The effect of Dielectric Thickness on Dielectric Barrier Discharge properties at Atmospheric Pressure

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Abstract

Non-thermal atmospheric pressure plasma is new branch and tool in physics .Building generation dielectric barrier discharge (DBD) system at atmospheric pressure and studying of its thermal characterizations. The discharge was produced by applying high voltage (5-25 KV) and frequency (12 kHz). The thermal characterization was done by measuring discharge temperature at different applied voltage and different distances from barrier. The results indicate that the applied voltage and distance between electrodes effect on discharge (increasing or decreasing) according to operation conditions because they affects, as expected, the DBD plasma temperature decreases with the increasing of the dielectric thicknesses which results in the decrease of the discharge voltage across the gap, accordingly, the discharge across gap is also weakened.

Key words: Atmospheric Plasma, High Voltage, DBD, Dielectric Thickness, Gap Distance**.**

تأثير سمك العازل على خصائص تفريغ حاجز العازل في ضغط جوي

الخلاصة

البلازما غير حرارية بضغط جوي هي فرع جديد ووسيلة في علوم الفيزياء.بناء منظومة لتوليد تفريغ حاجز عازل في ضغط جوي ودراسة خصائصه الحرارية،التفريغ كان منتج بواسطة فولطية مطبقة عالية (5-25كيلو فولط) ولتردد (12 كيلو هرتز).الخصائص الحرارية أجريت بقياس درجة حرارة التفريغ في فولطية مسلطة مختلفة و مسافات مختلفة من الحاجز.النتائج بينت ان الفولطية المسلطة والمسافة بين الأقطاب تؤثر على التفريغ (الزيادة او النقصان)تبعاً إلى شروط العمل بسبب هذه التأثيرات،كما متوقع ،درجة حرارة بلازما DBD تتناقص مع زيادة سمك العازل أي النتائج في تناقص فولتية التفريغ عبر الفجوة وتبعا لذلك التفريغ عبر الفجوة كذلك يضعف

الكلمات المرشده: بلازما الضغط الجوي،الفولتية العالية ، تفريغ حاجز العازل،سمك العازل ،مسافة الفجوة

INTRODUCTION

Plasma in physics is the fourth state of matter and most in the universe, as fire in the sun, stars. This term was introduced by Irving Langmuir in 1928 [1].Plasma consists of positively and negatively charged ions, electrons and neutral species (atoms, molecules).There are two types of plasma; hot and cold plasma.

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Hot plasma or non-equilibrium plasma consists of very high temperature particles and they are close to the maximum degree of ionization, while cold plasma composed of low temperature particles and relatively high temperature electrons and they have a low degree of ionization [2].

Recently, interesting increased in cold plasma processes worked at atmospheric pressure .The developments in this field taken place due to requirements growing to plasma technology that can allow continuous plasma processing, like plasma needle [3,4] ,the hair line plasma[5] and micro capillary plasma jet [6]. Cold plasma is used in many applications such as, surface modification of polymers [7], sterilization [8], and inactivation of bacteria [9]. The dielectric barrier discharge (DBD) is most frequently used as a non-thermal plasma source that can be operated with different gasses at elevated pressures (up to atmospheric pressure) [10, 11].

System setup

Dielectric barrier discharge DBD system is based on a conventional dielectric barrier discharge. It is basically a system that applies alternating current and high voltage between two conductors electrode where one or both of there are covered with a dielectric. That is to limit the current and to prevent transition to an arc. A simplified schematic of the DBD system setup is shown in Figure (1) and figure (2) shows plasma DBD. The plasma is created between two conductive electrodes connected to an AC or pulsed power source. At least one of the DBD electrodes was covered by a dielectric layer, which prevents the arc formation after breakdown. DBD discharge usually consists of a large number of short-living micro channels (filaments) that are randomly distributed over the entire area of the dielectric barrier. Despite a high breakdown voltage in gas at atmospheric pressure (several kV); the average electric current is low. [12]. The system consists of (5-25 kV) power supply connected by Teflon covered wires to the copper electrode 2.5 cm diameter , the end of the copper electrode was connected by contact with the glass 1 mm thickness. Other part of the system was gradually moving catcher a piece of mica was used to prevent the transmission of discharge from copper electrode to the catcher moving. Plasma was generated by applying alternating polarity or pulsed high voltage between the insulated electrode and the sample which must be treated. The sample was put on an aluminum substrate. A 1 mm thick polished glass was used as an insulating dielectric barrier. The discharge occurs between the bottom surface of the glass and top surface of the sample. The distance to allow the discharge to occur was controlled to be (1- 3 mm). To accomplish the control ability, the high voltage electrode was connected to a vertical catcher by a positioner. This positioner can be moved up and down easily. All the treatments were carried out at room temperature and atmospheric pressure and at the same procedure.

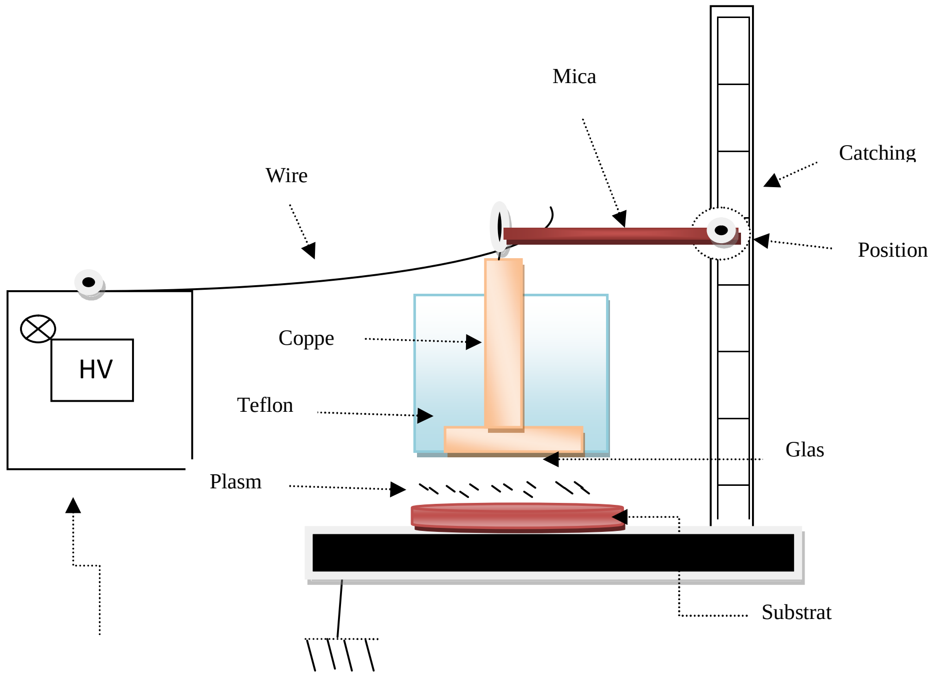

Figure (1): Schematic diagram for the DBD system

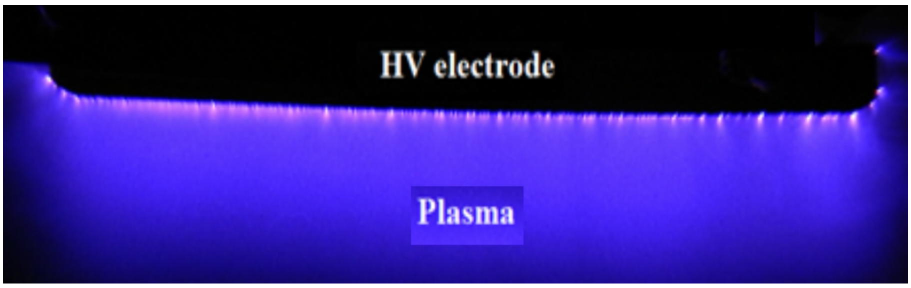

Figure (2) Picture of plasma DBD

Experimental work

The experiment was conducted in open air under atmospheric pressure and room temperature at 20°C**.** The temperature was measured using a mercury thermometer at various distances from barrier of the DBD electrode. In this work, the temperature is the more important, so that the temperature was measured at 1mm distance from the barrier when the applied voltages are 17, 22, and 25kV and frequency (12KHz). The variation of temperature along the experiment operation time is very important especially for material surfaces treatments. So that, this time was measured along 10 minutes . That was done under the operating conditions of applied voltages (17, 22, 25kV) and 1mm dielectric thickness.

Results and discssion

Effect of the thickness on the dielectric

The thickness of the dielectric is one of the most import parameter which affects the DBD plasma properties.

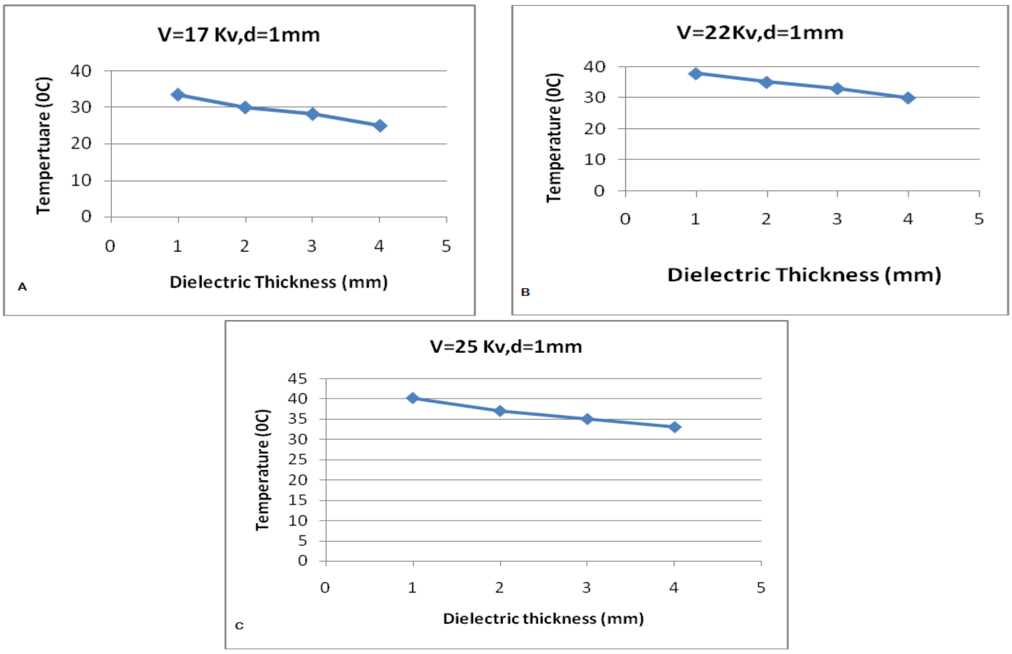

Figure (3) the dielectric thickness effect on the DBD plasma temperature when the gas gap is 1mm.

Figure (3) shows that, the DBD plasma temperature was decreased with the increasing of the dielectric thicknesses. The temperature was decreased about from 40^0C to 32 ^{0}C with the increase of dielectric thickness from 1 to 4 mm, due to the fact that the electric resistance of external circuit increases with the increase of dielectric thickness, which results in the decrease of the discharge voltage across the gap, accordingly, the discharge across gap is also weakened. Therefore, temperature decreases with increasing dielectric thickness [**13**].

The reducing of the distance between the electrodes play an important role in the generation of plasma, where DBD plasma characteristics in air depending on applied voltage as well as inter-electrode distance, where the increasing in the applied voltage affects the properties of (DBD) plasma such as the electric field, electron density, and the concentration of active species which depend on the applied voltage[**14**].

For more information about the DBD plasma temperature, the above measurements were repeated in a 2mm gap distance with same dielectric thicknesses. The results show same behavior in previous, but the temperature generally less, as in figure (4).

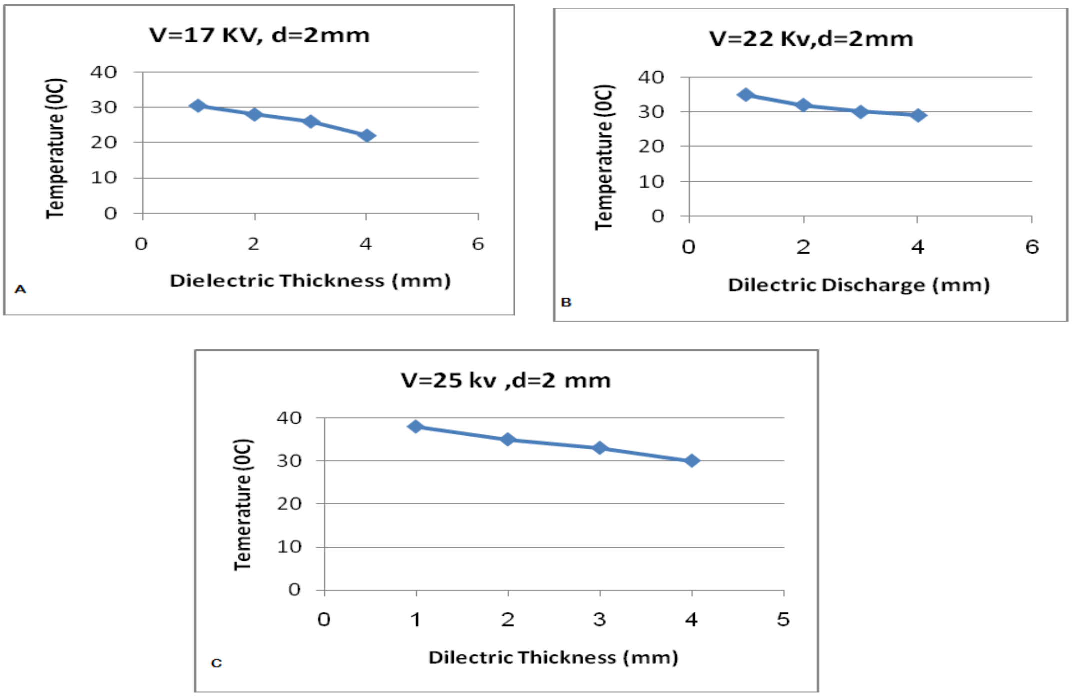

Figure (4) The dielectric thickness effect on the DBD plasma temperature when the gas gap is 2mm.

The strength of discharge becomes weakened with increasing dielectric thickness and the discharge plasma on the surface of dielectric layer decreased with the increasing of the dielectric thickness from 1 to 4mm [13]. It was recorded that the discharge strength reduced and the discharge area on the surface of dielectric layer reduces too with the increase of dielectric thickness [14].

The phenomenon of the discharge strength weakened and the discharge plasma decreases with increasing dielectric thickness can be explained from the following three aspects:

First, the equivalent capacitance of the dielectric layer decreases when dielectric thickness increases, and the accumulated charges on the dielectric layer surface decreases. When the negative pulse discharge takes place in the next half cycle, fewer charges on the dielectric layer surface are released into gas gap and participate in the process of discharge. So increasing dielectric thickness can result in the reduction of the electrons density, and the number of ions and excited molecules decrease [15].

Second, when the pulse voltage is kept constant, increasing dielectric thickness causes the decrease of discharge voltage in the gas gap, which result in a lower initial electric field or reduced electric field E/N (where E is the electric field and the N is the particle number density) in the discharge plasma[16]. Hence, the less proportion high-energy electron density can be produced and the electron mean energy is also reduced; accordingly, the rate of atomic or molecular electronic excitation and dissociation in plasma-chemical processes is also decreased. Third, increasing dielectric thickness can result in the reduction electric field E/N, which leads to that less number of electrons avalanches can be obtained [15, 16].

On the basis of above three aspects, therefore, the strength of discharge weaken and the discharge plasma area reduction lead to dielectric surface temperature reduction with its thickness increasing. When the dielectric thickness is kept constant, the discharge plasma obviously enlarges, and the discharge plasma is still in good uniformity is an effective method to obtain a much larger diffuse discharge. When 1mm thick dielectric layer, the discharge plasma almost spreads to a circular area of diameter on the dielectric layer surface [14]. The strength of the discharge becomes slightly stronger and the plasma distributes in a large area on the surface of the dielectric layer. So the plasma produced on the surface of the dielectric layer is most suitable for material surface treatment [17].

Experiment Time Effect

The variation of temperature along the experiment operation time is very important especially for material surfaces treatments. So that, this time was measured along 10 minutes and shown in figure (5) and figure (6). That was done under the operating conditions of applied voltages (17, 22, 25kV) and 1mm dielectric thickness.

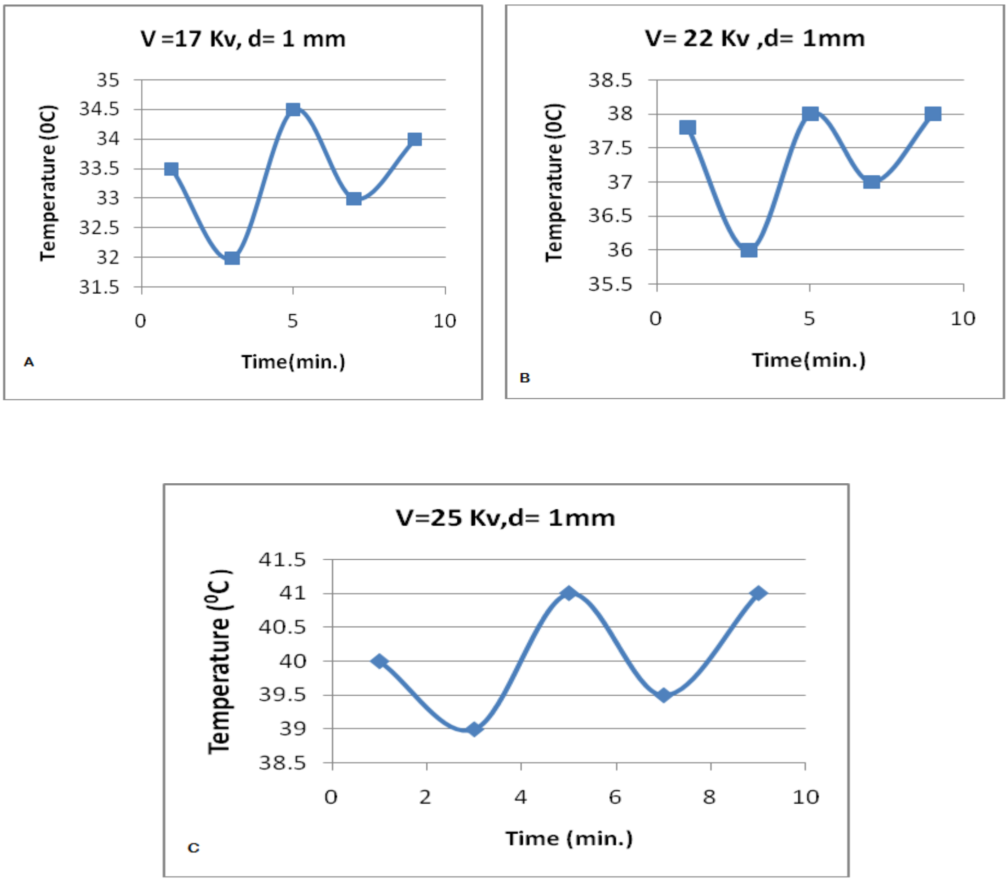

Figure (5) The DBD plasma temperature as a function of experiment operation time of different applied voltages and gap distance (1mm).

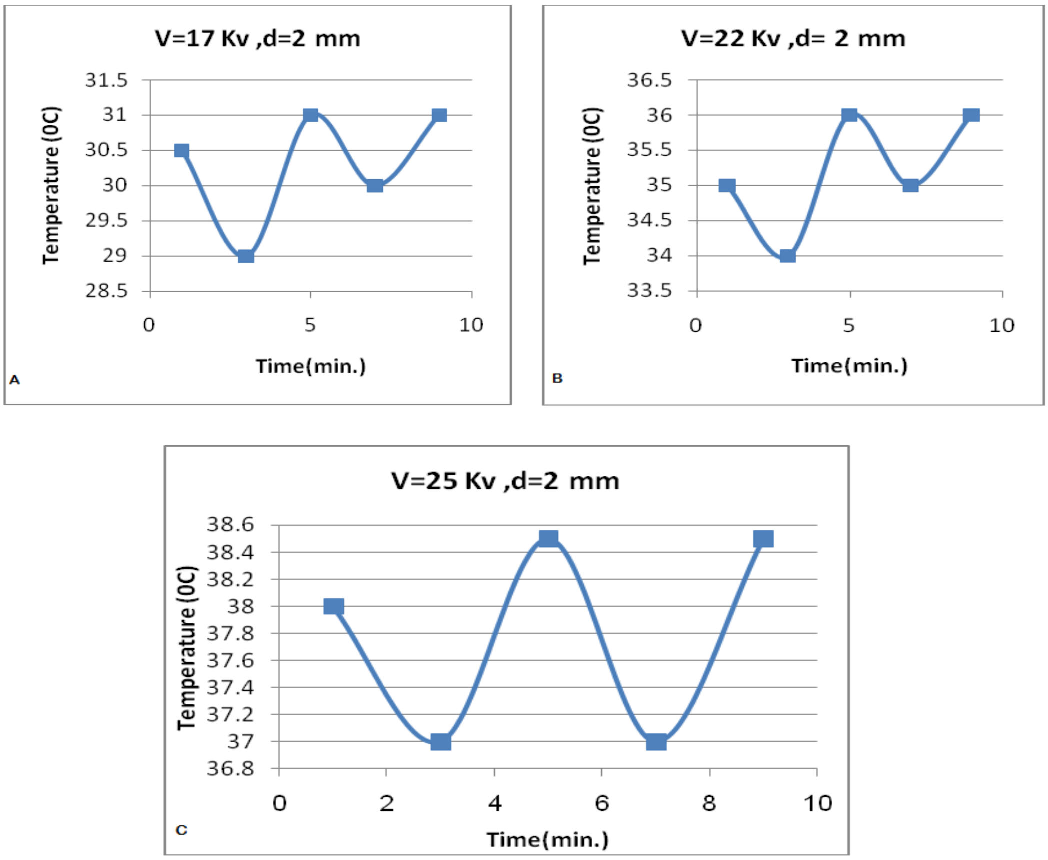

Figure (6) The DBD plasma temperature as a function of experiment operation time of different applied voltages and gap distance (1mm).

Figures (5) and (6) show that the plasma temperature on the surface of dielectric layer varies as a function of the operation. The plasma temperature is almost kept about $\pm 1^{0}$C and remains almost constant although the time is changed, which indicated that plasma gas temperature does not depend on the operation time of the device.

In DBD, more electrical energy can be applied to generate energetic electrons during the discharge compared with gas heating, which makes the DBD plasma exhibit very low gas temperature [18].

Conclusions

The strength of discharge becomes weakened with increasing dielectric thickness and the discharge plasma on the surface of dielectric layer decreased with the increasing of the dielectric thickness and temperature decreases with increasing dielectric thickness.

Increasing dielectric thickness can result in the reduction of reduced electric field E/N, which leads to that less number of electrons avalanches can be obtained, accordingly, the region for generating electrons avalanches also decreases in gas gap.

The plasma temperature is almost kept about ±1^{0}C and remains almost constant although the time is changed, which indicated that plasma gas temperature does not depend on the operation time of the device.

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