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

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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 [1-5]. 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. Okazaki *et al.* [6] studied the stabilization of homogeneous DBD at atmospheric pressure with 50 Hz power supply in air, argon, oxygen and nitrogen. Garamoon *et al.* [7] gave remarkable result of homogeneous DBD at atmospheric pressure with 50 Hz power supply in air using barrier of porous alumina ceramic. Kanazawa *et al* [8] purposed stability of homogeneous DBD in helium gas with certain gas mixture with the frequency 10-50 kHz. Luo *et al* [9] also investigated homogeneous barrier discharge in

nitrogen at atmospheric pressure by means of electrical measurement, fast photography and time resolved spectroscopy.
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. 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 is shown in 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.

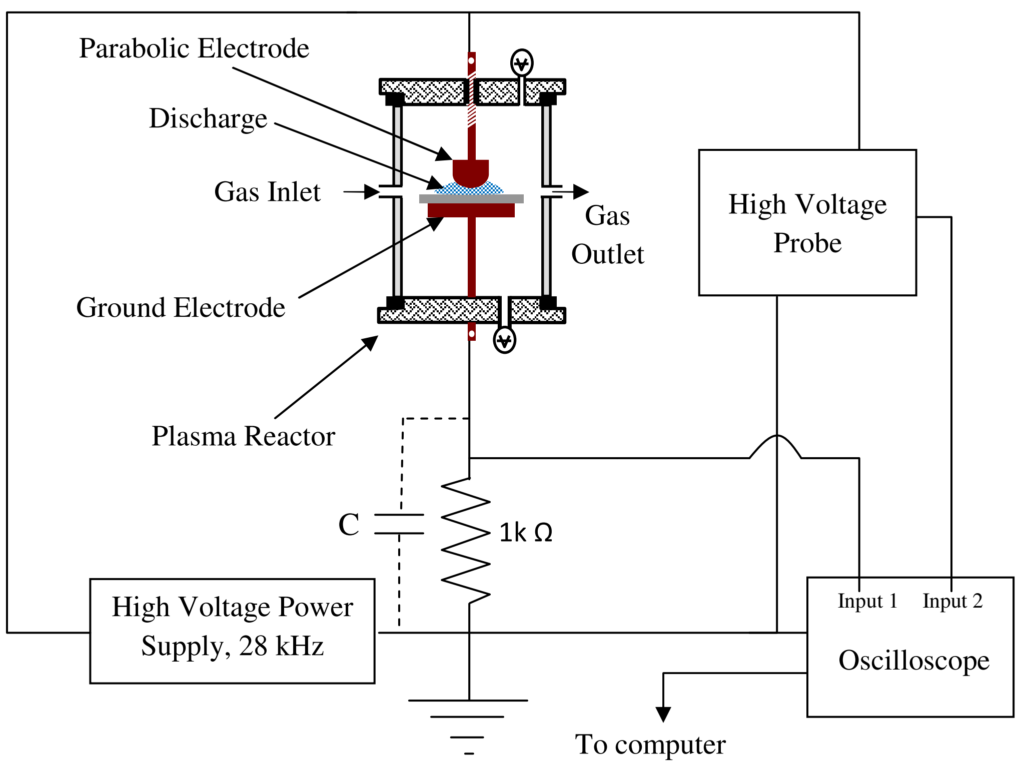

Fig. 1 Schematic diagram of experimental setup. In order to plot the Lissajous figure, the resistor was replaced by the capacitor.

RESULTS AND DISCUSSION

I-V waveform analysis of DBD

Fig. 2 shows the voltage and current wave-forms of the DBD in air at a frequency of 28 kHz. Fig (a)-(c) correspond to the discharges with 1 mm gap between the electrodes whereas fig. (d)- (f) correspond to a gap of 2mm. From the waveforms of the discharge it is evident that the number of current pulses per half cycle increase with the increase in applied voltage for both values of the electrode spacing.

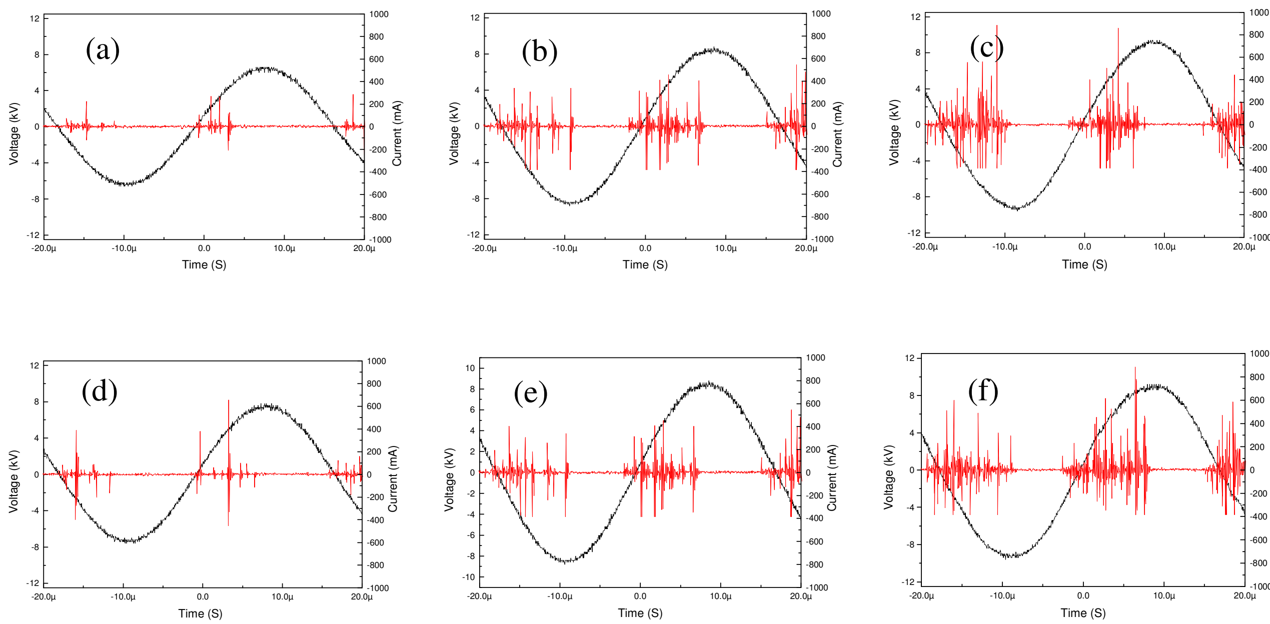

Fig.2 Voltage and Current wave form of DBD in air with 1mm gap (above) and 2 mm gap (below) using different applied voltage 3-7 kV rms at 28kHz.

Current – voltage waveforms of the discharge in nitrogen with 1mm of electrode spacing are shown in Fig. 3 (a)- (c). Similarly, the waveforms for the discharge with 2 mm gap are shown in Fig. 3 (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. Similar is the case of argon discharge as shown in Fig. 4 (a)- (f). Fig. 4(a) –(c) are the I-V waveforms of discharge with gap spacing 1 mm and 4 (d)- (f) for the discharge with gap of 2 mm.

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. This leads to the decrease in ionization rate and hence results a weak discharge [10]. 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. *Zhang et al* [10] have reported that the higher the flow rate of the gas, the more the heat can be taken away, resulting a weaker discharge.

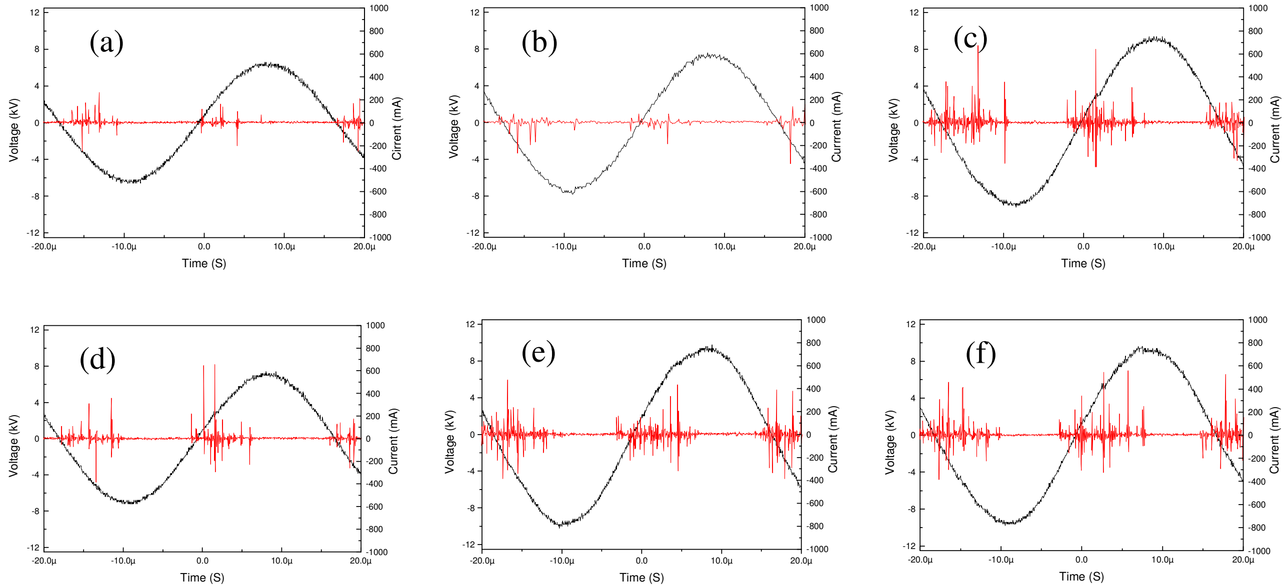

Fig. 3 Voltage and Current wave form of DBD in nitrogen with 1mm gap (above) and 2 mm gap (below) using different applied voltage 3-7 kV rms at 28 kHz.

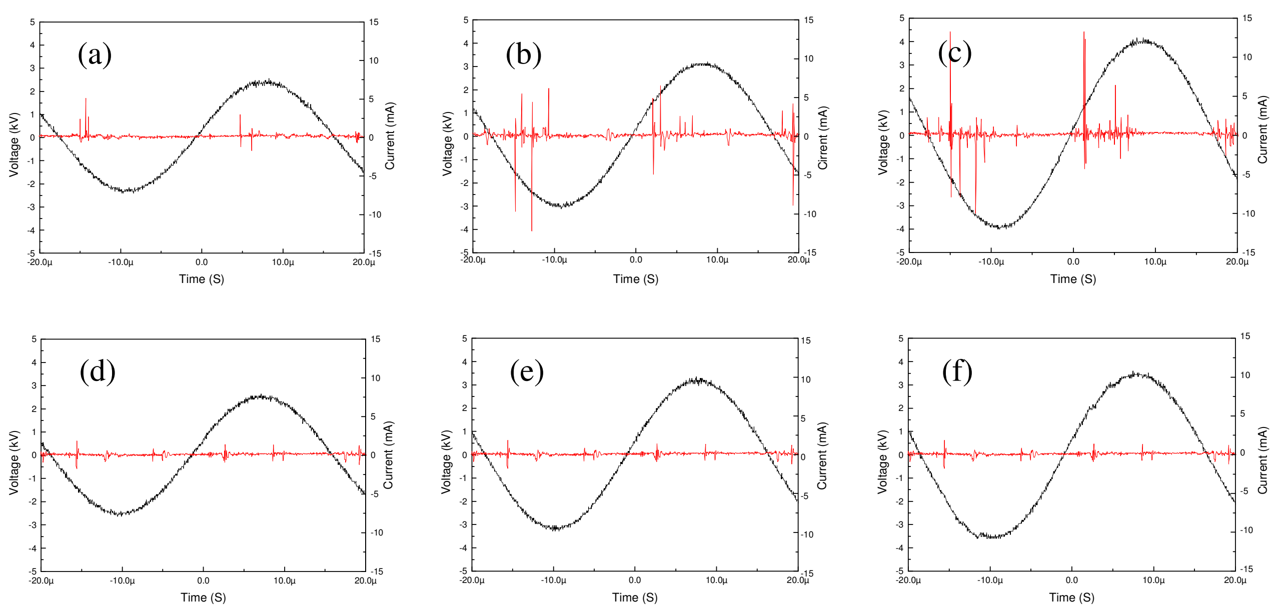

Fig. 4 Voltage and Current wave form of DBD in argon with 1mm gap (above) and 2 mm gap (below) using different applied voltage 1-3 kV rms at 28 kHz.

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 kΩ 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 as shown in Figure 5. 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 as shown in Fig. 2, 3 and 4. 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.

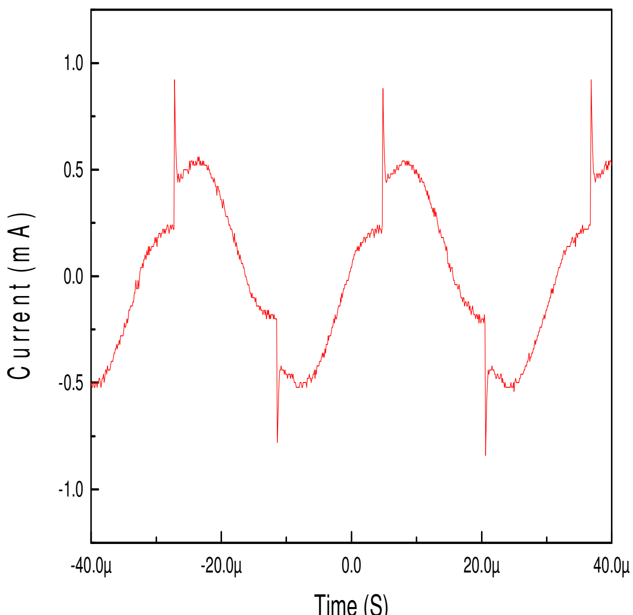

Fig. 5 Current waveform of AC Glow Discharge without using dielectric in 1mm gap at 30 kHz and its corresponding photograph.

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 in the Fig. 1 was replaced by capacitors of different capacitances. The relation between voltage and charge waveform with respect to time was shown in Fig. 6. Using this waveform, the Lissjous figure thus obtained for nitrogen DBD with 470µF capacitance connected in series is depicted in Fig 7.

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 in the Fig. 7 [6].

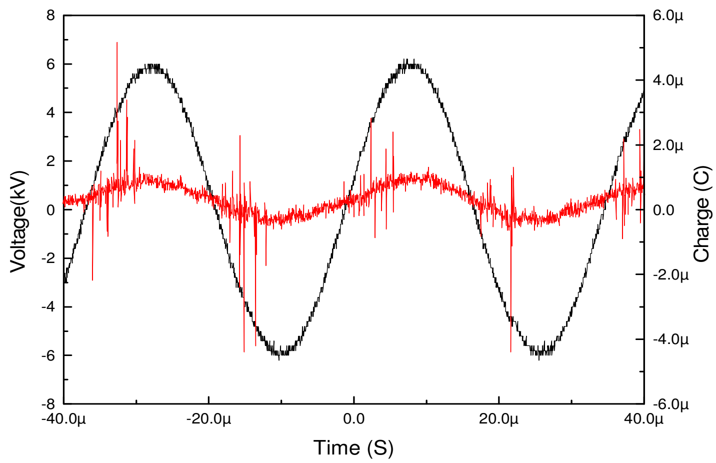

Fig. 6. Relation between Voltage and Charge of the DBD with respect to time in Nitrogen using a capacitor of 470 µF in 1mm gap.

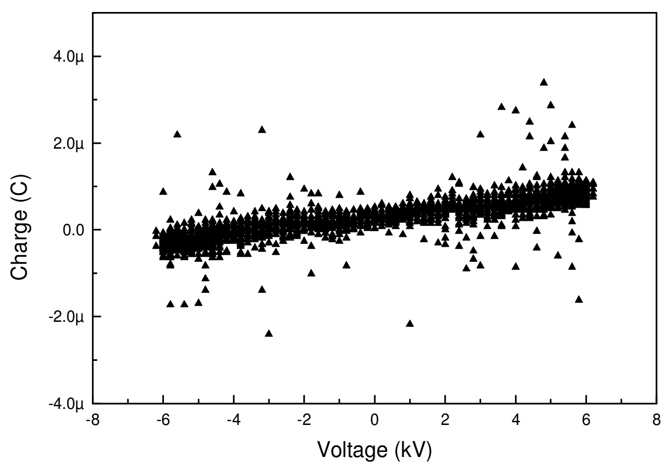

Fig.7. Lissajous figure of the DBD in Nitrogen using a capacitor of 470 µF.

CONCLUSION

A hemispherical-plane configuration of DBD has been developed and the effects of different gas environments and the electrode spacing on the quality of the generated plasma has been examined. It was found from the electrical measurement that the number of current pulses and the amplitude of the discharge strongly depends on the type of the gas used. Transition of the filamentary discharge to glow discharge in air was found to occur upon the removal of the dielectric barrier. The future experiments on the discharge without dielectric will be extended to 50 Hz power supply.

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