

ESTIMATION OF ELECTRON TEMPERATURE IN ATMOSPHERIC PRESSURE DIELECTRIC BARRIER DISCHARGE USING LINE INTENSITY RATIO METHOD

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ABSTRACT

Dielectric Barrier Discharge was produced by applying high voltage AC source of frequency (10-30 KHz) and potential difference of (0-20) kV across two parallel plate electrodes with glass as dielectric barrier. Optical emission spectroscopy was used for the characterization of the discharge produced at atmospheric pressure. The emission spectra in the range of 200 nm to 850 nm have been analyzed to estimate the electron temperature by line intensity ratio method. The results showed that the electron temperature is about 0.9 eV.

INTRODUCTION:

Atmospheric pressure dielectric barrier discharges (DBDs) are non thermal and non equilibrium plasmas [1]. These non-equilibrium plasmas have been widely studied for several emerging applications such as; surface and material processing, biological and chemical decontamination of media, light source, absorption and reflection of electromagnetic radiation and synthesis of nanomaterials. This process can be improved by a better understanding of basic plasma phenomena and by knowing its properties. The plasma properties depend on several parameters, mainly, the geometry of the electrodes, type of the dielectric barrier, cooling system, excitation frequency, power injected and gas composition [2, 3].

The electron density and electron temperature are most fundamental parameter in gas discharges and plays very important role in understanding the discharge physics and optimization of the operation of plasma [4, 5]. Different methods are available to measure the electron density and electron temperature of which the most commonly used are Langmuir probe, microwave interferometer, Laser Thomson Scattering and optical emission spectroscopy (OES) [6].

In atmospheric-pressure discharge, both the probe and the microwave-based methods are difficult to use due to the small plasma dimension and strong collision process. The OES based technique is suitable for measurement of electron density and electron temperature. To measure electron temperature line intensity ratio method is used, in which the intensity ratio of emission lines is related to electron temperature and electron density [7, 8, 9].

Another method involves the investigation of the stark broadening of emission lines profiles. Techniques based on optical emission are clearly non-invasive, require only moderate spectroscopic equipment, are easy to implement and measurement are usually fast [10, 11].

In this paper measurement of the electron temperature in filamentary DBD in argon at atmospheric pressure by line intensity ratio method is presented.

EXPERIMENTAL

The experimental arrangement is shown in Fig. 1. The system consists of two parallel discs of brass, 10 mm thick and 50 mm in diameter. The glass plate 1.2 mm thick was used as dielectric barrier between the two electrodes. A high voltage AC source (0-20) kV and frequency (10-30) kHz is applied to electrodes.

The whole apparatus is enclosed in cylindrical chamber and argon passed into it. The argon flow rate is maintained at 2 l/min. The amplitude of applied voltage was measured by high voltage probe (Tektronix TDS2002). The optical spectra were recorded by Linear Array Spectrometer VS140

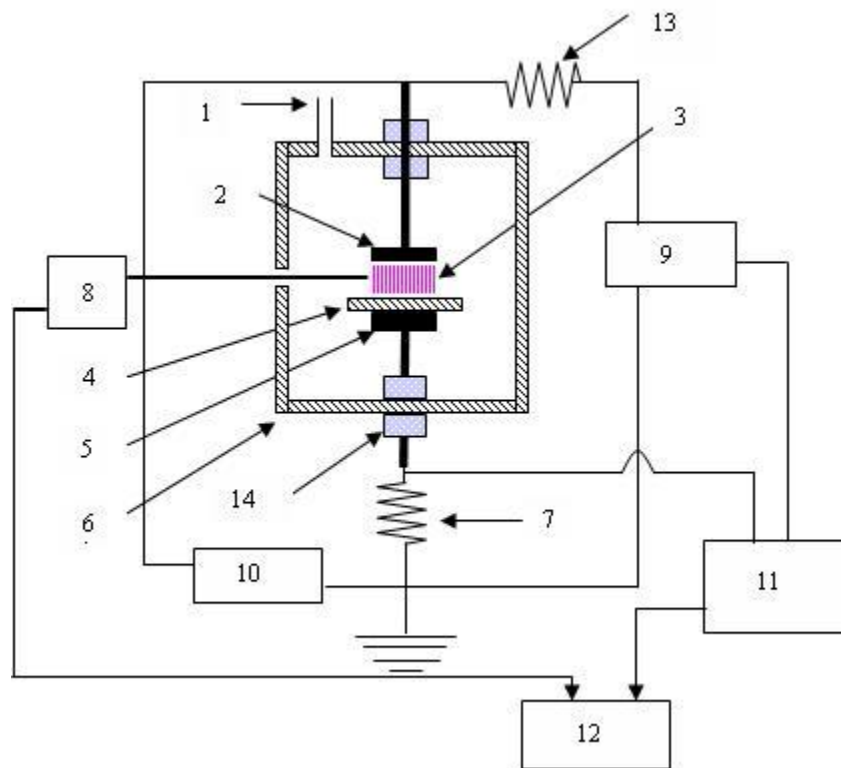


Fig. 1 Experimental arrangement for the diagnostics of the discharge. 1- Gas inlet, 2- Circular parallel plate electrode, 3- Discharge, 4- Glass plate, 5- Grounded electrode, 6- Plasma reactor, 7- Resistance 10 k Ω , 8- Linear Array Spectrometer VS140, 9- Voltage probe, 10- Power supply 11- Oscilloscope, 12- Computer, 13- Resistance 10 M Ω , 14- Teflon screw.

RESULTS AND DISCUSSION

Fig. 2, 3 and 4 show the optical emission spectra (OES) from the discharge between 250 nm to 850 nm at 3 mm electrode gap. The applied voltage, discharge current and spectrum are simultaneously measured and analyzed for determination of electron temperature. Four suitable

lines (two for Ar-I and two for Ar-II are chosen and electron temperatures is estimated using the lines intensity ratio method.

For the measurement of electron temperature, following equation is used,

$$\frac{R_1}{R_2} = \frac{I_1 / I_2}{I_3 / I_4} = \left(\frac{A_{pq}}{A_{rs}} \right) \left(\frac{g_p}{g_r} \right) \left(\frac{\lambda_{rs}}{\lambda_{pq}} \right) \left(\frac{A_{uv}}{A_{xy}} \right) \left(\frac{g_u}{g_x} \right) \left(\frac{\lambda_{xy}}{\lambda_{uv}} \right) \text{Exp} \left[- \frac{E_p - E_r - E_x + E_u}{KT_e} \right] \quad (1)$$

where R is the ratio of intensity of two lines, I is the intensity of spectral lines, A_{ij} is the transition probability of the transition $i \rightarrow j$, [5].

g_i - The statistical weight of the upper level,
 E_i - energy of the upper level,
 T_e - electron temperature.

λ - wave length of the radiation,
 K - Boltzmann constant,

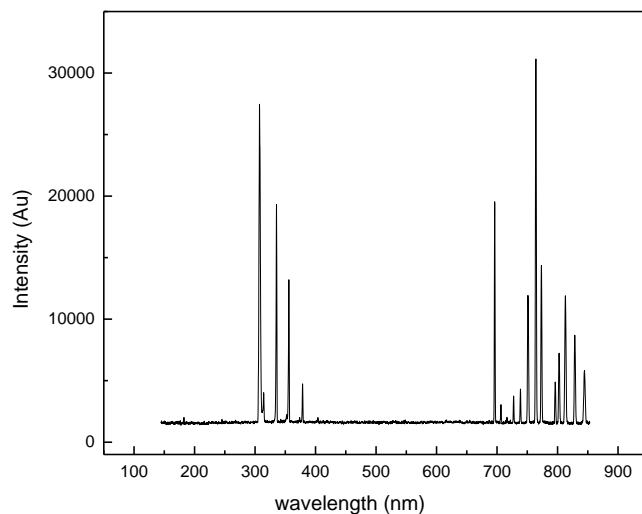


Fig. 2 Optical emission lines of atmospheric pressure discharge produced in Argon.

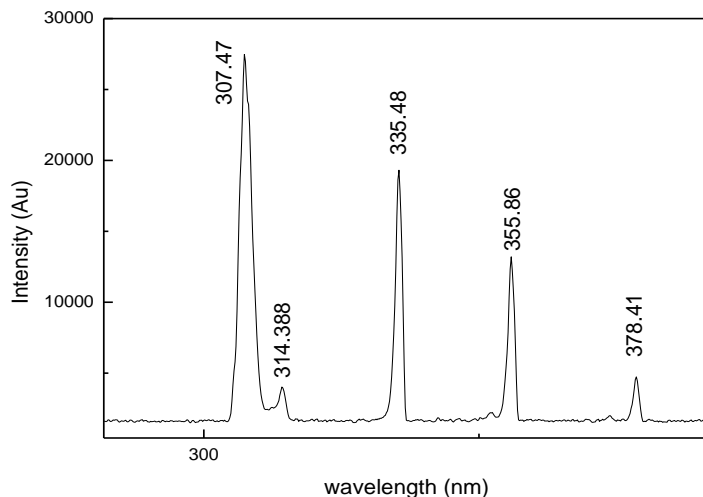


Fig. 3 Ar lines obtained from the APGD in the range of 200 nm to 450 nm

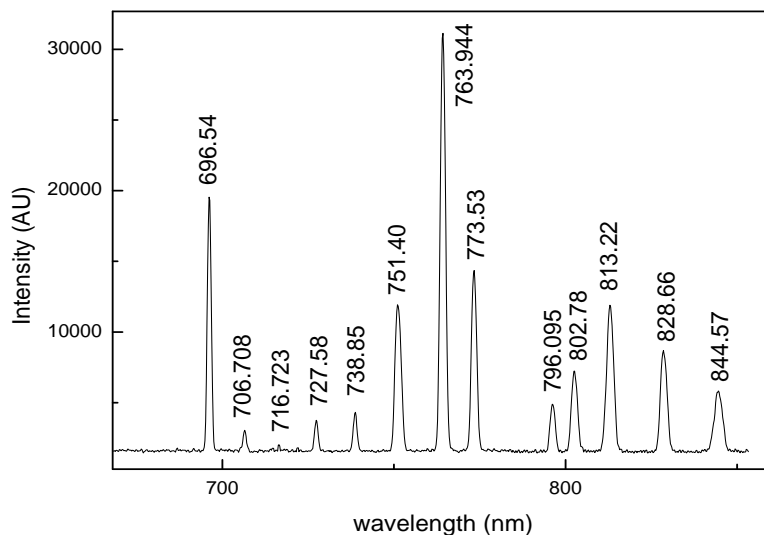


Fig. 4 Ar lines obtained from the APGD in the range of 650 nm to 850 nm

Considering two Ar I lines of wavelength 696.54 nm, and 751.034 nm and two Ar II lines with wavelength 314.13 nm and 378.75 nm we get,

ArI (696.54 nm),	$A_{pq} = 6.39 \times 10^6$	$g_p = 5$	$E_p = 11.564$
ArI (751.034 nm),	$A_{rs} = 4.02 \times 10^7$	$g_r = 3$	$E_r = 11.636$
ArII (314.13 nm),	$A_{xy} = 5.20 \times 10^7$	$g_x = 6$	$E_x = 19.249$

ArII (378.75 nm), $A_{uv} = 105 \times 10^6$ $g_u = 8$ $E_u = 16.797$
 Using the above data in equation (1), we obtain $\frac{R_1}{R_2} = 1.13941 \times 10^{-2} \exp\left[\frac{2.5225}{KT_e}\right]$

Table 1: Electron temperature and corresponding intensity ratio

Electron temperature	R_1/R_2
0.25	274.600
0.50	1.769
0.75	0.322
1.00	0.142

Table 2: Different argon lines with wavelength and intensity obtained from the recorded OES data.

Lines	wavelength	Intensity (a.u)	Ratio
ArI	696.54	19687.32	I_1
ArI	751.034	11945.13	I_2
ArII	314.13	3897.21	I_3
ArII	378.75	4681.67	I_4

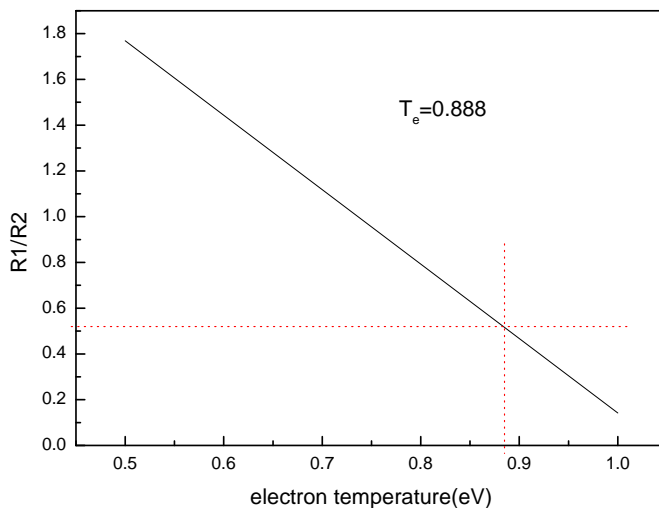


Fig. 5 Plot of R_1/R_2 as a function of T_e

Fig. 5 is the graph plotted between T_e and R_1/R_2 and used to determine the electron temperature by using value of R_1/R_2 obtained from observation. From the observation, $R_1/R_2 = 0.5051$ which corresponds to electron temperature 0.888eV. This result is in good agreement with the results reported in previous work.

CONCLUSION

The spectral line shape analysis is a reliable and non perturbing method for determining the electron temperature in argon at atmospheric pressure dielectric barrier discharge. The electron temperature is determined by line intensity ratio method and is to be about 0.9 eV

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