ELECTRICAL CHARACTERIZATION OF ATMOSPHERIC PRESSURE DIELECTRIC BARRIER DISCHARGE IN AIR

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ABSTRACT

This paper reports the electrical characterization of dielectric barrier discharge produced at atmospheric pressure using a high voltage power supply operating at 50Hz. The characteristics of the discharge have been studied under different values as such applied voltage and the electrode gap width. The results presented in this work can be helpful in understanding the influence of dielectric material on the nature of the discharge. An attempt has also been made to investigate the influence of ballast resistor on the magnitude of discharge current and also the density of micro-discharges. Our results indicated that with this power supply and electrode geometry, a relatively more homogenous discharge is observed for 3 mm spacing

1-INTRODUCTION

Recently, much attention has been paid to the development of atmospheric pressure non-thermal plasma sources. Gas discharges producing atmospheric pressure non-thermal plasma has been extensively studied in different configurations [1]. The interest in this topic is due to the potential benefit from numerous plasma technologies like ozone production, pollution control by oxidation of volatile organic compounds or nitrogen monoxide, bio-treatment of micro-organisms by oxidation, surface treatment (thin film deposition, wettability modification), UV or VUV generation, aerosol charging and electro filtration [1,2]. Electrical discharge will occur between two electrodes, separated by a gas layer, if the breakdown value of the electric field strength is reached about 30kV/cm for air at atmospheric pressure. Dielectric barrier discharge (DBD) is characterized by the presence of at least one insulating layer between electrodes. The dielectric barrier prevents arc formation and involves an alternative polarization of the system. Regardless of electrode geometry, the discharge mainly occurs as numerous filaments. The filamentary discharges are termed ‘micro-discharges’ as they last only a few tens of nanoseconds and have a diameter of 10-100 μm [2]. The characteristics of the discharges are controlled by the operating parameters: voltage, frequency, gap width, nature of materials of the reactor and nature and operating conditions (gas flow rate, temperature and moisture). The most important characteristics of dielectric barrier discharge are that thermally non equilibrium plasma conditions can be provided in a much simpler way at atmospheric pressure than with other alternative discharges [1, 2]. Atmospheric pressure dielectric barrier discharge using low frequency (50 Hz) is attractive for industrial applications as it avoids the high costs associated with vacuum based and high frequency plasma. We have been able to produce DBD in atmospheric air with a source frequency of 50 Hz and voltage 50 kV. Our study was mainly focused on electrical characterization of micro discharges produced by DBD.

1.1 Dielectric Barrier Discharge (DBD)

A dielectric barrier discharge (DBD), sometimes referred to as a barrier discharge or a silent discharge, is a type of discharge where at least one of the electrodes is covered with a dielectric material [3]. This dielectric layer acts as a current limiter and prevents the formation of a spark or an arc discharge. The electrical energy coupled into a DBD-plasma is mainly transferred to energetic electrons, while the neutral gas remains closest to ambient temperatures. The non-equilibrium plasma that is produced can be operated at elevated pressures. The combination of plasma properties makes it a unique device with many industrial applications [3]. The width of the discharge gap can range from less than 0.1 mm to about 100 mm, and applied frequency from below line frequency to several GHz. Typical materials used for the insulating layer are glass, quartz, ceramics, and also thin enamel or polymer coating on the electrodes [3]. For most operating conditions, a DBD consists of a (large) number of discharge filaments, which have nanosecond duration and are randomly distributed over the dielectric surface. These filaments, also known as micro-discharges, are the active regions of a DBD in which active chemical species and UV radiation can be produced. These micro-discharges act as individual discharges which work independently of one another [3]. In DBDs such micro-discharges are observed in every half cycle of the applied voltage, as shown in Figure 1.2

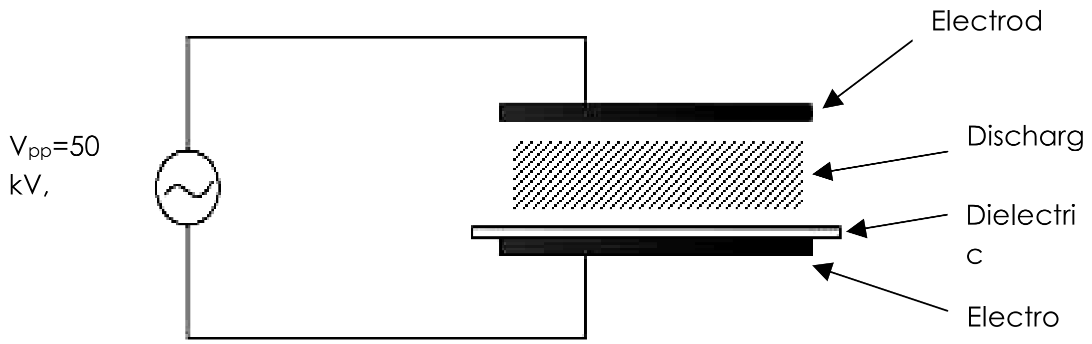

Figure 1.1: Schematic Diagram of DBD system. Black- metal electrode, Gray-insulator.

The aim of the research described in this work is to investigate the behavior of DBDs in the atmospheric pressure and applied voltage in the range of 0−50 kV. The experiments have been performed using parallel plate electrodes. Figure 1.1 shows the type of DBD we have used in our experiment. We characterized the discharge properties by recording voltage and current waveforms. Dependence of breakdown voltage of DBDs on applied voltage and electrode gap has been analyzed.

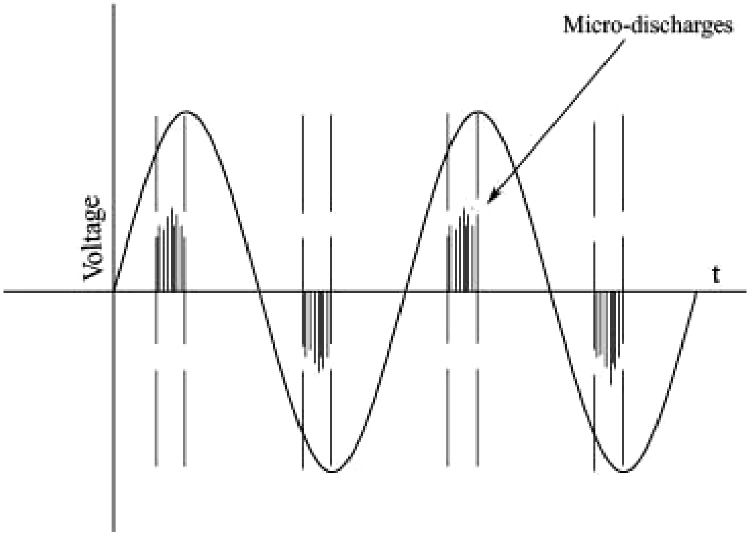

Figure 1.2: Schematic diagram of micro-discharges produced at applied voltage.

2-EXPERIMENTAL SETUP

The experimental arrangement is shown in Figure 3.1. A transformer is used to produce a high voltage of 50kV peak to peak at a frequency of 50 Hz. This AC high voltage is applied to the upper electrode with one output of the transformer connected to the grounded lower electrode as shown in Figure 3.1. A glass as a dielectric barrier of thickness 1.6 mm is placed over the lower electrode. The upper electrode of dimension 5.5cm × 3.7cm × 1.15cm and lower electrode of dimension 5.7cm × 3.7cm × 1.15 cm are used.

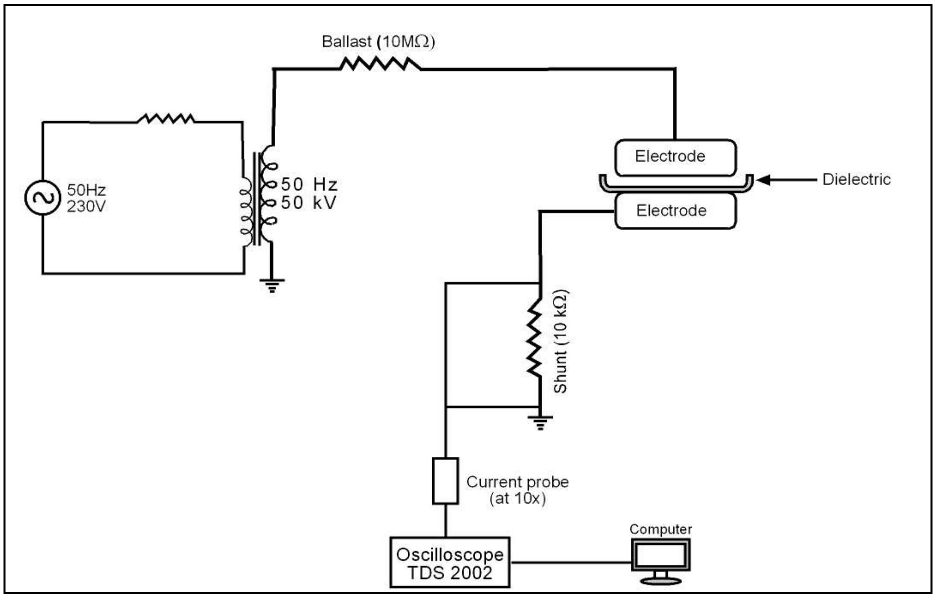

Figure 2.1 Circuit Diagram of the experimental setup.

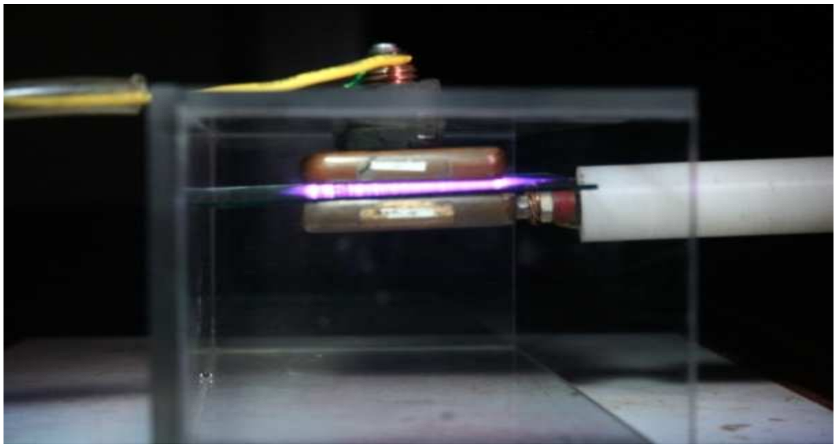

Figure 2.2: Photograph of plasma produced between two parallel electrode DBD systems.

3- RESULTS and DISCUSSIONS

Figure 3.1 shows breakdown characteristics and it is found that breakdown voltage increases linearly at atmospheric pressure with the increase in the electrode gap. It also reveals that with the increase in the ballast resistance the breakdown voltage also increases for the same electrode gap. Thus even the ballast resistor increases the nature of curve remains same. Figure 3.2 shows the spikes that correspond to the micro-discharges zoomed from the current versus time graph. This graph suggests that the time interval between the discharges is very small of the order of micro-seconds. Figure 3.3 and 3.4 shows the current voltage characteristics of the DBD. It is observed that discharge current increases linearly with applied input voltage and also with the increasing electrode gap. It is found that the increase in current for 2 mm gap is very small for different applied voltage but current increases linearly above 2 mm gap, which is clearly seen in Fig 3.4 and 3.5. From these figures we have found that the nature of variation of current with the applied voltage is similar for both values of ballast resistor. Figure 3.5 to 3.8 shows the current waveforms for different electrode gap and comparison for different ballast resistances. The study of magnitude of current in the discharge curve shows that with the increase in ballast resistor the magnitude of current also decreases and seen in all the curves for different electrode gap. In these figures the micro-discharges can be significantly seen with the numbers of spikes in the curves. The number of micro-discharges is found to increase with the increasing applied voltage. The increase of voltage leads to reduction of duration of micro-discharges, probably due to higher electric field. The source used was not perfectly sinusoidal and it was varying with time, during our experiment. Because of this, the observed numbers of micro-discharges in both sides of sine wave were not equal and increased numbers of micro- discharges were not observed significantly. However, the discharge is found to be more uniform for 3 mm electrode gap and also increase in numbers of micro- discharges is significant.

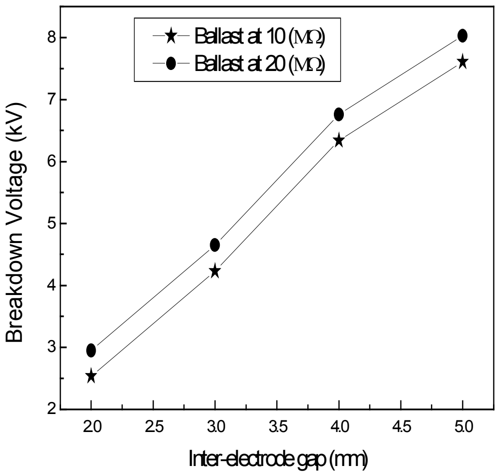

Figure 3.1: Breakdown characteristics

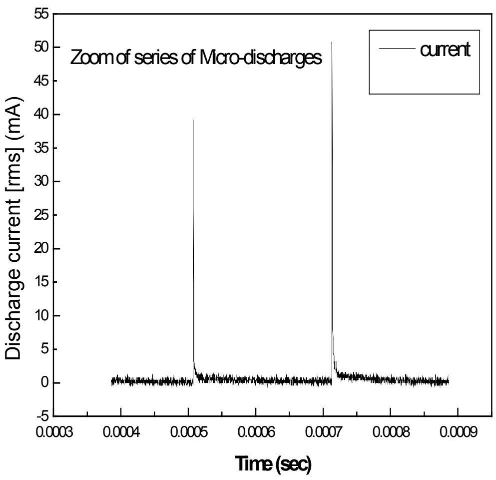

Figure 3.2: Zoom of series of Micro-discharges

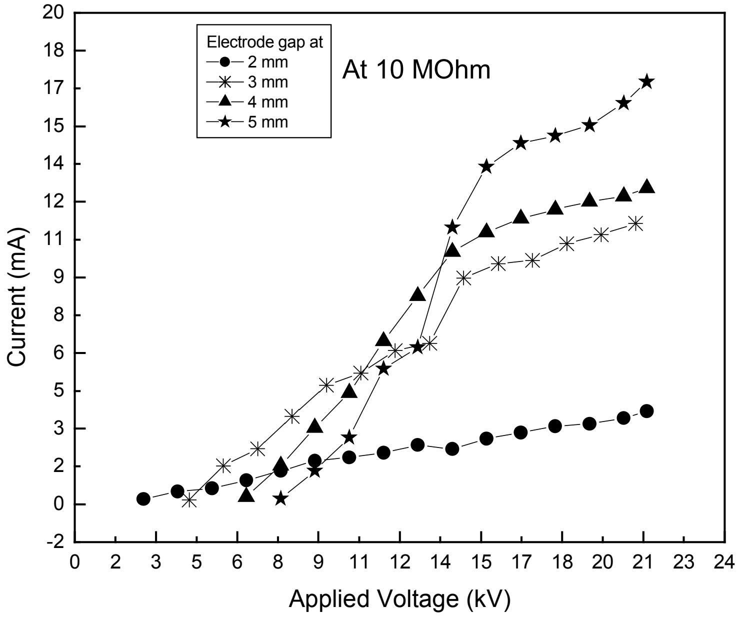

Figure3.3: Current and voltage characteristics of DBD (ballast at 10MΩ)

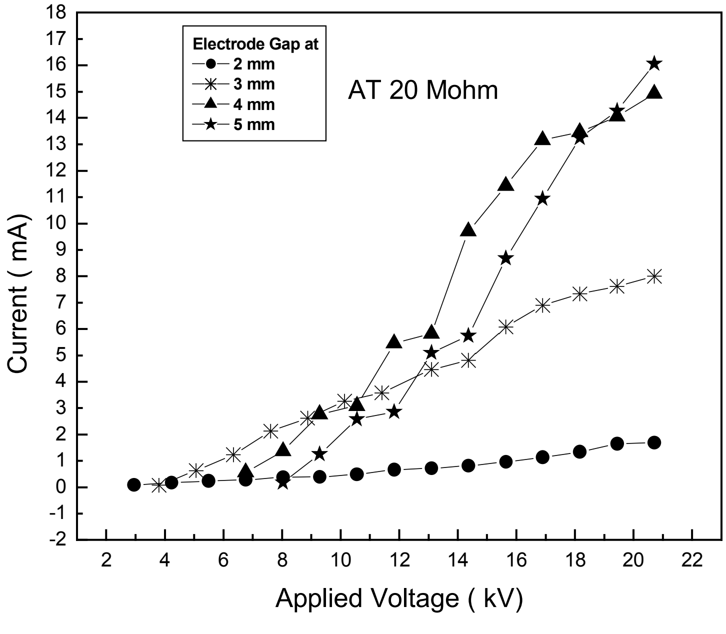

Figure 3.4: Current and voltage characteristics of DBD (ballast at 20MΩ)

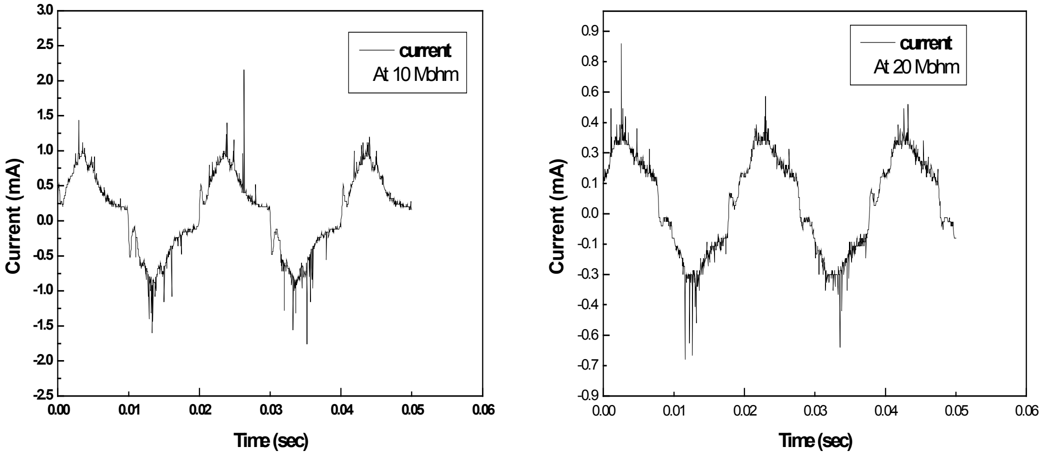

Figure 3.5: Current waveforms of DBD at electrode gap 2 mm

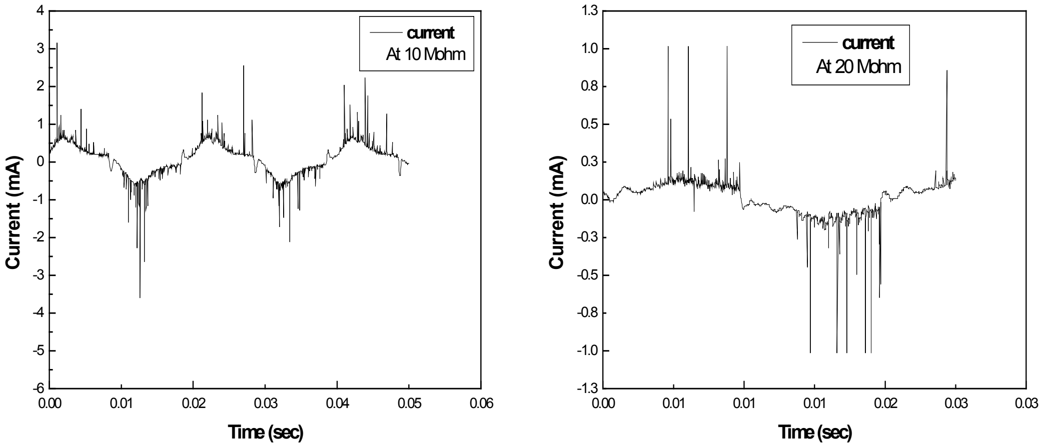

Figure 3.6: Current waveforms of DBD at electrode gap 3 mm

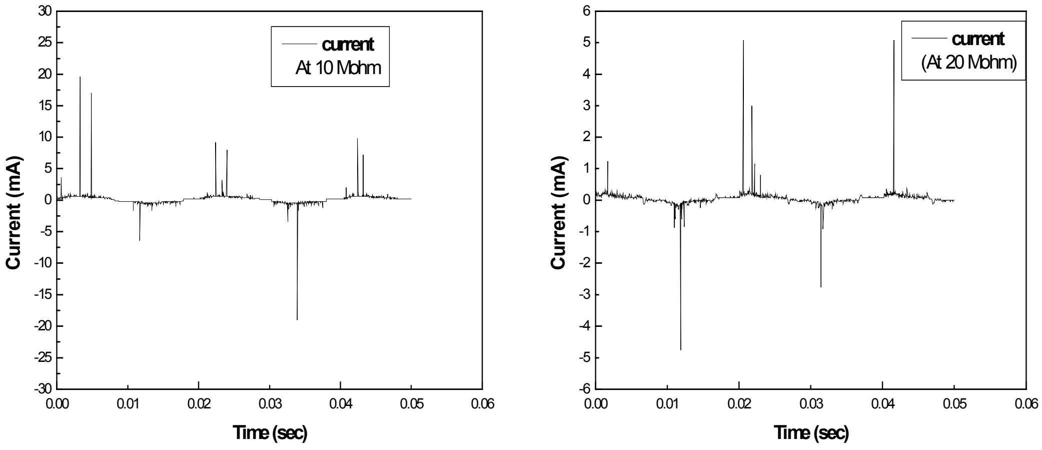

Figure 3.7: Current waveforms of DBD at electrode gap 4 mm

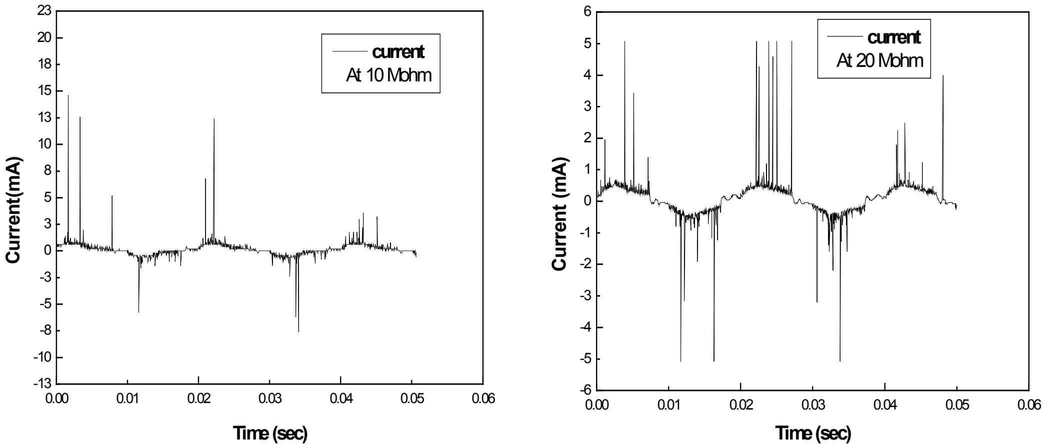

Figure 3.8: Current waveforms of DBD at electrode gap 5 mm

4- CONCLUSIONS

A typical DBD suitable for treatment of polymer surfaces has been designed and tested. The homogeneity of the discharge can be controlled by adjusting the electrode spacing and applied voltage. The further work is to stabilize the discharge by the use of inert gases like Argon, Neon or Helium. The produced DBD may also be used in industrial applications such as material processing, ozone generation, sterilization of biomedical applications and deposition of thin films.

Acknowledgements

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