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Characterization of argon-oxygen discharge using Langmuir probe and optical emission spectroscopy measurements

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1. Introduction

The glow region of an argon-oxygen mixture rf asymmetrically capacitively coupled plasma was studied using a self-compensated Langmuir probe. A systematic experimental study of the electron energy distribution function (EEDF) has been carried out for values of injected rf power and neutral gas pressure. Plasma parameters as plasma potential, electron temperatures, electron densities, are correlated with the elementary processes involved in the discharge.

Optical emission spectroscopy has been used to obtain information about different plasma parameters as well as the processes which take place in plasma in the range of the studied pressures and powers. Optical emission intensities of recorded spectral lines for atoms and ions increase with increasing both of power and pressure. Spectra have been recorded from 200 to 900 nm. The relationship between the relative intensities of the emission lines is a complicated function of the sputtering conditions (pressure, temperature), as well as the geometry and the target reactivity. Using this method the electronic plasma temperature has been calculated for different pressure and rf power values. A good concordance between the electronic temperatures estimated using optical emission spectroscopy and that one calculated for the same device using Langmuir probe measurements was obtained

2. Experiment and discussions

The investigated rf discharge was confined in a plasma chamber of an asymmetrical industrial OTP Plasmalab 100 capacitively coupled system. The pressure was controllable between 10 and 90 mTorr. The apparatus was controlled by Oxford Instruments software from a 486 DX33 PC.

Spectral scans from the discharge were obtained using a spectrophotometer Jobin-Yvon type coupled with a silica-silica high OH^- PYROCOAT^{TM} fiber consisting of a pure silica core with a silica cladding for high damage threshold and high-performance optical properties. The optical fiber has a high OH^- concentration for efficient power transmission from UV through visible range, so it provides low-loss transmissions in this domain. The chamber has a quartz window and the silica fiber was positioned outside the chamber very close to this window. All data presented here were obtained by observing the emission at 90^o from the central axis of the electrodes, parallel to the electrode surfaces (Fig. 1). A typical spectrum is shown in Fig. 2.

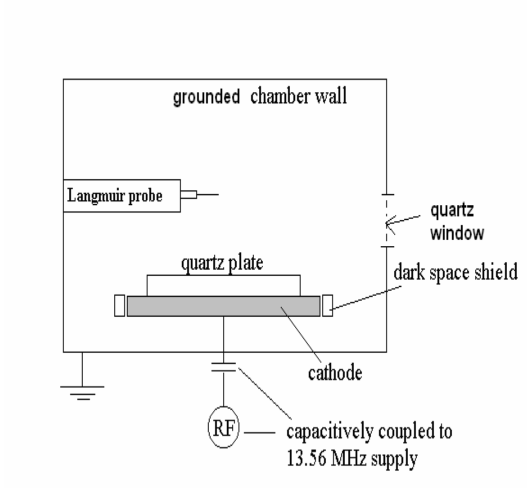

Fig. 1. A schematic diagram of the capacitively coupled discharge

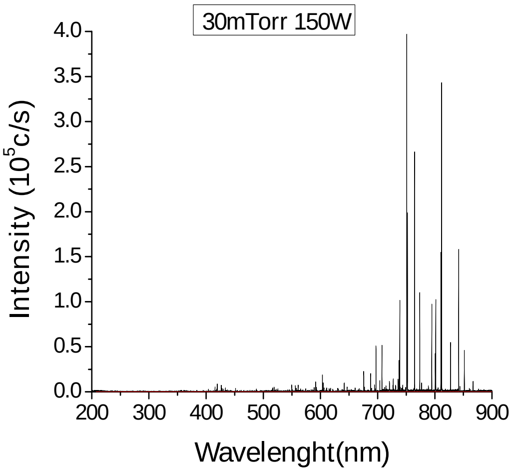

Fig. 2. A typical optical emission spectrum from 200 to 900nm

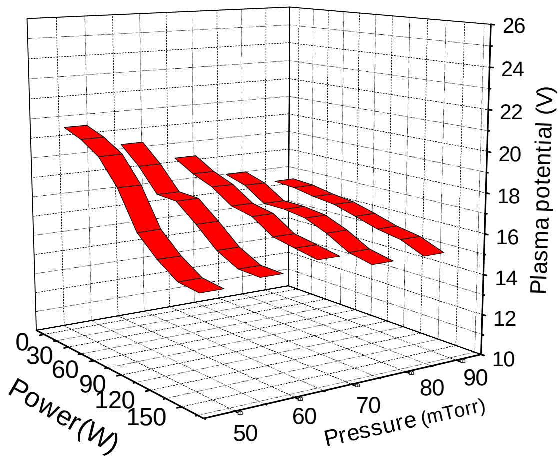

Figure 3 Plasma potential versus power and pressure

A Hiden Analitical RF-compensated Langmuir probe was inserted into the middle of the plasma (fig. 1). In order to sputter off any impurities by energetic ion bombardment, prior to each measurement the probe was negatively biased down to -200 V for about 2 min. From the Langmuir probe characteristics, two Maxwellian populations of electrons [1], with temperatures $T_{e1} \approx 2.5$eV and $T_{e2} \approx 0.9$eV respectively, and densities $n_{e1} \approx 1 \times 10^{13} m^{-3}$ and $n_{e2} \approx 2 \times 10^{14} m^{-3}$, are founded to be present in the discharge. The plasma potential is located by examining the maximum of the *dI/dV* function ($d^2I/dV^2 = 0$). In fig. 3 the mean values of the plasma potential are presented as function of pressure and RF power.

The electronic plasma temperature T_e can be also calculated using the relative intensity of two spectral lines, corresponding to the transition from different lower levels according to the following expression [2], considering plasma in the partial Local Thermodynamic Equilibrium (LTE):

$$T_e = \frac{1}{k} \frac{E_1 - E_2}{\ln\left(\frac{I_2}{I_1}\right) - \ln\left(\frac{(gf\nu^3)_2}{(gf\nu^3)_1}\right)} \quad (1)$$

where E_1 and E_2 are the energies of levels, I_1 and I_2 are the intensities of spectral lines, ν_1 and ν_2 are the frequencies of the two spectral lines, g_1 and g_2 are the statistical weights, f_1 and f_2 are the oscillator strengths, k is Boltzmann's constant. The partial LTE basically demands that the excitation and ionization process have been produced only by electron impact. Using equation (1) electron temperature has been calculated. The atomic argon peaks Ar at 750,5 nm and at 811,7 nm are considered. The values of E_1 and E_2, g_1 and g_2, f_1 and f_2 were obtained from the NIST Atomic Spectral Database [3]. The values obtained by using optical emission spectroscopy (Te $\approx$ 0,4 eV) shown in Figure 4 are in concordance with those obtained using Langmuir probe measurements for the "cold" group (Te $\approx$ 0,9 eV). The difference results because of the methods used to record data from the discharge and because of the method used to calculate the values of temperature. The temperature is only slightly influenced by the RF power values.

Fig. 4 shows the variation of spectral lines intensities for Ar 811,7nm at different pressures and rf powers. The intensities of spectral lines are increasing with the increase of both power and pressure. By increasing of the pressure, the neutral

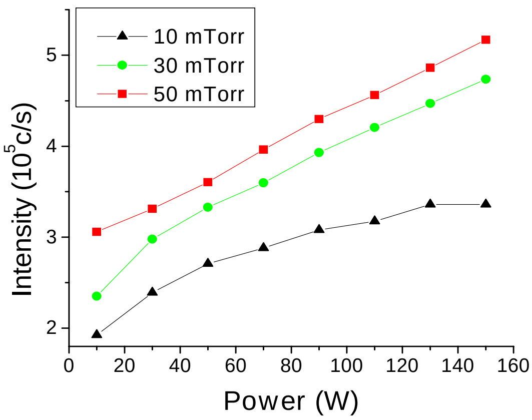

Fig. 4. The variation of spectral lines intensities for Ar 811.7 nm at different pressures and rf powers

density increases, the mean free path for the electron-neutral impacts excitations decreases, and the frequency of these collisions increases. By increasig the power, the ionization degree, as well as the electron energy increase, so the electron-neutral impact excitation rate will increase. The electron transfer their energy by impact with other particles and excite them. By dezexcitation, atoms and ions emit spectral lines.

3. Conclusions

Plasma parameters as plasma potential, electron temperatures, electron densities, were measured in the glow region of a argon-oxygen mixture rf asymmetrically capacitively coupled plasma, by using a self-compensated Langmuir probe and a spectrophotometer Jobin-Yvon type coupled with a silica-silica high OH^- PYROCOAT^{TM} fiber. The influence of the pressure and rf power on spectral lines intensities was analyzed.

4. References

[1] I.A. Rusu,G. Popa, J.L. Sullivan, *J. Phys. D: Appl. Phys.* 35 (2002) 2808

[2]G. Zambrano, H. Riascos, P. Prieto, E. Restrepo, A. Devia, C. Rincon, *Surface and Coatings Technology* 172 (2003) 144

[3]NIST Atomic Spectra Database, http://physics.nist. gov/egi-bin/AtData/main_asd