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Generation of uniform atmospheric pressure air glow plasma by dielectric barrier discharge with glass as a dielectric

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ABSTRACT

In this paper the non-equilibrium plasma under atmospheric pressure generated by parallel plate dielectric barrier discharge (DBD) system was investigated. The experiments were done by using two high voltage power supply, one (0-15 kV, 50 Hz) and other (0-20 kV, 100- 1500 kHz). TheI-V characteristic curves, power consumed and breakdown voltage were studied. A homogeneous and steady nonthermal plasma has been observed between the electrodes with gap space (1,2 and 3 mm). A sheets of glass with thickness (1,2, and 3 mm)were used as a dielectric between the electrodes. Our results shows that the power consumed in DBD system was less (100 W), also it was increased with the glass thickness, gap space and frequency of the applied voltage. It is found that the breakdown voltage in our experiment conditions at 1 atm. pressure was increased with the gap space and decreased with the frequency of the applies voltage.

Keyword:- Dielectric Barrier Discharge(DBD), dielectric thickness, gap space, frequency.

1.INTRODUCTION

Plasma is an ionized gas and could be divided into two categories: thermal and non-thermal. In the thermal plasma all the particles (electrons, positive ions, neutral atoms) are in thermodynamic equilibrium, whereas in non-thermal plasma, there is a significant difference in kinetic energy i.e. temperature of electrons and ambient gas particles [1]. There are two widely used methods for generating nonthermal plasmas at atmospheric pressure, namely the corona discharge and the dielectric barrier discharge DBD. Corona discharges have many applications in industry, where relatively small concentrations of excited or charged species are needed. Typical examples are electrostatic precipitators, copying machines and high speed printout devices. On the other hand, the DBD discharges are predestined for applications of large volume plasma. Barrier discharges, also referred as silent discharges are characterized by the presence of at least one insulating layer between two planar or cylindrical electrodes connected to an ac power supply [2]. The main advantage of this type of electrical discharge is that non-equilibrium plasma conditions in atmospheric pressure gases can be established in an economic and reliable way. This feature has led to a number of important DBD applications including industrial ozone generation [2], pollution control [3], plasma chemical vapor deposition and surface activation [4], excitation of excimer lamps, and more recently surface modification of diverse materials [5]. The main characteristics of a plasma discharge such as the breakdown voltage, voltage current characteristic and structure of the discharge depend on the geometry of the electrodes and the container, the gas used, the pressure in the chamber, the electrode material and the external circuit [6]. In order to optimize the design of a DBD rector, there is a necessity to calculate the power consumed in the silent discharge over a wide range of discharge conditions. The reactor with parallel plate geometry is the most frequently used for material processing.
Therefore, in this work the electrical properties of the parallel plate DBD reactor with glass as insulator layers has been measured for different glass thickness and gap space.

2.MATERIAL, METHOD AND EXPERIMENTAL SET-UP

A schematic of our experimental set-up is shown in figure 1.

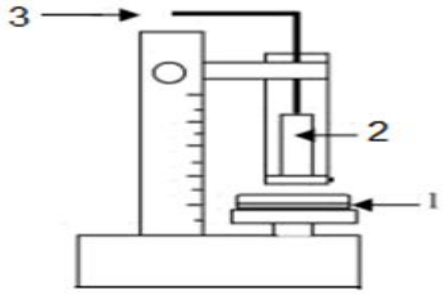

Figure 1: Schematic setup for of parallel plate DBD (1)glass layer (2) cupper electrode (3) High voltage.

Figure 2: Photograph picture for the electrodes

It consist of two cupper electrodes with 70mm diameter surrounded by a Teflon layer of thickness (10 mm),the gap between the electrodes can be varied from 1mm to 10mm .A glass is used as dielectric layer between the electrodes with three thicknesses (1,2 , 3) mm. as shown in figure 1. Both electrode are connected to high voltage transform (input voltage, 220 Volt, 50Hz and output voltage 15 kV,50Hz) (Sigutrade, model: NT-15-OUT, 50Hz) the output voltage of transformer can be varied from (1-15) kV by varying input voltage the high voltage across the gap is measured by using a high voltage probe type ((probe fluke, 80K- 40 H. V.) ,whereas the discharge current is measured by using 10 KΩ resister as voltage divider. Three different thicknesses of glass dielectric layer (1,2,3)mm. were used, for every thickness the voltage applied and current had been measure for three different gap spaces between electrodes (1,2,3)mm.

3.RESULTS AND DISCUSSION

It is found that the values of the discharge current stills very small (less than 1mA) and no silent discharge was observed in the gap space of DBD system, with increasing the applied voltage from zero to a given point called breakdown voltage. This is because the electrons gain enough energy to cause further ionization causing an electron avalanche and leading then to the formation of micro-discharge inside the discharge gap of the DBD system . Fig.3(a,b,c) shows the discharge current as a function of the applied high voltage at frequency 50 Hz and three thicknesses of glass, d(1, 2, 3) mm for three gap space between electrode, h (1,2, 3) mm .It was observed that for small values of the applied voltage (< 4 kV) there is no filamentary discharge can be seen between the two electrodes and the values of the current did not increase (0.5) mA .this is because that for this range of the applied voltage, the gas molecules did not gain enough energy to get first and secondary ionization and this small values of the current caused by the only current is that due to the generation of charge carriers in the gas by cosmic rays or other sources of ionizing radiation Initially, at small applied voltage no silent discharge was observed between the electrodes .However, when the voltage a cross the two electrodes increasing beyond (4) kV. some filamentary discharge was observed in some region between the electrode when voltage was about (8) kV. quite uniform and homogeneous discharge was produced throughout entire – electrode gap was observed. The discharge current at this value of the voltage was found about (4) mA. Fig.4(a,b,c) shows the power consumed in DBD system as a function of discharge voltage for three different gap space (1,2,3) mm and three values of glass thickness d(1,2,3) mm .It is found that the power consumed in DBD system still very low (less than 4w) for values less than (4Kv) of applied voltage and before silent discharge formation with

increasing applied voltage some filament discharge had been observed in some regions between electrodes of DBD system and power also increase exponentially with applied voltage .Also, it can be observed that for a given value of applied voltage the power consumed in DBD system increase with glass thickness.

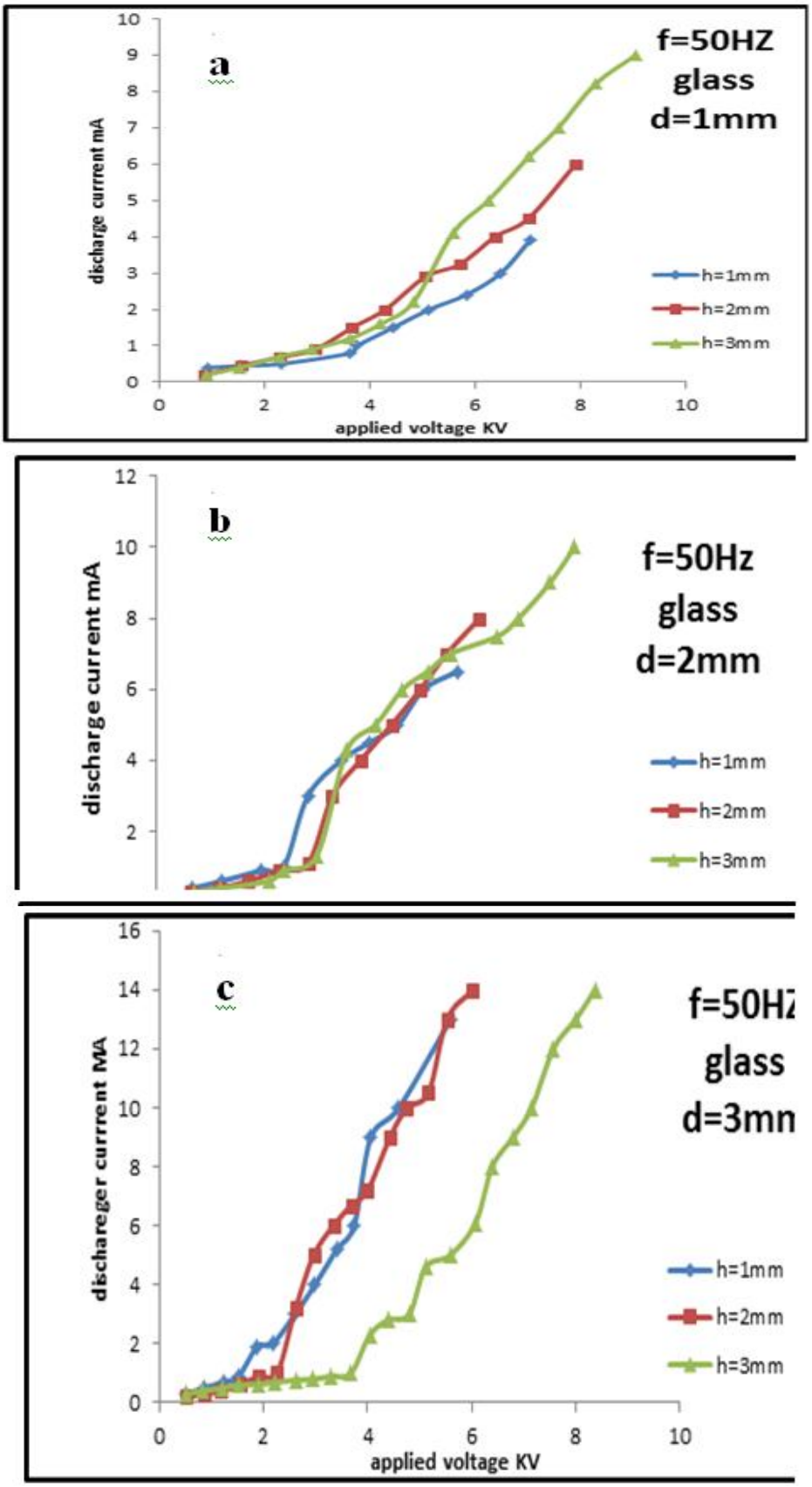

Fig.3.(a,b,c) shows the discharge current as a function of applied voltage with glass thickness d(1,2,3) mm, for three gap space, h(1,2,3) mm.

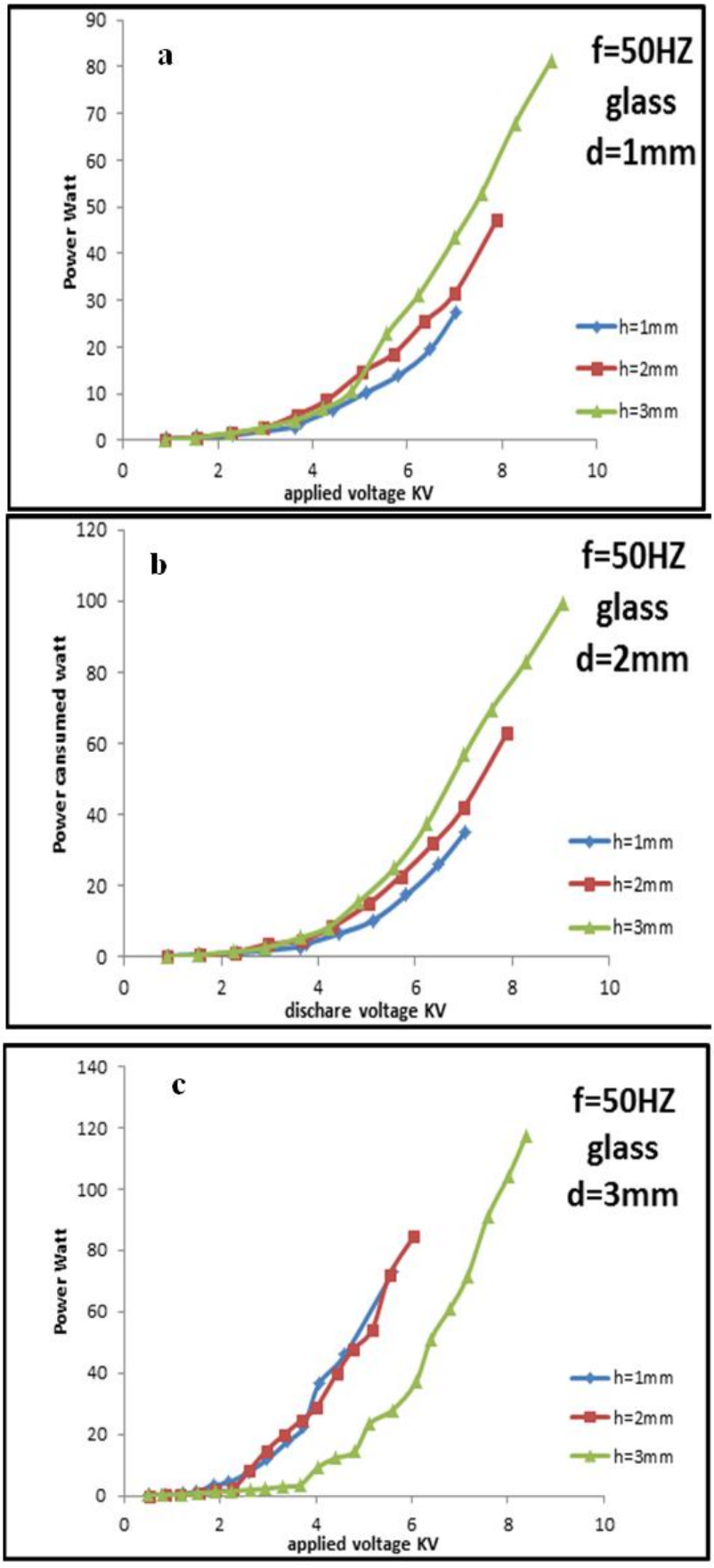

Fig.4(a,b,c) shows the power consumed in DBD system as a function of discharge voltage for three different gap space, h (1,2,3) mm and three values of glass thickness d (1,2,3) mm.

Fig.5. shows the power consumed as a function of gap space for three glass thickness (1,2,3) mm, it was observed that the power consummated in the system increase with increasing gap space. Also, it can be seen that for given gap space the power increase with glass thickness.

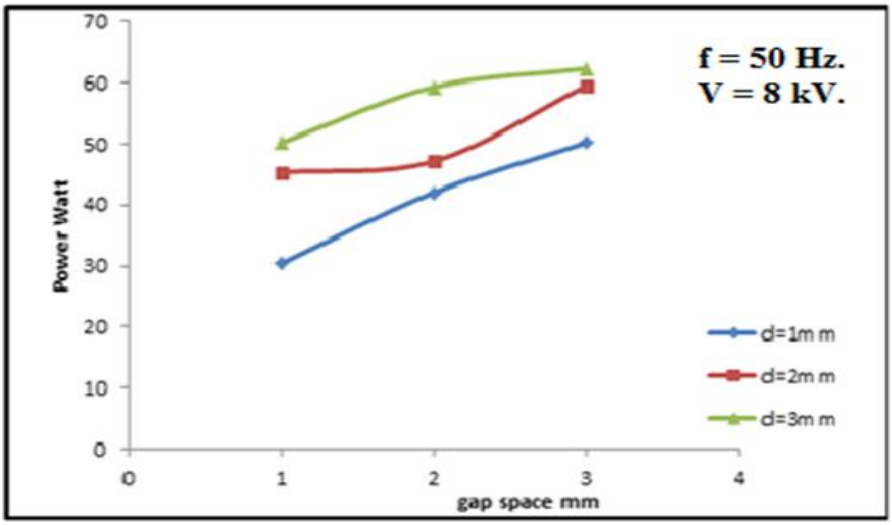

Fig .5. Power consumed in DBD system as a function of gap space for three different glass thinness (1,2,3) mm.

Figure. 6. shows breakdown voltage of DBD system as a function of gap space for different glass thickness, d (1,2,3 mm) and frequency, f (50Hz).From this figure it can be seen that the breakdown voltage increase with the gap space as predicted from Paschen's law, also at fixed gap space the breakdown voltage increases with increasing glass thickness.

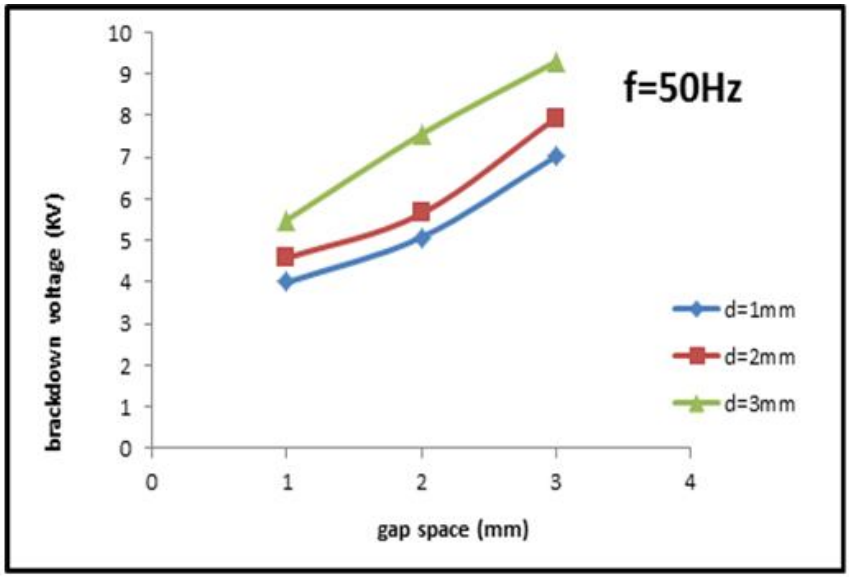

Figure. 6. shows breakdown voltage of DBD system as a function of gap space for different glass thickness, d (1, 2,3) mm. and frequency, f (50)Hz

4.FREQUENCY EFFECT

Fig.7.shows discharge current as a function of voltages for two frequencies (50, 1000) Hz. in glass thickness, d (2) mm. and gap space, h (2) mm. It can be observed that at a given voltage the discharge current depends on the frequency of applied voltage, where the values of the discharge current when the frequency was 1000 Hz higher than these for 50 Hz., increasing of the current with the frequency because of the increasing air molecules response to ionize with increasing frequency, so the DBD system would consume more power with frequency.

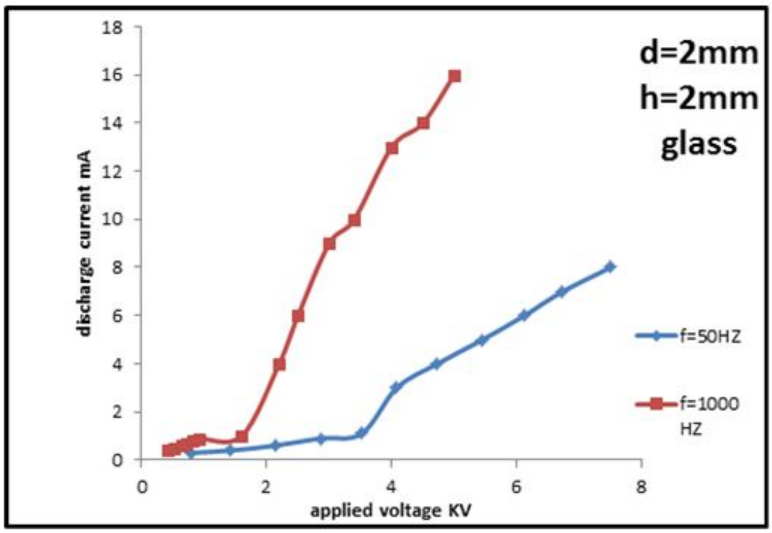

Fig.7.shows discharge current as a function of voltages for two frequencies in glass thickness, d (2) mm. and gap space, h (2) mm.

The same thing can be said about the power consumed in DBD system as shown in fig.8.

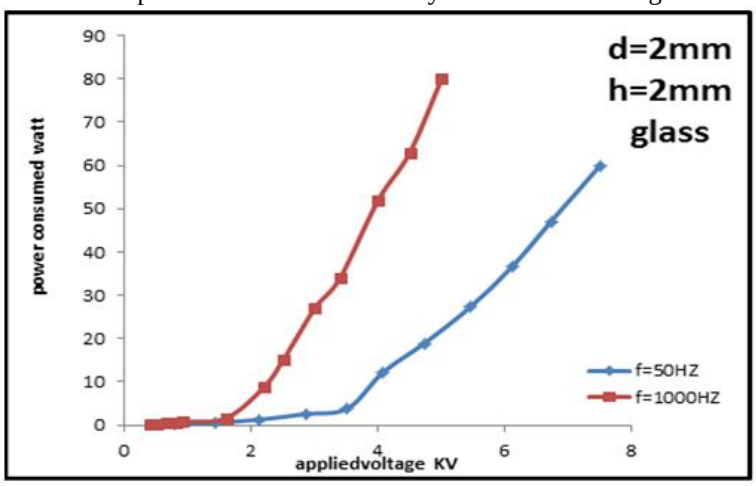

Fig .8. Power consumed in DBD system as a function of discharge voltage for two values of frequency (50, 1000) Hz. in glass thickness, d (2) mm. and gap space, h (2) mm

Fig.9.shows the breakdown voltage as a function of gap space for two frequencies (50,1000) Hz. and glass thickness d (2) mm . It can be observed that the breakdown voltage had been reduced five times when the frequency rises from 50 to 1000Hz. This is means the minimum breakdown voltage depends on not only on distance between electrodes and pressure but also on the frequency of the applied voltage.

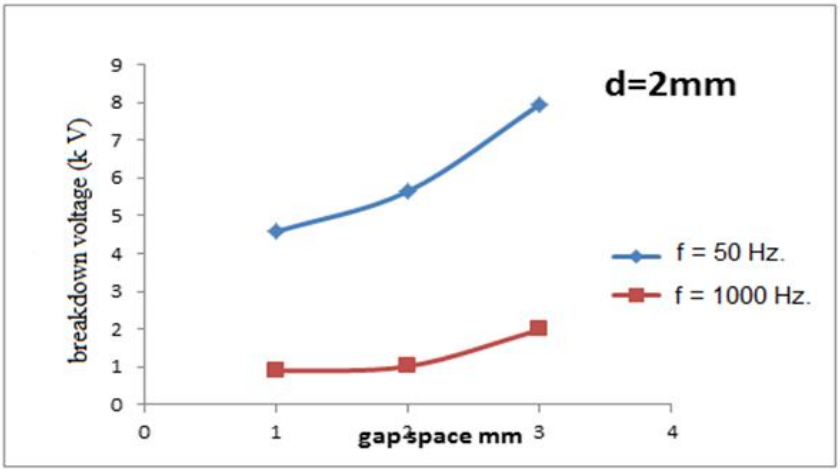

Figure. 9. shows breakdown voltage as a function of gap space for two frequencies (50,1000) Hz. in glass thickness, d (2)mm.

Fig .10. Power consumed in DBD system as a function of gap space for two different frequency (50, 1000) Hz in glass thinness, d (2) mm.It can be observed that at a given gap space the power consumed increases with frequency. This is because increases the ability to ionize the gas atom with increasing frequency and hence more power was needed.

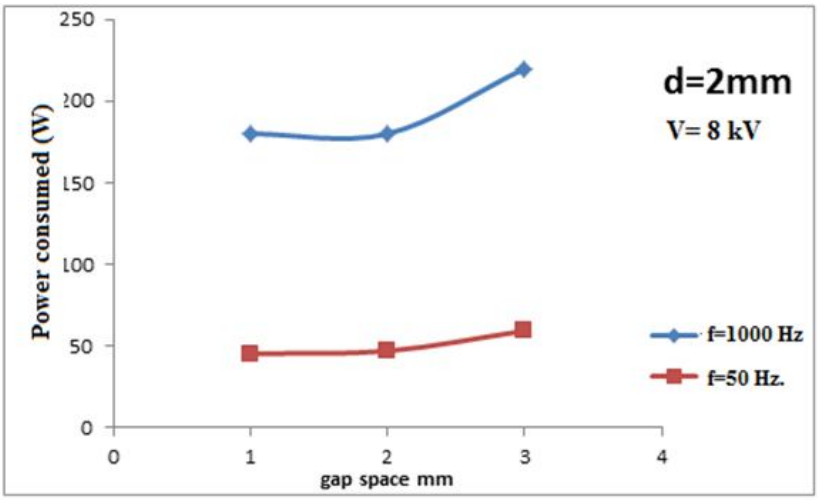

Fig .10. Power consumed in DBD system as a function of gap space for two different frequency (50, 1000) Hz in glass thinness, d (2) mm.

5.CONCLUSIONS

The experimental results presented in this paper showed that relatively homogeneous and non-thermal plasma could be generatedat atmospheric pressure inparallel plate dielectric barrier discharge system in the presence of He, using two high voltage power supply operating with a two frequencies 50 and 1000 Hz., witha glass as a dielectric with three thicknesses (1,2,3) mm, and gap space between electrodes (1, 2, 3) mm The experimental results presented in this paper showed that relatively homogeneous and non-thermal plasma could be generated at atmospheric pressure by using a glass as a dielectric with three thicknesses (1,2,3) mm, and gap space between electrodes (1, 2, 3) mm. Our results shows that the power consumed in DBD system was less (100 W), also it was increased with the glass thickness, gap space and frequency of the applied voltage. It is found that the breakdown voltage in our experiment conditions at 1 atm. pressure was increased with the gap space and decreased with the frequency of the applies voltage.

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