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Determination of the Electronic Temperature and the Electronic Density of Discharge Plasma

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Abstract: ***In the setting of characterization of discharge plasma we achieved a numerical survey on the experimental specters given by plasma of deposition on thin films of silicon. The purpose of this paper is to determine the electronic temperature and the electronic density of a discharge plasma provoked in the pure helium with a pressure of 0.1mb, a RF power (100-400W) and for positions (x = 0, x = 3 and x = 5).The shape of spectral line and the knowledge of the state of thermodynamic equilibrium of the medium are necessary to achieve our studies. We have used data from atomic physics databases for different elements of the medium as a basis (HeI, HeII, SiI, SiII…), and theoretical and numerical model to calculate the different reasons of broadening (Natural, Doppler, Stark and experimental). The obtained results show that plasma is not at local thermodynamic equilibrium and the electronic temperature is close to values found in the literature.***

Keywords: discharge plasma, broadening, shape of spectral line, thermodynamic equilibrium

1. Introduction

There is two categories of spectroscopic methods which are used for the determination the temperature and electronic density ~~as~~: methods based on the study of the line shape (broadening and shift), methods based on the study of the continuous spectrum using the ratio of the intensities of spectral lines [1]. We used the second method as a diagnostic.

2. Diagnostic Model

The aim of our work is to study the obtained experimental spectra. This study has several axes. It is necessary to determine the responsible elements for these emissions and the involved energy levels [2]. We can apply the equilibrium laws to estimate the electronic temperature and the electronic density at certain position in (our community). It's also possible to determine the concentration of all species. Finally we can study the causes of all the possible broadening [3]. To achieve this aim, we've developed a numerical program [4].

2.1 Experimental spectrum

The experimental spectra (Figure 1) are made of the research on thin films of Mr. and Mr M. S. Aida N.Ataf. The experimental setup is performed at the laboratory of thin films and interfaces at the University of Constantine.

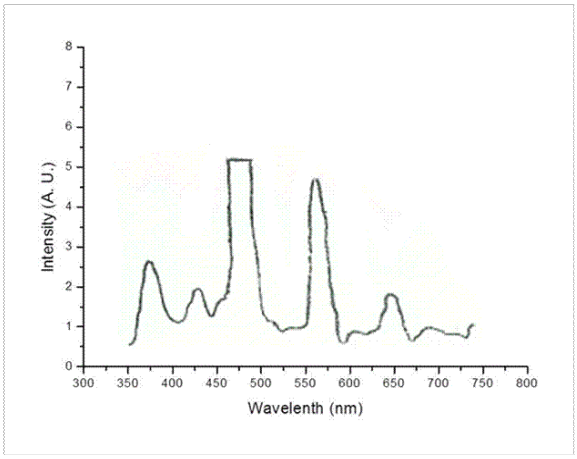

Figure 1: Experimental spectrum.

2.2 Method using the intensity relative spectral lines

In fact, the chemical composition of a medium is often difficult to know precisely [5], especially when it is studied from the spectra of impurities, electrodes (with the target and the substrate) or the walls of the enclosure. We preferred to determine the temperature, using the ratio of the intensities of two or more lines of the same atom or a single ion [1].

Let's take: λ_1 and λ_2 two lines from population levels N_m and N_p

The intensity Total each line is:

$$I_1 = N_m A_1 hc/\lambda_1 \quad (1)$$

$$I_2 = N_p A_2 hc/\lambda_2 \quad (2)$$

Where A_1 and A_2 are the corresponding probabilities of spontaneous emission.

A local thermodynamic equilibrium (LTE) **[6]**, the population of each level is given directly by the Boltzmann law according to the temperature of the medium **[7]**:

$$N_m = (N_{H_e} g_m / B_{H_e}(T)) \exp(-E_m / k_B T) \quad (3)$$

$B_{H_e}(T)$ is the partition function He

Where R the ratio between the intensities of peaks, from which:

$$R = I_1 / I_2 \quad (4)$$

Therefore

$$T = (E_m - E_p) / \ln(\lambda_1 A_2 g_p R / \lambda_2 A_1 g_m) \quad (5)$$

3. Results

The connection of our program [4] with six databases atomic (He, He^+ , Si, Si^+, H and O) can give the one hand, the theoretical spectra of each species and on the other hand, the total spectrum of the mixture according to density of each species

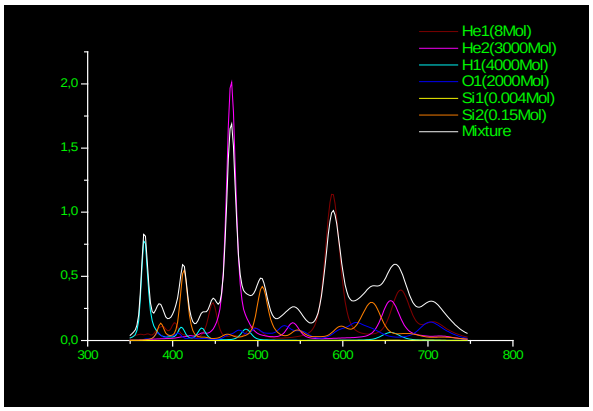

Figure 2: Theoretical spectrum of each species

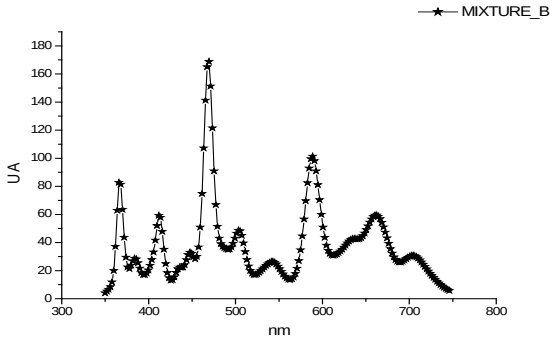

Figure 3: Theoretical spectrum of the mixture

For determination of Electronic Density **[8]**
Firstly the initial density of helium gas is:

$$N_o = p_t / K_B T \quad (6)$$

where p_t is the gas pressure

It is assumed that the ion density of He^{++} is negligible **[1]**.

So :

$$N_{He} + N_{H_e^+} = N_o \quad (7)$$

Therefore

$$N_e = N_{H_e^+} + N_{impu^+} \quad (8)$$

We've used numerical calibration to determinate the proportion of the eventual impurities (Figure 1).

Table 1 concentration of each species

Species	*Concentration %*
He I	***0.26***
He II	***99.72***
Si I	***0.01***

Table 2: Number of radiative transitions in the visible of each species

Species	*Transitions*
He I	**119**
He II	**242**
Si I	**119**
H I1	**66**
O I	**161**
Al I	**17**
Fe II	**204**

Table 3: Numerical values of the electronic temperature and the electronic density in the position x=0, and for RF Power=300W

Electronic temperature	*Electronic density*
0.11 ev	*5.68X 10^{+15}cm-3*

Table 4: Numerical values of the different broadening

Lines(nm)	*Natural*	*Doppler*	*Stark[9]*	*Experimental*
447.273 HeI	*0.2621 10-5*	*0.0573*	*0.091*	*0.12*
587.724 HeI	*0.1299 10-4*	*0.0754*	*0.157*	*0.12*

4. Conclusion

In discharge plasmas the experimental broadening is the most important. The widths of spectral lines are not good idea to calculate the electronic temperature and the electronic density. With some approximation and at local

thermodynamic equilibrium, we calculate the electronic temperature and electronic density by using ratio between the intensities of lines.

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