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Electrical Characterization of Dielectric Barrier Discharge

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Abstract

In this paper, the results of electrical characterization of DBD generated in air, nitrogen and argon at atmospheric pressure were analyzed. Filamentary mode and homogeneous DBD mode of discharge were studied. Glow-arc discharge mode was also studied by means of electrical characterization without using the dielectric barrier between the electrodes. This study has been carried out by measuring current and voltage with a high frequency digital oscilloscope. The number of filaments in the discharge observed in this experiment was found to be a function of the applied voltage and electrode gap. Lissajous figures were used to estimate the energy deposited to the discharge.

Keywords: DBD, Filamentary mode, Homogeneous DBD mode.

1. Introduction

The DBD is an electrical discharge that is generated between two electrodes of which at least one is covered by an electrical insulator. Common materials for dielectric barriers are glass, quartz, ceramics, or enamels. Also plastic films, silicon rubber, teflon plates and other materials can be used. Mostly cylindrical reactors are used for industrial propose which builds gas flow controller and facilitates of small variation of inside pressure [1-3]. The first experimental investigations of the dielectric barrier were reported in 1857 by Werner von Siemens [4]).The research was mainly focused on the generation of ozone. In the beginning of the 20th century Emile Warburg in Berlin conducted important investigations which lead to a much better control of these discharges. In the 1920s Otto and Becker separately industrialized the designs of the ozone generators. In the 1930s it was discovered by Buss that the breakdown of air between planar parallel electrodes covered by dielectrics always occurs in a large number of tiny short lived current filaments. He obtained the first traces of these micro discharges on photo-sensitive plates [5] and was able to obtain oscilloscope recordings of their current and voltage properties. The atmospheric pressure DBD typically operates in the filamentary mode, but under specific operating conditions it is also possible to operate it in a diffuse mode, where spatial homogeneity in the direction parallel to the electrodes is obtained. This enables the discharge to be used for homogeneous surface treatments at atmospheric pressure. In 1968, Bartnikas found that helium AC discharges between closely spaced plane parallel electrodes, metallic or covered with a dielectric layer, can exhibit diffuse glow discharge characteristics [6]. The successes of this discharge mode also investigate daround 1976 by Donohoe on the development and characterization of glow discharges in mixtures of helium and acetylene in his setup [7]. In1987 and afterwards uniform dielectric barrier glow discharges were developed by the research group of Okazaki (Okazaki, *et al.*, 1993). They used an electrode configuration using two metal foils covered with a special metal mesh and ceramic dielectrics. In this way homogeneous discharges were obtained in helium, nitrogen, air, oxygen and argon, even with or without the addition of organic precursors. They proposed to use the term atmospheric pressure glow discharge or APGD. Roth and coworkers also developed at the University of Tennessee a similar uniform dielectric barrier discharge reactor. Without using any special metal mesh on the electrodes they were able to obtain uniform glow discharges in helium and argon between electrodes with a separation length of several centimeters [8].In 1992 and afterwards Massines and her team made major contributions to the understanding of the glow mode in the atmospheric pressure DBD using both experiment sand simulations on mainly He and N_2 discharges[9-10].They made important steps in understanding which elementary processes are responsible for the existence of the glow mode. More recent activities of several teams[11-15]focused on obtaining high temporally and spatially resolved spectroscopic measurements as well as on developing detailed theoretical models, where the objective mainly lies in obtaining a better understanding in order to control these sometimes unstabletransient discharges.

2. Experimental Setup

The schematic diagram of experimental arrangement of this system is shown in Fig. 1. The upper electrode is hemispherical in shape with 3.15 cm diameter and 1.5 cm height and the lower electrode is circular with 5.05 cm diameter and thickness 1.02 cm. Both electrodes are made of brass. Polycarbonate plate of thickness 1 mm 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 of 28 kHz. The gap was varied in the range of 1-2 mm and the gas flow rate was set at 1-2 lit/min. Electrical characterization was carried out with the help of a high voltage probe coupled to Tektronix TDS2002digital-oscilloscope.

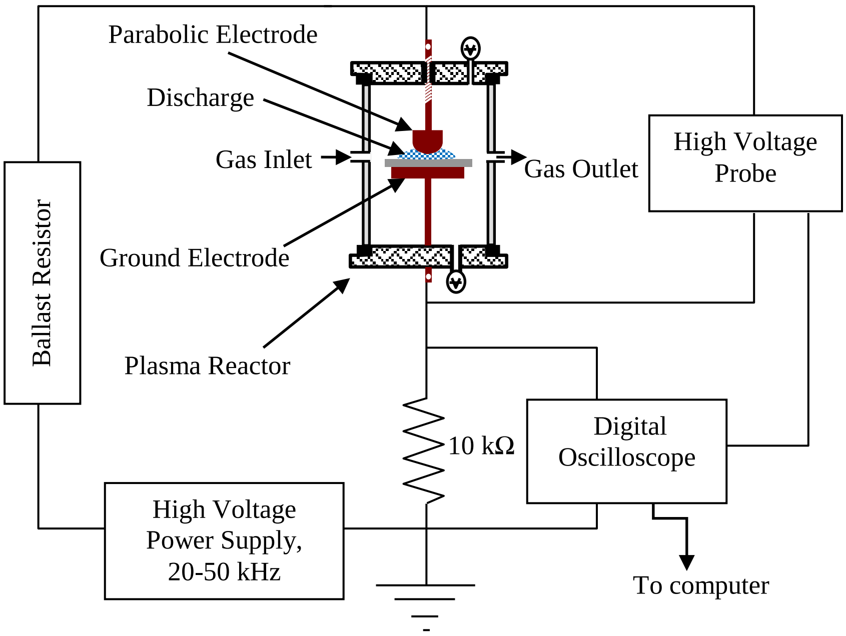

Figure-1.Schematic diagram of Experimental setup

3. Discussion and Results

DBD in atmospheric pressure is investigated in different gas environment namely air, nitrogen and argon. Electrical characterization of discharge is studied using polycarbonate as dielectric barrier. Usually, in atmospheric pressure DBDs in air, nitrogen and argon, the discharge regime is filamentary one even if, under specific conditions, a homogeneous diffuse discharge may be obtained. But it is generally difficult to obtain and reliably control such homogeneous discharges at atmospheric pressure. It is due to the fact that minor changes in the electrode configuration or small variation of the amplitude or repetition frequency of the applied voltage cause a transition from the relatively unstable diffuse mode to that of much more stable filamentary discharge.

(a) DBD with Polyethylene Dielectricbarrier

Fig. 2(a-c) show the voltage and current waveforms with discharge images of the DBD in air, nitrogen and argon in 1 mm gap respectively at a frequency of 28 kHz with discharge

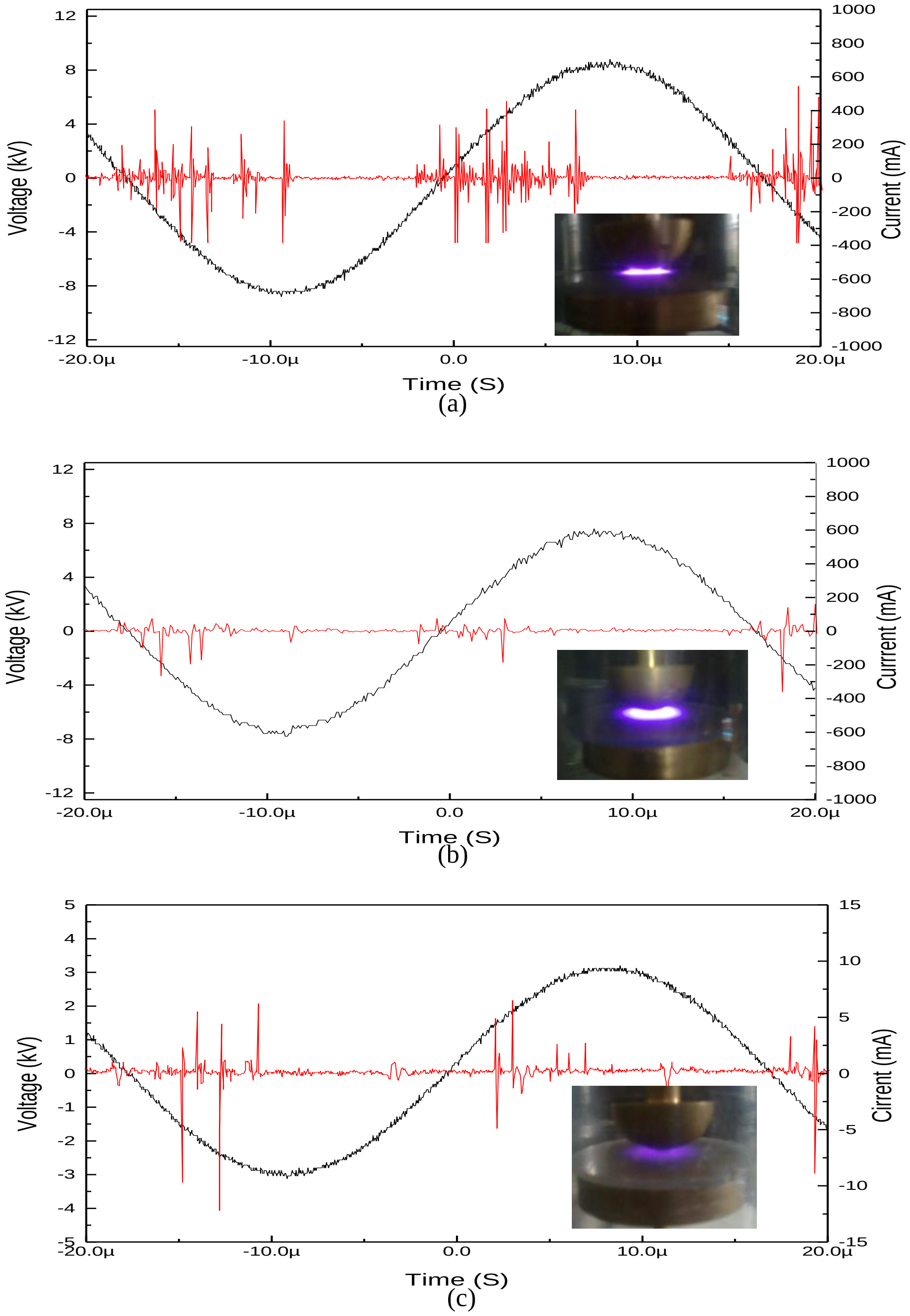

Figure-2. Voltage and current waveform with discharge images

photograph.

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. 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.

It can easily be observed that all the discharges show the current pulses due to streamers but significant differences are present. In air, current bursts are typically short and more intense while in nitrogen and argon they seem to be lower in amplitude and longer time with a peculiarly slow decaying current tail. This behavior can be connected to the dimension and duration of single micro-discharge. Current bursts are temporal superposition of more micro-discharges. It has been shown that oxygen admixtures to nitrogen or argon can lead to plasma channel reduction. Thus the lower intensity of the current bursts observed in nitrogen and argon can possibly be explained by the presence of wider streamers and less contemporary streamers developing close in time. Besides, different charges transported by a single discharge process must be considered. Moreover, the longer duration of current bursts in nitrogen or argon, characterized by slowly decaying current tail, suggests the presence of active species with longer lifetime metastable molecules that maintain active the discharge.

(b) DBD with Glass as Dielectricmaterial

In this case, nature of filamentary DBD was studied by counting the number of spikes in electrical signal. Figs. 3 (a-d) show the current waveforms and Figs.4 (a-d) the Lissajeous figure corresponding waveform of filamentary DBD in argon using dielectric (glass-2 mm) medium between the electrodes with a high voltage (0-10 kV) power supply operating at frequency 26 kHz. The

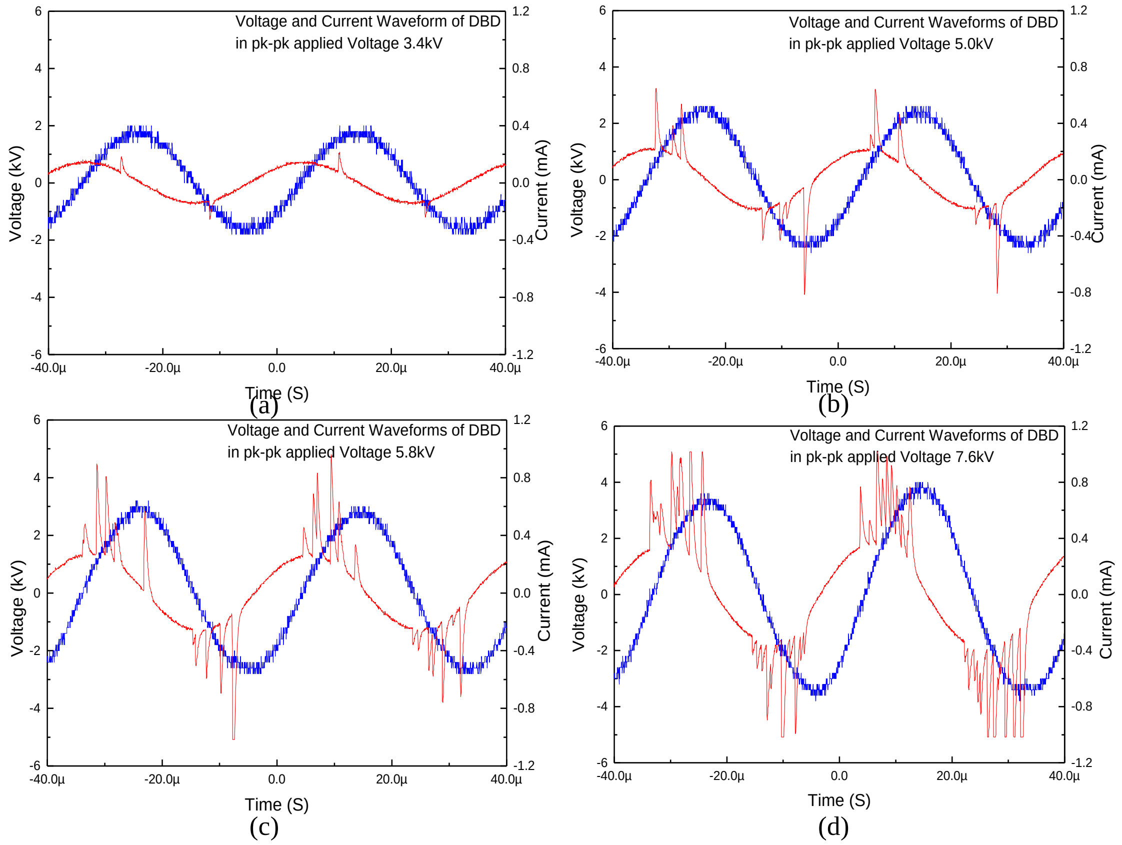

Figure-3.Voltage and current waveforms

discharge in hemispherical-plane electrodes system with 1mm gap consisted of number of spikes in current waveform. Introducing an argon gas at controlled flow rate 1 lit/min, the filamentary micro-discharge was obtained in argon with dielectric barrier (glass-2 mm) in hemispherical electrode geometry with frequency of 26 kHz power supply. It was investigated that the number of spikes was increased when the applied voltage was gradually increased. It means that multiple breakdowns occurred in every half cycle. It is evident that it is possible to count the number of current pulses per half cycle in the observation of the waveforms of the discharge.

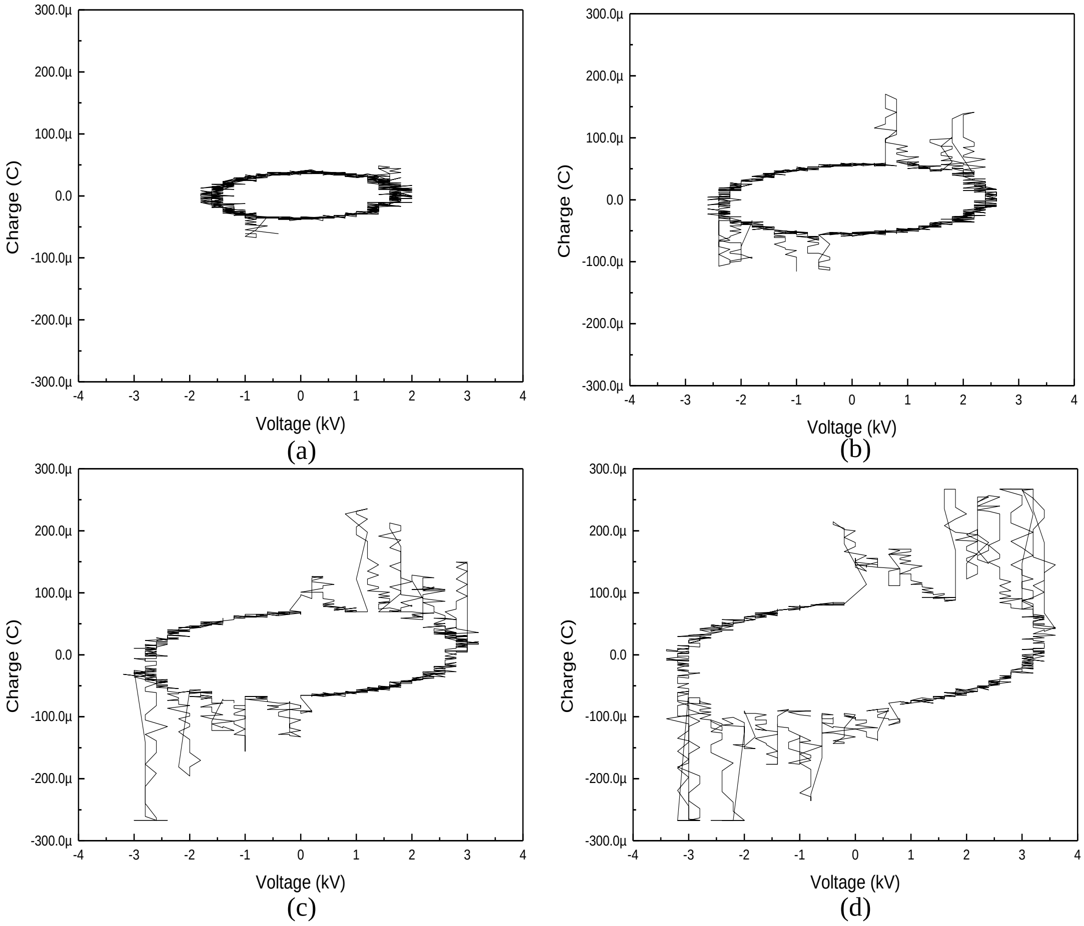

Figure-4. Lissajous figures

The Table-1 shows the relation between applied voltage and energy deposited in discharge corresponding. When applied voltage is gradually increased, the energy deposition to discharge is also increased.

Table-1. Relation between applied voltage and energy deposition

S. No.	Applied voltage (kV)	Energy deposited (mJ)
1	3.4	28
2	4.6	49
3	5.8	101
4	7.6	168

(c) Glow-arc Discharge without Dielectric Material

In this section, an electrical characterization of discharge is also investigated without using dielectric barrier between electrodes. The aim is to study the nature of current pulses of discharge. With an objective to examine the mode of the discharge without using dielectric barrier, we removed the barrier and used a ballast resistor of 690 kΩ in positive terminal of power supply to limit the current. In the absence of the dielectric barrier, when breakdown occurred, the current pulse was suddenly increased and voltage dropped. That means arc discharge formed as indicated by the appearance of single current pulse per half cycle in the current waveform as shown in Figs. 5(a-b). It is interesting to note that when applied voltage was increased, the current peak also increased. That means the transition from filamentary to glow-arc discharge takes place upon removal of the dielectric and can be detected from the current signal. The electrical characterization was conducted by plotting Lissajous figures. The plots of Lissajous Figures are show in Figs. 6(a-b). These shape of Lissajous figures clearly indicated that the discharge mode was transition from arc discharge to glow discharge. The energy deposited to the discharge has higher value in higher applied voltage.

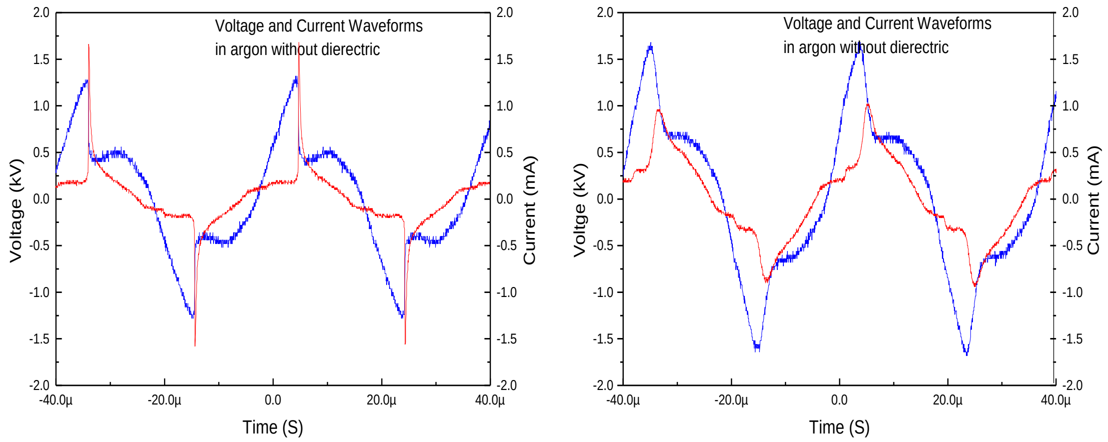

Figure-5. Voltage and Current waveforms

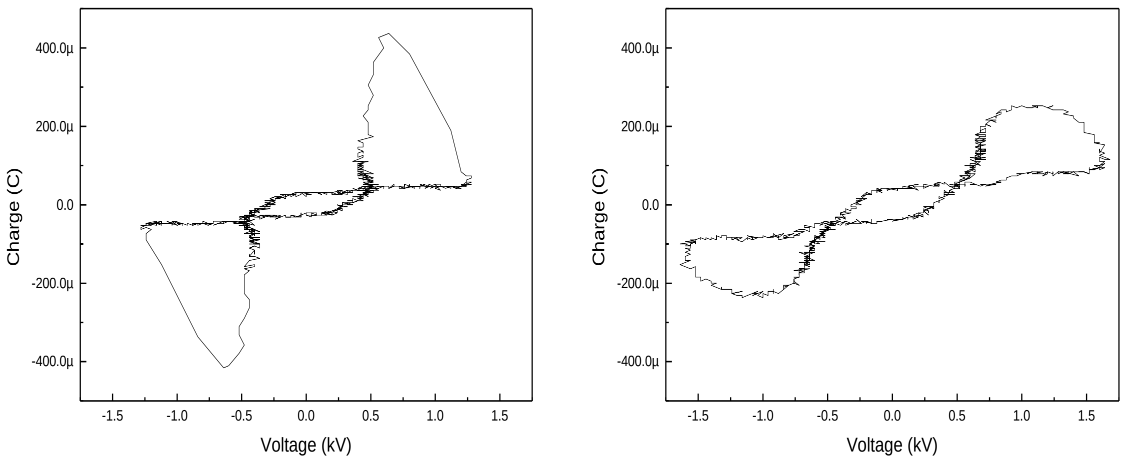

Figure-6. Lissajous figures

The image of glow-arc discharge in argon without dielectric barrier in different applied voltage in 1 mm gap is shown in Fig. 7. The measured values of the energy deposited to the discharge without dielectric is show in Table 2.

Table-2. Relation between electrode gap

Electrode gap	In low voltage	In high voltage
1 mm	3.85 μJ	5.65 μJ
2 mm	6.00 μJ	6.00 μJ
3 mm	6.50 μJ	8.25 μJ

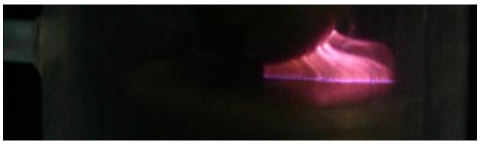

Figure 7: Image of glow-arc discharge

4. Conclusions

A hemispherical-plane configuration of DBD has been developed. The effects of different gas environments and the electrode spacing on the quality of the DBD have 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 and the presence and absence of barrier. Filamentary DBD, homogeneous DBD and glow-arc mode of non-thermal plasma has been identified in terms of electrical characterization.

5. Acknowledgement:

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