

## COMPARISON OF DIELECTRIC BARRIER DISCHARGE IN AIR, NITROGEN AND ARGON AT ATMOSPHERIC PRESSURE

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*Received 16 July, 2010; Revised 19 September, 2010*

### ABSTRACT

This paper reports the results of electrical characterization of dielectric barrier discharge (DBD) generated in air, nitrogen and argon at atmospheric pressure. Polycarbonate plate of thickness 1 mm was used as a dielectric barrier in a specially designed hemispherical-plane electrode system. A non-uniform filamentary type of discharge was observed in air. Introducing nitrogen and argon gas at controlled flow rate of 1-2 liters / minute resulted a more homogeneous discharge at a frequency of 28 kHz of the AC source. The discharge was investigated for two values of electrode gap of 1 mm and 2 mm by varying the applied voltage. The number of current pulse per half cycle and the magnitude of the discharge current were found to be higher in the case of air discharge in comparison to the discharge in nitrogen and argon. The characteristics of the discharge in air in the absence dielectric barrier was also examined and interestingly it was found that in this case the filamentary discharge turned to a glow discharge for specific value of applied voltage and electrode spacing.

**Keywords:** DBD, Glow Discharge, hemispherical-plane electrode, filamentary discharge, Polycarbonate Sheet

### INTRODUCTION

Dielectric barrier discharge in atmospheric pressure has been well known from few decades due to its wide applications in industry, environment and medicine such as ozone production, surface modification, material processing, biological decontamination and water treatment [1]. DBD treatment can be effectively used for surface modification and uniform thin film deposition when its nature is completely homogeneous. In recent years, several researchers have tried to obtain the homogeneous dielectric barrier discharge at atmospheric pressure using different working gases such as neon, helium, argon, nitrogen, air and their mixture with other gases [2, 3].

In recent years many studies have been concerned with the effects of gas flow and electrode geometry on the discharge mode and characteristics. While several authors have published experimental and modeling studies of plane-parallel DBD at atmospheric pressure, the present study attempts to address the case of hemispherical-plane geometry [4]. We developed a hemispherical-plane electrode system and examined the effects of gas environment and electrode spacing on the nature of the discharge. By selecting a hemispherical electrode of carefully machined diameter of 3.15 cm and precisely controlled gap spacing, electrical measurements were made in an extended range of parameters. An attempt has also been made to compare the mode of the discharge with and without the dielectric barrier.

## MATERIALS AND METHODS

The schematic diagram of experimental arrangement used in our study (Fig. 1). The upper electrode is hemispherical in shape with 3.15 cm diameter and 1.5 cm height and lower electrode is circular with 5.05 cm diameter and thickness 1.02 cm made of brass. Polycarbonate plate of thickness 1mm was used as a dielectric barrier. A high voltage AC power supply was used and the applied rms voltage was in the range of 3-7 kV at a frequency 28 kHz. The gap was varied form 1-2 mm and the gas flow rate was set to 1-2 liter per minute. Electrical characterization was made with the help of a high voltage probe coupled to Tektronix TDS2002 digital oscilloscope.

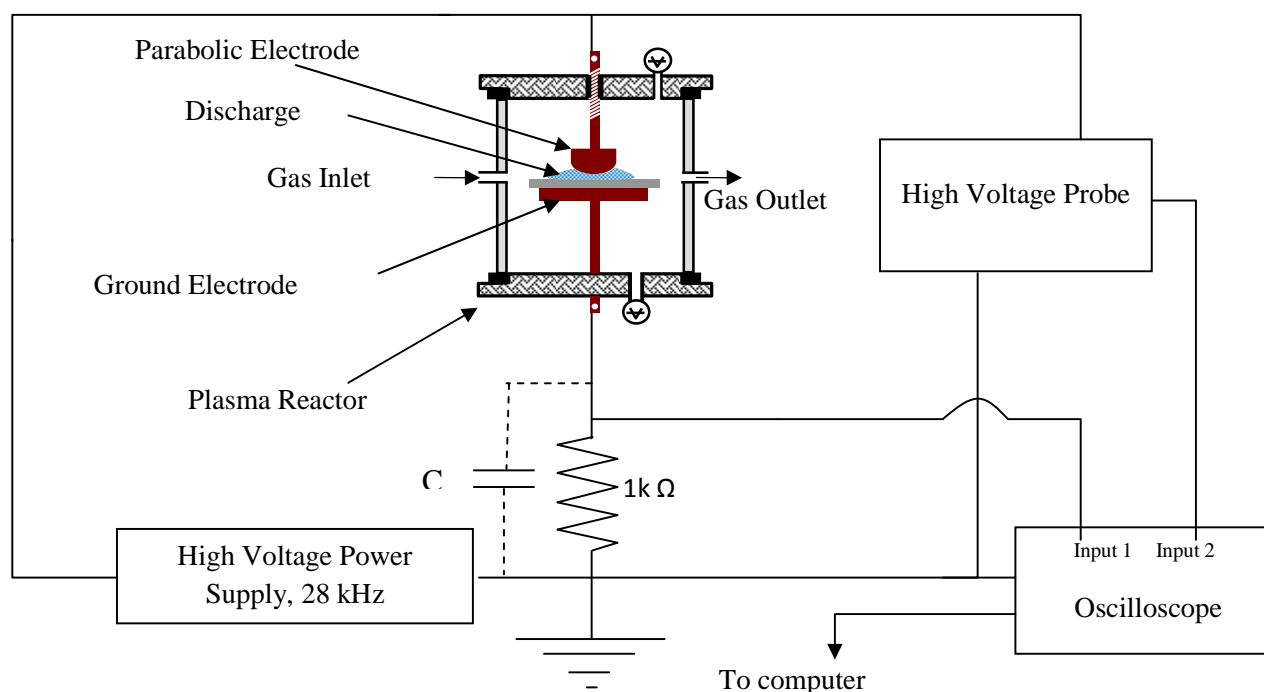


Figure 1 Schematic diagram of experimental setup. In order to plot the Lissajous figure, the resistor was replaced by the capacitor.

## RESULTS AND DISCUSSION

### I-V waveform analysis of DBD

Current – voltage waveforms of the discharge in nitrogen with 1mm of electrode spacing (Figs. 2 a-c). Similarly, the waveforms for the discharge with 2 mm gap (Figs. 2 d-f). The comparison of the current waveforms of the discharges in air and nitrogen indicate that the density of current pulses per half cycle and the amplitude of the discharge current is smaller in the case of nitrogen flow [5]. The reduction in the current amplitude after the  $N_2$  or Ar flow can be attributed to the fact that the flow of the gas will cause a decrease in static pressure in the discharge gap (Table 1). This leads to the decrease in ionization rate and hence results a weak discharge. In addition, the fast gas flow can control the discharge intensively by drawing off the heat deposited in the discharge space which is especially important in air discharge.

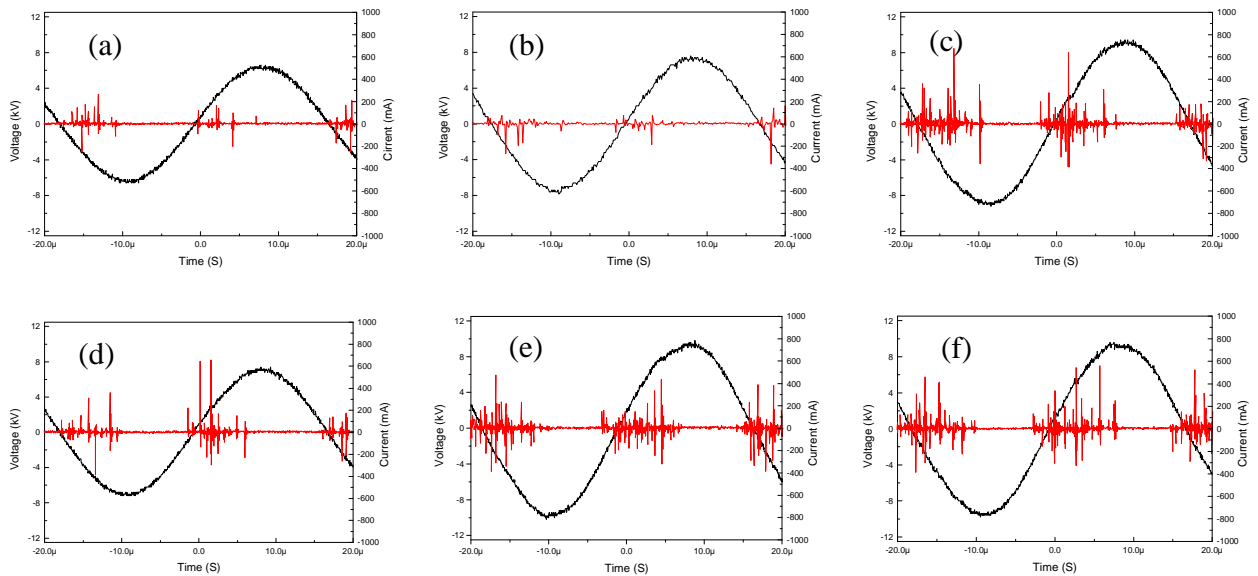


Figure 2 Voltage and Current wave form of DBD in nitrogen with 1mm gap (above) and 2 mm gap (below) using different applied voltage 3-7 kV rms at 28 kHz.

Table 1- Parameters Value

Parameter	Description	Nominal Value
Qf	Feed flowrate	100 L/min
V	Volume of reactor	100 L
Tf	Feed temperature	350 K
Tcf	Coolant temperature	350 K
Cp, Cpc	Heat capacity	0.239 J/(g.K)
E/R	Activation energy	1 X 10 <sup>4</sup>
Cf	Concentration of feed	1 mol/L
K0	Velocity constant	7.2X 10 <sup>10</sup> min <sup>-1</sup>

### DISCHARGE WITHOUT DIELECTRIC

With an objective to examine the mode of the discharge without using dielectric barrier, we removed the barrier and used a ballast resistor  $690\text{ k}\Omega$  in positive terminal of power supply. In the absence of the dielectric barrier, glow discharge was observed as indicated by the appearance of single current pulse per half cycle of the current wave form (Fig. 3). In contrast, a filamentary type of discharge is characterized by the presence of number of short lived micro-discharge resulting several current pulses per half cycle in the current waveform [6]. It is interesting to note that the transition from filamentary to glow like discharge takes place upon removal of the dielectric and detected clearly from the current waveform.

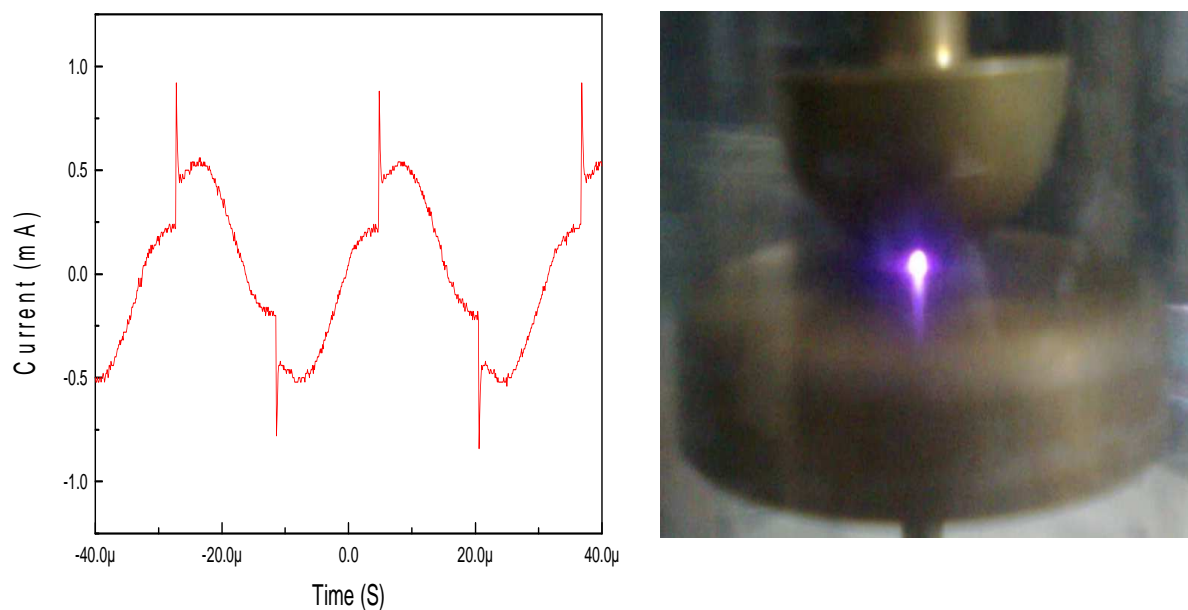


Figure 3 Current waveform of AC Glow Discharge without using dielectric in 1mm gap at 30 kHz and its corresponding photograph.

### LISSAJOUS FIGURE

Another method of electrical characterization of DBD is to plot the charge-voltage Lissajous figure. It gives the energy consumed by the discharge per cycle of the applied voltage. For this purpose, the 8 ohm resistor was replaced by capacitors of different capacitances. The relation between voltage and charge waveform with respect to time (Fig. 4). Using this waveform, the Lissajous figure thus obtained for nitrogen DBD with  $470\mu\text{F}$  capacitance connected in series is depicted.

The charge was calculated by dividing the voltage developed across the capacitor by its capacitance. Since the figure appears to be close to a parallelogram, the discharge must be filamentary in nature. It has been reported that when the discharge changes to APGD, only two parallel lines on the top and bottom of a parallelogram will be obtained.

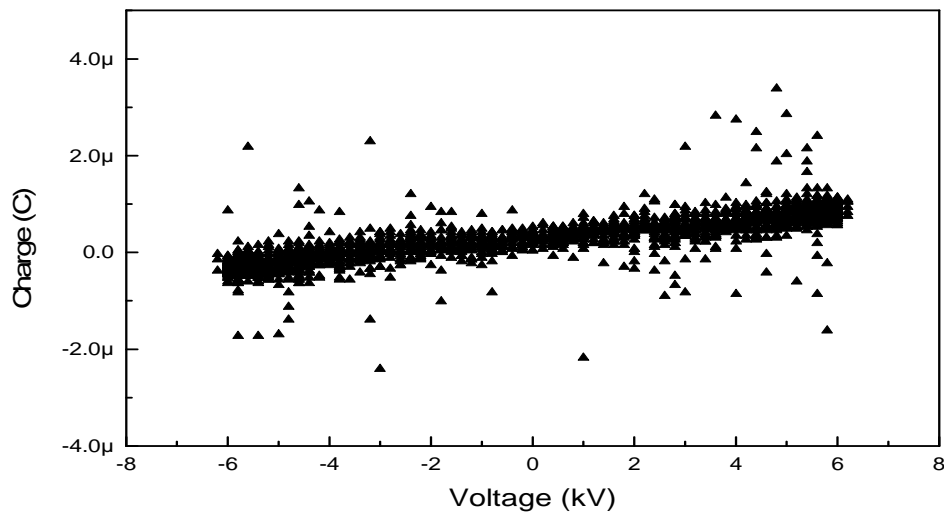


Figure 4 Lissajous figure of the DBD in Nitrogen using a capacitor of 470  $\mu\text{F}$ .

#### ACKNOWLEDGEMENT

This research was supported by the University Grants Commission (UGC), Nepal.

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