Study Effect Of Titanium Surface Temperature On Plasma Parameters

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ABSTRACT: In this work, we present experimental results demonstrating the effect of sample (cathode) temperature on the temperature and electron density of the glow discharge of arcon gas. The glow discharge system was run for half an hour to obtain the hot cathode as a result of bombarding the cathode with ions and unstable atoms formed in the glow discharge, then the cathode was cooled with cold water to obtain the cold cathode. Electron temperature and density were calculated using an optical spectra analyzer for both cases. It was found that the temperature and density of electrons are greater in the case of the hot target, and it was found that the temperature and density of electrons increase when the voltage increases, and also it was found that the temperature of the electrons decreases with increasing gas pressure while the density of electrons increases. The original impetus for this work was to better understand the effect of sample material temperature on the electrical and analytical behavior of the glow-discharge system so that there would be more control over the quantification.

KEYWORD: Hot Target, Cool Target, Glow Discharge, Spectroscopy, Electron temperature, Electron density.

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INTRODUCTION

A glowing discharge is actually a luminous plasma containing positive and negative charges and a large number of neutral particles, and this glow arises due to the fact that the energy and numerical density of electrons are high enough to generate visible light by excited collisions [1]. Glowing discharge is used in many applications, in the microelectronics industry, the laser and light industry, plasma panel display technology and analytical chemistry [2]. Cathode temperature affects the electrical properties of the glow-discharge and is thus a parameter that must be controlled to obtain accurate analytical results in a glow-discharge system [3]. Bombardment of the cathode with ions and unstable atoms formed in the discharge increases the temperature of the cathode, the temperature of the cathode has an important influence on the glow-discharge coefficients [4]. A distinctive feature of hot target discharge is the target thermal emission effect [5]. In order to be able to use glowing discharge in various applications, it is necessary to obtain detailed information about the temperature and density of electrons and to control these parameters. The efficiency of processes occurring in plasma and reaction rates in general depend on the density and energies of charged particles [6].

The impact of the sample's surface temperature on glow discharge electrical properties was investigated in this paper. The temperature and density of electrons were determined using an optical spectroscopic analyzer.

MATERIALS AND METHODS

Theoretical part

Typical methods for measuring electron density and temperature include the Langmuir probe, heterochromatic laser interferometry, Thomson laser scattering, as well as optical emission spectroscopy (OES) [7]. Optical emission spectroscopy (OES) is the most popular method for glow discharge examination because it is simple and does not produce any disturbance in the plasma. A convenient and commonly used method for determining temperature is by means of an emission ratio consisting of two spectral intensities, which produces an electronic excitation temperature that can equal the electron temperature, so the electron temperature can be obtained by the formula [6].

$$\mathbf{KT_e} = \frac{(\mathbf{E_1} - \mathbf{E_2})}{\ln\left(\frac{\mathbf{A_1 g_1 \lambda_2 I_2}}{\mathbf{A_2 g_2 \lambda_1 I_1}}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots.(\mathbf{1})$$

Where I_1, $\boldsymbol{\lambda_1}$, g_1, and A_1 represent the overall intensity, wavelength, statistical weight, and transition probability of one line, respectively, and E_1 represents the excitation energy. I_2, $\boldsymbol{\lambda_2}$, g_2, A_2, and E_2 are the comparable variables for the other line.

Analyzing the Stark expansion for two different emission lines yields the electron density. This approach is based on the fact that the Stark expansion of various lines is dependent on electron density and temperature in different ways. We can diagnose electron density and temperature simultaneously by comparing two or more lines of line expansion [8]. So the electron density can be obtained by the formula [9,10].

$$\mathbf{n_e} = \exp\left(\mathbf{44.2476 + 1.20 \ln \Delta\lambda_{\frac{1}{2}} - 0.6 \ln T_e}\right) \ldots\ldots\ldots\ldots\ldots(\mathbf{2})$$

where T_e is the electron temperature in K and 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.

Practical Part

A cylindrical glow-discharge chamber locally made of stainless steel was used with two windows with dimensions (R_{out} = 29.5, Rin = 26.5, h = 30.5) cm, Fig. (1). As well as using a planar magnetron cooled with cold water, which was manufactured locally with dimensions (R= 9 cm, h= 9 cm) Figure (2), where a titanium plate with a diameter of (9cm) was placed from the outside opposite the magnetic field that represents the cathode pole. A circular aluminum disc with dimensions (R= 9 cm, h= 1.2 cm) was used to represent the anode electrode. The magnetic field strength was measured using (Digital Gaussmeter) along the surface of the target and found to be (940 Gauss) at the center of the target and (420 Gauss) at the ends of the target. The electrodes are connected to a DC voltage source. A two-stage rotary vacuum pump was also used. Pure argon gas was introduced into the chamber through a precision valve controlled for a range of low pressures (0.02-0.8) torr. The gas pressure inside the chamber was measured with a Pirani Gauge (Edwards) manometer, and a pump was used to circulate the water to the magnetron. The glow-discharge system was run for half an hour to obtain the hot target, then we start working and data recording, then we cool the target with cold water, then we start work and record the data for the same conditions.

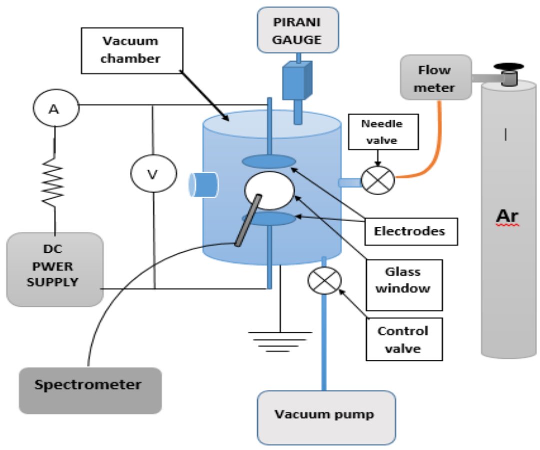

Figure (1) represents a schematic diagram of the glow discharge system

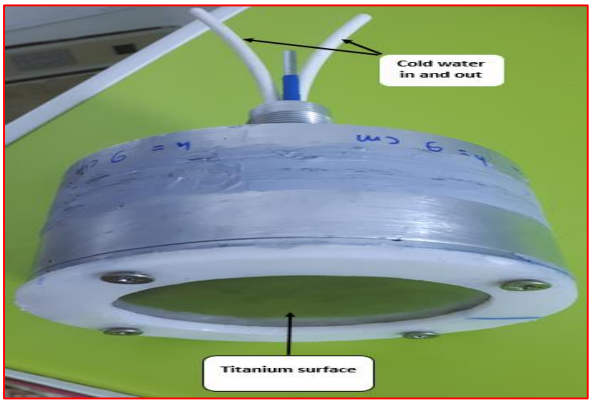

Figure (2) shows the magnetron used in the work

An Ocean (S3000-UV-NIR) optical spectra analyzer was used to know the plasma flow by electronic monitoring of the excited species, their temperature and density in the Argon plasma discharge. Spectra were obtained with a range (161.95-1081.18) nm immediately after the plasma flow Figure (3) shows the device used.

Figure (3) shows the optical emission spectrophotometer used in the work

The distance between the electrodes was fixed at (8 cm) and the emission spectra were measured by an optical spectra analyzer in order to calculate the temperature and density of electrons.

RESULTS AND DISCUSSION

Calculate The Temperature Of The Electrons

Using the ratio approach between the two spectral lines, the temperature of the electrons (T_e) was estimated, as in equation (2), where the two spectral lines (Ar II - 338.8, Ar I - 741.2) were chosen as in Figure (4), when the pressure values were (0.09, 0.01, 0.15, 0.2) torr and with different discharge voltages (420, 440, 460, 480) volt.

In order to calculate the temperature of the electrons, we used equation (1), as well as the values of the parameters (E, A, g) from the (NIST) website (Atomic Spectra Database**)** [11].

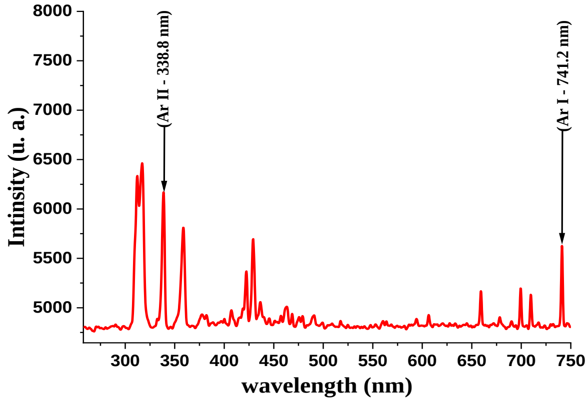

Figure (4) shows the two spectral lines used in calculating the temperature of electrons

Figure (5) show the change in the intensity of the spectral lines as a function of the wavelength of the states of the hot target and the cold target when the applied voltage increases at a constant pressure. These graphics serves as an example of the variability in spectral line intensity between the two states at a pressure of (0.2 torr). Because of the rise in electron energy and degree of ionization that results in various spectral lines, we see an increase in the intensity of the spectral lines as the applied voltage increases [12]. We also see a drop in the intensity of the spectral lines for the cold target compared to the hot target, which is caused by an increase in the energy of the electrons on the hot target as a result of the hot target emitting more heat than [13-14].

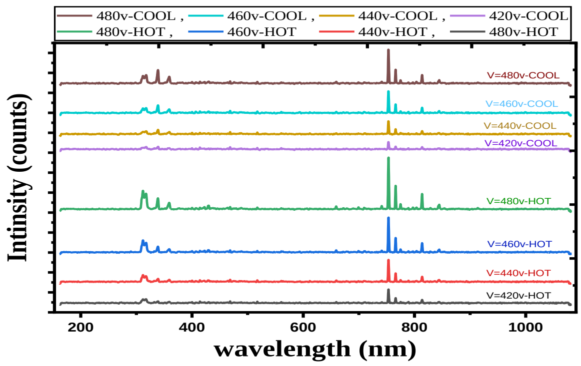

Figure (5) shows the change in the intensity of the spectral lines as a function of the wavelength change at constant pressure for the hot and cold target state.

Figure (6) show the electron temperature as a function of the voltage change at constant pressure for the hot and cold target state. When the applied voltage is increased while the pressure remains constant for each case, we observe an increase in the temperature of the electron (T_e), and this can be explained as follows: "The increase in voltage causes an increase in the energy of the electron as well as the degree of ionization. Different spectral lines will result from the various atomic and ionic excitations that happen when energy levels rise, and this agrees with the results of the source [15].

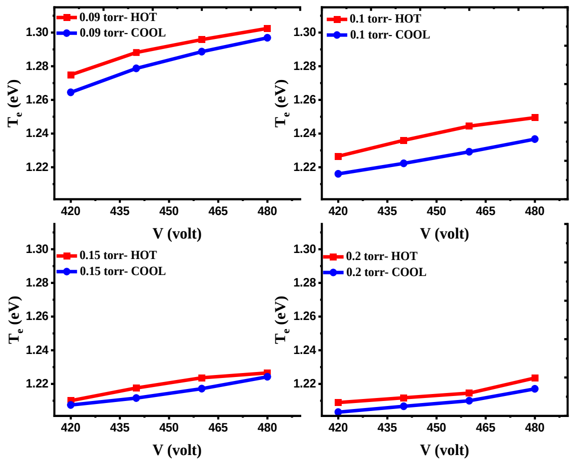

Figure (6) show the electron temperature as a function of the voltage change at constant pressure for the hot and cold target state

Figure (7) show the electron temperature as a function of the pressure change at constant voltage for the hot and cold target state. When the gas pressure is increased, we see a reduction in electron temperature in both cases. This is explained as follows: "As the gas flow rate increases, the number of collisions between electrons and gas atoms increases, and the energy transferred from electrons to atoms or gas molecules increases." As a result of the decreased temperature of the electrons, the temperature of the gas rises". This agrees with the results of the source [16].

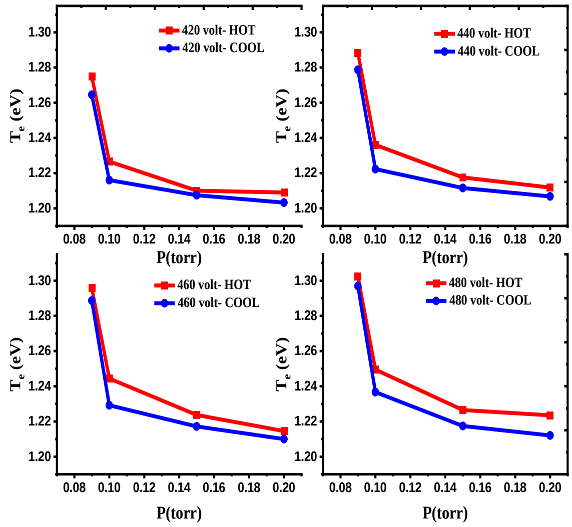

Figure (7) show the electron temperature as a function of the pressure change at constant voltage for the hot and cold target state

It was also observed that the temperature of the electrons in the case of the cold cathode is lower than it is in the case of the hot cathode, and this can be explained as follows: An increase in the temperature of the cathode leads to an increase in the electron's energy as a result of emitting more heat from the hot surface than from the cold surface, and this agrees with search results [13].

Electron Density Calculation

The electron density(n_e) was calculated using the half-width method and according to equation (2) at working pressures (0.09, 0.1, 0.15, 0.2) torr when the applied voltages were (420, 440, 460, 480) volts after compensating the temperature values obtained using The method of the ratio between the two intensities of the two spectral lines, as well as the compensation for the values of the half width obtained from the spectral line (Ar II - 753.3 nm), and using the program Origan (data analysis software) the width of the half-maximum intensity (FWHM) was obtained, and as in Figure (8), which is an example showing how to get the width of the half maximum intensity.

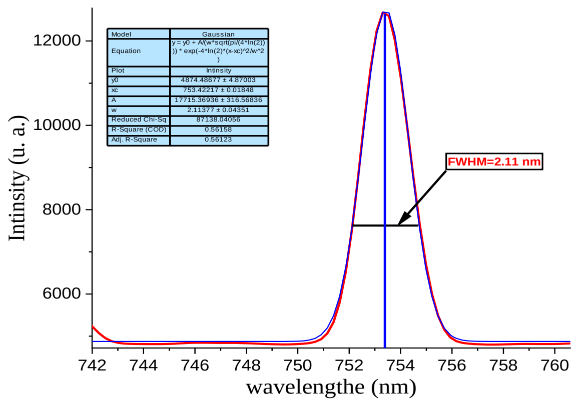

Figure (8) shows the spectral line (Ar II - 753.3) used to obtain the width of the half maximum intensity

Figure (9) show the electron density as a function of the voltage change at constant pressure for the hot and cold target states. The electron density increased with increasing applied voltage at constant pressure in each case, which can be explained by the fact that increasing the applied voltage with increasing electric field strength causes the electrons to heat up and increase their speed, resulting in active electrons (electrons with a lot of energy) colliding with atoms or molecules, this agree with Abdulhussain and Wessam [12].

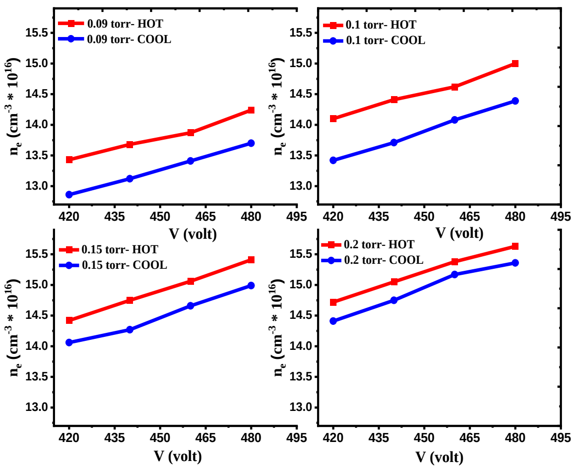

Figure (9) show the electron density as a function of the voltage change at constant pressure for the hot and cold target statesFigure (10) show the electron density as a function of the pressure change at constant voltage for the hot and cold target states. The number of gas molecules or atoms was shown to grow with an increase in gas pressure, which in turn causes an increase in inelastic collisions, atom ionization, and, ultimately, an increase in electron density, which is consistent with the results of the sources [16-17].

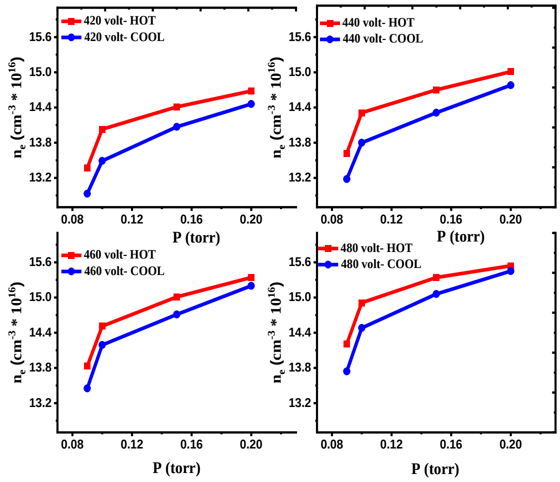

Figure (10) show the electron density as a function of the pressure change at constant voltage for the hot and cold target states

It was also noted that the density of the number of electrons in the case of the hot cathode is greater than in the case of the cold cathode as a result of the increase in ionization of the plasma due to the increase in the collision between the atom and the electron, and this agrees with the results of the source [13].

CONCLUSION

The effect of the surface temperature of the target as well as the effect of argon gas pressure and applied voltage on the temperature and electron density of glow discharge were studied. It was found that the surface temperature of the cathode has an effect on the parameters of the argon plasma. The temperature and density of electrons were calculated using an optical spectra analyzer, where it was found that the temperature and density of electrons in the case of a hot target is greater than in the case of a cold target, and thus the discharge energy and electron density increase with the target. Hot This is the main objective of this study. Finally, we see that cooling the target is very important to keep the sample (cathode) from melting at very high temperatures, even though it lowers the electron density.

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