The Effects of Different Electrode Holes on Ozone Generation

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Abstract- The research investigates the effects of different electrode holes and configuration parameters of ozone chambers on ozone generation. Ozone has been widely used for various applications without producing residues that are harmful to the environment. In most applications, higher ozone concentrations are required to fulfill this task. This study is an attempt to generate ozone at high concentration with parameters such as the holes shape of perforated electrodes, the gap spacing, and the input voltage. The total capacitance has been measured through this system. The effect of capacitance on ozone concentration was obtained by measuring the density of the charge across the gap while the discharge occurred. The amount of charge formed, which was then split, affected the increase in ozone concentration. The total capacitance also affected the ozone generation. It was found that maximum ozone concentration of 2185.31 ppm was obtained when using the hexagonal (honeycomb) shape of a perforated stainless electrode with 1 mm gap spacing, and 772.14 ppm was obtained when using the round shape of a perforated aluminum electrode with 1 mm gap spacing. It shows that the hexagonal (honeycomb) shape of perforated stainless electrode contributes to high electric field strength between the gap spacing, leading to high ozone concentration.

Index Terms — Electrode, Dielectric Barrier Discharge, Ozone concentration.

I. Introduction

Ozone is one of the strong oxidising agents that do not produce harmful residues in the environment. It has thus been widely used for various applications, such as water disinfection, deodorising, CO2 reduction, sterilisation and purification [1][2][3][4][5]. Ozone has been studied in recent years, since it is capable of providing sustainable and environmentally friendly technology. The rapid development of ozone applications has improved ozone generation systems, which is a central problem in the process of producing a high ozone concentration.

Ozone can be produced by exposing normal diatomic oxygen gas to energetic electrons, X-rays, nuclear gamma rays, short-wave (UV) radiation and electricity release, which can form triatomic oxygen [6].

Ozone can be produced using dielectric barrier discharge, which is already well known as the most widely used method nowadays. Dielectric barrier discharge, which is called DBD, consists of two electrodes separated by a barrier that have a gap distance between them. Under atmospheric pressure, this system is a good method for ozone production and is the most cost-effective method [7][8][9][10][11][12].

The DBD configuration was firstly proposed by Siemens in 1857 for producing ozone [1]. The mechanism of ozone formation and decomposition occurs simultaneously, and it is thus necessary to consider reducing the amount of ozone decomposition through the impact of the electrons [13][14][15][16]. One purpose of this experiment is to produce a high ozone concentration by varying the electrodes, gap distance and applied voltage using atmospheric pressure and room temperature.

The dissociation that occurs between O_2 and O_3 is the impact of excited electrons. Excited electrons under a high electric field have an advantage of efficiently producing high ozone concentrations, due to the reduction in the population density of low-energy electrons by decomposing ozone produced using short gap distances and due to the chamber length being used.

Perforated aluminum electrodes and hexagonal (honeycomb) stainless electrodes are used as an electrode medium and are expected to generate high ozone concentration, since they have sharp edges that can generate a high electric field. Consequently, high ozone concentration is to be expected. In this research, the effects of two different types of electrode holes have been compared and studied.

II. Experimental Setup

The experimental setup consisted of DBD reactor with plate–plate electrode, glass dielectric, power sources, flow control system, ozone analyzer and measurement systems. This involved a hexagonal stainless electrode with 1 mm thickness and 2 mm diameter with sharp edges in each hole and a perforated aluminum electrode with 1.2 mm thickness and 1.2 mm diameter with sharp edges in each hole (Fig.1). Dielectric barriers in 1 mm sheet of soda lime glass have relative permittivity of 7.75 for the DBD reactor.

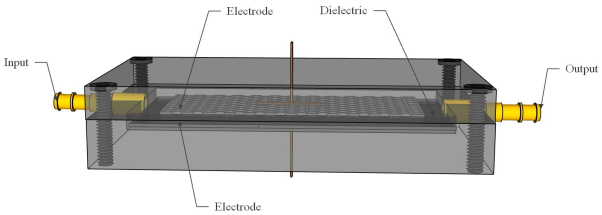

Fig. 1. Dielectric barrier discharge chamber

As a dielectric barrier, soda lime glass has high insulation resistance, breakdown voltage strength of 13kV/mm and thermal conductivity about 0.7–1.3 W/(m-k). Perforated aluminum measuring 72 mm x 33 mm and hexagonal stainless measuring 81 mm x 33 mm were inserted into the plate chamber electrode. The electrode was connected as high voltage and another side as grounding. The high-voltage connection was energized by an AC power source *(Tektronix P6015A, 1000:1,3.0 pF, 100 MΩ)* and was connected to the DBD reactor for measure input voltage (Fig.2). The ozone efficiency was measured under different levels of applied voltage from 1kV to 7 kV with 1 kV incremental steps. The applied voltage and voltage waveform was measured with a PicoScope 3206B (200 MHz, 500 MS/s). Oxygen with 99.99% purity as input gas has flowrate of 1L/min when injected through the chamber with an ambient temperature and atmospheric pressure. An ozone analyzer (BMT 964) was used to measure ozone concentration at the outlet of the DBD reactor. The DBD reactor using the planar chamber has advantages for simple construction, easy adjustment for air gaps with filler materials, simple replacement and arrangement for different types of electrodes and dielectrics [17].

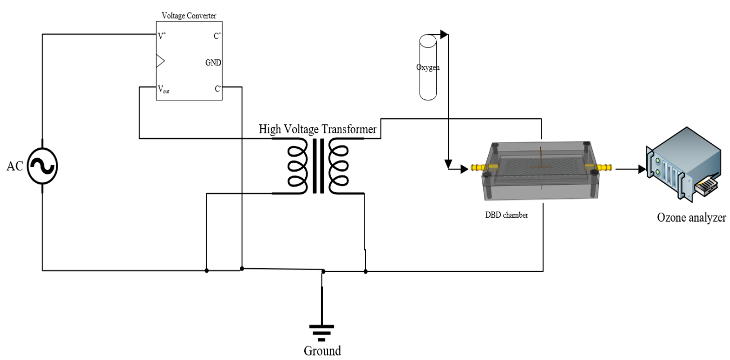

Fig. 2. High voltage power supply system

III. Results and Discussion

This experiment, which compares hexagonal stainless electrodes and perforated aluminum electrodes, produces a high ozone concentration. Both have sharp edges for high electric strength in discharge space. Hexagonal stainless electrodes would work better in ozone generation due to their sharp-edged holes in each angle, which produce electric field strength in a high-discharge region with predetermined variations. Using hexagonal stainless electrodes may produce a high ozone concentration and reduce the amount of ozone decomposition. A new DBD system has a positive effect on ozone generation by using hexagonal stainless electrodes.

The ozone concentration obtained by using perforated aluminum electrodes is lower than for hexagonal stainless electrodes. A 2 mm gap spacing using perforated aluminum electrodes obtains an ozone concentration of 713.86 ppm (Fig. 3), while using hexagonal stainless electrodes obtains an ozone concentration of 1573.42 ppm (Fig. 5). For 1 mm gap spacing, using perforated aluminum electrodes obtains an ozone concentration of 772.14 ppm (Fig. 4), while using hexagonal stainless electrodes obtains an ozone concentration of 2185.31 ppm (Fig. 6). All of the experiments had the same conditions, with applied voltage from 1 kV–7kV. The above results show a positive contribution towards ozone generation by using a short gap length with hexagonal stainless electrodes. These purposes are the equivalent of Kitayama et al. [16], where the strength of a high electric field with a short gap length for an ozone generator provides the advantage of suppressing the gas temperature increase. This plays an active role in ozone decomposition, resulting in an efficient generation with a high ozone concentration. However, these results still necessitate further observations on varied dielectric materials.

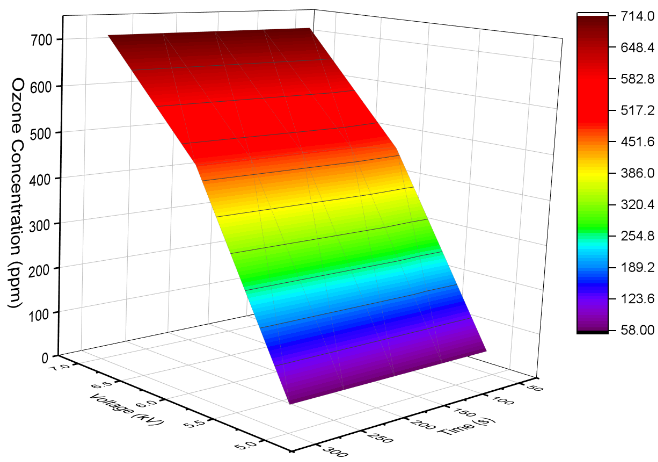

Fig. 3. Effect of gap spacing (2 mm) on ozone concentration as a function of Vac using perforated aluminum electrodes.

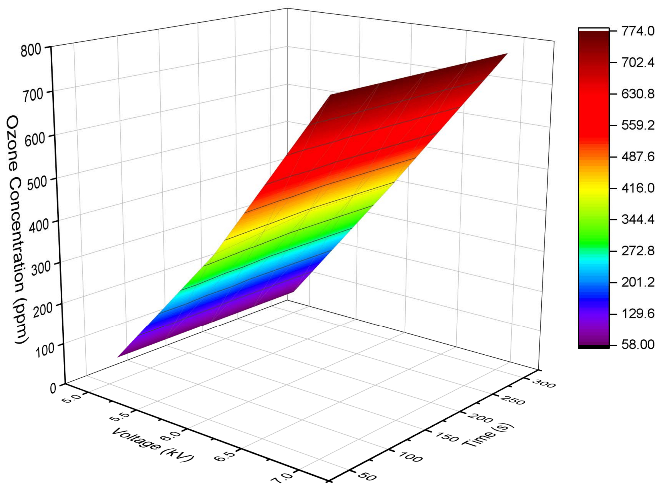

Fig. 4. Effect of gap spacing (1 mm) on ozone concentration as a function of Vac using perforated aluminum electrodes.

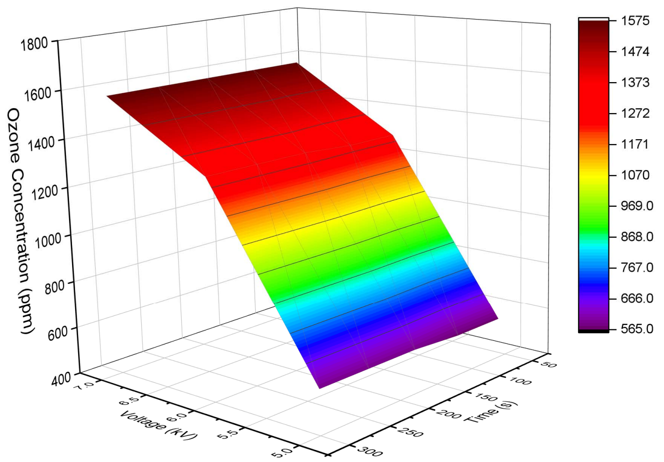

Fig. 5. Effect of gap spacing (2 mm) on ozone concentration as a function of Vac hexagonal stainless electrodes.

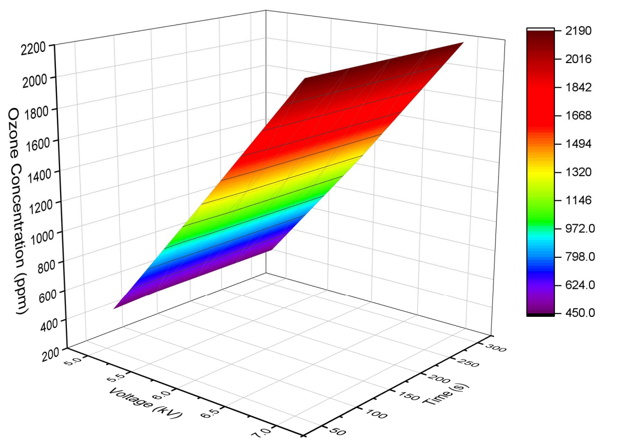

Fig. 6. Effect of gap spacing (1 mm) on ozone concentration as a function of Vac hexagonal stainless electrodes.

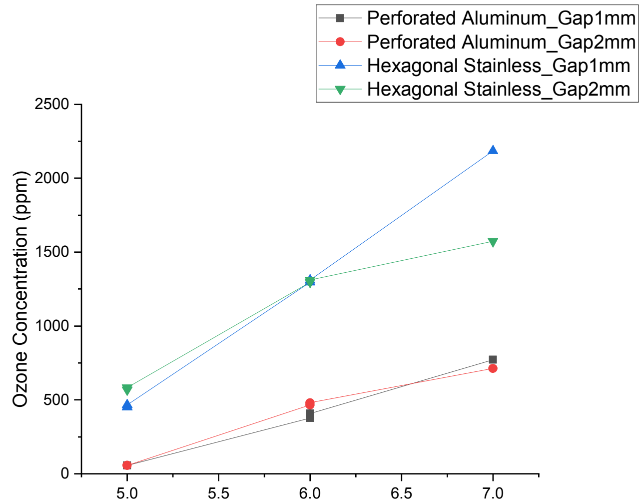

Fig. 7. Effect of gap spacing on ozone concentration as a function of Vac using hexagonal stainless electrodes and perforated aluminum electrodes.

Based on Buntat et al., using perforated aluminum electrodes at both low and high voltages will give a greater perforation density with small diameter holes and will influence the breakdown mechanism, which creates the necessary discharge stability for ozone generation [18]. Therefore, the understanding of the results when using perforated aluminum electrodes gives a new perspective on hexagonal stainless electrodes, which have a wider space and are solid with sharp edges on the sides. Consequently, the results obtained show significant differences when using two different electrodes (Fig. 7).

Based on the results, perforated aluminum electrodes have a 30.35% open area with a capacitance of 12.97 pF in gap spacing of 1 mm and 6.88 pF in gap spacing of 2 mm. Ozone concentration obtained 772.14 ppm in gap spacing of 1 mm and 713.86 ppm in gap spacing of 2 mm at 7 kV of applied voltage. However, hexagonal stainless electrodes have a better result than perforated aluminum electrodes, with a 93.5% open area when the capacitance is 1.362 pF in gap spacing of 1 mm and 0.722 pF in gap spacing of 2 mm. Ozone concentration obtained 2185.31 ppm in gap spacing of 1 mm and 1573.42 ppm in gap spacing of 2 mm at 7 kV of applied voltage. It can be concluded that ozone concentration was influenced by electrode area (percentage of open area in the electrode area), gap spacing, voltage and capacitance. The increasing voltage with total capacitance affected the amount of charge once a breakdown occurred in the gap, resulting in microdischarge filling the dielectric capacitance.

These studies use linear analysis, which shows in Fig.8 that the value for perforated aluminium has pearson's r 0.99 (Gap 1 mm) and 0,98 (Gap 2 mm) approaches the test value, which has been done with the coefficient of each independent variable and significant, with a coefficient of determination (r^2) of 98% and 96%. There are only 2% and 4% values that are not affected by the gap applied but may be influenced by other factors such as changes in voltage increase. These also found in

Fig.9 that the value for the hexagonal stainless has pearson's r 0,99 (Gap 1mm) and 0,96 (Gap 2 mm) with a coefficient of determination (r^2) of 98% and 92%. There are only 2% and 8% values that are not affected by the gap applied but may be influenced by other factors such as changes in voltage increase.

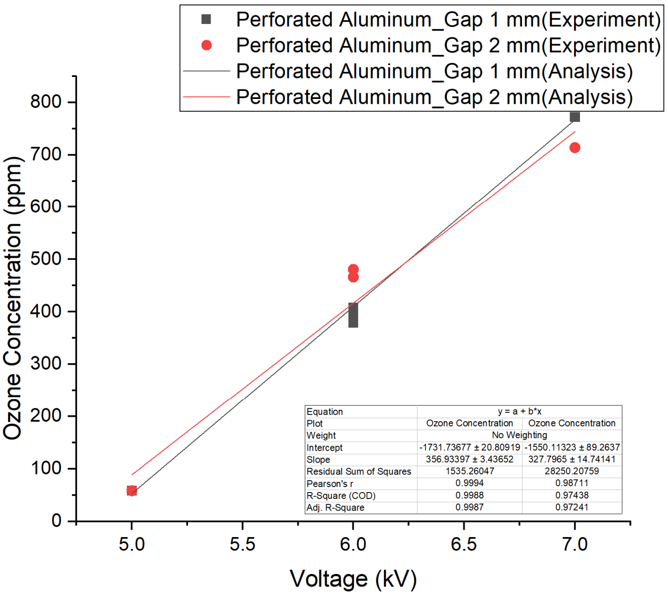

Fig. 8. Experiment and analysis of polynomial perforated aluminum electrodes on ozone concentration.

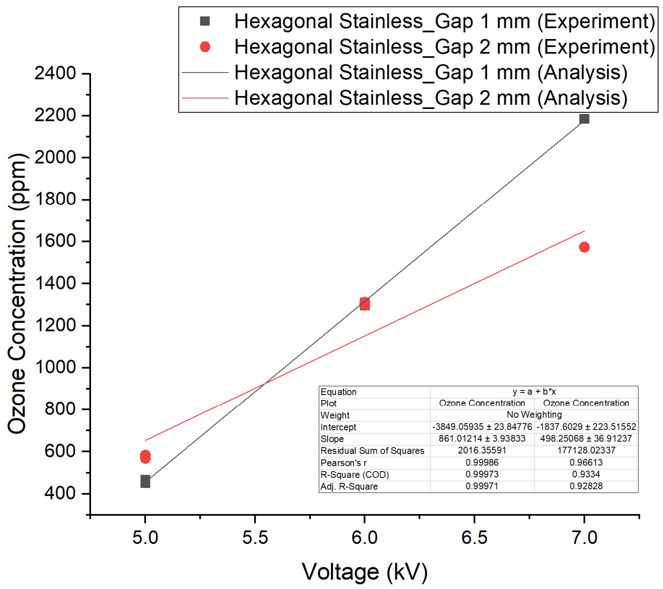

Fig. 9. Experiment and analysis of polynomial hexagonal stainless electrodes on ozone concentration.

Some factors that affect the capacitance value are the surface area and gap spacing. The effect of capacitance on ozone concentration can be found by measuring the density of the charge that crosses the gap during the discharge, which occurs because the charge binds the formed electrons to be split. The amount of charge formed, which was split, affects the increase in ozone concentration.

IV. Conclusion

Ozone generation with the DBD method using perforated aluminum electrodes and hexagonal shape perforated stainless electrodes has been conducted in this study. Both electrodes have sharp edges that create a high ozone concentration. The ozone concentration measurements were carried out using two electrode cavity types, voltage and gap spacing. This system uses ambient temperature and atmospheric pressure. The total capacitance from each type of electrode has measured that hexagonal stainless electrodes showed a lower capacitance than perforated aluminum electrodes. The total capacity has an effect on ozone generation. It was found that a maximum ozone concentration of 2185.31 ppm is obtained when using hexagonal stainless electrodes with 1 mm gap spacing and that 772.14 ppm is obtained when using perforated aluminum electrodes with 1 mm gap spacing. This range of ozone concentration is made suitable for a new system of DBD by using hexagonal stainless electrodes, which have a positive effect on ozone generation.

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V. References

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