

# Comparison between corona and dielectric barrier discharges plasma using of pin to single and dual ring electrodes configuration

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## Comparison between corona and dielectric barrier discharges plasma using of pin to single and dual ring electrodes configuration

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**Abstract.** Research on one of the study plasma corona discharge and plasma dielectric barrier discharges (DBD) with positive polarity using the configuration of pin to single and dual ring electrodes has been done. The both discharge plasma generator used in this study was formed by stainless steel, pin electrodes as anodes and ring electrodes as cathodes. The diameter of pin was 0.1 mm and diameter outside of single ring was 2.60 cm and insite 2.40 cm. For dual ring, we install other ring insite the big ring (with diameter outside was 2.60 cm). The second ring, outside diameter was 2.00 cm and insite diameter was 1.80 cm. Barrier of DBD reactor was made by dielectric material of glass with thickness of 3 mm with an area that can cover all ring electrodes. Characterization of the corona discharge plasma and the DBD Plasma were used to locate the respective working areas of the reactor. Variations of voltage used from 0 kV to arc with specified intervals of 0.2 kV, with variations of distance between electrodes were from 0.5 cm to 2.0 cm with intervals 0.5 cm. The result of I-V characterization shows the current produced by DBD plasma reactor was bigger than the corona discharge reactor and it follows the I-V quadratic law. Moreover, the value of unipolar ion mobility DBD plasma reactor were also greater than corona discharge reactor.

### 1. Introduction

The corona discharge is one of the plasma discharges at atmospheric pressure that has been discussed deeply [1,2,3]. This discharge is commonly used for producing ions, synthesizing dyestuffs for textiles [4] and reducing pollution in air [2]. In addition, corona discharges can also be used to kill bacteria [5], reducing textile dyes and as an ozone generator [6].

Plasma discharge at other atmospheric pressures which are widely utilized is silent plasma discharges known as dielectric barrier plasma. This silent plasma discharge is usually used to produce ozone [3,7]. Corona discharge, as well as DBD, is formed in a non-uniformly strong electric field between electrodes. This non-uniform electric field is influenced by the geometry configuration of the electrode which will then affect the resulting ionization [3]. The ion flow in the corona discharge with the pin-multi ring electrode is larger than the pin-single ring electrode [8]. The ionic wind flow in the study is related to the mobility of unipolar ions from plasma discharges generated by the generator. The objectives of this study were to analyze I-V characteristic and unipolar ion mobility on corona discharges and DBD

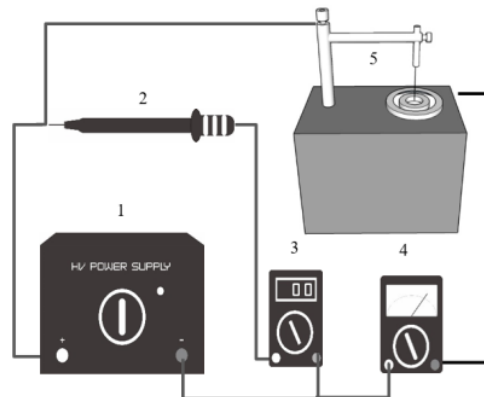


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generator by using pin-dual ring configuration. Plasma corona and DBD using power DC source having positive polarity.

## 2. Methods

Figure 1 shows the experimental set up of this research. The instrument that is used in this research is Power Supply HV as the high voltage source connected with probe-HV to lower the voltage to be read by voltmeter. The voltmeter is connected in parallel with the generator to know the applied voltage. The amperemeter is connected in series with the plant to determine the current generated by the generator. In this study, corona discharges are generated by pin electrode subjected to high voltages with positive polarity and single ring/dual ring electrodes are subjected to voltages with negative polarity. The ionized electrons will move to the electrode pin while the positive ions will move to the electrodes single ring/dual ring. These ions are detected as saturation currents and will be measured by the amperemeter. Electrical parameters of DBDP determined through a voltage divider (HV Probe DC Voltage DC max 40 kV; 28 kV AC EC code number 1010, En G1010). Electrical signal from the probe detected by an Oscilloscope GOS-653, 50 MHz. DBD circuit scheme as in figure 1 with the addition of a glass barrier placed over the single/dual ring electrode. The characterization steps of saturation current, as well as ion mobility calculations, are similar to saturation current characterizations and mobility calculations on corona discharges.



**Figure 1.** Experimental set up with DC HV power supply (1) HV, Probe (2), Voltmeter (3) Amperemeter (4) and plasma reactor (5).

The determination of the value of average charge carrier mobility can be made based on current characteristics as a function of voltage using equation Sigmond [9]. The value of this unipolar ion mobility can be calculated using equation (1). But for the case of the multi-point electrode, this equation can be necessary modified a factor of the number of electrode points, which is considered N. In addition, the dielectric constant values also should be corrected. We have to use constant of dielectric samples between two electrodes, these samples can be considered as a dielectric material. Thus, the above equation becomes:

$$I_s = \frac{2\mu\epsilon_r N}{d} (V^2) \quad (1)$$

From equation 1, a linear curve  $\sqrt{I_s}$  as a function of V can be made, in order to obtain the gradient of the curve linearity. From the gradient value may be determined and average mobility of the charge carriers in the corona discharge.

### 3. Results and discussion

#### 3.1. $I-V$ Characteristic and breakdown voltage

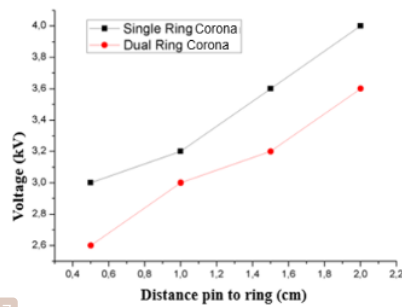


Figure 2. Breakdown voltage as function of distance pin to ring for single and dual ring corona reactors.

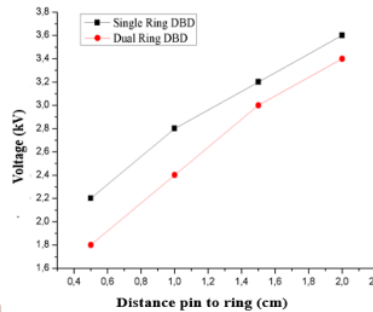


Figure 3. Breakdown voltage as function of distance pin to ring for single and dual ring DBD reactors.

#### 3.2. $I-V$ Characteristic in Corona

Figure 4 shows the  $I-V$  characteristics of corona with configuration point to single ring. We found that the relationship  $I/V \propto V$  (Townsend relationship) in this characteristic. According to Sigmond, this regime in unipolar corona discharge [9]. Other researchers also get the same thing among others, point-to-plane [10], point-to-grid [11] or point-to-ring [12]. We found that the  $I-V$  in our configuration better matches with the relationship  $\sqrt{I} \propto V$ . Characteristic  $I-V$  for corona reactors with configuration pin to dual ring is shown in figure 5.

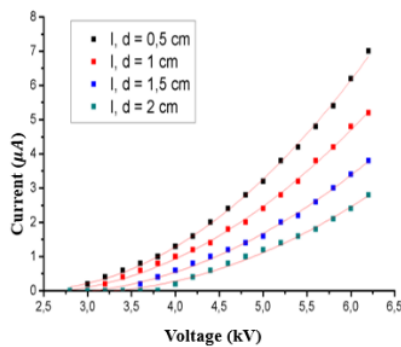


Figure 4. Characteristic  $I-V$  for Corona reactor with configuration of pin to dual-ring.

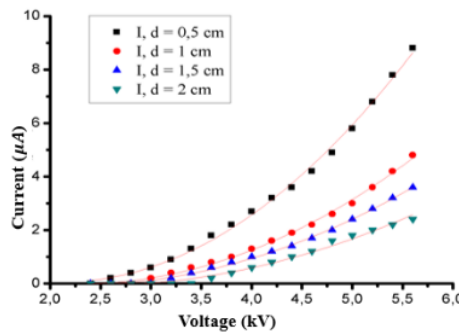
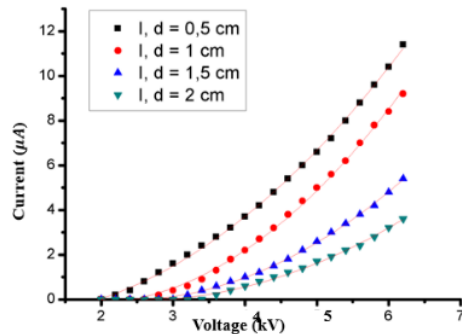


Figure 5. Characteristic  $I-V$  for Corona reactor with configuration of pin to dual-ring.

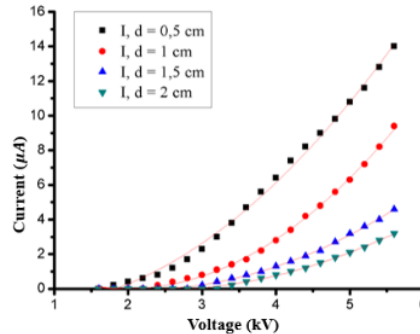
#### 3.3. $I-V$ Characteristic in DBD

Figure 6 and figure 7 show the  $I-V$  characteristic for the discharge of the pin-single ring and dual ring pin electrodes, but the ring is coated with glass as a barrier. These discharges are often called stripped dielectric barrier discharges (DBD), or often also called silent plasma. From both figures, at the same distance and voltage, the electrical current are greater than the current generated in the corona discharge (figure 4 and figure 5). It can be explained that in the dielectric material (glass) the electrical dipoles are formed, so that the previous glass barrier is the insulating material become a region of electrical dipoles collectio. Cause

of this condition the distance between two electrodes slightly decreased by the thickness of the dielectric material placed on the rings electrode. Furthermore, the reduction of the distance between the electrodes makes the rise of capacitive electrical current.



**Figure 6.** Characteristic I-V for DBD reactor with configuration of pin to *single-ring*.

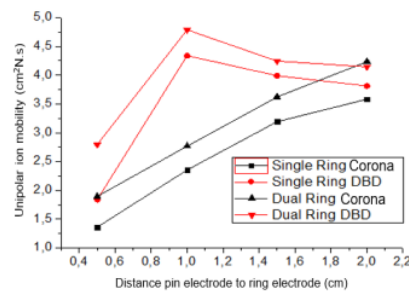


**Figure 7.** Characteristic I-V for DBD reactor with configuration of pin to *dual-ring*.

### 3.4. Charge carrier mobilities

Figure 8 shows the charge carrier particles mobilities as the function of distance inter electrodes, for pin-to single ring and pin to dual ring electrodes configuration. Ionization occurs by glow corona discharge will produce  $N^+$  ion. These ions will flow toward the anode and cause ion currents called the unipolar saturation current. This current is greatly influenced by the mobility of the charge carriers. Calculation of the charge carrier mobility is obtained from the Sigmond's equation of charge carriers rate of positive ion or negative ion [9]. Figure 8 shows that the values of mobility increases against distance between electrodes. This condition occurs due to reducing of electric field between the electrodes, so that the movement of the electrons collision with free air becomes slow.

The results of mobility with and without sample are extremely different. The value of mobility without sample is lower than mobility using a sample. This difference is influenced by the speed of the ions to infiltrate the mung bean seed is faster than without sample. Figure 6 shows the comparative value of mobility with sample will always be higher than without the sample. The value of this ratio is only between grades 1 and 3 with an average ratio of  $1.87 \pm 0.21$ . The addition of distance provides the smaller in mobility ratio value. It is influenced by the growing distance between electrodes resulting smaller electric field is getting smaller. The smaller the electric field causes the free charge carrier particles to be difficult to move.



**Figure 8.** Mobilities of charge carrier as function of distance inter electrodes.

The mobility of the charge carriers can be determined using equation (1). By using the value of the gradient of the linear graph the relationship as a function of  $V$  average mobility can be found. The charge carrier particles, in this case, are positive ions, negative ions, electrons, in electric field would move with the average speed. The magnitude of the drift velocity is proportional to the magnitude of the electric field and the value of mobility. Mobility is defined as the freedom of the particles to move, either in random motion [6].

#### 4. Conclusions

Unipolar ion saturation currents at the corona discharge have a value greater than the unipolar ion saturation currents flowing on the DBD plasma generator. These both currents for the corona discharge plasma and the for DBD Plasma are inversely proportional to the distance between the electrodes. The unipolar ion mobility of the corona discharges plasma generator is lower than the unipolar ion mobility of DBD plasma.

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