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APPLICATION OF DIELECTRIC SURFACE BARRIER DISCHARGE FOR AIR DISINFECTION

Yassine BELLEBNA, Amar TILMATINE
Department of Electrical Engineering, Faculty of Technology, APELEC Laboratory,
Djillali Liabes University of Sidi Bel-Abbes, Algeria, tel. +213 55 707 2141, e-mail: yassinebellebna@yahoo.fr, atilmatine@gmail.com

ABSTRACT

The aim of this paper is to show that disinfection system using ozone generated by dielectric barrier discharge (DBD) is an effective alternative to be used in food industry and ensures a safe quality of air for optimum preservation of fruits and vegetables. The DBDs are specific kind of discharges because one (or sometimes both electrodes) is covered by a dielectric material, thereby preventing the discharge to move towards electrical breakdown. A succession of micro-discharges occurs rapidly; their "lifetime" is in the range of a few nanoseconds. One of their most important applications is the production of ozone for air treatment, used mainly in the area of food industry, for extending the storage life of foods. After the achievement of a surface DBD reactor of cylindrical shape and its electrical characterization, it was then used as an ozone generator for air disinfection. Obtained results have shown that this reactor used as an ozone generator is effective for disinfection of air by removing viruses, bacteria and pathogens, causing the slowdown of the ripening process of fruits andvegetables.

Keywords: *DBD; high voltage; ozone; electrode; plasma; ozone generator*

1. INTRODUCTION

Dielectric barrier discharge plasma reactor enables the generation of plasma-active species at atmospheric pressure without expensive vacuum systems [1]. Active species can include ultraviolet or visible photons, charged particles, including electrons, ions and free radicals, and highly reactive neutral species, such as reactive atoms (oxygen, fluorine, ozone, nitrogen oxides, etc), exited states atoms, and reactive molecular fragments. Emission of UV-light and generation of radicals and charged particles contribute for destruction of microorganisms in plasmas.

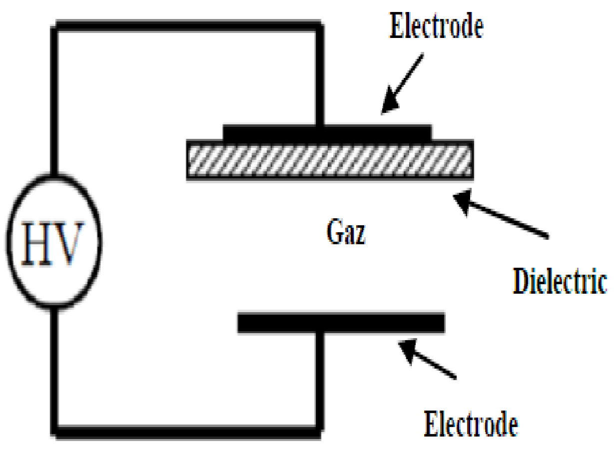

Fig. 1 Classical configuration of DBD discharge

Ozone produced in plasma region is a powerful oxidizer that could destroy microorganisms effectively. Ozone concentration in nature varies between 0.01 ppm to0.05 ppm, depending on season and geographic location. High voltage ozone generators produce ozone/gas mixture, which contains 1 % to 3 % ozone when using dry air, and from 3 % to 6 % ozone when high purity oxygen is used as a feed gas.

The dielectric barrier discharge (DBD) has been known more than a century and the early experiences on such discharges were reported by Siemens in 1857 [2-3]. Their field of application is very large: ozone generation, waste gas treatment, activation and surface treatment, CO_2 laser, excimer lamps, plasma screens, etc... and involves many industrial fields: water treatment, environment, electronics, textile, packaging, automotive ... [4-6]. One of their largest applications is the generation of ozone for treatment of water and disinfection of air.

This type of electrical discharge is a "cold non-equilibrium" plasma source, characterized by the presence of at least one dielectric layer between two metal electrodes (Figure 1). The presence of insulation can reduce energy flowing through the discharge channel and avoid the transition to the arc; however this requires the use of an alternative electric excitation.

2. MATERIAL AND METHODS

A surface DBD reactor of cylindrical shape was achieved. The dielectric barrier is constituted by a glass tube having a diameter of 50×10^{-3} m and a thickness of 2×10^{-3} m. The electrodes are a fine strip of adhesive aluminum bonded directly on the outer surface of the glass tube (Figure 2). The other metal electrode, a stainless steel mesh was placed inside the glass tube in contact with it (Figure 3). When a high voltage is applied to these electrodes, a bluish color plasma is formed on the surface of the tube in contact with the mesh electrode and is distributed homogeneously along the tube (Figure 4).

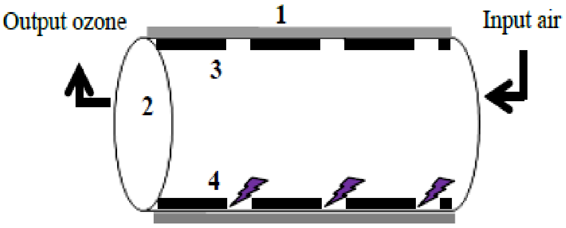

Fig. 2 Schematic description of the DBD reactor

where: 1 – electrode, 2 – glass tube, 3 – internal stainless steel electrode, 4 – DBD discharge

Fig. 3 Cylindrical DBD reactor with internal mesh electrode

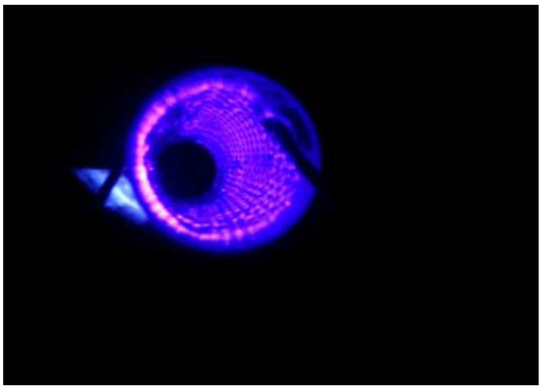

Fig. 4 Dielectric barrier discharge occurring in the reactor

An experimental study was conducted including two aspects:

- Electrical characterization of the plasma reactor.
- Using the reactor as ozone generator for air treatment.

3. ELECTRICAL CHARACTERIZATION

The purpose of this section was to make an experimental study for the electrical characterization of the reactor, for calculating its power by measuring the applied voltage and the current through the discharge. The circuit assembly used is shown schematically in figure.5 and figure 6.

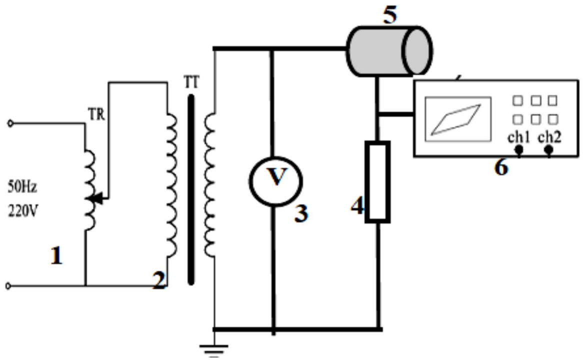

Fig. 5 Schematic representation of the experimental device

where: 1 – variac, 2 – HV transformer, 3 – electrostatic voltmeter, 4 – resistance, 5 – DBD reactor; 6 – scope

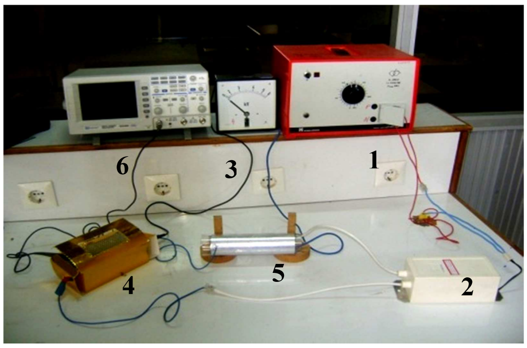

Fig.6 Test bench for measuring the current

An electrostatic voltmeter and an oscilloscope where used to measure the applied high voltage and the current. The high voltage was delivered by a power supply of voltage 6 kV, current 30 mA and frequency 10 kHz. A 100 Ω resistor was placed in series with the circuit, whose voltage drop is visualized by the oscilloscope to measure the current generated by the DBD.

The measured values from the current diagram are the peak value of micro-discharges and the "glow" current amplitude; these parameters are shown in figure 7 on the diagram of the current registered by the oscilloscope. The power measured is the product of the "glow" current amplitude by the applied voltage. Obtained results for different values of voltage are shown in Table 1.

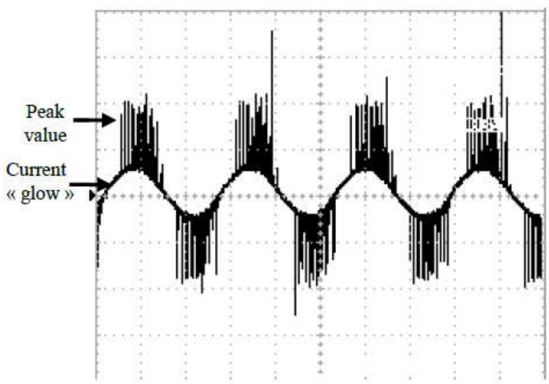

Fig. 7 Characteristic parameters of discharge current

Table 1 Current value measured as function of voltage

U (kV)	Peak values of microdischarges (mA)		Amplitude « glow » (mA)	Power (W)
	Positive	Negative		
2	8	8	8	16
3,5	14	16	14	49
4,5	19	22	18	81
5,5	22	26	22	121
7,5	26	28	23	173
9	28	32	24	216

It appears from these results that the DBD filamentary discharge starts from 2 kV, which is a rather low breakdown voltage compared to a volume DBD. Indeed, in the case of a surface discharge there is almost a micrometer intervals gas between the mesh electrode and the dielectric barrier, while this interval is of the order of some millimeters in volume DBD. Micro-discharges reach high peak values, much greater than the "glow" current amplitude. Also, should be noted that for this reactor, having length of 25 cm and a diameter of 8 cm, consumed power varies from 16 to 138 Watts.

4. APPLICATION OF THE REACTOR FOR DISINFECTION OF AIR

The reactor was then used as an ozone generator for disinfection of air in order to extend the shelf life of food products. The laboratory setup used is described in figure 8. The products to be stocked are put inside a glass enclosure; ventilation system allows the injection of ozone inside the enclosure.

Ozone is mainly used for the treatment of air and water, removing bacteria, viruses and unpleasant odors, but it must not exceed a certain limit amount which may produce the opposite effect. There commended amount of ozone is approximately 20ppm (parts per million) for effective conservation of food products [7].

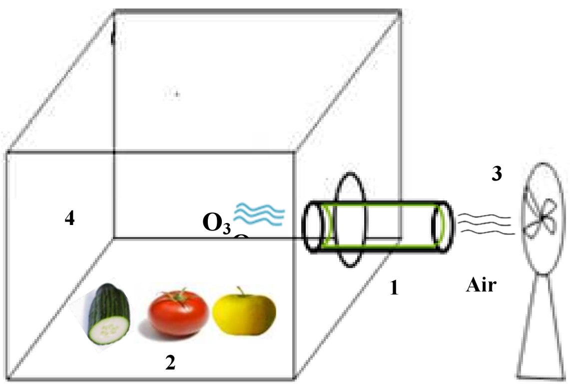

Fig. 8 Schematic description of the disinfection process

where: 1 – Ozone generator, 2 – Foods to be processed, 3 – Fan, 4 – air treated

Fig.9 Measuring instrument rate of ozone (ozone analyzer)

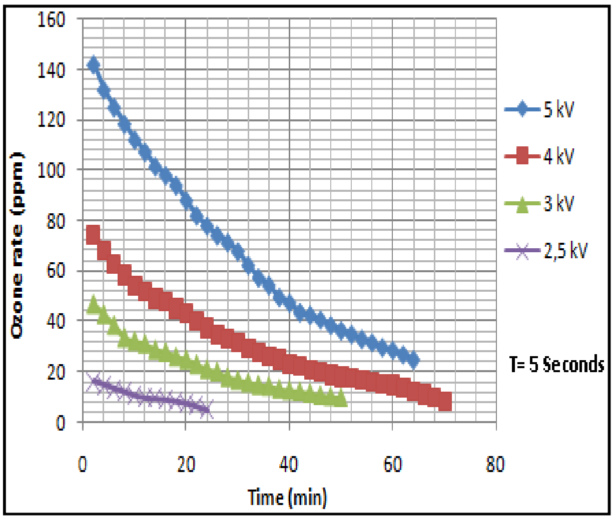

Fig. 10 Change in ozone levels according to the applied voltage

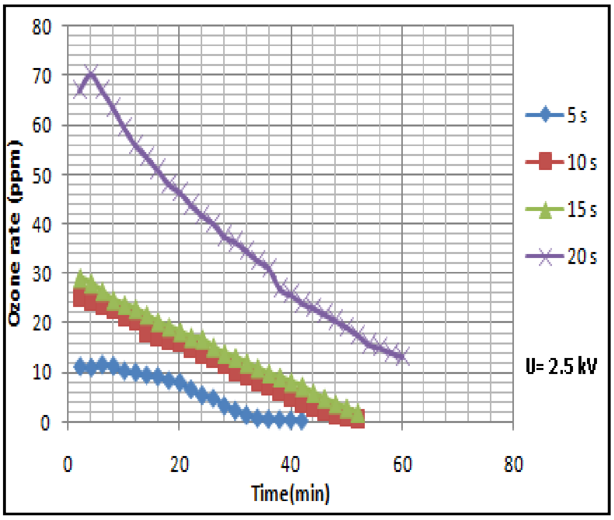

Fig. 11 Change in ozone levels according to the application period

Production of ozone is controlled by two main parameters:

- applied high voltage
- application period of ozone generator

The influence of these two factors was studied by setting one factor a constant value and varying the other. After switching on the generator for determined values of voltage and period application, the rate of ozone which measured by the ozone analyzer at intervals of 2 minutes time decreases as a function of time (figure 9).

The rate of ozone depletion for different values of voltage is shown in figure 10, and in figure11for different values of period application. It follows from these results that the level of ozone is proportional to the voltage and period exposure and it is halved after nearly 30 minutes. The values of appropriate values of voltage and duration derived from these results that achieve a rate of 20 ppm is U = 2.5 kV and T= 8 s respectively.

A second enclosure of untreated "normal" air, within which identical food are placed, was used as an "indicator enclosure". The results were expressed in days of food preservation by taking photographs of the food put in the two enclosures. Obtained results are shown in the following figures, comparing the state of the products, after several days of storage (figure 12).

Fig. 12 Comparison between the states of the food products treated with ozone (left) and food products untreated (right)

These results show clearly that food stored in the enclosure treated with ozone are resistant to contamination much more compared to products placed in the untreated enclosure, eliminating bacteria and slowing their development. Production of ozone by DBD reactor is an effective way to disinfect air and represents a well adapted solution in the agri-food sector.

5. CONCLUSION

Production of ozone by dielectric barrier discharge is a cost effective method, which achieves high levels of ozone. Using the dielectric barrier discharge reactor as an ozone generator is effective for disinfection of air in agro-food industry for extending the shelf life of foods. The DBD which consists in a multitude of micro-discharges, enables the generation of ozone which is then pumped into the air, killing bacteria and viruses. Indeed, it has been proven through experiments performed on samples of fruits and vegetables, that the installation of a system of air disinfection by ozone for food storage provides an ambience of pure disinfected and a well oxygenated air.

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BIOGRAPHIES

Yassine BELLEBNA was born in Sidi bel-abbes Algeria, in 1985. He received his bachelor's degree in natural science and life of the Institute of Sidi bel-abbes 2004 and MS degree from the Institute of Electrical Engineering, University of Sidi bel-abbes in 2009 where he is currently Professor of electrical engineering. He is a member in Applications of Plasma, Electrostatics and Electromagnetic Compatibility (APELEC).

Amar TILMATINE was born in Oran, Algeria, in 1964. He received the Eng. degree in Electrical Engineering from University of Sciences and Technology, Oran, Algeria, in 1988, and the Ph.D.degree from University of Sidi bel-abbes 1991. Since 1992, he is Professor at the University of Sidi-bel-Abbes (Algeria) and Director of in applications of Plasma, Electrostatics & Electromagnetic Compatibility Laboratory at this University.