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DDBD ozone plasma reactor generation: the proper dose for medical applications

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Abstract. Double Dielectric Barrier Discharge (DDBD) ozone plasma reactor generation are presented in this paper. The generation of this reactor generates ozone concentration which can be arranged upon the proper dose for medical applications. AC high voltage is applied to the range of 0-3 kV and the frequency of 50 Hz. Pure oxygen gas was piped into the DDBD reactor with flow rate variations of 2, 4 and 6 L/min. The results showed that current as a function of voltage where the current is increased with the increasing of voltage. Ozone productivity is shown by the significant increase of current. Ozone concentration is increasing as the increase of the voltage provided, but rather the concentration of ozone is decreasing as the increasing of flow rate. The Ozone capacity is affected by ozone concentration and flow rate, and can be used to determine the ozone dose. The proper dose of ozone can be ozone therapy for various kinds of diseases.

1. Introduction

Ozone consists of 3 oxygen atoms and has an O_3 chemical formula. The ozone molecule is unstable with a lifetime (20-30 minutes) before returning to oxygen at environmental temperature and decomposes very quickly (<1 s) at high temperatures [1]. Over the past few decades, ozone studies have been utilized for medical therapy and experience a number of amazing things. Ozone therapy can increase the delivery or utilization of oxygen, stimulate detoxification, reduce inflammation, support antioxidant enzymes and enhance the immune system so that it can help the body naturally fight external pathogens [2]. When used in certain diseases and conditions, medical ozone receives the same or similar therapeutic results worldwide. Improper application in the form of methods and doses is the cause of ineffectiveness and side effects which later cause the occurrence of severe controversy [3].

Ozone can be produced from a Dielectric Barrier Discharge (DBD) plasma system . DBD will appear in a gas gap when AC voltage or RF is applied to the electrode system with one or both electrodes covered by a dielectric layer [4]. In DBD, air gas or pure oxygen gas is passed through the gap between two electrodes. Dielectric barrier layer blocking the thermalization of DBD that is extinguishing discharge in the duration of time short (several tens of nanoseconds) [5]. Under the influence of high energy electrons in the space between electrodes there is a dissociation of oxygen molecules. The reaction of Ozone formation begins with the formation of oxygen free radicals, then oxygen radicals will react with oxygen to produce ozone [4] [6] [7]. DBD has two types, namely single DBD and Double DBD. Single DBD is an electrode system with one covered by a dielectric barrier. Whereas Double DBD is an electrode system with two covered dielectric barriers [8]. The barrier is an important part of the Atmospheric Pressure Dielectric Barrier Discharge (AP-DBD). In addition to affecting discharge characteristics [9], it also influences its application. In the research of Nur (2017) using Single DBD with gas free air input and concluded that there was corrosion due to ozone interaction with an in (active) electrode material made of Copper (Cu). Corrosion reactions occur due to continuous exposure to electrodes which causes electrodes to oxidize tobe Copper Oxide (CuO and/or CuO_2) . As a result, it can reduce the quality and purity of Ozone produced [10]. In 2010, Travagli concluded that the use of pure oxygen flow sources for medical ozone applications is preferable rather than air , because the raw material for air (78% Nitrogen) when used for ozonation the saturated substrate can cause the production of NO (Nitric Oxide) which is potentially toxic , and decrease the significant efficiency of ozonation [11].

In this study using DDBD Plasma Ozone Reactor and using a pure oxygen gas flow source. The DDBD reactor is made with a double dielectric that isolates the two electrodes in the reactor. Thus, the electrode does not undergo a chemical reaction because the interaction of ozone with the electrode causes corrosion [12]. The resulting zones become more sterile and safe for medical ozone applications.

2. Research Methods

High voltage AC (V) = 0 – 3 kV and frequency (f) = 50 Hz is applied to the Double DBD system configured cylinder- cylinder. The inside electrode (active) and the outer electrode (passive) are made of a copper plate with thickness (K_T) each of 0.01 cm, length (L_T) each 12.56 cm and 25.12 cm. Pyrex tubes (inside and outside diameter (D_P) and thickness (T_p) are respectively 2 cm and 4 cm and 0, 75 cm; length (L_P) 16.5 cm) function as a barrier (barrier) given to the outer electrode and the inner electrode (double DBD). In this system using pure oxygen gas as a source of flow with flow rate variations of 2, 4 and 6 L / min. Measurement of ozone concentration uses the Iodometric titration method. The calculation of ozone concentration is as follows [13] [14]:

$$O_3(^{mg}/_{L}) = \frac{24000 \cdot V_t \cdot N_t}{V_g} \quad (1)$$

O_3 is the ozone concentration (mg/L), V_t is the volume of $Na_2S_2O_3$ (ml), N_t is the Normality of $Na_2S_2O_3$ (mol/L), and V_g is input gas volume (L) namely flowrate (L/min) × time (min).

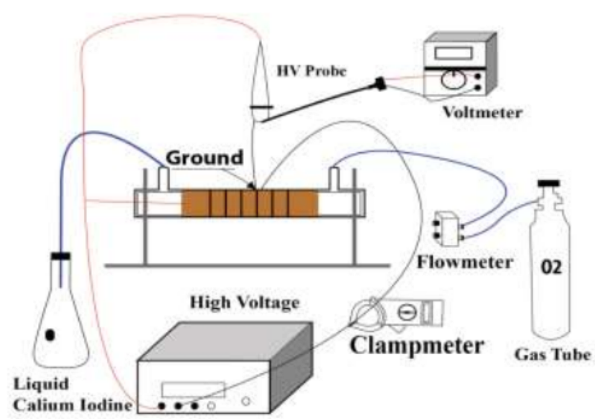

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Figure 1 Experimental Set Up

3. Results and Discussions

3.1 Characterization of Current as a Function of Voltage

In this study, the voltage used is between 1 kV to 3 kV with an increase of 0.1 kV and a variation of flow rate of 2 L / minute, 4 L / minute and 6 L / minute. Figure 2 shows that the current flowing in the reactor increases with increased voltage, starting voltage of 1 kV and 2.5 kV and a surge of current at a voltage of 2, 5 to 2.6 kV. This is because of the influence of the electrical charge that is formed. When the voltage is increased it will increase the electric charge. Electric current is directly proportional to the electric charge. The current surge that occurs at a voltage of 2.5-2.6 kV is caused by an ozone formation process where oxygen undergoes an excitation, ionization process and continues to the recombination stage [15] [16]. At a voltage of 2.5 kV to 3 kV, an increase in current is accompanied by ozone production.

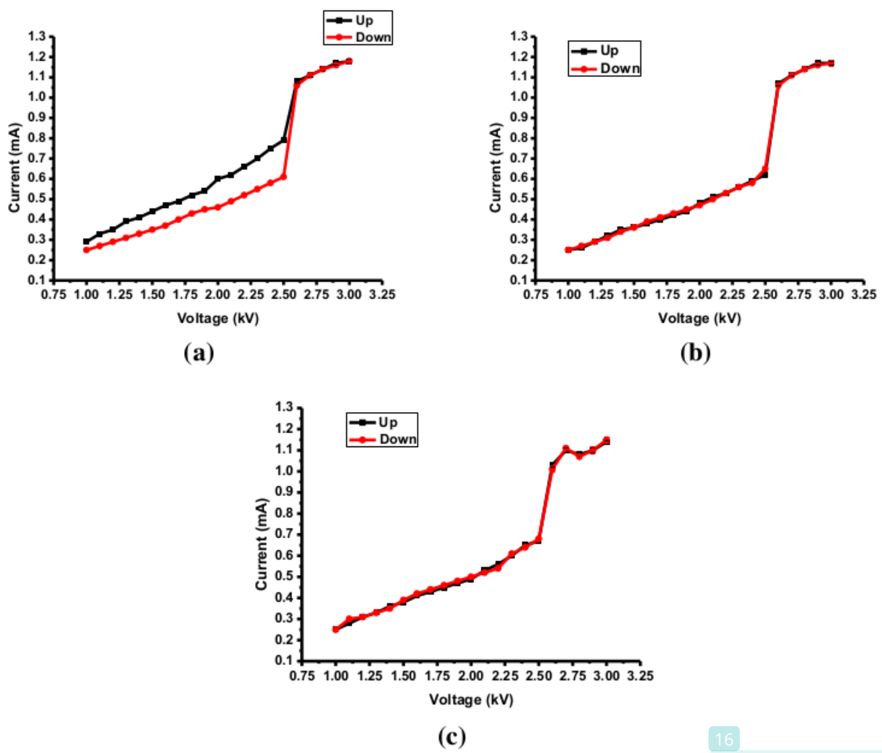

Figure 2 The characteristic of electric current as a function of voltage at the flow rate of (a) 2 L/min; (b) 4 L/min; (c) 6 L/min

3.2 Effect of Voltage on Ozone Concentration

Figure 3 shows the value of ozone concentration as a function of the voltage applied to the flow rate of 2 L / min, 4 L / min, and 6 L / min. The result shows that the initial production of ozone at a voltage of 2.6 kV. Then the ozone concentration increases when the applied voltage increases. This is because an increase in voltage will increase the electrical charge (the density of electrical energy) that more energy is transferred to electrons which increases the probability of collisions between more gas molecules and results in ionization, dissociation, recombination, etc. [15] [16] . At 1-2.5 kV voltage, the energy produced is not enough for the ionization, dissociation, recombination, etc.

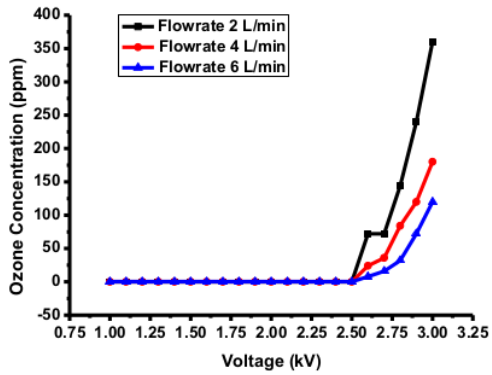

Figure 3 The ozone concentration (at the flow rate of 2 L/min, 4 L/min, 6 L/min) as the function of Voltage

3.3 Effect of Flow rate on Ozone Concentration

Effect of Flow rate on ozone concentration is shown in Figure 4. It appears that ozone concentration decreases with increasing flow rate. This is because the gas residence time in the reactor is inversely proportional to flow rate. With increased residence time it will take time for the ozone-forming reaction process [15] [16] and the resulting ozone concentration is higher.

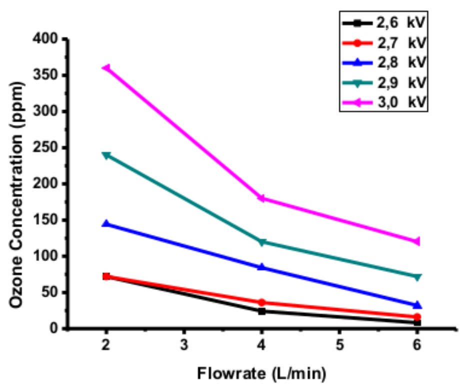

Figure 4 Ozone Concentration Vs Flowrate of O_2

3.4 Medical Ozone Therapy

Unlike the benefits of ozone for an industry, ozone for medical uses 99.99% pure oxygenic input gas, not allowed to use oxygen concentrators or oxygen/air mixtures, because the nitrogen component will allow the formation of nitrogen oxides which are harmful to the human body [3] [11].

Like other medicines, medical ozone is a molecule that must be clearly defined with a clear range of actions. With a half-life of 55 minutes in a 50 ml injection (fully siliconized and ozone resistant), medical ozone must be prepared on site and made specifically available for the type of application needed [11].

The following is a table of Application-relevant Concentration and Dosage Ranges in Ozone Therapy.

Table 1. Application-relevant Concentration and Dosage Ranges in Ozone Therapy [11]

Application	Ozone Concentration Range	Ozone Volume	Dosage/Ozone Amount Per Treatment
Systemic Treatment			
Major autohemotherapy (MAH)	10-30μg/ml (max. 40 μg/ml)	50 ml	500-1,500 μg (max.2000
Rectal insufflation	10-25 μg/ml	Max. 300 ml	3,000-7,500 μg
Minor autohemotherapy	10-20 μg/ml	10 ml	100-200 μg
Topical Treatment			
Wound cleansing	80-100 μg/ml		
Wound healing	10-25 μg/ml		
Injections in pain Syndrome	1-10 μg/ml	1 ml-20 ml	1-200 μg
In combination with local anesthetic	10-20 μg/ml	1 ml-20 ml	10-400 μg

From table 1 it can be seen that medical ozone applications are applied to various therapy for healing diseases. Table 2 is the output of this research ozone concentration with pure oxygen input gas sources and variations in voltage and flowmeter.

Table 2. The output of Ozone Concentration with Voltage Variations and Flowmeters

Flow rate (L/min)	Ozone Concentration Output (ppm)				
	2,6 kV	2,7 kV	2,8 kV	2,9 kV	3,0 kV
2	72	72	144	240	360
4	24	36	84	120	180
6	8	16	32	72	120

From table 2 shows that the output of ozone concentration with n voltage from 2.6 to 2, 7 kV for flow rate (2,4,6 L / min), voltage 2,8 kV for flow rate (2 and 4 L / min), and voltage 2,9 kV for flow rate (6 L / min) can be applied to various disease healing therapies (table 1). However, there needs to be a deeper study of the effect of flow rate on medical ozone treatment and the need to research the use of lower flow rate so that narrower ranges can be obtained.

4. Conclusion

Ozone concentrations in DDBD Plasma Reactors with pure oxygen input gas sources and variations in voltage and flow rate were examined in this study. it was found that the higher the voltage the higher the current generated. Ozone productivity is characterized by significant current surges. Ozone concentrations are higher along with the given voltage increase, but on the contrary, the ozone concentration is lower in the increase of flow rate. The output of ozone concentrations with a pure gas input source and variations in stress and flow rate can be applied to various healing therapies.

5. Acknowledgement

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