

SPATIAL PROFILES OF ELECTRON AND ION CONCENTRATIONS IN A LARGE SIZE CCP DISCHARGE OBTAINED BY USING A LANGMUIR PROBE

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Abstract. Electron and ion concentrations in a large scale capacitively coupled plasma are measured using Hiden ESPION Langmuir probe system for different distances from the powered electrode. The reactor is cylindrical and has a radius of 60 cm. Derivative probes were used to measure rms Volte/Ampere characteristics and from these curves it was possible to determine that plasma runs in the alpha mode. From the spatial profiles of ion concentrations optimum distance can be found for treatment of samples of different sensitivity.

1. INTRODUCTION

Langmuir probe techniques can provide useful information on plasma and floating potentials, concentrations of ions and electrons, electron temperature and energy distribution functions, ion fluxes. Low cost, simplicity in construction and operation and the fact that plasma parameters can be measured in very wide ranges recommend this technique for application in research and industry as well.

Major disadvantages of Langmuir probes are contamination of the probe tip, perturbation of plasma and in most cases complexity of the theory that is needed to interpret the results. Nevertheless, for the industrial application, in many situations, it is only needed to check that plasma parameters are not changing significantly during the process and exact measurement of parameters is not always necessary. Langmuir probe measurements in RF discharges draw another set of problems due to the effects of RF time averaging, ionization near the probe, and expansion of the probe sheath (see Braithwaite et al. 2009 and Hershkowitz et al. 1988).

Main advantage of RF plasmas is that they can be used for treatment of both conductive and non-conductive materials (see Lieberman and Lichtenberg 2005 and Makabe and Petrović 2006). Treatment of textiles in RF low pressure discharges leads to several effects (see Radetić et al. 2007). For example, affinity to water of treated sample can be changed from hydrophobic to hydrophilic. Fat ac-

ids covering thread can be removed by plasma. Dyeing of textile can be done much more efficiently, compared to conventional methods, with prior plasma treatment.

A large scale discharge chamber has been made and studied in our laboratory with the objective to optimize plasma for low pressure textile treatment. Uniform and stable low-pressure, capacitively coupled plasma, safe from mode transitions to streamers and sparks was diagnosed using a Langmuir probe. The aim was to optimize plasma parameters for fast and reliable textile treatment. In that manner, concentrations of charged particles arriving at the sample surface play major role and are strongly dependent on the distance from the powered electrode for the cylindrical system.

In this paper we present spatial profiles of ion and electron concentrations obtained using Hiden Analytical ESPION Langmuir probe system on asymmetric large scale low-pressure capacitive coupled plasma.

2. EXPERIMENTAL SETUP

Experimental setup can be seen at Fig. 1. The setup consists of discharge chamber (1) in which powered electrode is placed axially (2) and Langmuir probe (3) perpendicular to the powered electrode. Current and voltage waveforms are obtained using derivative probes (4 and 5) connected with oscilloscope (8) and the computer (9). Discharge is run by an RF generator Dressler Cesar 1010 (7) through Variomatch matching network (6). The discharge chamber is 2.5 m long and 1.17 m in diameter and made of stainless steel. Powered electrode is placed in the centre of the chamber and is 1.5 m long, 3 cm in diameter and made of aluminum. Outer chamber wall is the grounded electrode.

Derivative probes are placed into a stainless steel box opposite to each other. The box is placed as close as possible to the powered electrode. Derivative probes were connected to the oscilloscope Agilent 6052A with the cables of identical length. All waveforms are collected by the computer for further analysis. Low pressure is maintained using mechanical vacuum pump with a constant flow of feeding gas (air).

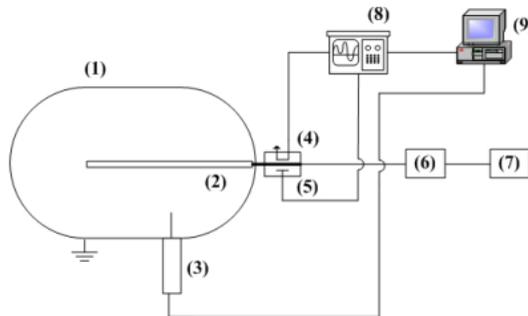


Figure 1: Experimental setup.

Hidden Analytical ESPION advanced Langmuir probe system is placed side-on. The system has a linear motion drive which enables probe positioning with the spatial resolution of 0.1 mm. The chamber has a platform at the bottom where samples are placed. The distance between the platform and the powered electrode is adjustable by moving the platform. We have chosen distances for Langmuir probe measurements within this range. All measurements were done in air at 100 mTorr. We have used platinum probe tip, 10 mm long and 0.15 mm in diameter. Linear motion drive was used to position the probe at the distances from 20.5 cm to 50.5 cm from the powered electrode. Measurements of U-I curves were made for all those positions of Langmuir probe.

At every position 10 measurements were made each being an average of 100 scans with pre-cleaning for each measurement. Prior to each acquisition, probe tip was cleaned for 120 ms providing -50 V to it. Voltage range was from -50 V to 85 V with resolution of 1 V. U-I curves were smoothed using 25 point Savitzky-Golay algorithm and data was further processed using Hidden ESPSoft.

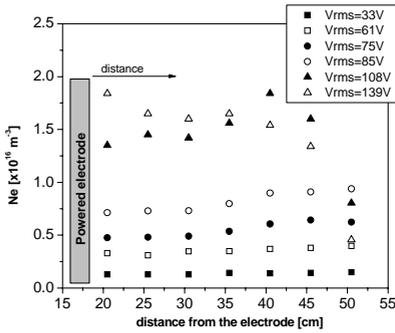


Figure 2: Electron concentrations at different distances from the powered electrode and different applied RMS voltages.

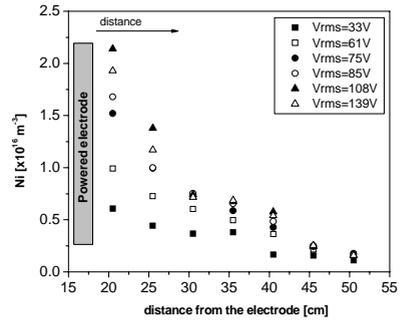


Figure 3: Ion concentrations at different distances from the powered electrode and different applied RMS voltages.

3. RESULTS AND DISCUSSION

Derivative probes were used to obtain RMS voltage and current values and from obtained $V_{\text{RMS}}-I_{\text{RMS}}$ curves we can see that our discharge operates in the alpha mode. By using Langmuir probe we have recorded V-I curves for the range from 10W to 100W of powers given by RF power supply. In Figs. 2. and 3. dependences of concentration of electrons and ions on distance from the powered electrode are shown. We can see that with the increase of the distance electron concentrations do not change significantly. On the other hand, with an increase of the RMS voltage, and consequently power transmitted to the plasma, concentration of electrons increases (see Fig. 2). Also, N_e does not change significantly even when approaching powered electrode.

On the other hand, concentrations of ions (see Fig. 3) decrease with the increase of the distance from the powered electrode. Also, for the longest distances ion concentrations do not change even with the increase of the V_{rms} i.e. of the power transmitted to the plasma. This change is only significant for two closest positions of the Langmuir probe, where ion concentration rises with applied RMS voltage. Since ions play important role in plasma treatment, depending on sensitivity of the sample, one can determine optimal position for their placement from ion concentration and their energies.

4. CONCLUSION

Large scale 13.56 MHz asymmetric capacitive coupled plasma in air at 100 mTorr was diagnosed by using Langmuir probe and derivative probes. From the shape of the $U_{\text{rms}}-I_{\text{rms}}$ characteristics it was determined that discharge operates in alpha mode. Electron and ion concentrations were measured at the several distances from the powered electrode at which the treated samples could be placed.

With the increase of RMS voltage, therefore power transmitted to the plasma, concentration of electrons increases, but it does not change significantly when approaching the powered electrode. On the other hand, concentrations of positive ions remain nearly constant with the RMS voltage increase and start to increase only for the distances less than 30 cm.

From the presently obtained results one can see a complex development of spatial profiles of ions and electrons. One could perhaps elucidate how is continuity of current maintained as the area increases towards the grounded electrode.

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