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Effect of Crossed Magnetic Field on Ozone Production in Air

Z. Buntat[1*], **I. R. Smith**[2] and **N. A. M. Razali**[1]

[1]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.
[2]Department of Electronic and Electrical Engineering, Loughborough University, Loughborough, Leicestershire LE113TU, UK.

*Corresponding author: zolkafle@fke.utm.my, Tel: 607-55335431, Fax: 607-5578150

Abstract: An application of magnetic field, B to a discharge chamber under transverse electric field, E is studied, with the objective to view the effect of magnetic field to the electrons in a plasma. Theory of gas discharge stated that this configuration will create a helical motion to electrons due to gradient drift or gyration. Experimental result from previous research showed, however that this magnetic field has no effect to corona current, in contrast to the theory that the helical motion will increase the ionisation collision process and cause more electron emissions. To verify the result, application of B effect to ozone chamber is constructed under AC and pulsed power supply, and the result shows that the B does not influence gas discharge characteristic agreeing with the result from previous author.

Keywords: Magnetic field, Ozone production.

1. INTRODUCTION

In a discharge region, state of chemical reaction and frequency collisions between energetic electron and background gas particles determine the density of plasma. It is very important to increase the ionisation process to achieve efficient production which is the objective of this paper, to generate higher yield of ozone. It is stated in [1,2], a transverse magnetic field can increase a greater number of collisions due to the gyration of electrons causes an increased path length in spanning a given distance. Therefore, an effort of applying magnetic field towards the electrode in ozone reactor is expected to increase the ionisation process thus increases collision process between electron and oxygen gas.

When an electron is moving freely through a magnetic field B, it gyrates about the field lines and produces rotation with radius depends upon the electron's linear velocity component that is perpendicular to B [1]. If E also acts on electron under transverse B, it creates a helical motion of the electrons due to gradient drift (gyration). The electron will move in helices around the magnetic field lines and has much more longer path-length to travel [1-3]. A kind of 'magnetic ring' is formed at the cathode surface, with average radius *R* and width *w*, which 'traps' the electrons that are accelerated away from the cathode by the electric field [2].

In application of this effect to ozone discharge chamber, it gives rise to more ionisation collisions, and consequently higher ion fluxes for electron now is confined in bulk plasma and cathode region while the charge particles which have higher mass and are much less influenced by the magnet could not move to opposite electrode directly, instead they bombard the cathode and cause more secondary electron emissions [2]. The dissipation of heat to gases and ions would be reduced and the length residence time for the gas particle and electron collision would be increased [1,2]. This cyclic and drift motion of the electron is considered as an advantage for the ozone generation as it increases the frequency collision between electron and oxygen gas to form higher ozone concentration.

In surface streamer discharge monitoring [4], streamer channels are deflected in the counter clockwise direction and some small branches can be seen on the side of the main channel in presence of magnetic field. It is agreeing with [5], when a magnetic field acts upon a discharge, various changes such as a change of radial ion and electron density and a marked alteration to the voltage-current characteristic takes place. The application of magnetic field would produce a higher discharge current and a lower voltage breakdown to the plasma [2].

However, the application of this crossed magnetic field on ozone concentration is still little on literature. From [3] it revealed that the use of AC corona subjected to a cross magnetic field, produced very little changes in ozone production. Therefore, the objective of this experiment is to confirm (or reject) the previous findings, as well as to consider an alternative approach using AC and pulsed power supply. All the results from both configurations are presented and discussed below through graphs.

2. EXPERIMENTAL SET-UP

A discharge reactor for this experiment is depicted in figure 1. The reactor is configured in coaxial tube consists a copper cylinder for discharge region and double barrier of pyrex glass tube around it. The relative permittivity for the dielectric used is 7.2 and the thickness is 2mm with a gap spacing of 1.4mm. The inner copper cylinder is supplied by high voltage AC or pulsed power supply and outer electrode of copper foil acts as a ground pole. The outer copper foil is wrapped around the dielectric barrier and on top long solenoid of 1000 turn copper wire. This copper wire was wound on a PVC former. It generates a nearly uniform magnetic field throughout the volume of discharge reactor orthogonal to the electric field and it produces magnetic flux density from 0.0265T to 0.1058T.

To compare the result, the reactor also is prepared for the evaluation without magnetic field. Following the ozone reactor system as in [6], this reactor is fed by dry air oxygen with concentration (by volume) between 17 to 21%. The air flow rate is varied between 0.2 to 1 l/min and monitored by a flow-rate meter. The pressure of the dry air was kept constant at 1 bar throughout the investigation. Any movement of the discharge caused by the magnetic field was observed through a viewing window located on one side of the discharge chamber.

Generation of AC of 1-20KV is supplied through a step up transformer 240V/20000V, 5 mA and 50 Hz to the outer electrode [7] while for the generation of pulsed streamer discharge PSD, the system used Blumlein type pulse generator with a rotary spark gap switch with peak pulsed voltage varied from 13 to 17 kV [6]. The voltage for AC is measured by means of a voltage divider R1 and R2 and a high-voltage probe (Tektronix P6015A, 1000x) is used for measuring PSD voltage. Both measurements applied with an aid of 0.22 μF capacitor connected series in ground. Rogowski coil/Pearson current monitor (model 2877, 1: 1 V/A) is used to measure current and the signals are displayed by a digital oscilloscope (LeCroy 9344) with a bandwidth of 500 MHz and a sample rate of 1 GS.

3. RESULT AND DISCUSSION

From the window observer, the discharge activity inside chamber is observed same with or without magnetic field. No visual difference in movement detected in discharge region for both signal AC corona and PSD configuration. Even when the magnetic fields are increased from 0.0265 T to 0.1058 T, the activity remain the same. Investigation on corona starting voltage, breakdown voltage, corona discharge current and ozone concentration are carried out for further clarification and are shown in graphs. All the experiment is repeated at least for three times for confirmation and the flux density is frequently measured as the current is increased from 1 to 8 A.

Figure 2 and 3 show the I-V characteristics of AC corona and PSD with a magnetic flux density varies between 0.0265 T and 0.1058 T. The results show an increase in corona current as the input voltage is increased in both signal supply. However, neither case shows any difference in I-V characteristic when the magnetic field is applied. The effect of magnetic field is same without the magnetic field. Even though the magnetic field is raised up to a higher value, the result is still same. The result for AC corona is in fact in general agreement with previous findings [3], but no previous result has been reported for the PSD technique.

Figure 4 and 5 show the effect of increasing the magnetic flux density on the ozone concentration at increasing input voltage for AC corona and PSD techniques. At zero magnetic field with a constant air flow rate of 1.0 l/min, an increased input voltage results in an increased ozone concentration in both techniques, with the maximum concentration obtained in the AC corona and the PSD being approximately 600 ppmv and 1100 ppmv. Though, increasing the magnetic flux density from 0.0265T to 0.1058T still produced no effect on the concentration in either technique, which confirmed [3], although the reason for this remains unclear. It may be related to the use of an alternating voltage or a pulse repetitive voltage, but no reason has yet been obtained and further investigation is required.

Further experiments were conducted to observe the influence of the air flow rate on the cross magnetic field chamber. The result in Figure 6 and 7 show that a variation in the air flow rate varies ozone concentration, however under the magnetic field influence they also show no apparent effect on the ozone concentration for both discharge techniques.

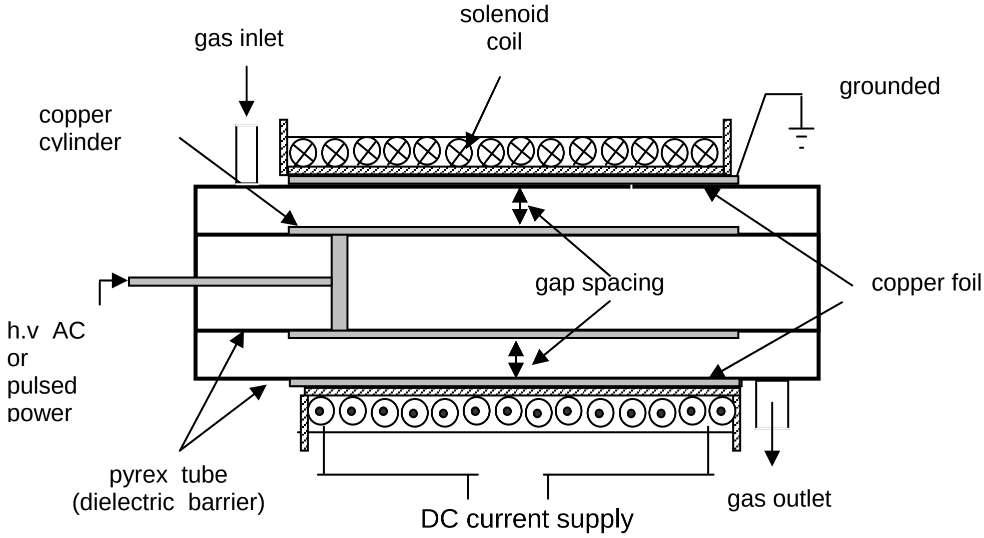

Figure 1. Schematic diagram of discharge reactor [6]

VOL. 11, NO. 2, 2009, 16-19
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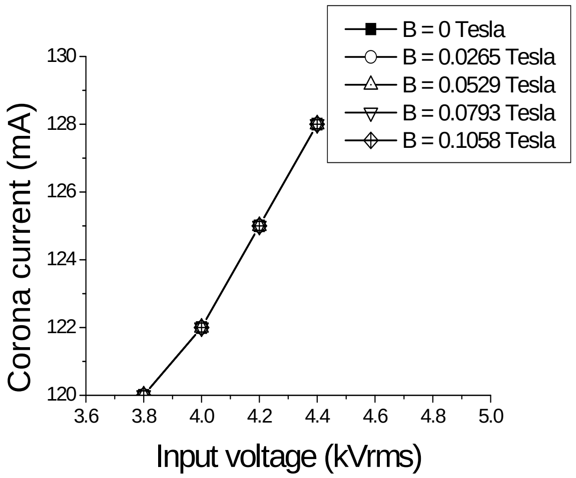

Figure 2. I-V characteristic of AC with and without magnetic field. Condition: dielectric material pyrex glass (ε_r = 7.2), gap spacing 1.4 mm, air flow rate 1.0 l/min, chamber length 100 mm, pressure 1 bar.

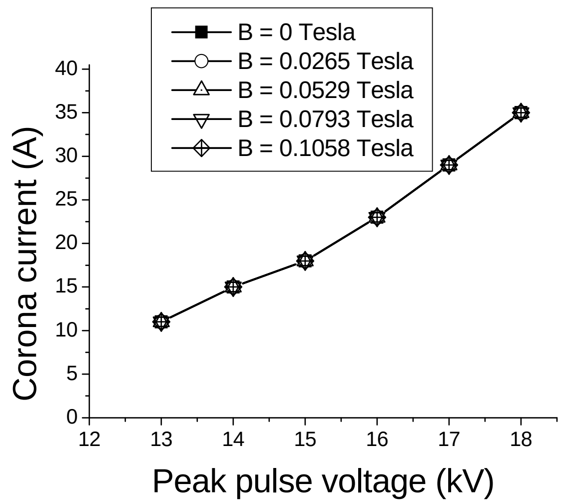

Figure 3. I-V characteristic of PSD with and without magnetic field. Condition: dielectric material pyrex glass (ε_r = 7.2), gap spacing 1.4 mm, air flow rate 1.0 l/min, chamber length 100 mm, pressure 1 bar.

The reason why a magnetic field has no effect to corona current and ozone concentration in this experiment remains unclear, since the results showed that chamber under magnetic field has same effect with chamber without magnetic field though the magnetic field is raised up to 0.1058T. Nevertheless, the result of this experiment is in general agreement with previous finding [3].

It may however be that the size of gap spacing used in this experiment of 1.4mm is too small for the electrons to move in helical motion. The movement of the electrons and gas particles inside chamber are very limited in the short space which may therefore be the reason why the magnetic field has no significant effect on the I-V characteristic and ozone production. As a result a similar feature of discharge under magnetic field is same with a discharge without magnetic field.

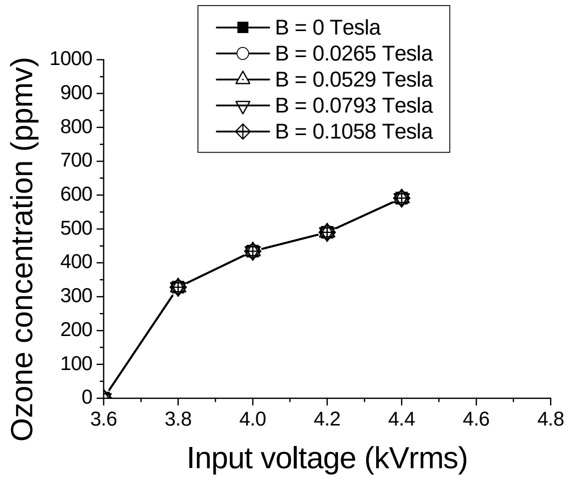

Figure 4. Ozone generation characteristic of AC corona discharge with and without magnetic field. Condition: dielectric material pyrex glass (ε_r = 7.2), gap spacing 1.4 mm, air flow rate 1.0 l/min, chamber length 100 mm, pressure1bar.

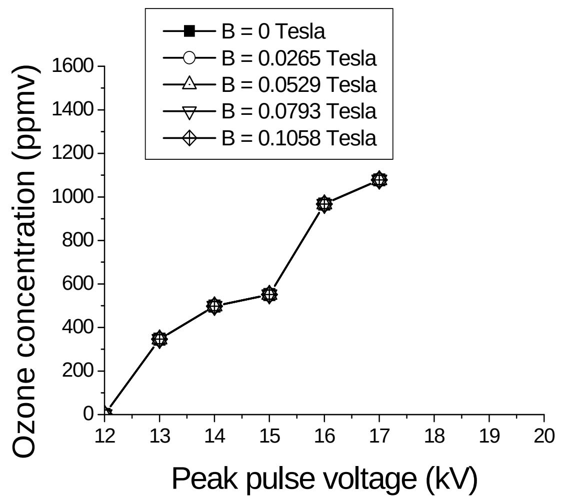

Figure 5. Ozone concentration characteristic of PSD with and without magnetic field. Condition: dielectric material pyrex glass (ε_r = 7.2), gap spacing 1.4 mm, air flow rate 1.0 l/min, chamber length 100 mm, pressure 1 bar.

4. CONCLUSION

In conclusion of this experiment, the effect of magnetic field to ozone concentration is opposing expectation and does not supporting the theory. The effect of magnetic field to ozone reactor gives the same result as without the magnetic field. No visual difference observed on corona activity and no difference reading detected in corona current and ozone concentration. Both AC and PSD power supply configuration show same result. Result for investigations on AC corona confirmed the conclusions reached by previous researchers [3] and the present study on PSD revealed no influence in ozone efficiency when subjected to a cross magnetic field. Even though there is no positive result reported from this study, the present finding at least provides important information for future reference. The reason of disagreement remains unclear, it may however be due to the short gaseous gap spacing used. Therefore, it is proposed that the future research probably can use a longer gaseous gap spacing to observe the effect of the magnetic field to ozone chamber.

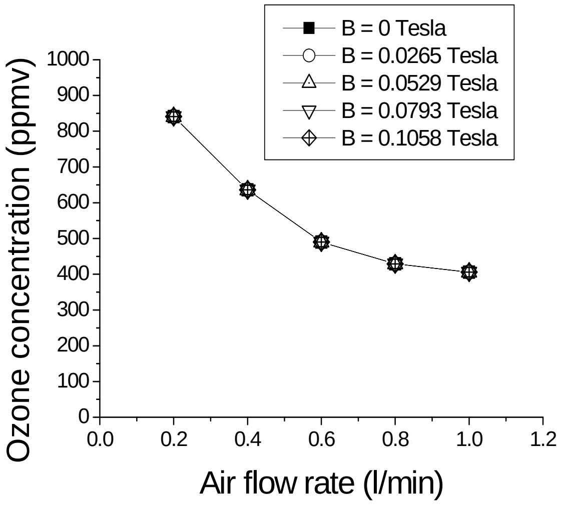

Figure 6. Effect of air flow rate on ozone concentration in AC corona discharge with and without magnetic field. Condition: dielectric material pyrex glass (ε_r = 7.2), gap spacing 1.4 mm, input voltage 4.2 kVrms, chamber length 100 mm, pressure 1 bar

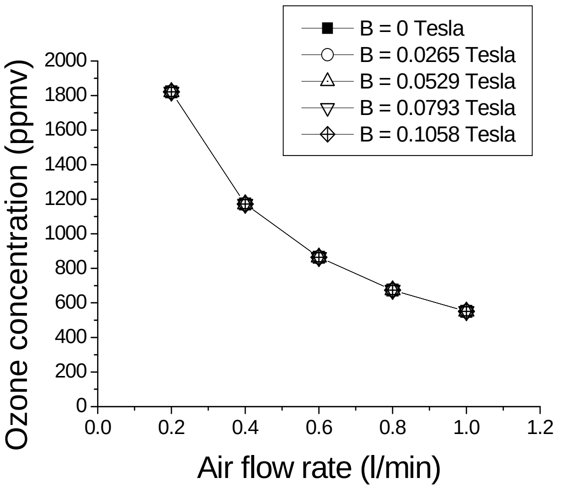

Figure 7. Effect of air flow rate on ozone concentration in pulsed streamer discharge with and without magnetic field. Condition: dielectric material pyrex glass (ε_r = 7.2), gap spacing 1.4 mm, peak pulsed voltage 15 kV, chamber length 100 mm, pressure 1 bar

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