Non-intrusive Method for Electron-Density determination in Low-pressure Microwave Plasma

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The power supplied by the plasma at the surface of a glass substrate is measured and calculated. The total contribution of the heating mechanisms is calculated according to the theories commonly used in the literature, and measured by exploiting the temperature curve variation in the heating phase (plasma on). The cooling mechanisms are leads by the conduction with the gas and the substrate holder, their contribution is measured using the temperature variation during the cooling phase (plasma off). Assuming that our plasma obeys the hypothesis of the corona balance, the Modified Boltzmann Plot (MBP) method is used to determine the electron temperature T_e. A correlation between the power deposited by the plasma and the results of the MBP is established. This correlation indicate that it is possible to estimate the electron density (n_e) without using the Langmuir probe.

1. Introduction

This work is dedicated to the determination of plasma electron-density without using the Langmuir probe (intrusive method which can be unhandy in some cases). The method developed allows to calculate the electron density by combining two non-intrusive methods: the temperature measurement [1] and the modified Boltzmann plot [2].

2. Experimental sut-up

This study was carried-out in a pure argon gas at pressure range of 10 to 30 *Pa*. Plasma is generated by a coaxial microwave plasma source (*Hi-Wave*) switched-on by a 2.45 *GHz* Solid State Generator which the power can vary from 1 to 200 *W*. The parameters of the discharge are measured by a double Langmuir probe (*Impedence Ltd*). The temperature time variations are measured by a *K-type* thermocouple. Optical Emission Spectroscopy measurements are performed by an *Avaspec 2048-2-Avantes* spectrometer with a resolution of 3 *nm*.

3. Experimental results

In this work, we will shown that P_{th}=P_m, where P_{th} is the calculated power at the surface obtained by summing the contributions of electron, ions and electron-ion recombination [3], and P_m is the total experimental power measured by exploiting the temperature curve variations. Thus, the following relation between P_m and n_e is established:

$$n_e = \frac{P_m}{A_s}\left[\sqrt{\frac{k_BT_e}{2\pi m_e}}\exp\left(\frac{e_0V_{sh}}{k_BT_e}\right)(2k_BT_e + E_{ion}) + 0.3k_BT_e\sqrt{\frac{k_BT_e}{M}}\frac{1}{2}k_BT_e\left|\ln\frac{2\pi m_e}{M}+1\right|\right]^{-1} \quad (1)$$

One can see in this equation that electron density depends on one unknown parameter (T_e). The determination of T_e by the MBP method allows the calculation of the electron density. In equation 1, V_{sh} represents the sheath potential taken equal to $(k_BT_e/2e_0)(\ln(M/2\pi m_e)$, E_{ion} is the ionization energy of argon, M is the mass ion and A_s is the total substrate surface.

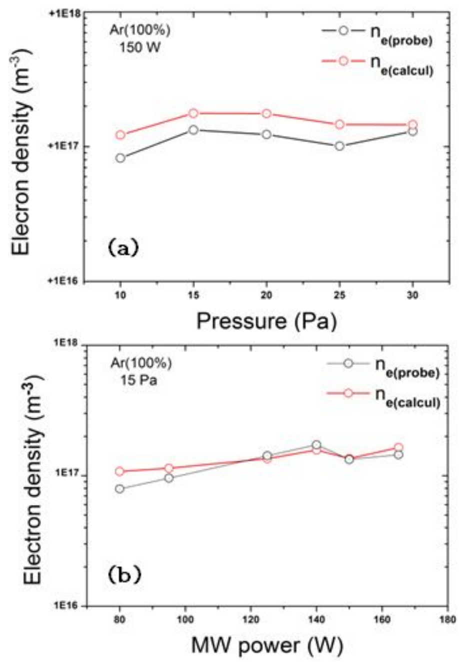

Figure 1: Electron density calculated from Eq.1 compared with Langmuir probe measurments: effect of the pressure (a) and the microwave power (b).

4. References

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