# CHARACTERISTICS OF DIELECTRIC BARRIER DISCHARGE (DBD) AS AN OZONE GENERATOR REACTOR

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## ABSTRACT
Ozone is a gas formed from three oxygen atoms that are highly reactive and unstable compared to oxygen. Ozone can be generated by using a dielectric barrier discharge (DBD) generator. To know the ability of DBD reactor in producing ozone performed a characterization. Characterization is done by measuring the electrical current, electrical voltage, observing the plasma discharge, charge mobility, and ozone concentration. In this research using DBD reactor derived from the development of research Teaching Industry of Diponegoro University. DBD reactor containof pyrex glass material as a dielectric barrier and parabolic wire made of aluminum as inner and outside electrodes in the dielectric barrier. DBD reactor was generated using high AC voltage of 2, 4, 6, 8, 10 and 12 kV and air flow rate is 10 L/min. The characterization results show that the higher the voltage can results increases of electrical current, for a discharge plasma produces a purplish color as a result of ionization process on the electrode. The calculation of charge mobility is 9.71 x $10^{-3} m^2 V^{-1} s^{-1}$ and the lowest and highest ozone concentration is 80 ppm and 280 ppm, respectively. In the future, application of DBD reactor has been characterized can be usedfor ozone gas production as food preservatives, improvement of the environmental quality of aquaculture and as an industrial and medical waste treatment system.

**Keywords:** Dielectric Barrier Discharge, Ozone, Plasma

## INTRODUCTION
Ozone is a gas formed from three oxygen atoms that are highly reactive and unstable compared to an oxygen atom (Prasetyo et al., 2015). Ozone is known as a strong oxidizing and disinfecting agent (Kuracia et al. 2004; Jodpimai et al., 2015). Ozone is one of the applications of the field of Plasma Physics which is produced by involving various processes consisting of ionization, recombination, dissociation and association within an ozone generator reactor (Nur et al., 2016). One of reactor used to generated ozone is using a dielectric barrier discharge (DBD) reactor by utilizing high voltages (Teke et al., 2014; Saraslifah et al., 2016; Boonduang et al., 2012; Yao et al., 2015).

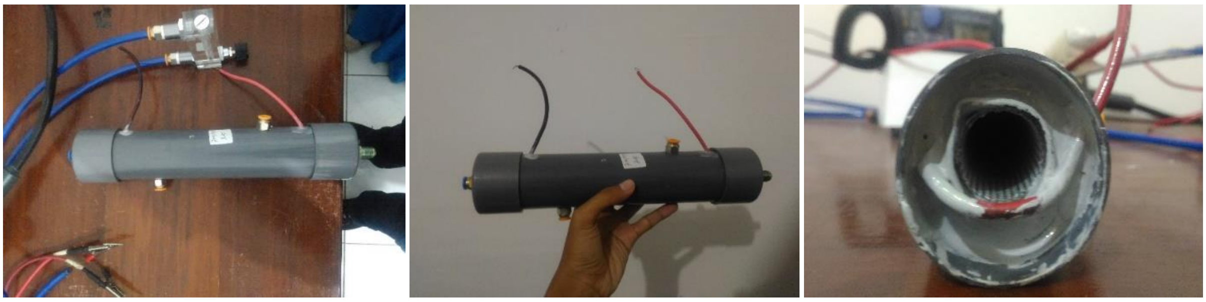
DBD reactor is an ozone generator reactor by utilizing plasma discharge generated in the gap between two electrodes using a dielectric barrier. The first electrode as the active electrode is inside the dielectric barrier and the second electrode as the outer electrode (the passive electrode) is on the outside of the dielectric barrier. To generate ozone using a DBD reactor, free air or oxygen gas at atmospheric pressure is fed into the reactor and when passing through the gap between the two electrodes will undergo ionization as an interaction between the electrons with the air particles or oxygen molecules resulting from an ozone (Nur, 2011). DBD reactor has been widely applied in various applications such as air pollution control, eliminating bacterial endotoxins, medical treatment and light source for excimer ultraviolet light (Jolibois et al., 2011; Can et al., 2016; Matra and Wongkuan, 2016)

To see the ability of DBD reactor, characterization is a method to the investigated ability of DBD reactor with measured electrical current, electric voltage, observing the plasma discharge formed in the reactor, calculated thecharge mobility and measured ozone concentration. In this study, the DBD reactor using a free air for characterization.

## RESEARCH METHODS

*Tools and Materials*

In this research,we using one tube reactorozone generator type DBD that has been made by the Teaching Industry of Diponegoro University, the DBD reactor shown in Figure 1.



(a) (b) (c)

**Figure 1.** Ozone generator type dielectric barrier discharge(DBD) (a) top view, (b) side view and (c) front of opened DBD reactor.

The material used to make the DBD reactor consists of pyrex glass (Herma) with 1.1 mm thick, 23 cm long, 27 mm inner diameter and 31 mm outside diameter. Theparabolic wire with the size of 20 x 20 $cm^2$ inside glass of pyrex wrapped as much as 2 loops used as an inner electrode. A parabolic wire with a size of 21.5 x 21.5 $cm^2$ is wrapped as much as 2 loops on the outside of a pyrex glass used as an outer electrode. The parabolic wire itself is made of aluminum.

Some research tools consist of power supply (Dipo Technology) with AC voltage, digital multimeter (Sanwa CD 772), amperemeter (Kyoritsu), flowmeter (Wierbrock), air pump (Amara AA-250), probe, 50 mL chemical measuring cup (Herma), erlenmeyer 250 mL (Herma), buret 50 mL (Herma), statif, plastic hose, Aquades (CV Indrasari Semarang), potassium iodide powder (KI) (Kimia Farma, Jakarta), $Na_2S_2O_3$ powder and 13megapixel camera (Asus ZenFone 2 Laser).

*Research Method*

The experimental system used for this research is shown in Figure 2. In this research activity, we have been done to characterization of DBDreactor with variations of voltage to see the electric current generated, giving ozone exposure to KI solution and perform the titration process.

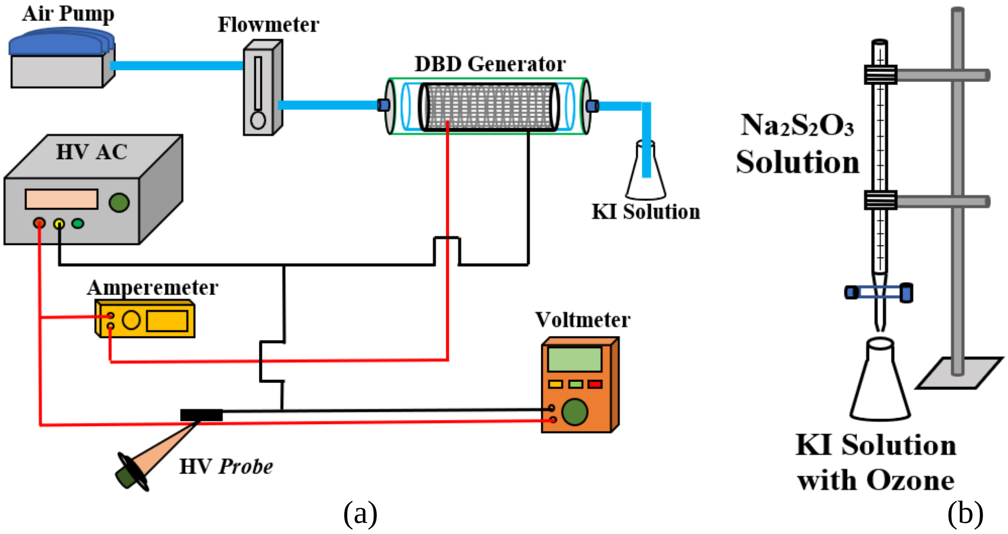



Figure 2 (a) experimental scheme system (b) titration process of KI solution with Na2S2O3 solution

Based on Figure 2, DBD reactor generated with high AC voltage, with various AC voltage of 2, 4, 6, 8, 10 and 12 kV. The air was input in DBD reactor using air pump with flowrate 10 L/min has been setting on flowmeter. The high voltagein DBD reactor was measured by digital multimeter and for electric current was measured by amperemeter. The ozone has been produced from DBD reactor was given to Erlenmeyer contain the KI solution with the size of 50 ml and 0,2 M during 2 minutes. After giving ozone, KI solution was done titration process using $Na_2S_2O_3$ solution with 0,4 M and observed a few drops $Na_2S_2O_3$ solution was given to the KI solution.

In this research, the data collection are voltage (*V*), electrical current (*I*), observation of plasma produced, charge mobility ($\mu_{RT}$) and ozone concentration based on various voltage. For mobility charge was calculated using modification equation from Robinson equation has been done by Nuret.al (2017) with the following equation:

$$I_s = \frac{2\mu_{RT}\varepsilon_t S}{d^3}(V - V_i)^2 \quad (1)$$

with $I_s$ is electrical saturation ion unipolar in Ampere unit, V is voltage of plasma reactor in Volt unit, $V_i$ is korona threshold voltage, $d$ is space of electrode in meter unit, $\varepsilon_t$ is total permittivity in Farad.meter$^{-1}$ unit and $\mu_{RT}$ is charge mobility in m$^2$.Volt$^{-1}$.Second$^{-1}$ unit. For equation of ozone concentration using a following equation:

$$\mathrm{C_{Ozone}} = \frac{\mathrm{Mr_{O_3}}.\mathrm{V_{Na_2S_2O_3}}.\mathrm{N_{Na_2S_2O_3}}}{\mathrm{v_{air}}.\mathrm{e}.\mathrm{t}} \quad (2)$$

with $\mathrm{Mr_{O_3}}$ is mass molecule ozone relative in gram.mol$^{-1}$ unit, $\mathrm{V_{Na_2S_2O_3}}$ is drop of $Na_2S_2O_3$ solution volume in ml unit, $\mathrm{N_{Na_2S_2O_3}}$ is concentration of $\mathrm{N_{Na_2S_2O_3}}$ solution in Molar unit, $\mathrm{v_{air}}$ is air flowrate in L.min$^{-1}$ unit,*e* is a constant with a value of 2 times the mass of electrons and t is time of ozone dissolution time in KI solution (Suraidin et al., 2016).

## FINDINGS AND DISCUSSION

*Characteristic of Electrical Current as Function of Voltage (I-V)*

The characteristic of electric current as a function of voltage has been done using air flow rate of 10 L/min, the results has been shown in Figure 3. Based on Figure 3, the increasing of voltage can produce an increasing electrical current. It caused that, the magnitude of the electrical voltage affect to the multiplication electric charge as an electron and electrical field generated on DBD reactor. The large electric field can affect the electrons accumulate in the inner electrode and an electrons will accelerate to make a electron has a enough energy to ionize the air gas molecules passing through the inner electrodes.

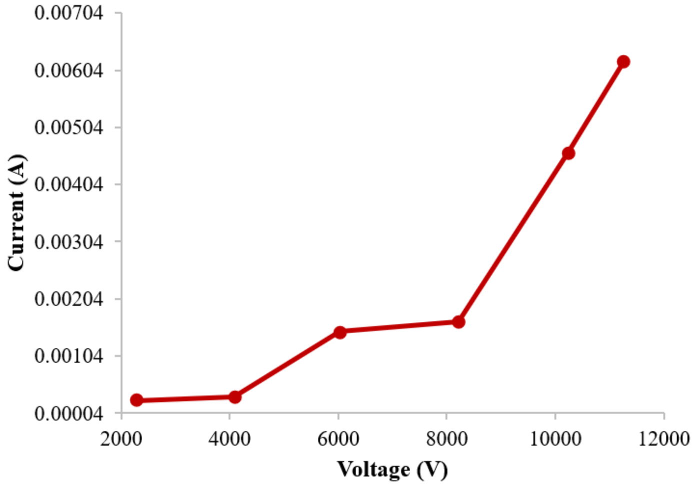



Figure 3. Graph of electric current as a function of voltage with an air flow rate of 10 L / min

*Color of Discharge Plasma*

The color of the discharge plasma produced by the DBD reactor can be used as one of reactor characterization besides using current and voltage as one of characterization indicator. The color of discharge plasma has been shown in Figure 4. The color of discharge plasmawas generated because of the particles of air gas was ionized by an electron. The more ionized air gas particles can make the color of discharge plasma become lighter and the less of ionized air gas particles can make the color of dischargeplasma becomes dimmed. It caused that, the amount of voltage applied to DBD reactor can give a effect to the color of discharge plasma. Besides that, the difference of thickness barrier dielectric material, the surface of barrier dielectric and the structure of electrode can be affected to plasma discharge produced in the DBD reactor (Wang et al., 2010; Wang et al., 2010).

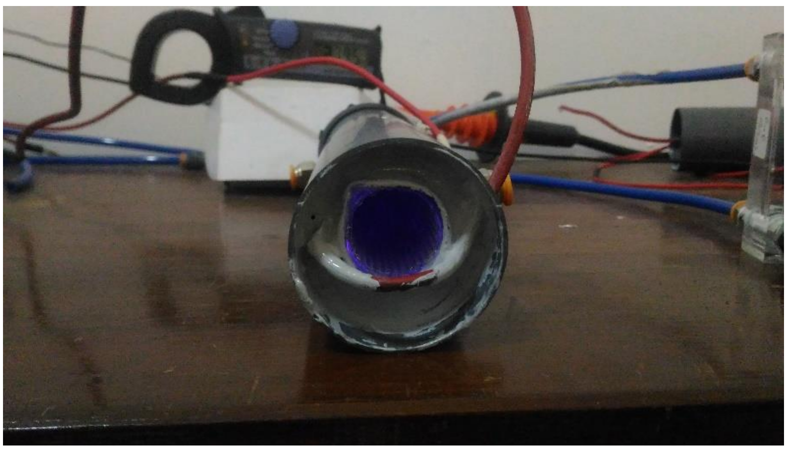


**Figure 4.** The color of plasma discharge produced in DBD reactor.

*Charge Mobility*

The amount of charge mobility ($\mu_{RT}$) can be calculated using equation (1), before using equation (1) first make the graph of the electric current root ($\sqrt{I}$) to the voltage ($V$) and the result has been shown in Figure 5.

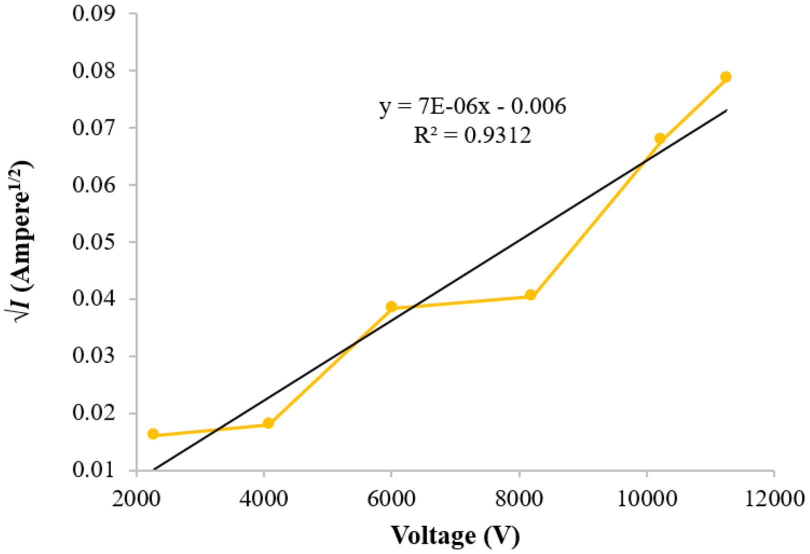



Figure 5. Graph of electric current root as a function of voltage

Figure 5 is used to find the average charge mobility ($\mu_{RT}$) by deriving the equation (1) as follows

$$I_s = \frac{2\mu_{RT}\varepsilon_t S}{d^3}(V - V_i)^2$$

with$V_i$ = 0, the equation (1) became

$$I_s = \frac{2\mu_{RT}\varepsilon_t S}{d^3}V^2 \quad (2)$$

Then, we are rooted on both sides

$$\sqrt{I_s} = \sqrt{\frac{2\mu_{RT}\varepsilon_t S}{d^3}}V \quad (3)$$

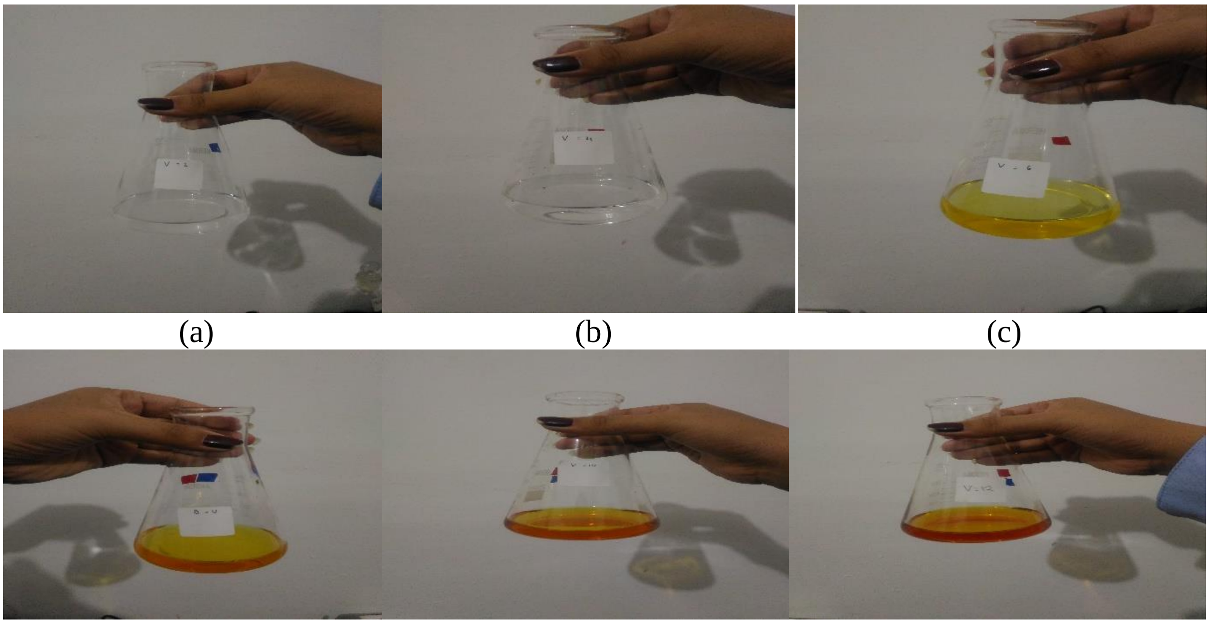
This equation is a straight-line equation through the center (0.0) with the equation $y = mx$, where$y$as$\sqrt{I_s}$ , $x$as$V$ and$m$as$\sqrt{\frac{2\mu_{RT}\varepsilon_t S}{d^3}}$. Then, the average mobility charge is obtained

$$\mu_{RT} = \frac{m^2 d^3}{2\varepsilon_t S} \quad (4)$$

From equation (4) can be calculated by entering data experimental and the mobility charge is $9.71\ x\ 10^{-3} m^2 V^{-1} s^{-1}$.

*Effect of Voltage on Ozone Concentration*

The effect of the electric voltage on the resulting ozone concentration can be seen in Figure 6.Figure 6 is the results of ozone delivery of any voltage variation into the KI solution. The results show that the greater of voltage can change the color of KI solution from a clear (white color) becomes a solution with a rich orange color.



(a) (b) (c)

(d) (e) (f)

**Figure6.**Color change of KI solution (a) 2 kV, (b) 4 kV, (c) 6 kV, (d) 8 kV, (e) 10 kV and (f) 12 kV

At a voltage of 2 and 4 kV, the color of KI solution has no change. This indicates the possibility of ozone produced has a very low concentration cannot change the color of the KI solution. However, for the KI solution given ozone with a voltage of 6, 8, 10 and 12 kV, there is a change in the color of the KI solution, where the color of the KI solution continues to increase is more orange by the increase of the electric voltage. This shows that the possibility of ozone being generated has increased a significant concentration. By chemical reaction, when KI solution reacts with ozone ($O_3$) produces $KIO_3$ solution with old orange color.

To ensure this, we calculated an ozone concentration using equation (2) to know the amount of ozone concentration in each voltage. The results of ozone concentration calculation have been shown in Figure 7. Based on Figure 7, the amount of ozone concentration produced accurately indicated an increase in the amount of ozone concentration by increasing the voltage. However, at 8 kV and 10 kV, the ozone concentration is equal to 160 ppm. At a voltage of 12 kV produces the highest ozone concentration of 280 ppm and for the lowest ozone concentration is produced at a voltage 6 kV with the amount is 80 ppm. For 2 kV and 4 kV, there are no an amount of ozone concentration.

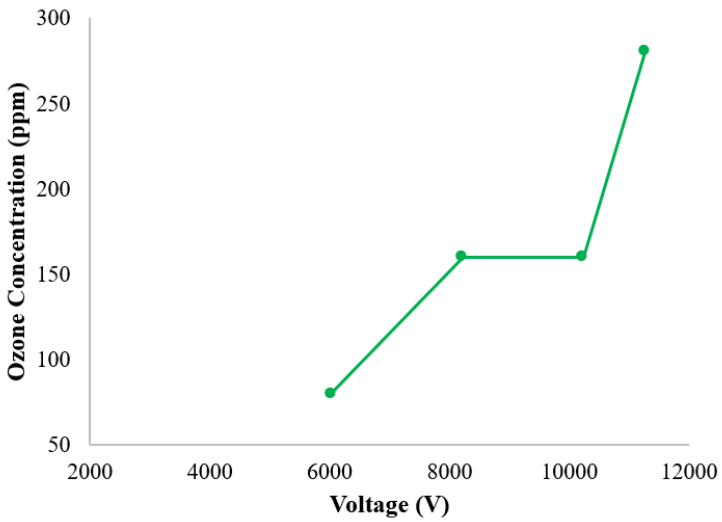



Figure 7. Graph of Ozone concentration as a function of voltage with an air flow rate of 10 L/min

## CONCLUSION

The DBD reactor characteristic has been known from the measurement of electric current ($I$), voltage ($V$), plasma discharge observation, calculation of charge mobility ($\mu_{RT}$) and the concentration of ozone gas. For electric current indicates an increase in the voltage increases. The color of plasma discharge shows the purpilsh color as a result of the ionization process on the electrode. The result of charge mobility is $9.71 \times 10^{-3} m^2 V^{-1} s^{-1}$ and the lowest and highest ozone concentration is 80 ppm and 280 ppm, respectively. In the future, application of DBD reactorhas been characterized can be used to ozone gas production as food preservatives, improvement of the environmental quality of aquaculture and as an industrial and medical waste treatment system.

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