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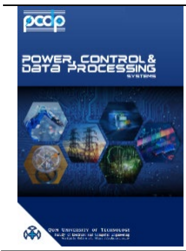

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Investigation of the Effect of Pressure Parameter in Glow Discharge Plasma on Electron Density of Plasma

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ABSTRACT

In this research, optical emission spectroscopy measurement technique OES was used to determine and calculate the electron density parameter of the low-pressure cold glow discharge Ar plasma. For achieve this purpose, the Stark broadening of Balmer line of hydrogen spectrum H_β obtained from plasma system in different pressure conditions were used to calculate the electron density. By calculating the electron density values obtained at different plasma pressures of 0.05, 0.13, and 0.65 Torr, it was found that there is a significant relationship between the plasma pressure and its electron density. The results showed that with the increase in the plasma pressure, its electron density also increases. Therefore, for use of this plasma system in different applications such as in industrial applications, treatment of biomaterials, medicine or print and packaging of polymers, by changing the pressure parameter of plasma system, the optimum conditions of surface plasma treatment can be obtained.

Keywords: Glow discharge plasma; Optical emission spectroscopy; Stark broadening; pressure parameter.

1 Introduction

As the plasma forms, it starts emitting characteristic spectra of the utilized gas. In atomic systems involving atoms, ions, molecules, and plasmas of electrons and ions, photons are absorbed or emitted due to electronic transitions from one energy state to another. The shape of the emitted spectral lines is highly dependent on the plasma medium. Therefore, identifying mechanisms that cause broadening of spectral lines is essential for study the plasma. The main types of broadening present in a plasma spectrum include natural broadening, Doppler broadening, and Stark broadening [1-3]. Studying plasma broadening provides a wealth of information about the plasma.

Different methods are used to calculate the electron density in plasma, which include the use of Langmuir probes, Thompson scattering, plasma emission spectroscopy, and the Stark broadening method. The Stark broadening method is of particular interest due to its simplicity and acceptable accuracy. The fundamental basis of this method has been well studied far [4-6]. this phenomenon occurs due to Coulomb interactions between the radiating atoms and free ions and electrons inside the plasma through an electric field, which is known as the Stark effect. In various studies, the Stark broadening of the hydrogen Balmer line H_β has been widely used to calculate the electron density in plasma. If Stark broadening is the primary cause of spectral broadening in the system and contributions from Doppler broadening and other broadening mechanisms, such as pressure broadening due to collisions with neutral atoms, are neglected, measuring electron density n_e using Stark broadening is a relatively simple method [7-10]. By accurately fitting the shapes of the lines measured by the emission spectroscopy system with combinations of Lorentzian and Gaussian line shapes, known as Voigt profiles, the full-width at half-maximum (FWHM) of Stark broadening can be determined. Then, using Stark broadening tables, the electron density can be estimated [11-14].

The full-width at half-maximum (FWHM) of Stark broadening is related to the electron density through the following equation:

$$\Delta\lambda_{stark} = 2\times 10^{-11}(n_e)^{\frac{2}{3}} \qquad \text{Eq 1}$$

The electron density obtained from this equation is in units of cm^{-1}. As previously mentioned, the Stark broadening of the H_β spectral line at the wavelength of 486.13 nm provides an acceptable approximation of the electron density. Therefore, by plotting the spectrum obtained from the emission spectroscopy of plasma generated from argon gas and fitting it with a Voigt curve, the electron density can be measured [15-16].

In this study, the Stark broadening method was used to determine the electron density and investigate the changes in electron density with respect to plasma pressure. The full-width at half-maximum parameter was used to describe the broadened line shape.

2 Results and Discussions

The glow discharge plasma system used in this research, located in the Plasma Research Institute, includes a large cylindrical chamber made of steel with a diameter and height of 50 cm. Using a vacuum pump, the initial pressure of the discharge chamber is stabilized at 0.01. The flow of argon gas is controlled by a gas flow controller. After injecting the gas at desired pressures into the discharge chamber, a voltage of 300 volts is applied inside the chamber, causing an electric discharge and creating glow argon plasma. The plasma forms between a cathode in the shape of a disk with a diameter of 10 cm and a grounded anode also in the shape of a disk. The formed plasma is analyzed using Optical Emission Spectroscopy (OES). The spectroscopy system used in this research is a fiber optic spectrometer model V900 with a wavelength range of 200-1058 nm and a spectral resolution of 1 nm. To use the Stark broadening method, 0.5% hydrogen was added to the gas mixture.

Initially, the optical emission spectrum of the plasma was measured under different pressure conditions. Optical emission spectroscopy in the argon glow discharge plasma was measured at pressures of 0.05, 0.13, and 0.65 Torr. The results are shown in Figure 1.

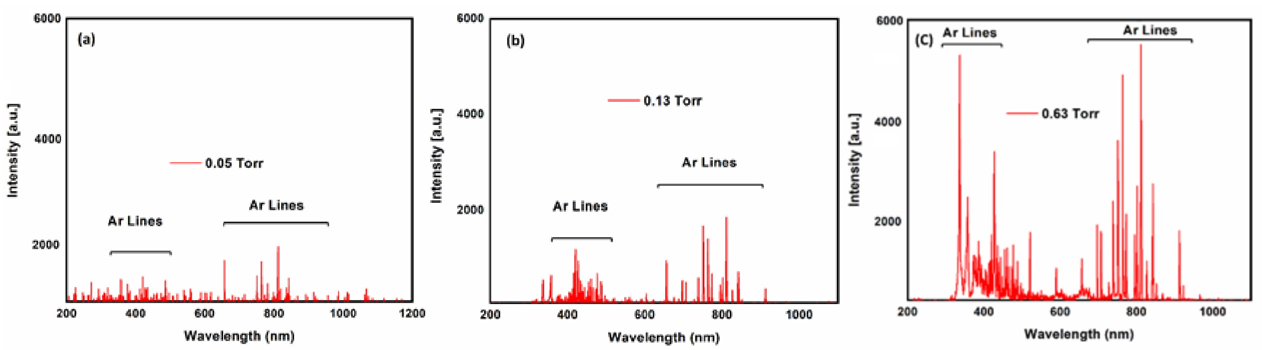

Figure 1: The optical emission spectrum resulting from argon plasma at different pressures.

The spectral broadening of the Balmer line of hydrogen at a wavelength of 486.13 nanometers, along with the fitted Voigt curve corresponding to each spectral line at different pressures, is shown in Figure 2.

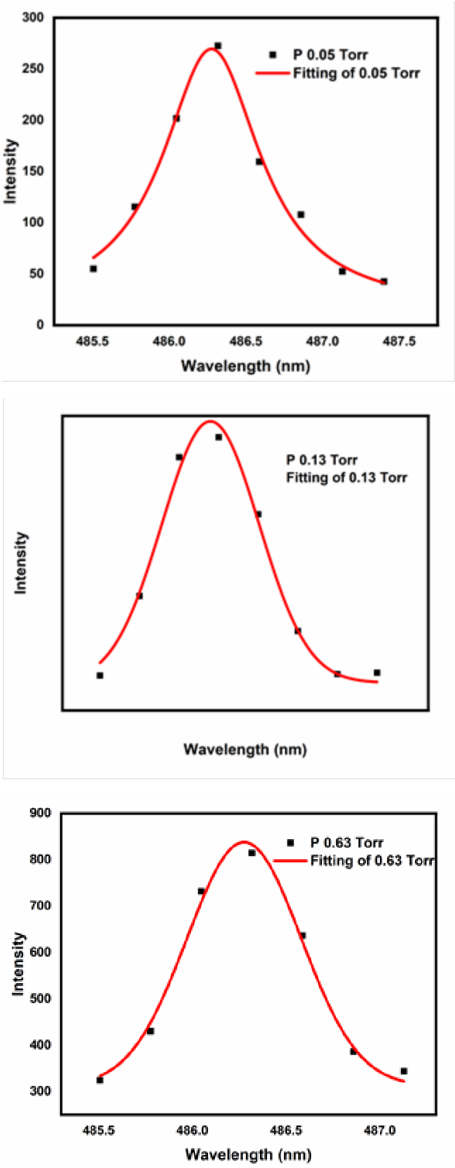

Figure 2: The Voigt line shape fitting to the spectral broadening at different pressures.

By measuring the full-width at half-maximum (FWHM) value of the fitted Voigt line shape of Figure 2, and substituting it into Equation 1, the electron density at different pressures is obtained. The results of these calculations are presented in Table 1:

Table 1: Electron density values at different pressures

Electron Density	$\Delta\lambda_{stark}$	Pressure (Torr)
1.619× 1019	0.4717	0.05
1.688×1019	0.4848	0.13
1.888×1019	0.5226	0.63

Figure 3 illustrates the relationship between electron density and plasma pressure.

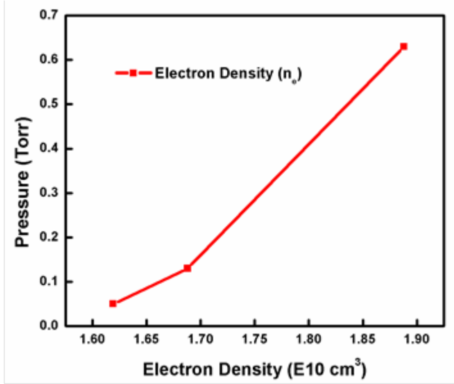

Figure 3: Electron density at different plasma pressures.

Figure 3 shows that with an increase in the pressure inside the plasma generation chamber, the electron density of the plasma increases. Therefore, for using plasma in various applications that require higher electron density, it is necessary to generate plasma at higher pressures.

3 Conclusion

This study examined and discussed the effect of various plasma pressures on the electron density of the glow discharge plasma. The Stark broadening method of the Balmer line of hydrogen was used to calculate the plasma electron density. The results showed that as the pressure in the plasma generation chamber increased, the obtained electron density also improved.

Disclosure of Potential Conflicts of Interest

The Authors declare that there is no conflict of interest

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