Study of spacial evolution of EEDFs and plasma parameters in RF-CCP argon stochastic mode discharge by Langmuir probe

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An rf compensated cylindrical Langmuir probe system has been developed and used to characterize a Capacitively Coupled Plasma RF-CCP. This article presents an experimental study of two temperatures plasma. Measurements of the electron distribution function (EEDF) and plasma parameters were conducted at 50 W of rf power and 5×10^{-2} mbar of argon pressure and at different radial position from the discharge axis in the mid-plane of electrodes to the wall. The EEDF is found to be double Maxwellian and remains the same shape throughout the radial distance, with the reduction of its size. The radial dependence of the hot and the cold electron temperatures end densities are presented and discussed here.

In order to investigate the plasma parameters such as the electron density and temperature, the plasma and floating potential, and the electron energy distribution function (EEDF), the Langmuir probe is one of the most used techniques [1]. The discharge mechanism in low-pressure CCP is mainly maintained by collisionless stochastic heating of electrons due to interactions with the oscillating sheath [2]. According to this discharge mechanism, we will investigate in this paper, by a developed Langmuir probe, the radial profile of the experimental EEDF and the electron density and temperature at 50 W of input rf power and 5×10^{-2} mbar of argon pressure.

The schematic diagram of experimental setup used in this work is shown in previous work of [3]. The apparatus consisted of a cylindrical chamber with 215 mm inner diameter and 204 mm height. The gap distance between the two plate electrodes (110 mm in diameter) was fixed to 60 mm. The upper powered electrode without confinement ring was subject to an rf power supply (13.56 MHz), hence the plasma is thus created around the cathode. The constructed cylindrical Langmuir probe, consisted of 0.3 mm diameter tungsten wire probe tip, with exposing 7 mm length to the plasma. In our radiofrequency plasma, a passive compensation method was used to minimize the RF disturbance.

Figure (1) shows the EEDFs measured by a Langmuir probe, based on the Druyvesteyn method [3], at pressure cited above, for different radial positions, and reveled that the EEDFs exhibit bi-Maxwellian distributions for all radial positions, with two electron populations, and which is caused by the collisionless electron stochastic heating mode near the plasma boundary. We can distinguish, the cold electron population with low temperature (0.6-1.4 eV) and the hot electron population with high temperature (2.3-4 eV). At the center of the electrodes at position R = 0 cm, the low temperature group of the EEDF bulk presente the major part of the bi-maxwellian with respect to the high temperature part of the EEDF tail by a factor of 25. As increasing the radial position R, the low-energy ($\varepsilon \leq 6$ eV) electron peak of the EEDF decreases quickely while the tail ($\varepsilon \geq 6$ eV) remains relatively without significant change. By decoupling the two populations , as shown in Figures (2a) and (2b), it can be seen that the low-energy electron density $n_{e\text{-}cold}$, deduced by fitting the bi-Maxwellian EEDFs, decreases from 1.1×10^{10} to 1.7×10^{8} cm^{-3} when moving from R = 0 toward the wall, while their temperatures $T_{e\text{-}cold}$ remain constant between R = 0 and R = 4, and then decrease to a minimum at R = 7, and then increase toward the wall. However, the electron density $n_{e\text{-}hot}$ of high-energy population increases to reach its maximum at R = 6, near the cathode edge (5.5 cm), and then decreases after this position while the electron temperature $T_{e\text{-}hot}$ decreases to reach its minimum at R = 7, and then changes the slope to increase then slightly outside this position. The appearance of a $n_{e\text{-}hot}$ peak, at 0.5 cm outside the cathode edge, may be due to the existence of a strong electric field in this region. As high-energy electrons have a smaller collision cross section, therefore when the temperature $T_{e\text{-}hot}$ is higher at R = 0 than at the cathode edge, the density $n_{e\text{-}hot}$ is lower at R = 0 than at the cathode edge. Figures (2a) and (2b) shows also a radial profile of the electron density n_e deduced by integrating the

EEDF [3], the densities sum (n_{es}= n_{ec}+ n_{eh}) of the two electron populations, the effective electron temperature T_{eff} and the weighted mean temperature T_e. Both densities n_e and n_{es} decrease closely with gaussian profile as function of radial position, and are estimated to be 25 times higher than n_{eh},, while the two temperatures remain canstant and increase outiside the cathode edge region. The same radial behavior of electron effective electron temperature was seen in the previous work of [4] with helicon discharge, and of [5] with DC discharge.

As summary, the measured EEDFs at low pressure are found to be bi-Maxwellian, caused by the collisionless electron stochastic heating mode, and remain the same shape throughout the radial position with reduction of its size. A radial profile of electron density is found to be gaussian and effective temperature present an increase outside the radial edge region. The radial profile is found to be different between the high-energy and the low-energy populations in the stochastic heating mode.

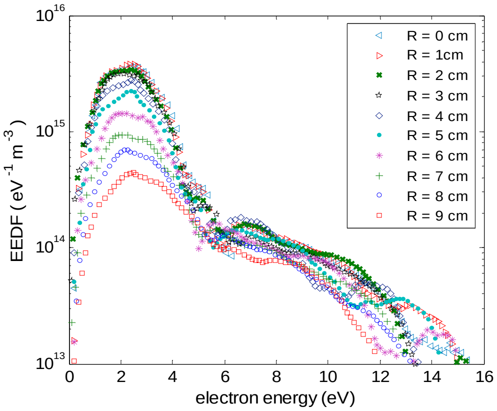

Fig. 1: Radial dependence of the EEDFs with different radial position from the midplane of electrodes (R=0) to the wall (R=10 cm) measured at 50 W of rf power and 5×10^{-2} mbar of argon pressure.

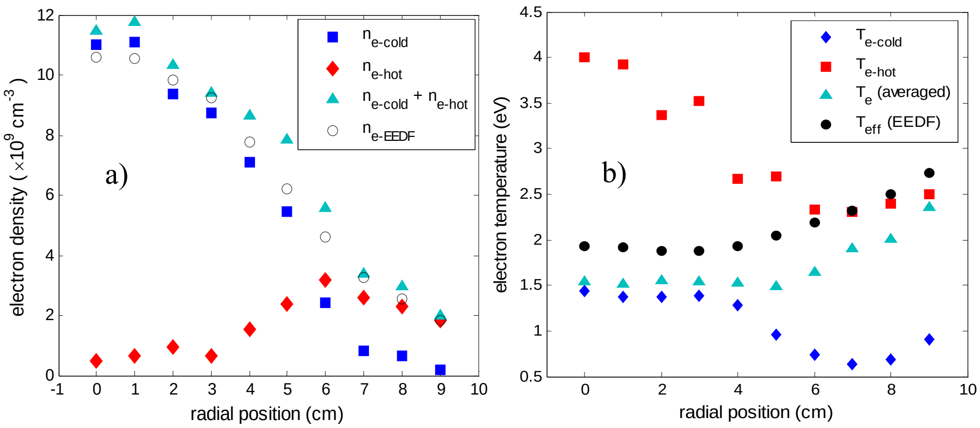

Fig. 2: Radial profile of: a) electron densities and; b) electron temperatures, from the midplane of electrodes (0 cm) to the wall (10 cm), measured at 50 W of rf power and 5×10^{-2} mbar of argon pressure.

References

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