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Research paper

Measurement of plasma electron temperature and density by using different applied voltages and working pressures in a magnetron sputtering system

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Abstract

This paper discusses applying different voltages and pressure in the presence of silver target and argon gas to produce plasma. Home-made dc magnetron sputtering system was used to produce glow discharge plasma. The distance between two electrodes is 4 cm. Gas used to produce plasma is argon that flows inside the chamber with flow rate 40 sccm. Intensity of spectral lines, electron temperature and electron density were studied. The results show that the intensity of spectral lines increases with the increase of the working pressure and applied voltage. Electron temperature increases by the increase of applied voltage but decreases with the increase of working pressure, while electron density decreases with the increase of applied voltage and increases with the increase of working pressure. This research demonstrates a new low cost approach to start producing high corrosion resistance materials.

Keywords: *Plasma; Glow Discharge; Optical Emission Spectroscopy; Magnetron Sputtering.*

1. Introduction

Plasma is commonly an ionized gas. It is combining of charge particles (electron, ion and molecules). The term ionized return to the existence of one or more free electron. Which are not required to an atom or molecules [1], [2]. It have free charge particles where the positive and negative charge approximately stasis each other at the level of the macroscopic. It resulted when the elements are heated to temperature more than the thermal energies and above binding energies for special state of matter. When the environment temperature increasing the division of atoms can be break down in to negative charge electron and positive charge ion. These particles will contact with each other through the electromagnetic [3], [4]. Sputtering process plays an important role in surface modification. There are a number of ways to enhance sputtering process. One common way to do this is to use what is known as a magnetron sputtering system. The main difference between this and a basic DC sputtering system is the addition of a strong magnetic field near the target area. This field causes traveling electrons to spiral along magnetic flux lines near the target instead of being attracted toward the substrate [5]. Magnetron sputtering (especially closed-field unbalanced magnetron configuration) has gained wide acceptance in both research and commercial purposes and is routinely used in different industries like cutting tools, forming tools, semiconductor, optical glass coating, decorative, biomedical, and tribology applications[6] glow discharge is simply produced by applying an electric potential on a gas sample between two electrodes placed inside a vacuum chamber .This glow discharge is a common source of plasma that can be established through an avalanche like ionization of gas neutrals at specific conditions for gas pressure and applied voltage [7]. Glow discharge plasma can generate in magnetron sputtering system, which are extensively used in various applications such as modification of surfaces [8], [9]. However, most of previous study do not take in account studying plasma diagnostics, but current research on plasma is focused on it.

All plasmas emit radiation depending on their gas composition and plasma parameters. Optical emission spectroscopy (OES) is using to measure and analysis plasmas radiation to get perception in to the plasma. The significant advantage of OES is its invasive measurement process. Optical emission spectroscopy (OES) use the radiation to measure plasmas parameters without contact with the plasma (like Langmuir-Probe or Multipol Resonance Probe) which may be affect by the plasma itself [10], [11], [12]. In addition, the Optical emission spectroscopy (OES) can investigate very small plasmas, often smaller as probes themselves. Therefore, it is often the only usable measurement technique in addition to laser absorption spectroscopy .One common remote diagnostic is optical emission spectroscopy (OES), which is the optical part of the more general treatment of radiation. Optical emission spectroscopy (OES) has a lens to collect and focus the visible light on the slit of spectrometer. We can measure. The temperature of electron and the density of electron, etc.. By using the information from optical emission spectroscopy [13 - 16]. The temperature of electron and the density of electron obtained by the following equation respectively:

$$\frac{I_1}{I_2} = \left(\frac{\lambda_{n,m,z}}{\lambda_{k,i,z}}\right)\left(\frac{A_{k,i,z}}{A_{n,m,z}}\right)\left(\frac{g_{k,z}}{g_{n,z}}\right) e^{\left(\frac{-E_{k,z}-E_{n,z}}{KTe}\right)}$$

$$ne = \left(\frac{2\pi m_e K}{h^3}\right)^{3/2} \times \left(\frac{2A_{k,i,z}\, g_{k,i,z}\, \lambda_{N,M,Z}\, I_2}{A_{n,m,z}\, g_{n,m,z}\, \lambda_{k,i,z}\, I_1}\right) e^{\left(\frac{-E_{k,i}-E_{n,m}}{KT_{ex}}\right)\times T_e^{3/2}}$$

Reported by F.J. Vazquez et al the density of electron increasing and the temperature of electron decrease with increasing gas

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pressure , while electron temperature increase with increasing the power .Althought several studies have indicated to electrical characteristics of plasma , little attention has been paid to spectrum characteristics of plasma [17].
The aim of this research is to study the effect of changing applied voltage and working pressure on electron temperature , electron density and intensity of the spectral lines in argon plasma discharges to determine the optimum condition of produced plasma.

2. Experimental part

In this research home – made magnetron sputtering was used to generate glow discharge plasma fig. (1). Sputtering system consist of an evacuated chamber; cathode(a target of silver) and anode disk of stainless steel .The cathode faced the anode, which provides electric field for the gas discharge . The distance between cathode and anode is 4 cm. The target which used in sputtering process is silver. The diameter of the target is (2) cm, with presence argon gas (Ar) with flow rate (40 sccm). Different working pressure was used, where working pressure values ranging from (5 $\times 10^{-1}$) to (3.5 $\times 10^{0}$) mbar .In addition we used different voltage ranged between (430 V) and (700 V) .The technique which used for optical diagnosis, for generated plasma by magnetron sputtering, is Optical emission spectroscopy (OES). Radiation emitted from the plasma are collected by (Surwit technology V2100 - UV-NIR) spectrometer with spectral resolution (FWHM) of (>2.5 nm). Optical system including spectrophotometer and optical fiber which was connected with collecting lenses.

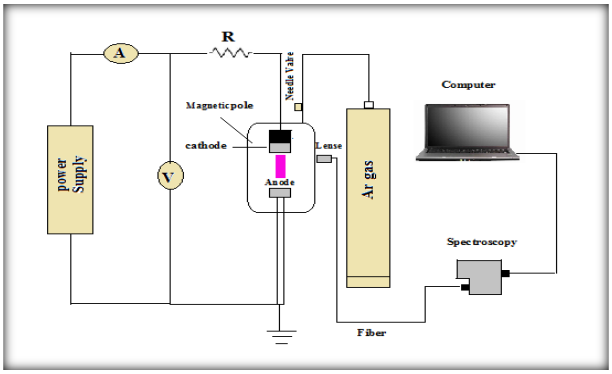


Fig. 1: Experimental Setup of Magnetron Sputtering System.

3. Result and discussion

Spectrum characteristic of discharge plasma, such as dependencies of intensities, electron temperature and electron density on the applied voltage and gas working pressure inside the vacuum chamber, are of importance to introduce the homogeneity of the generated plasma.
It is evident that the intensity of Ar I and Ar II increase with increasing supplied voltage, this because the electric field accelerates the ion and the electron and then collide with the atom of working gas and this lead to generate new free electron and positive ion. The intensity of Ar I and Ar II increase with increasing working pressure this because when the pressure in the chamber increases, it causes an increase in the number of collisions between the gas atoms and the electrons [18] as can be seen from in figures (2) , (3) ,(4) , (5). Figures (6), (7) present that the electron temperature and electron density as a function of applied voltage. The electron temperature increase while the electron density decrease with increasing applied voltage at constant pressure this attributed to increase of electron collision with argon atom which lead to decrease the electron energy. Figures (8) and (9) depicted the temperature of electron and the density of electron as a function of working pressure of argon gas at constant applied voltage .When the pressure increase the mean free path and the energy acquired by the electron decrease therefore reducing the ionization process .at an increase pressure the number of atom and molecules are increase , therefore, instead of gaining energy by the electron from the electric field, more and more energy is transferred from electron to plasma species during inelastic collision the mean free path decrease and the collision rate of electrons with atoms is increased and the acquired energy of electron reduces, therefore the electron density increase and the electron temperature decrease [19 - 21].

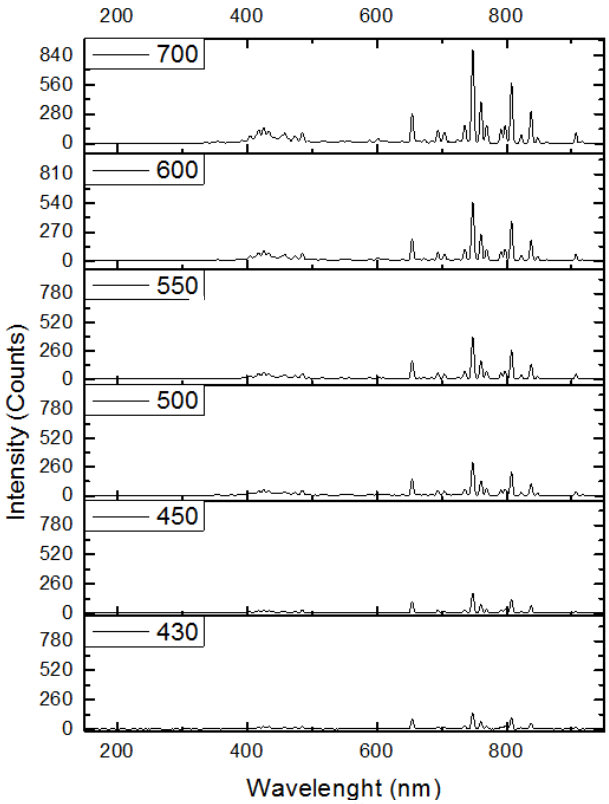


Fig. 2: The Plasma Intensity in Different Applied Voltage.

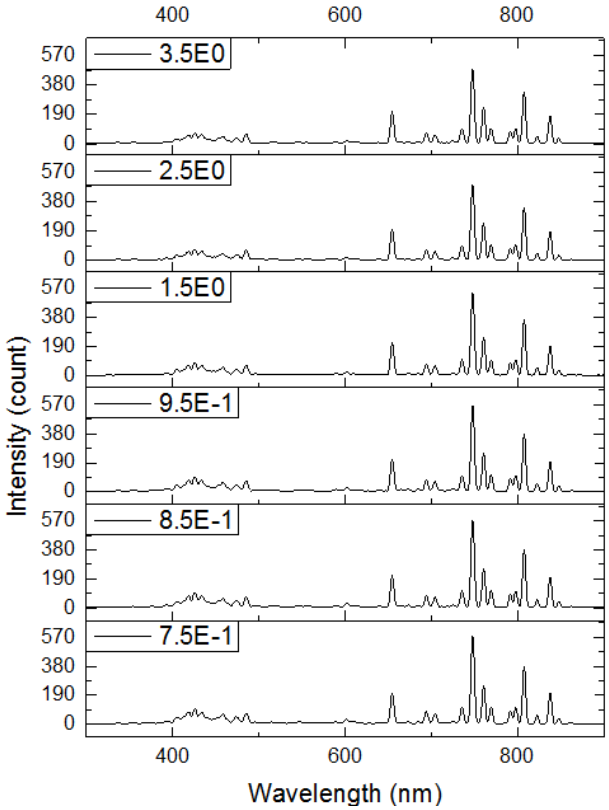


Fig. 3: The Plasma Intensity in Different Working Pressure.

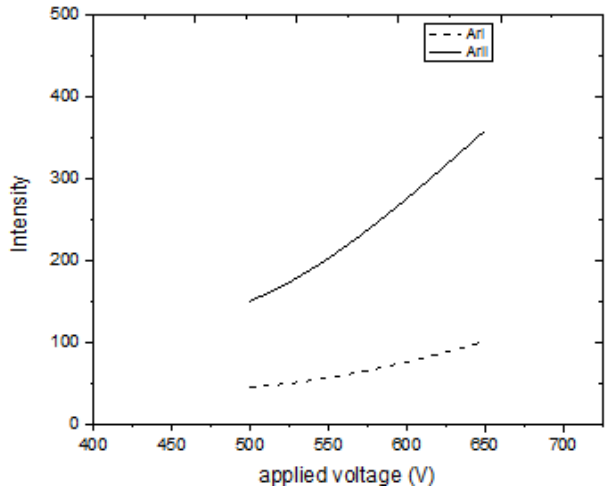


Fig. 4: The Variation of Plasma Intensity with Applied.

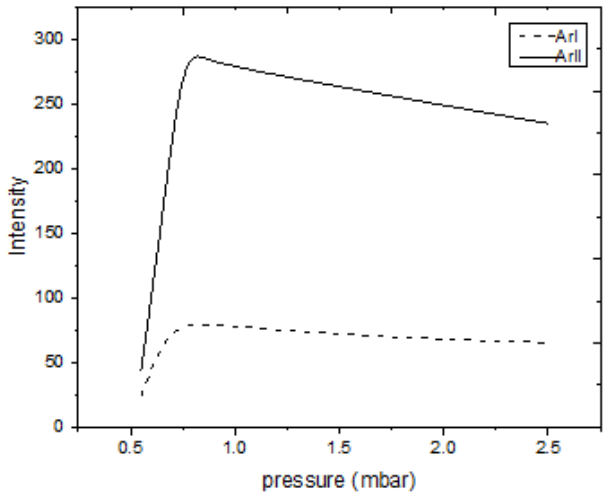


Fig. 5: The Variation of Plasma Intensity with Voltage Working Pressure.

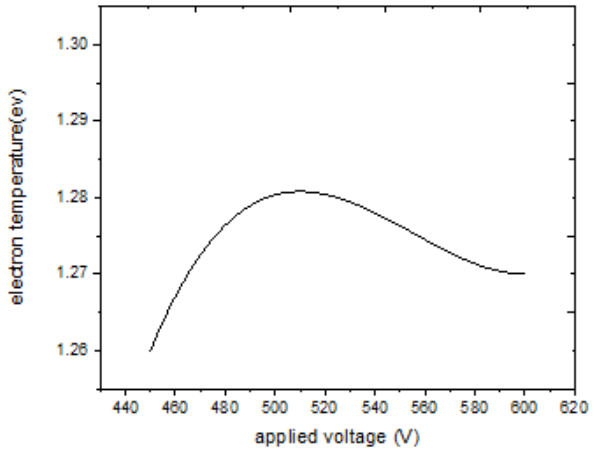


Fig. 6: The Variation of Electron Temperature with Applied.

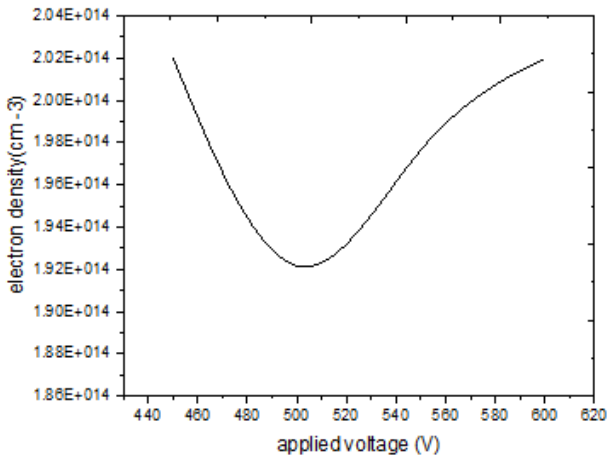


Fig. 7: The Variation of Electron Density with Applied Voltage Voltage.

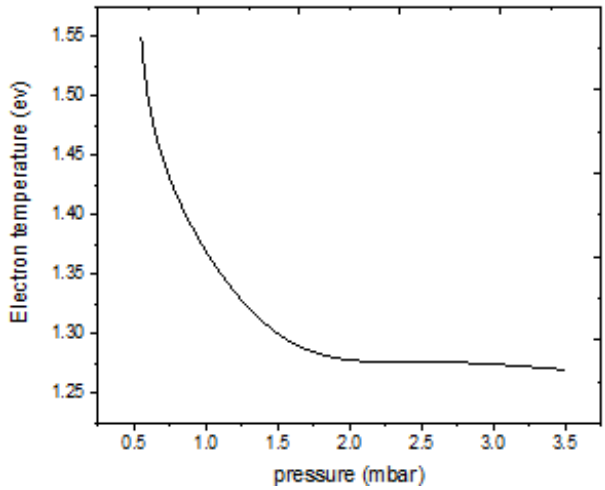


Fig. 8: The Variation of Electron Temperature with Working Pressure Working Pressure.

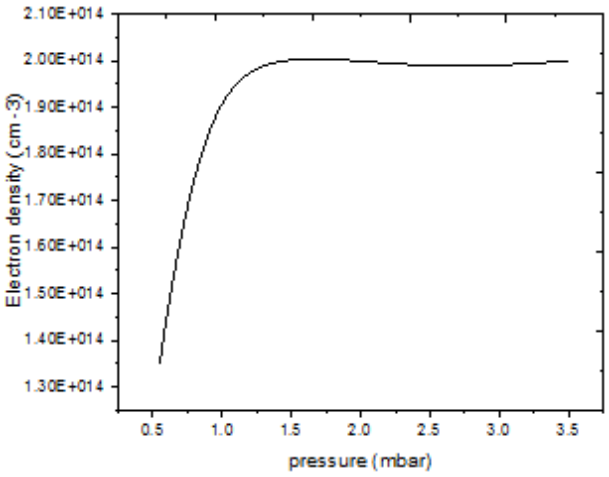


Fig. 9: The Variation of Electron Density with Working Pressure Working Pressure.

4. Conclusion

In conclusion, it is evident that this study has shown the effect of changing working pressure and applied voltage on spectral characteristics which including (intensity, electron temperature and electron density). The results were shown that the increase in applied voltage and working pressure can be contributed to increase intensity. Electron temperature increase with increasing applied voltage while electron density decrease. Conversely electron temperature decrease and electron density increase with increasing working pressure

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