PRESSURE DEPENDENCE OF THE ELECTRON DENSITY IN A HYDROGEN RF PLASMA DISCHARGE

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ABSTRACT

A microwave interferometer is constructed in order to measure the variations of the electron density, in a Rf discharge, as function of the Rf power and the discharge gas pressure. The discharge is operated in hydrogen. For Rf power up to 100 W, the density increases with the Rf power and the gas pressure increase to reach a maximum around 3-4 mbar and then decreases. This is related to the processes of gas ionization and to the flow of neutral particles.

Keywords: Plasma, Rf discharge, Interferometry, Micro wave.

1- INTRODUCTION

Rf plasma discharges are now widly used in many technological applications, / 1 /, such as semiconductor device fabrication, / 2 /, and metallurgical applications as surface hardening, corrosion treatment, and thin layer deposition, / 3 /.

One of the most important parameters of this type of discharge is the electron plasma density, which influence the discharge dynamics.

Measurements of the electron density in different plasma conditions help in the optimization of the processes occurring in plasma aided manufacturing.

2- EXPERIMENTAL SET-UP

The discharge occurs in a stainless steel vacuum chamber evacuated by a turbomolecular pump, / 4 /. The hydrogen gas is introduced through a needle valve. The Rf power is applied through two circular electrodes of 100 mm each introduced in the vacuum chamber and distant from each other by 40 mm. The Rf power at a frequency of 4 MHz and maximum power of 100 W, is coupled through a matching network, which permits the optimization of the power to the plasma. The Rf power is applied symetrically between the upper and lower electrode as shown in Figure (1).

3- ELECTRON DENSITY MEASUREMENTS BY MICROWAVE INTERFEROMETRY

An 8 mm microwave interferometer is used to measure the electron density variations.

The interferometer circuit is built as an unmodulated interferometer, / 5 /, the microwave signal emitted from a reflex klystron at a frequency of 35 GHz is devided into two parts, one crossing the plasma and the other going through an external reference way.

The phase detector arrangement is essentially made of two pairs of diodes, each connected to a mixer having as input the transmitted and the reference signals, the output signals measured by the two diodes are fed into a differential amplifier. Between the two mixers a phase shift of $\pi / 2$ has been set. When we plot the output signals coming from the two differential amplifiers on an X-Y display, the result is a point. In the case of a time varying electron density, this point rotates and describes a circle on the condition that the level measured on the four diodes is in equilibrium. The line density can be calculated using the relation :

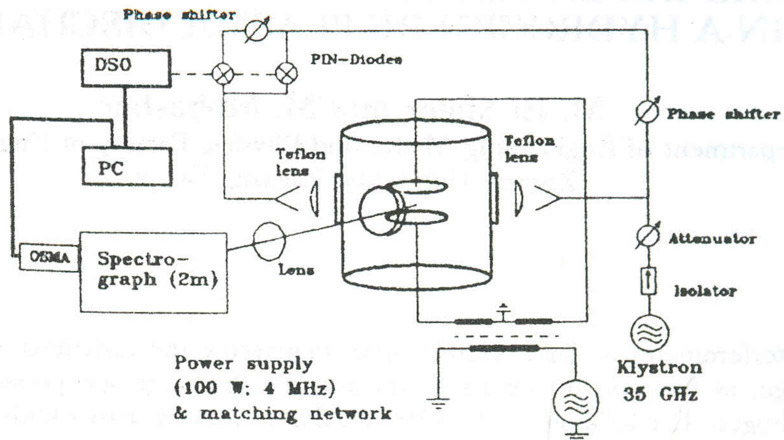

Figure 1. Experimental set-up.

$$\int n\,(e.\,cm^{-3})\,dl\,(cm) = 118.4\,f\,(Hz)\,\Delta\phi$$

Where n is the density , l is the distance in the plasma between the horns, f is the klystron frequency, and $\Delta\phi$ is the phase shift produced by the plasma.

In our case due to the short value of l, which represent the plasma cord, the density is taken to be homogeneous along l, and the line integral is simply divided by l to obtain the value of the density n in the middle of the discharge.

In order to minimize parasitic reflections from the metallic walls the microwave is concentrated on the discharge center using two teflon lenses.

4- RESULTS

Figure (2) shows the dependence of the measured electron density on the chamber base pressure. The electron density increases with pressure to a maximum of $n_e \sim 10^{11}\ cm^{-3}$ at a pressure 0f 3-4 mbar. With further increase in pressure the density smoothly decreases. This effect has be seen for different Rf powers. The density increase is almost linear with Rf power. This can be explained as follows, the pressure increase is accompagnied by an increase in the density of neutral particle, this leads to two competing processes the first one is related to the fact that when the pressure increase more particles are ionized leading to an increase in the electron density , the second one is the fact that the increase in the neutral density leads to a decrease in the ionization rate coefficient, / 6 /, which reduces the ionization of the neutral particles lowering the electon density.

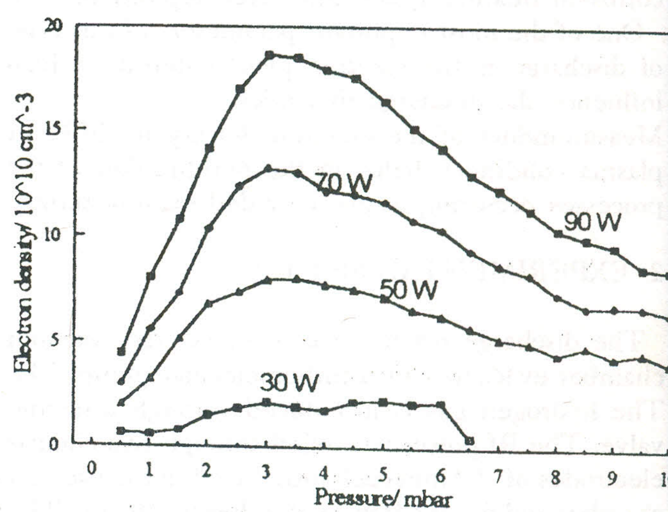

Figure 2. Pressure dependence of the electron density for different Rf powers.

From Figure (2) we can observe that a change occurs aroud a pressure value of 3-4 Torr , we expect that below this value the first process is dominent leading to an increase in the electron density. After this value the second process, which is related to the decrease in the ionization rate coefficient, is more pronounced making the electron density lower in spite of the increase in the neutral gas density.

5- CONCLUSION

The exact determination of the profile of the electron density help in defining the work parameters, for discharges used in technological applications . In Rf discharges, the gas pressure can be adjusted to obtain a certain electron density for the used Rf power.

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