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Plasma Spectroscopy Diagnostics of V_2O_5 at a Variable of Operating Power and Pressure With Radio Frequency Magnetron Sputtering.

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Abstract

In this paper, we investigate the basic characteristics of "magnetron sputtering plasma" using the target V_2O_5. The "magnetron sputtering plasma" is produced using "radio frequency (RF)" power supply and Argon gas. The intensity of the light emission from atoms and radicals in the plasma measured by using "optical emission spectrophotometer", and the appeared peaks in all patterns match the standard lines from NIST database and employed are to estimate the plasma parameters, of computes electron temperature and the electrons density. The characteristics of V_2O_5 sputtering plasma at multiple discharge provisos are studied at the "radio frequency" (RF) power ranging from 75 - 150 Watt and gas pressure (0.03, 0.05 and 0.007) torr. One can observe that the intensity of the emission lines increases with increasing the sputtering power. We find that the electron temperature excess drastically from 0.95 eV to 1.11eV when the emptying gas pressure excess from 0.03 to 0.05 Torr. On other hand excess electron temperature from 0.9 to 1.01 eV with increasing sputtering power from 100 to 125 Watt, while the electron density decrease from 5.9×10^{14} to 4.5×10^{14} cm^{-3} with increasing sputtering power. and electron density decrease with increasing of pressure from 4.25×10^{14} to 2.80×10^{14} cm^{-3}, But the electron density maximum values 5.9×10^{14} at pressure 0.03 Torr.

Keywords: Electron Density, Electron Temperature, Magnetron Sputtering, Plasma Spectroscopy, V_2O_5 .

Introduction:

The use of plasma for "material deposition" is vastly used in industrial process and technology, "Magnetron sputtering" is the anymore lower-class for thin films deposition (1). Noble gases are generally used to generate the plasma because they are inactive. Commonly, plasmas are properties by exogenous parameters such as radio frequency input power, pedestal siding, gas and pressure, flow rate. Anyway, saving these exogenous parameters does not retrofit adequate knowledge of the sputtering practicality. Further, the film construct and accretions ratio, is provided by achieving the internal plasma parameters. Many diagnostic techniques are used to show properties plasma such as "Langmuir probe", optical emitting spectroscopy (OES) and "mass spectrometry" (2).

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Among these techniques, "Langmuir probe" is widely used to gauge plasma parameters like "electron density" (n_e), "ion density" (n_i), "electron temperature" (T_e), etc. in low-pressure glow discharges. Also among the same techniques, there is "Optical emission spectroscopy" (3). This technique is based on the measurement of the light pattern transmitted by the plasma because it distinguishes the plasma properties. Radiation is the result of the interaction of the electron or ions with other plasma molecules. Four types of this plasma were proposed by MC Whiter, which depends on the electron interaction mechanism. Many of the methods to "electron temperature measurement" can be reached, these are (4, 5):

1) The density ratio read between the lines.
2) The ratio of line density to the connected string.
3) The intensity of the two parts of the connection.

The first pattern is used in this study for the valuation of the suggesting "electron temperature" in the (Ar) DC glow discharge. The intensity of these spectral stripe depends on (KT_e), and always proportional to the resident's density of fervid states. Thence, (KT_e) it could be determined using these spectral stripe intensities and "Boltzmann plot" equation (6):

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

The indices number 1 and 2 transmit to the first and second spectral stripe, I is the intensity, K is the "Boltzmann constant", g is the statistical weight, E is the excited case energy and A is the transition probabilistic. "The Boltzmann plot" manner is only proper if the evacuation plasma under study is in "complete local thermodynamic equilibrium" (LTE). In this spectrum, the argon sent outa stripe observed in the scope of 200-900 nm and kT_e determine by selecting two Ar-I spectral stripes. In a titration, the E, g and A for choices stripe is taken from the National Institute of Standards and Technology NIST "Atomic Spectra Datasheet" (6, 7). The n_e can determine using the near intensities of atomic and ionic spectral lines in "Boltzmann - Saha equation" (8).

$$n_e = \left[\frac{(2\pi mkT_e)^{3/2}}{h^3}\right]\left[\frac{2A^+g^+\lambda^o I^o}{A^o g^o \lambda^+ I^+}\right] e^{\left[\frac{-(E^+-E^o+E_i^o-\Delta E_i)}{kT_e}\right]} \ldots\ldots \quad (2)$$

Where, (0, +) include the ionized atoms and neutral, E is the energy of the emissive echelons, E_i^o is "the ionization energy" of the different atoms and ΔEi is the lower of ionization energy (9). In this study, we focus to investigate the plasma parameter of "magnetron sputtering plasma" using V_2O_5 target and its deposited V_2O_5 thin film.

Materials and Methods:

The main parts of the clogged plasma system are shown in Fig.1. Our work, V_2O_5 films were by the RF magnetron system (CRC600 CO. Manufactured in the USA). Films are placed on the glass base with changing powers. Glass slides were cleaned sequentially in the ultrasound course with ethanol and acetone. Finally, rinse with distilled water and come out. The spray chamber leaves the base pressure 3 $\times 10^{-5}$ torr using the turbine and the mechanical pump mixture before deposition. Before deposition of V_2O_5 films, target V_2O_5 (99.99% pure and diameter 5 cm) in a pure argon atmosphere for 15 minutes to remove the oxide on the target face. Deposition of V_2O_5 used "sputtering RF system" in pure gas (99.9%) with pressure (3 × 10^{-2}, 5×10^{-2} and 7×10^{-3} torr), with various strengths (75, 100, 125, and 150 watts), respectively.

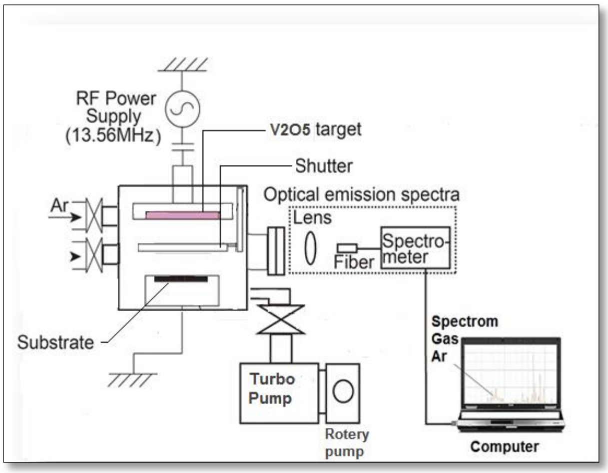

Figure 1. Graphical diagram of the setup used in this study.

Results and Discussions:

The emission spectra of argon plasma produced between electrodes at different RF power (75, 100, 125 and 150 Watt), are shown in Fig. 2. The intensity of two lines, one for Ar I at wavelength (750.37 nm) and the other for ArII at wavelength (434.5 nm) identical with NIST data, were chosen to estimate electron temperature by using lines intensity ratio method equation (1), NIST data, upper level energies, statistical weights (g) and transition probabilities(A), is listed in Table 1.

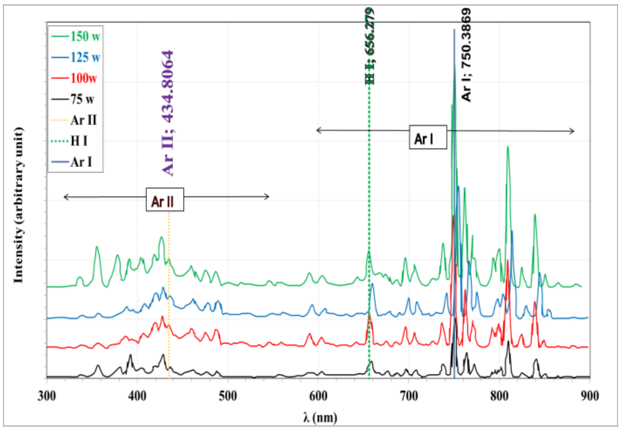

Figure 2. The emission spectra for plasma argon at different sputtering power.

Table 1. Values of transition probability, upper energy level and statistical weight that used to calculate T_e (10).

Wavelength (nm)		Transition probability A, (S-1)		Statistical weight g		Upper energy level E,(eV)	
ArI	ArII	A_1	A_2	g_1	g_2	E_1	E_2
750.37	434.5	4.45e+07	1.171e+08	6	3	11.82807106	14.68065021

As a appears in Table 1, the lower agitation energies for the argon lines are relatively high, >11.8 eV for Ar I.This refers to the emission of argon lines adoption on the presence of electrons in the plasma. An exception is that some Ar lines can also outrage efficiently from the Ar "metastable levels". Evidently, the energy required for excitation is less than that required for ionization because the electron of a stir atom does not remove completely from this atom. For example, the stirring energy of argon atoms is 11.8 eV while the ionization energy is 14.6 eV. Besides, the stirring energy should be greater than or equal to the energy of the electronic case in order for the excitation to occur (7, 11).

Figure 3. represents the variation of intensity for (750.37 nm) line and (434.5 nm) line respectively as a function of the RF Sputtering power at 3×10^{-2} torr. It is clear that intensity of Ar I increases from (47.7 to 74.5) with the increasing rf power. This is mainly due to the strong impact of the electron density on the ionization process: higher power means higher electron density which results in more ionized atoms. On the other hand, there are a large number of single-ionized argon lines (Ar II) emitted from the argon spectrum for each discharge technique. The intensity of the Ar II lines reflects relative population among different energy levels of Argon ion, thus dependent on discharge Conditions: Gas pressure, discharge current and/or Input power rf. These results are in agreement with the results of (9, 12).

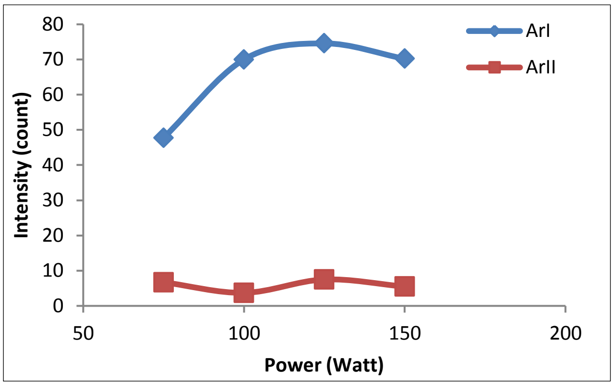

Figure 3. Variation of ArI (750.*37* nm) and ArII (434.5nm) lines intensity with RF power at 3×10^{-2} torr.

Figure 4. shows the temperature variation is lower from (1.08 to 0.88 eV) and high to 1.01 eV at 125 watt as a function of increasing energy. However, the decrease with the increase in energy that is expected to be the temperature of most electrons is more superior, which is observed to decrease with excess energy due to the transition α - γ The amplitude of the radio frequency with the wireless capability may increase by noting that there are usually two types of energy at the rate of discharge of radio frequencies capacitive; alpha and alpha modes. An indication of the α pattern in low voltage, in this pattern, the electrons in the plasma are initially questioned in order to stimulate excitation stimulation in the plasma. In increasing the great powers RF that meets in our experimental conditions, the. The mode is displayed. In this pattern, electrons are sent from electrode surfaces that play an important role in total ionization and excitation in the plasma. Therefore, with increased energy, strong secondary electrons will be sent from electrodes that improve ionization, which may increase in T_e. The deviation in plasma temperature causes a nonlinear change in the energy of the ions with increased power. In the figure below shows that the average ion energy reaches maximum RF power at about 75W (11, 13, 14).

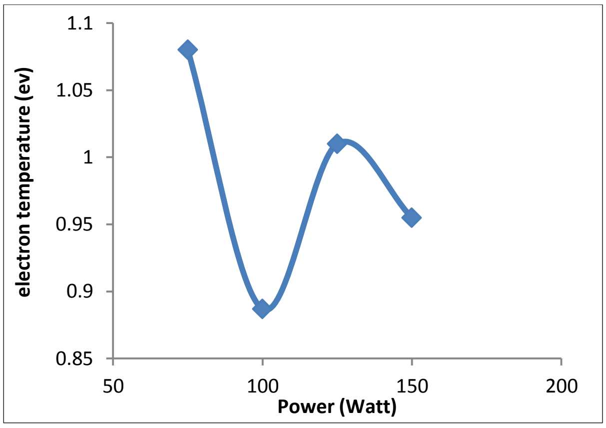

Figure 4. Effect of RF power on the electron temperature (eV).

Figure 5. indicates the variation of electron density (n_e) with RF power. This Figure shows that the electron density excess from(3.03 to 5.98 cm^{-3}) with increasing RF power. In turn, the increasing in RF power leads to excess the number of electrons emitted from the cathode, hence the increasing in the ionization processes leads to the excess density of electrons. In another way, the electron density lowered from (5.98 to 3.84 cm^{-3}) with an excess of RF power. This behavior may be due to the losses of electrons with increasing of RF power (9). On the other hand the electron density excess, through the particle equilibrium been ions which generated by electron influence and ions missing on the source walls, it is maybe that the (T_e) is independent of the (n_e). So higher proceeds in RF power to an increase in electron density (15).

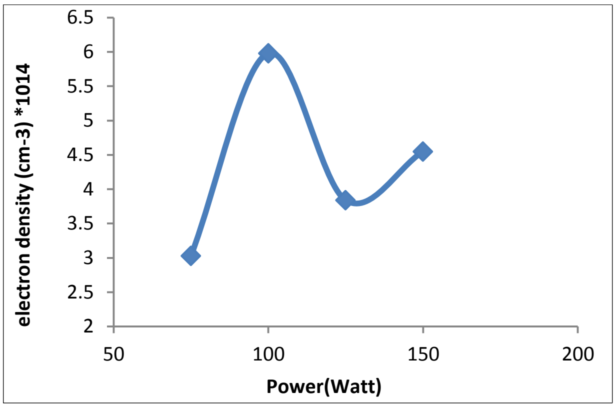

Figure 5. Effect of RF power on the electron density (cm^{-3})*10^{14}.

The emission spectra of the plasma argon produce between electrodes at pressure (0.03, 0.05 and 0.007) torr are in Fig. 6. The intensity of the lines excess the invader pressure excess, where the intensity of the lines, found to be relative to p^{α}, where α is constant, which differs between 0.2 – 0.5, adopting on the wavelength (6). Considering Ar I line of wavelength 750.37 nm and ArII line with wavelength 434.5 nm by using NIST we get show the Table (1).

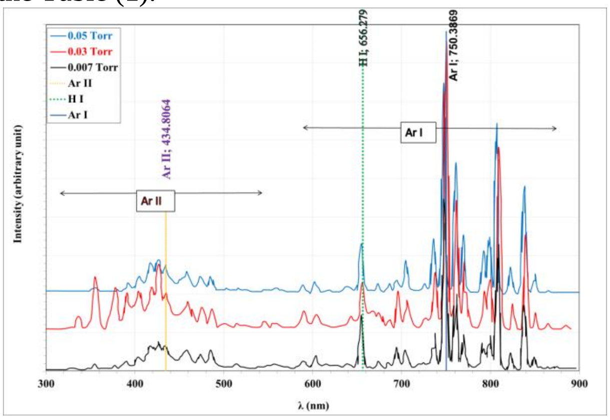

Figure 6. The emission spectra for plasma argon at different working pressures.

The change of the intensity of the special line as a function of working pressure is shown in Fig.7. The marked improvement in emission lines employed at 750.37 nm and 434.5 nm at ArI and ArII, individually. The observe that the intensified at the pressure 0.03 torr the intensity of (ArI) because of Ar emission intensity and energy of Ar ion. Then, the energetic Ar ions can increase the sputtering of from the target, which results in an increase the Ar sent out intensity. Energetic (Ar) ions can haunt an increasing in the secondary electrons sent out from the target, this effect which increase in the plasma intensity.

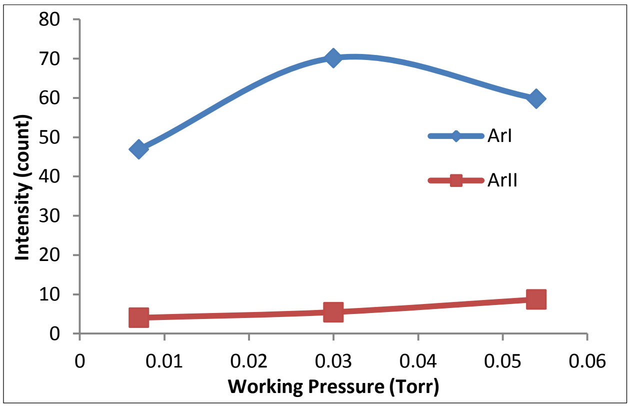

Figure 7. Effects of varying working pressure on Intensity.

Figure 8. shows the electron temperature (Te) decreased with increase working pressure, from (0.007 to 0.03) torr, increasing pressure leads to a reduced average of the free path for electron collisions, so that electrons ionize to the atoms will be, then more frequently to give a higher plasma density, where electrons may easily lose their energy resulting in a reduced electron temperature, on other hand at pressure values increase the "Paschen minimum", stubborn collisions become more dominant resulting in a decreasing of plasma electron temperature. These results are in agreement with results of previous Study (16).

As it is observed that T_e will increase linearly with increase pressure by increased electron impact. The T_e was a measure to a little decrease from 0.97 to 0.95 eV and increasing to 1.11 eV with different working pressure. higher T_e with pressure is probably because of less electron scattering and as a result, less energy will be lost. The significantly decreased "electron temperature" decrease the ionization efficiency significantly. These results are in agreement with the results of reference (17).

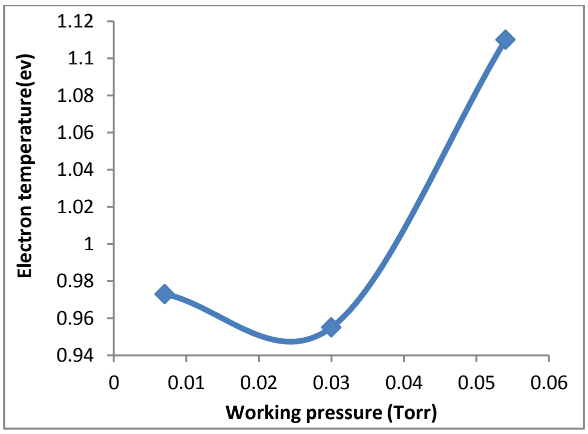

Figure 8. Effects of varying working pressure on T_e (eV).

Figure 9. shows the variation in operating pressure, which causes a difference in the collision rate without a change in plasma density. This occurs because the external discharge power is insufficient. So that more pairs can be produced and higher intensity at high pressure. The increase comes after changes, with a 150W power value, the maximum energy value of 0.03 torr due to an increase in energy consumption at low-density values of 0.05 Torr. The maximum density (4.55 cm^3) at (0.03 torr) is higher than the rest pressures.

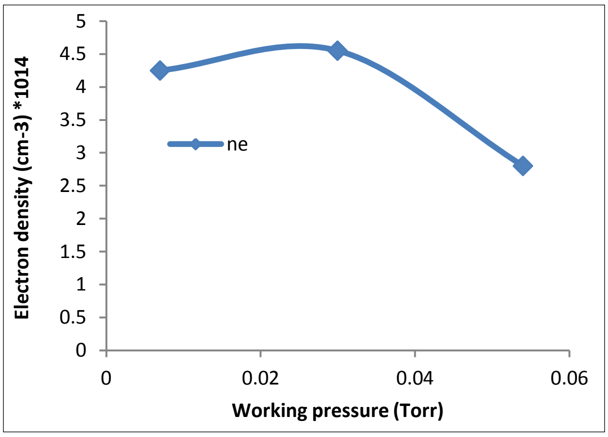

Figure 9. Effects of varying working pressure on n_e (cm^{-3}).

Conclusions:

In this study, the influence of working pressure and RF power on the plasma characterization is investigated for sputtering the V_2O_5 target. The optical emission spectroscopy (OES) device is used as a diagnostics device to plasma parameter in RF discharge. The results show that the increasing of RF power and pressure will increasing of lines intensity. As well as, the results show variation electron temperature low and up gradually increase with increasing of pressure and RF power. as will electron density decreases and increase with increasing RF power and pressure.

Conflicts of Interest: None.

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التشخيص الطيفي للبلازما لمادة خامس اوكسيد الفناديوم في الترذيذ الماكنتروني بالترددات الراديوية مع تغير طاقة التشغيل والضغط

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الخلاصة :

في هذا البجث، تم التحقق من الخصائص الأساسية لبلازما الترذيذ الماكنتروني باستخدام الهدف V_2O_5. تم إنتاج البلازما باستخدام الترذيذ الماكنتروني ببمجهز طاقة بالترددات الراديوية وغاز الاركون. تم قياس شدة الانبعاث الضوئي من الذرات والجذور في البلازما باستخدام مقياس الطيف الضوئي البصري، وكانت القمم التي ظهرت في جميع الأنماط متطابقة مع خطوط معيارية من قاعدة بيانات(NIST) وتستخدم لتقدير معلمات البلازما لحساب كثافة الإلكترونات و درجة حرارة الإلكترون. تمت دراسة خصائص البلازما في ظروف التفريغ المختلفة. طاقة الترددات الراديوية تتراوح من 75 إلى 150 واط وضغط الغاز(0.03 ، 0.05 و 0.007) تور. وجدنا أن كثافة خطوط الانبعاثات تزداد مع زيادة طاقة الترذيذ . و أن درجة حرارة الإلكترون زادت من (0.95 إلى 1.11) الكترون فولت عندما زاد ضغط غاز التفريغ من 0.03 إلى 0.05 تور.من جهة أخرى زادت درجة حرارة الإلكترون من (0.9 إلى 1.01) الكترون فولت مع زيادة طاقة الترذيذ من 100 إلى 125 واط ، بينما تنخفض كثافة الإلكترون من $(4.5 – 5.4) x10^{14} cm^{-3}$ مع زيادة طاقة الترذيذ. ايظا كثافة الإلكترون تنخفض من $(2.80 - 4.25) x10^{14} cm^{-3}$ مع زيادة الضغط ، ولكن اقصى قيمة لكثافة الإلكترون كانت $5.9 x10^{14} cm^{-3}$ عند ضغط 0.03 تور .

الكلمات المفتاحية : طيف البلازما، خامس اوكسيد الفناديوم، كثافة الالكترون، درجة حرارة الإلكترون، الترذيذ الماكنتروني .