Dielectric Barrier Discharge Plasma Reactor Analysis as Ozone Generator

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Abstract— **Ozone generator by using dielectric barrier discharge plasma (DBDP) has been studied. DBDP reactor was constructed with spiral cylender configuration. We found that ozone concentration increased with increasing of voltage, number of spools coil. The ozone concentration decreases with increasing distance between spiral electrode and cylender electrode. We found something very interesting in the generation of ozone, where electrc current has been measured, in other words ionization has occurred, but ozone was not formed. It can be interpreted that although ionization has occurred but oxygen molecular dissociation has not happened or is not enough for the formation of ozone .**

Keywords-plasma; ozone; dielectric; discharge; spiral, cylender

I. INTRODUCTION (HEADING 1)

Ozone can be produced by using electrical discharge in pure oxygen gas or air that was in the between two electrodes. The factors that can affect ozone formation in general are voltage, dielectric materials , the pressure, the system configuration of the plasma reactor and a gas insert in the plasma reactor [1,2]. Ozone formation mechanism of ionization and recombination involves both dissociation and association. The reaction of ozone formation can occur in a plasma reactor has been explained for example by Fridman in his book [4]. In the reactor, when the gas in a plasma state, ionization and excitation of O_2 molecules and become O- , O_2- , and O_2* through process the following reaction [4] ;

$$e + O_2 \rightarrow O^- + O \quad \text{(R-1)}$$

$$e + O_2 \rightarrow O_2^- \quad \text{(R-2)}$$

$$hv + O_2 \rightarrow O_2^* \quad \text{(R-3)}$$

Next O_3 reaction occurs through the formation of several possible reactions between lai :
reactions of ions and molecules

$$O^- + O_2 \rightarrow O_3 + e \quad \text{(R-4)}$$

reaki molecular ions and atoms

$$O_2^- + O \rightarrow O_3 + e \quad \text{R-5)}$$

(Three - body recombination of ions)

$$O^- + O_2^+ + O_2 \rightarrow O_3 + O_2 \quad \text{(R-6)}$$

reaction of the excited molecules and molecules (R - 3)

$$O_2^* + O_2 \rightarrow O_3 + O \quad \text{(R-7)}$$

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Application of ozone point of view, we found that Ozone has wide application as a powerful disinfectant in water treatment, food processing and preservation and various other environmental applications. Ozone as an oxidant has numerous potential applications in the food industry because of its advantages over traditional food preservation techniques. Application of ozone in grain processing has been developed by Tiwari et al. [5] Ozone application in the treatment of grain for insect pests fungal contaminants, and mycotoxins [6,7] Other research has been done by Mendez et al. by penetration of ozone into columns of stored grains and observing of effects on chemical composition and processing performance [8]. In the liquid foods, study on modeling approaches to ozone processing of liquid foods has done by Cullen et al. [9]'and inactivation of escherichia coli in orange juice using ozone was investigated by Patil et al [10]. The effect of ozone on microbial, chemical and sensory atrributes of shucked mussels have been reprted by Manousaridis et al. [11]. More recent, Nur et al. [12] used ozone for microbial inactvation in rice and rice can storaged more long time with assurance of quality standart. Ozone production by plasma technology depends on voltage, cofiguration of electrodes, and other parameters [13]. In this paper, we present our study on efectiveness and efficiency of ozone production by using dielectric barrier discharge plasma. In this study, we used wire spiral-cylender electrodes configuration with variation of distance interelectrode, number of spools coil, and applied voltage.

II. EXPERIMENTALSET UP

Figure 1 shows a series of experiments in this study. Ozone has been to utilize Dielectric Barrier Discharge Plasma (DBDP)) produced by spiral-cylindrical reactor configured. DBDP generated by high voltage AC voltages up to 25 kV and maximum frequency of 23 kHz. Electrical parameters of DBPP 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. The electric current, that was generated in the reactor was measured by using a multimeter (Sunwa TRXn 360). Photo taken from experiments using a CCD camera (Creative, DV Cam). The concentration of ozone generated DBDP reactor Dangan spiral-cylindrical configuration measured using an ozone monitor (Quant Ozone "2"). Measurements were taken at applied voltage variations and multiple electrode diameter cylinders / Pyrex tube. The reactor used in this research was Dielectric Barrier Discharge Plasma reaktor (DBDP) reactor, with wire spiral - cylinder configuration (Figure 2).

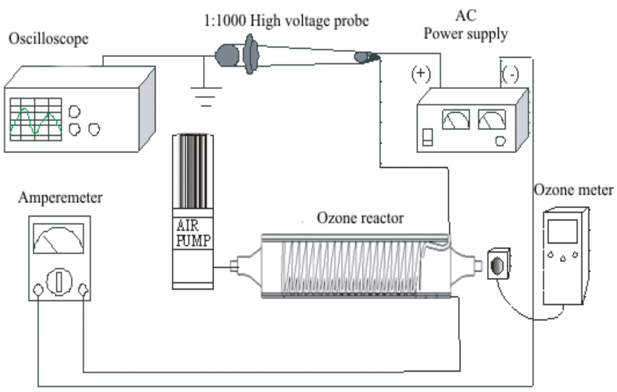

Figure 1. Experimetal set up

The reactor consists of an active electrode in the form of a spiral-shaped copper wire (wire diameters variation (D_W) are 0.4 mm and 1.2 mm), the diameters of the wire coil windings (D_C) are 9.2 mm, 15 mm, 20 mm, number of loops coil windings (N) are 10, 20, 30, 40, 50 loops. Wire spiral was inserted in a dielectric barrier was shaped pyrex tube pyrex diemeter (D_P = 30mm) and pyrex thickness (T_P = 1mm) and pyrex length (L_P = 15 cm). the outer part of the dielectric barrier will be veiled with a copper plate that serves as a passive electrode, with copper thickness (TC =0.4 mm) and copper length (L_C = 13.70 cm).

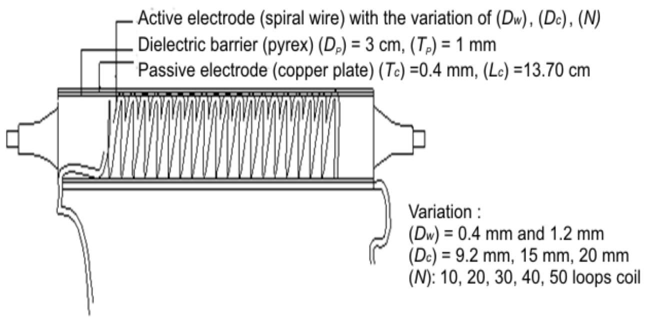

Figure 2. Dielectric Barrier Discharge Plasma Reaktor

Difference types of reactors that have been used in this research are shown in the table 1.

TABLE I. TYPES OF REACTOR

Reactor	Parameters configuration reactors			
	Pyrex Diameter	***Diameter of spiral***	***Diameter of cylender***	***Interelect rodes Distance***
Reactor 1	30 mm	9.2 mm	30.2 mm	21 mm
Reactor 2	30 mm	15 mm	30.2 mm	15.2 mm
Reactor 3	30 mm	20 mm	30.2 mm	10.2 mm

)

III. RESULTS AND DISCUSSION

A. Ozone concentration Vs Voltage

We used air as source of ozone generator. The air most constituent is nitrogen and oxygen. The air introduced into the reactor with a pump and with certaine flow rate. According to Krupenie [15] and Lofthus and Krupenie [16], O_2 molecules have ionization and dissociation energies lower than N_2 molecules . So the O_2 molecule more susceptible to ionize and dissociate of than nitrogen molecules. Energy levels of molecules O_2 and N_2 molecules that can be found in [15,16] and the ionization energy of O_2 molecule is 12 eV. If the O_2 molecules gain energy 12 eV can ionize the O_2 . Because the conditions of ionized molecules in an unstable state and tends to return to its normal state (recombination) , O_2+ ions can capture electrons and emit an energy of 12 eV . How the same is true of N_2 molecules having ionization energy of 15 eV can ionize and go back to the normal state (recombination) to emit an energy of 15 kV. Figure 3 shows that the change in the number of windings coil (N) affect the value concentration of ozone generated. At a fixed voltage, the higher the ozone concentration when the amount of twist in each wire. It is closely related to the electric field distribution and decomposition of ozone. When the number of windings coil on the more active electrode electric field between the electrodes is much more uniform and almost complete in the area so that the ionization electrode is also much more intense and uniform. The concentration of ozone produced is also higher .

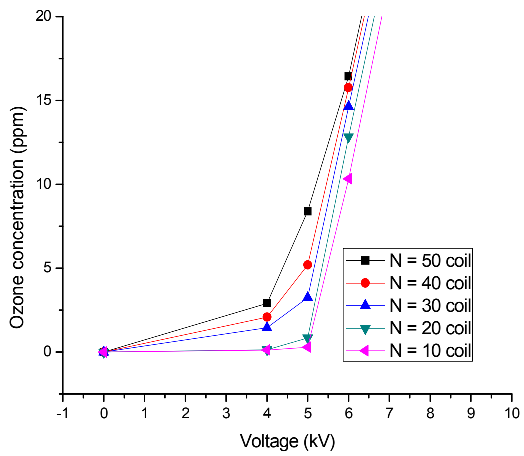

Figure 3. Ozone concentration as function of voltage with several number of spools coil, for D_W =0.4 mm, D_C= 20 mm, and D_P = 30 mm

B. Infuence of Distance interelectrodes

In this studi, the infuence of distance between interelectrodes . The distance between spiral electrode and cylender electrode is shown in the table 1.

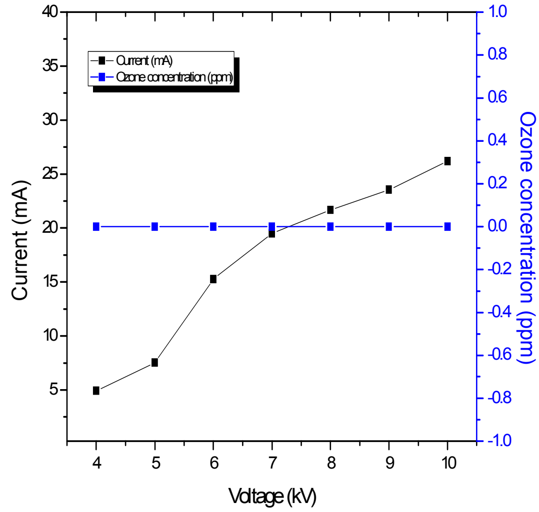

Figure 4. Ozone concentration as function of voltage with several number of winding coil, for D_W =1.2 mm, D_C= 9.2 mm, and D_P = 30 mm

We found something very interesting in the generation of ozone with DBDP. Electric current has been measured, in other words ionization has occurred, but ozone is not formed (see Figure 4 and Figure 5). It can be interpreted that although ionization has occurred but oxygen molecular dissociation has not happened or is not enough for the formation of ozone the such as tree body reaction that has been described in introduction.

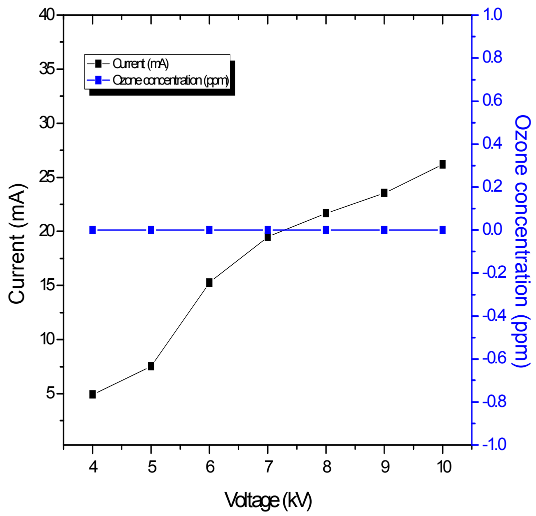

Figure 5. Ozone concentration as function of voltage with several number of winding coil, for D_W =0.4 mm, D_C= 9.2 mm, and D_P = 30 mm

This phenomenon can be explaned that ionization of nitrogen molecules or oxygen molecules are more easier than dissociation of molecules. This is due to the occurrence of dissosiation required specific distances between molecules. The probability that a certain distance is less than the probability of the distance between the molecules that allows for the excitation and ionization curves potentioan energies for Oxygen can be found in the Krupenie [15] and for nitrogen in the Lofthus and Krupenie [16]. , O_2 molecules have ionization and dissociation.

Figure 6 shows the comparison curves of ozone concentration measured for several distance (d) between spiral electrode and cylender electrode. Figure 6, higher amounts of output ozone were obtained from the plasma reactors with smaller interelectrodes distance . We found in comparation 3 types of reactors (see Table 1), reactor with distance d = 10.2 mm gives ozone concentration output of 19 ppm for applied voltage of 6 kV. In the same applied voltage, reactor with distance interelectrodes d = 15.2 mm gives ozone output of 4 ppm, and there is no ozone that has been produced for distance interelectrodes of 21 mm.

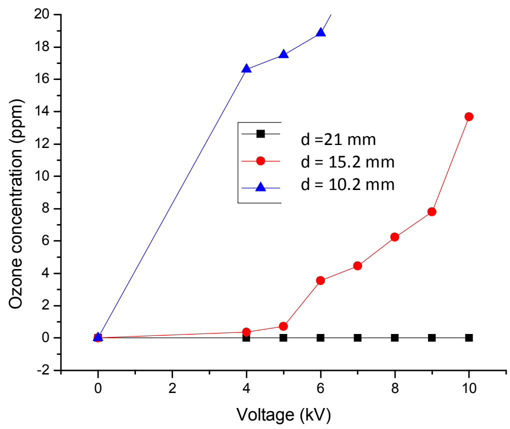

Figure 6. Ozone concentration as function of voltage, for D_W =0.4 mm, D_w= 1.2 mm, Dc are 9.2 mm, 15 mm and 20 mm, N = 50 spools coil and D_P = 30 mm

For comparassion, Moon and Jung [14] used a wire plate type nonthermal plasma reactor and utilizing a slit dielectric barrier and a third Electrode, they found also that higher amounts of output ozone were obtained from the plasma reactors with smaller interelectrodes distance.

C. Infuence of Diameters of Wire and Spiral Coil

Figure 7 shows the graph of the concentration of ozone as a function of voltage with diameter of wire Dw = 0.4 mm and diameter of wire Dw = 1.2 mm, N = 50 spools coil and pyrex diameter D_P = 30 mm. In this figure, we found that larger wire diameters of spiral coil produced greater concentrations of ozone for the same voltage. In other words, we get the concentration of ozone at Dw = 1.2 mm higher than the Dw = 0.4 mm. Both for two reactors with difference of wire diameter the concentration of ozone increases with increasing applied voltage.

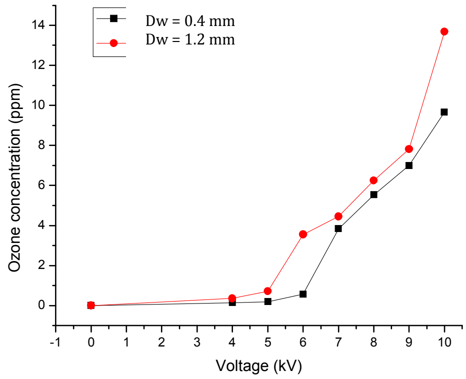

Figure 7. Ozone concentration as function of voltage, for D_W =0.4 mm, D_w= 1.2 mm, Dc = 15 mm, N = 50 spools coil and D_P = 30 mm

Zhi Fang, et al. obtained same trend in the cylinder-cylinder reactor and in the wire-cylinder reactor where the ozone concentration increase with increasing applied voltage. It is quite useful for industrial applications, where the ozone generation efficiency is the most important factor in designing a reactor [13].

IV. Conclussion

Dielectric barrier discharge plasma (DBDP) with spiral cylender configuration.can be used to produce ozone as ozone generator. In the DBDP ozone generator, ozone concentration increased with increasing of voltage, number of spools coil. The ozone concentration decreases with increasing distance between spiral electrode and cylender electrode.

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