Effect of Applied Voltage in Electron Density of Homogeneous Dielectric Barrier Discharge at Atmospherice Pressure

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Abstract: *A homogeneous dielectric barrier discharge (DBD) was produced in air with a mixture with argon by applying high voltage A.C. source of potential difference (0-20) kV and frequency (20-50) kHz across two parallel disc electrodes with glass as dielectric barrier. In this paper, the determination of electron density in glow mode based on power balanced method is presented. Significant effects in electron density were found with the variation applied voltage.*

Keywords: DBD, electron density, glow discharge, power balance, I-V characteristics,

1. INTRODUCTION

A dielectric barrier discharge (DBD) is generated in the gap between parallel disc electrodes at which at least one dielectric barrier between them and connected to an AC source. The dielectric barrier discharges have great potential in industrial applications such as plasma processing, ozone generation, surface modification of materials and film deposition [1, 2].

These processes can be improved by a better understanding of the basic plasma phenomena and by knowing its properties. The plasma properties depend on several parameters such as electrode geometry, type of dielectric, applied voltage, frequency, gas composition and gas flow rate [3, 4]. In atmospheric pressure discharge system the probe and microwave based methods are difficult to use the small plasma dimension and strong collision process. Power balance method is one of suitable technique for measurement of electron density.

The report published by different researcher shows that the glow discharge is found to be stable only in low pressure discharge of pressure less than few mbar [5]. At atmospheric pressure, the glow discharge is normally unstable and in most cases it tends to change to a filamentary discharge. The stable glow discharge at atmospheric pressure was reported on [6] and shows that glow discharge depends on the (a) source frequency (b) material of dielectric plate between two metal electrodes (c) gap spacing and humidity of the gas. The homogeneous glow discharge in air at atmospheric pressure using perforated aluminum sheet is reported in [7].

In the present study, the parallel disc is used to produce the homogeneous glow discharge in argon. The glow mode discharge is homogeneously spread over the whole electrode area. The electron density can be estimated using power balance method.

2. EXPERIMENTAL SETUP

Schematic diagram of the dielectric barrier discharge (DBD) plasma is shown in the Fig. 1, which consists of two parallel disc of diameter 5.1 cm and thickness 0.8 cm. The glass sheet 1.5 mm thick was used as dielectric barrier to limit the current and to prevent the formation of spark and arc discharge. The plasma is generated in gap space 2 mm using high purity argon at flow rate 2 lit/min by applying AC source of (0-20) kV and frequency (20-50) kHz. The current and voltage signals of discharge were fed to high frequency digital oscilloscope through current and voltage probe respectively and recorded in the personal computer coupled with oscilloscope.

The applied frequency for all measurement is fixed to 27 kHz and applied voltage is varied to study the variation of electron density.

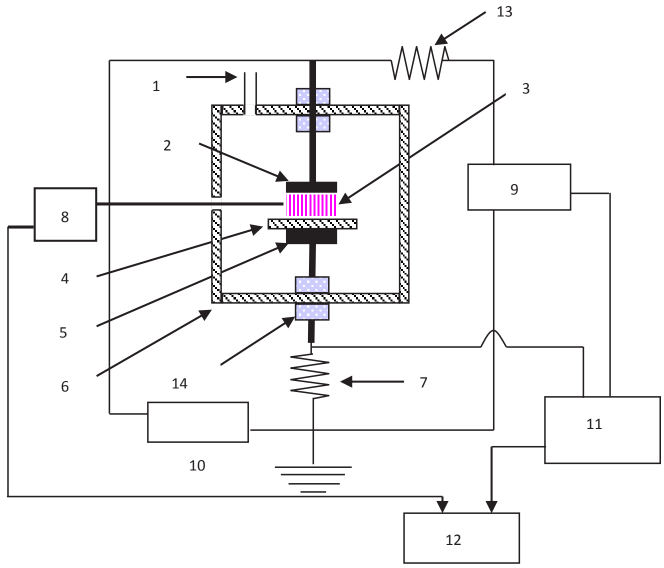

Fig.1: 1-Gas inlet, 2- Parallel disc electrodes, 3- Discharge, 4-Glass plate, 5-Grounded electrode, 6-. Plasma reactor, 7-Resistance 10k W, 8-Linear Array Spectrometer VS140 , 9-Voltage probe, 10 - Power supply (A.C), 11-Osciloscope, 12-Computer, 13- Resistance 10 MW , 14- Teflon screw,

3. MEASUREMENT OF ELECTRON DENSITY

The power balance method to determine the electron density in glow mode

In the power balance method described in [8], the energy lost by the system per electron -ion pair can be written as $E_{lost} = V_p + E_e + E_{col}$ 1

where, V_p be plasma potential (kinetic energy gain by each ion falling down the wall sheath of $\approx 5KT_e$), E_e be kinetic energy of electron lost to the wall ($\approx 2KT_e$), E_{col} be collisional energy loss per electron ion pair. E_{lost} depends on the electron temperature Te which is expected to be between 1eV and 2eV and under this condition E_{lost} can be reasonably approximated to 50eV for the argon. The total power absorbed by capacitive coupled plasma can be written as

$$P_{abs} = 2A\, e\, n_e v_b E_{lost} \qquad 2$$

where, $2A\, e\, n_e v_b$ represents the total current of the discharge over the area 2A of electrode , A is area of each electrode, v_b is Bohm velocity $\approx 2\times10^5$ cms^{-1}. Ignoring the large sheath and collisional system, the balance between the input power from high voltage power supply and power lost in the plasma leads to [8]

$$n_e = \frac{P}{2Aev_bE_{lost}} \qquad 3$$

The discharge gap = 2 mm, Gas flow rate = 2 lit/min, Applied frequency = 27 kHz, Area of each electrode =20.43 cm^2, Bohm velocity = 2×10^5 cms^{-1}, E_{lost} = 50eV (in our condition).

Using Eq. 3, electron density is calculated for different value of power supply in same electrode gap with same frequency and same gas flow rate.

4. RESULTS AND DISCUSSIONS

The voltage and current waveforms of discharge obtained with 2mm gap spacing and corresponding images of the discharge are shown in Figs. 2-6. These waveforms are nearly sine wave which indicated the glow like discharge. The voltage current waveform shows that current leads the voltage indicating the capacitive nature of DBD system. The value of potential different across two electrodes and corresponding current in the discharge is taken from the Fig. 2 and using these values in Eq. 3, the electron density is found to be 1.507×10^{11}cm^{-3}.

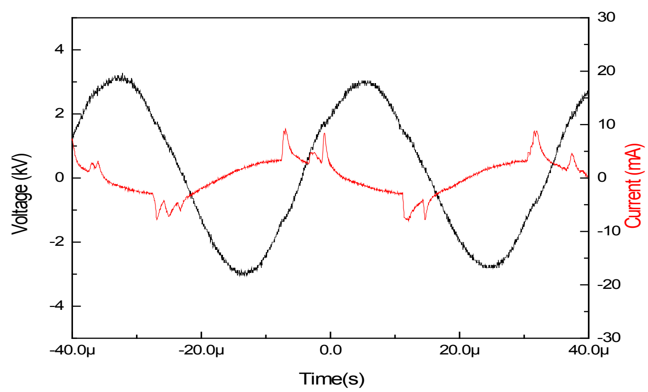

Fig. 2: Voltage and current waveforms of the discharge at applied voltage 2.1 kV

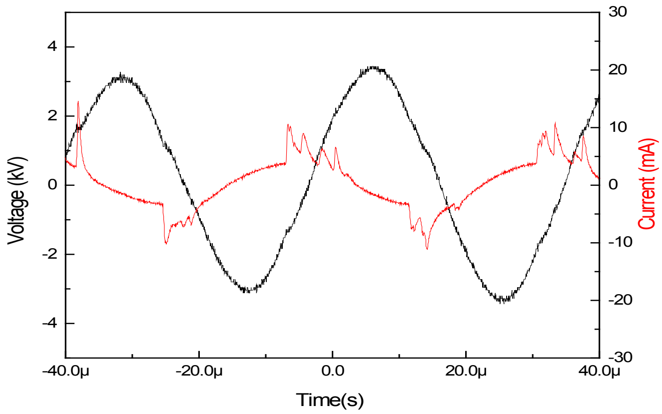

Fig. 3: Voltage and current waveforms of the discharge at applied voltage 2.3 kV

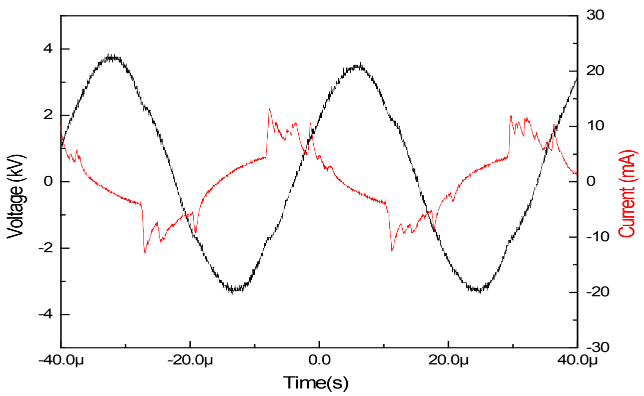

Fig. 4: Voltage and current waveforms of the discharge at applied voltage 2.5 kV

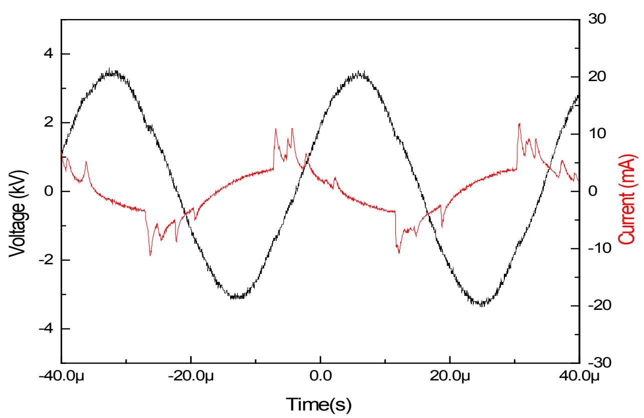

Fig. 5: Voltage and current waveforms of the discharge at applied voltage 3.3 kV

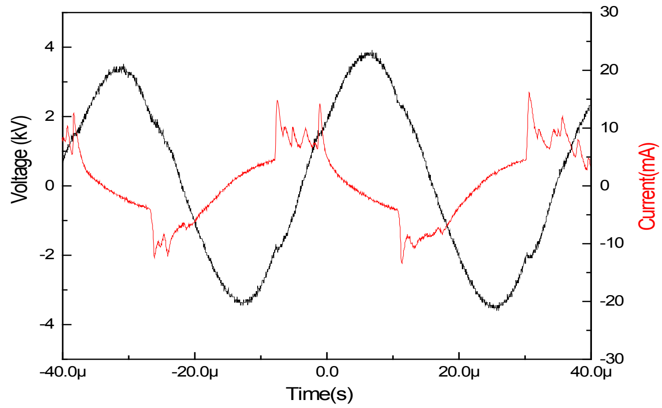

Fig. 6: Voltage and current waveforms of the discharge at applied voltage 3.5 kV

The calculated values of electron density for different applied voltage are shown in Table 1. This value clearly resulted that electron density depends on the applied voltage.

Table 1: Calculated values of electron density for different applied voltage

S.N.	Applied voltage (kV)	Electron density $n_e \times 10^{11}$
1	2.1	1.50
2	2.3	1.81
3	2.5	2.70
4	3.3	3.28
5	3.5	3.70

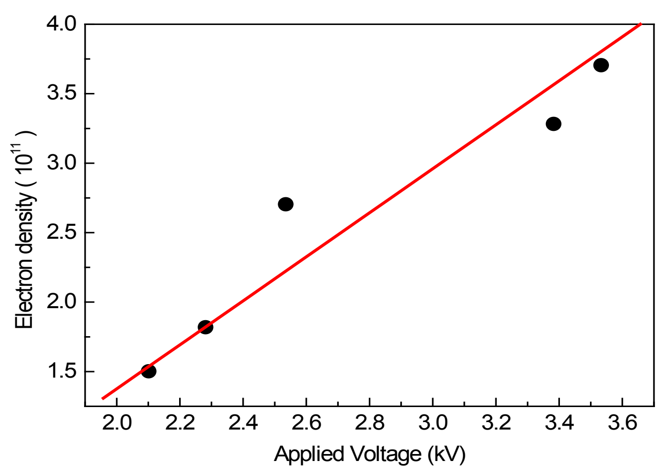

Fig 7: Graph between applied voltage and electron density

5. CONCLUSION

A homogeneous argon glow discharge can be produced using a parallel disc electrodes configuration with glass as dielectric barrier. The electron density in atmospheric pressure glow discharge in argon is calculated by power balanced method. Our results showed that the electron density increased with the increase in applied voltage.

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