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Investigation the effect of operating conditions on T_e and n_e of Argon plasma glow discharge at cathode graphite

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ABSTRACT

In this study, the spectral analysis technique was used to calculate the electron temperature and density of argon gas using the ratio method between the two spectral lines. These parameters were calculated at different pressures (0.375, 0.75, 1.5, 1.875, 2.25 torr) and voltages (240, 250, 260, 270, 280 volt). The results showed that the temperature of the electron increases by increasing the voltage and decreases with increasing pressure, while the density of the electrons increases by increasing the voltage and the pressure. where the temperature of the electrons was calculated and it was at the limitations of (0.28 - 0.54eV), As for the density of electrons was at the limitations of (1.5×10^{12} - 3.7×10^{12} cm $^{-3}$) .

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دراسة تأثير ظروف التشغيل على ne, Te لتفريغ توهج بلازما الأركون لكاثود من الكرافيت

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الـــخُــلاصـــة

في هذه الدراسة تم استخدام تقنية التحليل الطيفي لحساب درجة حرارة وكثافة الالكترون لغاز الاركون بأستخدام طريقة النسبة بين شدتي الخطين الطيفيين حيث تم حساب هذه المعلمات عند ضغوط مختلفة (٠.٣٧٥,٠.٧٥,١.٥ ، ١.٨٧٥، ٢.٢٥ torr) وفولطيات (٢٤٠,٢٥٠,٢٦٠,٢٧٠,٢٨٠ volt) . واظهرت النتائج ان درجة حرارة غاز الالكترون تزداد بزيادة الفولطية وتتناقص بزيادة الضغط ، اما كثافة الالكترونات تزداد بزيادة الفولطية وتزداد بزيادة الضغط . حيث تم حساب درجة حرارة الالكترونات وكانت بحدود (٠.٢٨ -٠.٥٤ eV) اما كثافة الالكترونات فكانت بحدود (١.٥ × ١٠^١٢ - ٣.٧ × ١٠^١٢ cm $^{-3}$) .

الكلمات المفتاحية:

تفريغ التوهجي
التحليل الطيفي
الجرافيت

1. INTRODUCTION

There are many spectral methods for diagnosing plasma in laboratory and space. Plasma in laboratory which is at low temperature and density gives electromagnetic radiation emission in relation to plasma space. Through analyzing the spectrum of this radiation, plasma parameters, such as density and temperature, are determined [1] and the sedimentation processes are monitored in many .[scientific centers [2

The emission spectral of plasma is mainly due to the electrons' irritation when a certain energy is acquired and then electrons move to a lower energy level with a photon emission of energy equal to the difference between the two energies of the two levels [3].The spectrum of plasma is generally divided into two parts: Absorption spectrum of where emission and the plasma spectrum is diagnosed through the two spectrums, or one of them, but the absorption spectrum is more effective for diagnosis than the emission spectrum [4]. The color which is emitted from the plasma depends on the nature of the gas, such as the light of argon plasma is pink,while that of nitrogen is orange and that of neon is red [5]. In general, there are two common ways to determine electron density and temperature: optical emission spectroscopy and Langmuir probe. Optical emission spectroscopy (OES) is one of the most common methods because of its easiness and the absence of disturbances in the plasma during measurement. When considoring Langmuir probe, it depends on the electrical properties (I-V) obtained from the previous data to determine the intensity and the temperature of the electron [6]. Different types of atoms, ions and molecules are distributed according to the energy levels that are possible. On this basis, plasma is determined in terms of electron temperature T_e and electron density n_e . There are different ways to measure electron's temperature; some ways depend on the density of the spectral two lines and others depend on one spectral line. Thus, Te can be determined by the density ratio of two or more spectral lines belonging to the same ionization of calculating electron temperature[7]:

$$T_e = -\frac{E_k - E_i}{k}\left[\ln\left(\frac{A_k g_k I_i \lambda_i}{A_i g_i I_k \lambda_k}\right)\right]^{-1} \text{------------(1)}$$

where E is the energy of the corresponding level , k is the Boltzmann constant, A is the transition probability ,λ is wave length gi is the statistical weight of the upper level , gk is the statistical weight of the lower level, Ek is the energy of the lower level, Ei is the energy of the upper level ,i and k represent the upper energy level and lower energy level of transition respectively . used the values of the parameters

E (energy level) and Ag (Transition probability) taken from NIST (The National Institute of Standards and Technology) (NIST atomic spectra database),also The values of E_k,E_i, A_k g_k, A_i g_i, and are obtained from the NIST atomic spectral database.

The density of the electron can be measured in several ways, namey the Doppler and Stark expansion [8] where Stark expansion is in relation to local electric fields; therefore, it is one of the most important characteristics of the expansion of the plasma spectral line [9]. Through these methods, density of electrons can be measured with reasonable accuracy. Through the expansion of the Stark line to an isolated atom or a single charged ion, this method can be used even if the plasma is not in the case of local dynamic equilibrium (LTE) whereas the density of electrons is determined by ± 5% inaccuracy of the theoretical calculations. Stark's expansion of spectral lines in plasma results from collisions with other charged species which leads to the expansion of the spectral line and a change at the top of the wavelength. (FWHM) of the Stark expansion lines $\Delta\lambda_{\frac{1}{2}}$ is associated with density electrons with the following formula:[7]

$$\Delta\lambda_{\frac{1}{2}} = 2\mathrm{w}\left(\frac{N_e}{10^{16}}\right) + 3.5\,A\left(\frac{N_e}{10^{16}}\right)^{1/4}$$

$$\times\left(1 - \frac{3}{4}N_D^{\frac{-1}{3}}\right) w\left(\frac{N_e}{10^{16}}\right) A^{\circ} ----(2)$$

Where W is the electron effect factor, A° is the ionic expansion factor, and N_D is the number of particles in the Debye ball. The final formula for computing electron density in Debye ball using the half-width is

$$logN_e = 1.452\ log\Delta\lambda_{\frac{1}{2}} + 16.017 - -(3)$$

The electron density can be calculated by depending on the temperature through the following equation[10]:

$$n_e = \frac{I_z}{I_{z+1}^*} 6.04x10^{21} T^{3/2}\, e^{\frac{E_{j,z} - E_{j,z+1} - x_z}{K_B T}} - -(4)$$

Where I_z is the intensity of the first spectral line , I_{z+1}^* is the intensity of the second spectral line , $E_{j,z}$ is transmission energy of the first spectral line , $E_{j,z+1}$ is transmission energy of the second spectral line, x_z is ionization energy for argon gas or

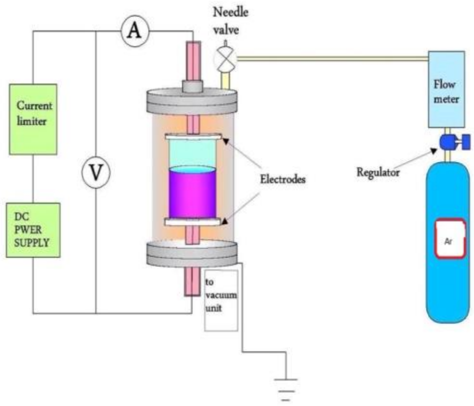
$$n_e = \exp\left(44.2476 + 1.20\ Ln\ \Delta\lambda_{\frac{1}{2}} - 0.6\ Ln\ T_e\right) - - \quad (5)$$

where n_e is the electron number density in (cm^{-3}) and $\Delta\lambda_{\frac{1}{2}}$ is the line width at half maximum intensity of any line, T_e values are obtained from the two lines' intensity method. The expansion of the spectral line occurs as a result of the union of all influences in this spectrum, and that each mechanism of spectral line expansion has an independent and different role in extending spectral range which dependent on plasma conditions [10]. Determination of plasma properties such as electron temperature and density is of great importance in the removal and drilling of thin films. The temperature and the density of the electron were summed up in the discharge of nitrogen and argon at controlled pressure through the use of spectroscopy [11].

2- EXPERIMENTAL SETUPs

The cathodic discharge system of argon consists of two parallel electrodes, cathode circular disk (diameter 8 cm and 1.7 cm) from graphite and the anode is made of aluminum as a disk (diameter 8.8 cm and thickness 1.1 cm), the electrodes are placed in a glass cylinder (diameter 10cm, length 15 cm) and the figure (1) illustrates the diagram of the used system.

The external DC discharge system is operated after connecting the digital devices used to measure the voltage and the current. The vaccum system using a rotary pump (Trivac D 16 E), mass (24Kg) and vaccum speed (16m3/h), Pirani Gauge (Edwards). The rated voltage is controlled by a DC power supply with continuous high voltage (0-3000V) and current of (0-500mA).



Figure(1): The diagram of the used system.

The S3000-UV-NIR Ocean spectrometer was used to determine the flow of plasma through electronic monitoring of the irritable species and their temperature and density in the discharge of the argon plasma(337.6-913.3 nm) after plasma flow directly.

3- RESULT AND DISCUSSION

The two spectral lines (752.35, 827.73 nm) were selected when the pressure values were at (0.375,0.75,1.5,1.875,2.25 torr) and the rated voltage at (240,250,260,270,280 volt). Figure (2) shows the emission spectrum of Argon Ar gas plasma at 1.5 torr and the applied voltage (270,280 volt), respectively. These two figures are an example illustrating the difference in the intensity of the spectral lines as a function of the rated voltage increase voltage when pressure is confirmed.

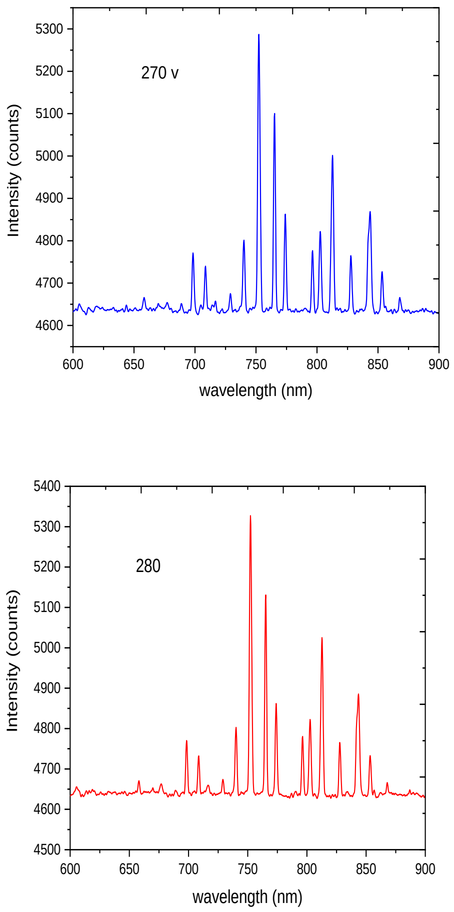


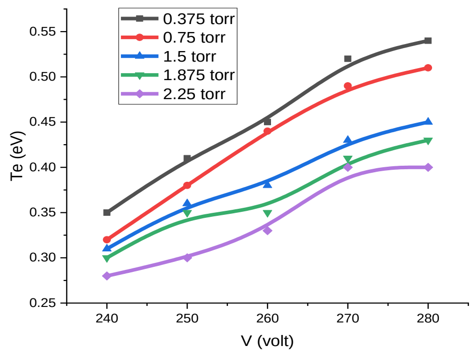
Figure (2): shows the emission spectrum of the argon plasma at a pressure of 1.5 torr for two different voltages.

Table(1) shows the electron temperature values (Te) found for the graphite cathode at different pressures and voltages.

Table (1): electron temperature Te (eV) at different working pressures (torr) and applied voltages (V).

Applied Voltage (V)	Working pressure (torr)				
	0.375	0.75	1.5	1.875	2.25
	Electron temperature T_e (eV)				
240	0.35	0.32	0.31	0.30	0.28
250	0.41	0.38	0.36	0.35	0.30
260	0.45	0.44	0.38	0.35	0.33
270	0.52	0.49	0.43	0.41	0.40
280	0.54	0.51	0.45	0.43	0.40

Figure (3) shows the change in temperature of the electron with the rated voltage when the pressure is confirmed for each case.



Figure(3): Change the temperature of the electron with the applied voltage.

Where it can be seen that the increase in the temperature of the electron with the increase in voltage controlled pressure of each case and it can be explained that the increase in voltage increases the energy of the electron as well as the degree of ionization and thus increase the excitation rate of electrons and neutral atoms and increase the temperature of the electron this is consistent with the behavior of reference [12].

Figure (4) shows the temperature change of the electron with the pressure of the voltage stabilizer for each case.

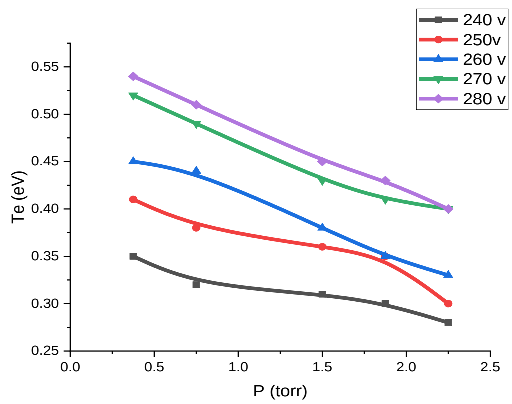


Figure (4): shows the electron temperature as a function of pressure. It was noticed that the a decrease in the temperature of the electron Te with increasing the pressure of gas voltage stabilized for each case can be explained that when the increase in the rate of gas flow, it leads to an increase in the number of collisions between electrons and gas atoms and thus increase the energy transferred from electrons to atoms or molecules of gas and this increases gas temperature by lowering the temperature of the electron, and this is consistent with the behavior of reference [13]. The density of the electron was calculated using equation (4) and the density was calculated at different pressures (0.375,0.75,1.5,1.875,2.25 torr) when the voltage values (240,250,260,270,280 volt) after compensating electron temperature values obtained previously The ratio between the two spectral lines, and Figure (5) shows the change in the density of the electrons with the voltage applied to the pressure stabilizers for each case.

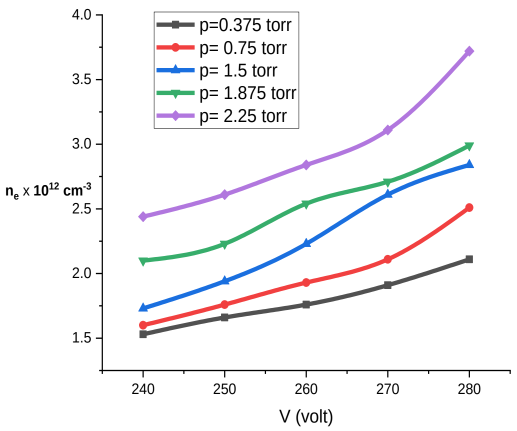


Figure (5): shows the electron density change with the applied voltage.

Where the increase in the density of electrons by increasing the voltage of each pressure can be explained that when the applied voltage increases, the strength of the electric field increases, which leads to the heating of electrons and increase the speed of electrons to form active electrons (electrons that have a large amount of energy) and these electrons collide with atoms or molecules and ionize them resulting in an increase in the density of the electrons and this agreed with behavior of reference [14]. In Figure (6) it represents the change in the density of the electrons with the pressure of the gas stabilized voltage for each case.

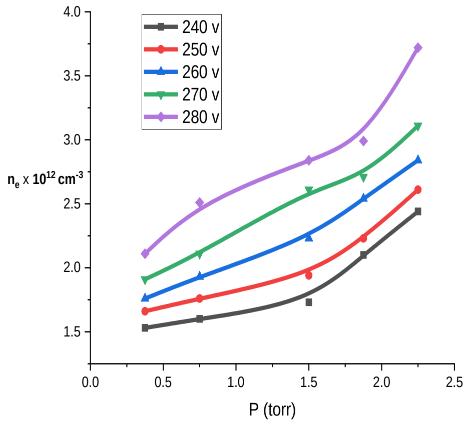


Figure (6): The change in the density of the electrons with the pressure exerted on the voltage stabilizers for each case.

We note an increase in the density of electrons with increased gas pressure due to the increase in the number of atoms or molecules of gas, which in turn increases the number of inflexible collisions and increases the rate of ionization of atoms and result in the increase in the density of electrons, and this agreed with behavior of reference [15]

4- CONCLUSION

Plasma parameters (temperature and density of electrons) were studied using OES for argon plasma where calculated the temperature and density of electrons through the work, the results that can be concluded are as follows: Firstly, It is found that the temperature of the electron increases by increasing the voltage applied due to the increase of the electric field between the electrodes while the temperature of the electron decreases as the pressure increases. Secondly , the density of the electrons was increased when the voltage between the electrodes increased, while the density of electrons increases when gas pressure increases.

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