the plasma parameters, thus affecting to the structure of the dust formation.

1. Introduction

Combined RF and DC gas discharge is used in many industry technologies, especially in surface treatment of materials, in cleaning and sterilization of medical instruments, etc. [1-3]. It is caused by the fact that the parameters of the plasma could be controlled with the imposition of an additional electrostatic field on the RF discharge [1].

In our experiments the influence of additional electrostatic field on RF plasma and on characteristics of complex plasma was investigated.

2. Experimental setup

Experiments were performed in a conventional RF discharge chamber where gas handling and control were performed through modernized VUP-5 facility. The main part of experimental setup is the electrode system (figure 1), which produces a radio-frequency capacitive gas discharge. Disk electrodes of 100 mm diameter are positioned parallel to each other at a distance 33 mm.

The lower electrodes connected with RF generator providing signal with the frequency f = 13.56 MHz and with DC source. Since the sources of AC and DC power are connected directly to the one electrode, the high-frequency field produced by the RF generator may negatively affect to the operation of the DC source. Therefore, the DC source is connected to the electrode through the coil and a high frequency LC filter. In the experiments the dust particles of melamine formaldehyde diameter of 10.17 mm were used. Schematic diagram of the experimental setup is shown in Figure 1.

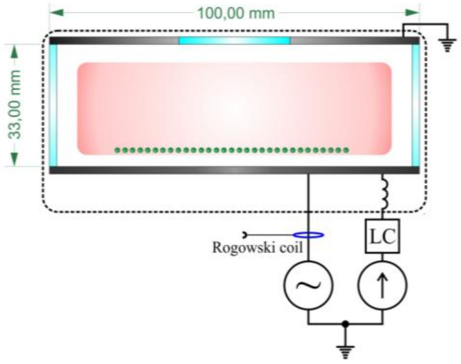

Figure 1 – Schematic diagram of the experimental setup

3. Experimental results

In the experiments the following phenomena were considered: first, it was changes of the axial position and the intensity of glow of the plasma buffer; the second – changing of the spatial position of the dust particles in the plasma.

With adding constant field to the RF discharge, the plasma sheath was shifted, which can be seen in Figure 2, which shows the image of the discharge for different values of the U_{dc}. In Figure 3, this phenomenon can be seen as a shift of glow intensity of the plasma vertically upward, thus noticeable that at the top of the burning plasma glow intensity becomes larger than lower part.

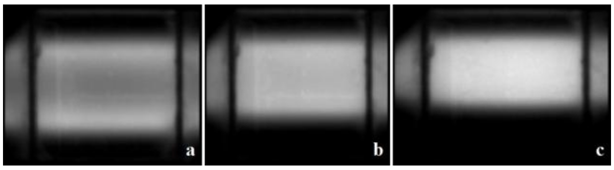

Figure 2 – Displacement of the plasma sheath according to the applied constant field.
a – U_{dc}= -30 V; b – U_{dc}= -50.7V; c – U_{dc}= -70.1V.

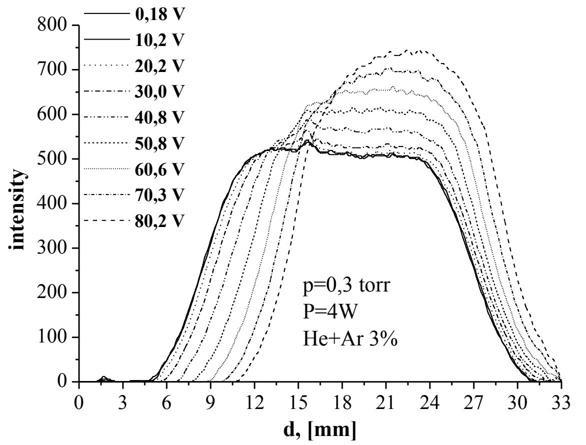

Figure 3 – Axial distribution of glow intensity of the buffer plasma at pressure of He-Ar gas mixture p=0.3 Torr.

The figure shows the distribution of the glow intensity in the interelectrode space of RF at p=0.3 Torr, as can be seen they are symmetric (excluding the area of the upper grounded electrode) [Yu. P. Raizer, 1987, PP. 530-533].

The curve of distribution of the glow in the electrode gap (Figure 3) shows that most of the glow of the discharge is distributed evenly (excluding near-electrode region), therefore, in this area, the process of excitation of atoms occurs approximately uniformly too. It follows, that under these conditions, electrons has time to acquire enough energy to excite the atoms.

The figures 2 and 3 also shows that with the increase U_{dc} glowing plasma region narrows in the axial direction, thereby increasing of dark space. It can be seen that at the maximum values of U_{dc} plasma glow intensity has a maximum value, based on this, we can assert that in this area under these conditions of discharge (U_{dc} = -80.2 V) the plasma density becomes larger than compared with the plasma RF discharge.

4. Changes in the spatial-structural properties of the plasma with dust particles

At this stage of the experimental study the behavior of structures of dust particles was investigated. Since the plasma-dust structures formed in the plasma boundary and plasma sheath [4,5], then with increasing DC source the plasma sheath increases, thereby shifting the location of the dust particles is observed (Figure 4).

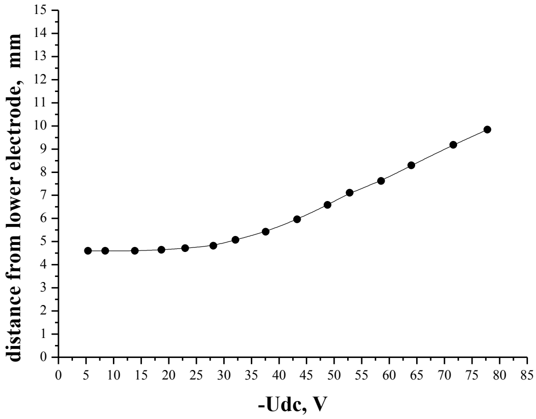

Figure 4 – Displacement of dust particles in the axial direction

Also the chain structures in the vertical direction in the gas mixture and the effects of additional permanent field were studied. In this case, the effect of the ion flux of the plasma on dust structures was considered. The analysis of results the experimental data was proposed the interpretation of ion focusing in chain structures.

5. Conclusion

The distribution of the glow intensity in the axial direction in the RF discharge adding the constant electric field was experimentally studied. It has been shown that increasing the DC voltage, leads to increase the density of plasma, thereby increase the glow intensity. Further, the behavior of dusty plasma was considered. It is shown that, the plasma sheath increases by increasing the DC voltage, thereby the spatial position of the dust particles can be controlled.

6. References

1. Lai W.T., Hwang C.J., Wang A.T., Yau J.C., Liao J.H., Chen L.H., Adachi K., Okamoto S., *Proceedings of the International Symposium on Dry Process. Japan: Nagoya, Institute of Electrical Engineers* (2006) 109.

2. Kawamura E., Lieberman M.A., Lichtenberg A.J., Hudson E.A. *J. Vac. Sci. Technol. A.* **25** (2007) 1456-1474.

3. Denpoh K., Ventzek P.L.G. *J. Vac. Sci. Technol. A.***26** (2008) 1415-1424.

4. Ticos C.M., Dyson A., Smith P.W., Plasma *Sources Sci. Technol*. **13** (2004) 395–402.

5. Arnas C., Mikikian M., Doveil F., *Physical Review E: Statistical, Nonlinear, and Soft Matter Physics, American Physical Society* **60** (1999) 6.