# The characteristics of atmospheric pressure flexible electrode DBD and its application to odor reduction

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**Abstract:** Odor generated from various industrial field such as factories, disposal facilities, etc causes serous health effects and physical symptoms. In order to reduce odor, we developed a DBD system with flexible electrode configuration. We analysed the characteristics of the DBD system, and we also measured the concentration of ozone generated from the plasma system. Finally, we performed the odor treatment experiment through developed DBD system, and the odor was decreased about 70% after 20 minutes treatment.

**Keywords:** Odor reduction, DBD, flexible electrode, ozone treatment

## 1. Introduction

With industrialization around the world, the problem of air pollutions including fine dust, odor exposure and exhaust gas emission, etc are globally critical issues [1,2]. Especially, the emission of odor from various sources such as factories, wastewater treatment, municipal solid waste (MSW) treatment facilities, landfill have become a public concern due to their negative effect on air quality and human health [2,3]. Odor control in the industrial field is important to ensure a comfortable environment for people. Various method for odor reduction are being researched and developed including combustion [4], active carbon adsorption [5] and biofilteration [6]. However, these methods have drawbacks such as high operation cost, by-product generation, difficulty in using at a high concentration of odor, and a need for a large space. The method of ozone treatment can oxidize and decompose odor gas by using ozone molecules which is a strong oxidizing agent [7]. Particularly, ozone is effective to abate not only inorganic substances but also complex organic compounds. In addition, it easily decomposes into oxygen molecules in atmosphere without forming any secondary contaminants. As such, ozone treatment is a desirable technique for the abatement of odor. However, ozone generators have been limited to commercial applications due to high power consumption and the large space. Ozone generation technologies have different method, but they mainly use UV [8] or corona [9]. Corona discharge have high ozone generation but it requires relatively high power consumption and the wear of electrodes are occurred.

In this regard, we have developed and applied a dielectric barrier discharge (DBD) with flexible electrode configuration operating at an atmospheric pressure. The odor reduction system using a flexible electrode DBD is consisted with a flexible high-voltage wire covered dielectric tube, quartz plates, Alternating Current (AC) high voltage generator, small fan and odor reduction reactor. This system is capable of generating a large amount of ozone at low power consumption, and possible to install it without being confined to spaces because of the advantages of flexible electrode structure. In addition, the odor reduction system has the advantages of handling a high concentration of odor according to the structure of the reactor and electrode. Therefore, we observed optical and electrical characterization of a flexible electrode DBD plasma and conducted experiments of odor reduction.

## 2. Experimental setup

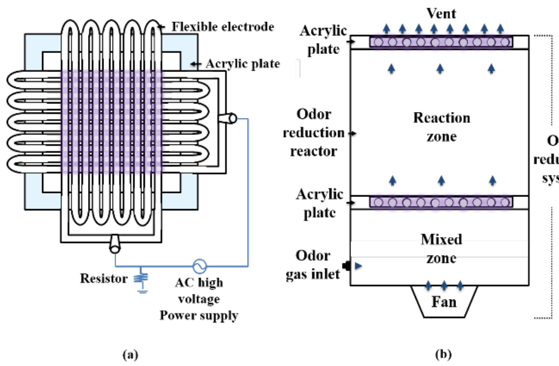


Fig. 1. Schamatic drawing of (a) DBD system using flexible electrode, (b) the odor reduction reactor and system

Fig. 1 presents a schematic drawing of the DBD using the flexible electrode wire and odor reduction system. The odor reduction system consists of a flexible high-voltage electrode wire covered silicon rubber with an outer diameter of 4mm (UL3239, IEWC global solutions, USA), acrylic plates, high-voltage power supply, odor gas inlet, small fan (TB-B95-1, Inno Tech, South Korea) and odor reduction reactor. The power supply shown in the figure was a commercially available 25 kHz AC transformer (NTO-500, NT electronics, South Korea) and was connected to flexible electrode wires. As shown in Fig. 1(a), the acrylic plates of square shape without center region were manufactured with 40 holes having an outer diameter of 4mm. The flexible electrode wire with a length of 1000 mm is passed through 20 holes in the direction of horizontal axis. Another electrode wire is passed through in the opposite direction of vertical axis. As a result, the acrylic plates were contacted with 100 points where two flexible electrode wire meet. The gap between each point is 2 mm. The flexible electrode in the vertical axis direction was connected to H.V and the horizontal flexible electrode was connected to the ground. The small fan and gas inlet are located at a bottom of odor reduction system as shown in the Fig. 1(b). We designed and suggested an odor reduction system to pass the mixture odor gas through two acrylic plates where the DBD plasma is generated. As shown in Fig. 2, points contacting two flexible electrodes are break downed by strong electric field. When the electric field is enough high to breakdown air, the DBD plasma is generated at the points between two flexible electrode wires. We confirmed the conditions for DBD plasma applied in this study were optimized to maintain a stable and high ozone concentration. A digital phosphor oscilloscope (DPO405-4B, Tektronix, USA) and an emission spectroscope (spectra view 2100, K-MAC, South Korea) were used to analyse the electrical and optical characteristics of the DBD plasma. The amount of ozone generated from the DBD plasma was measured using an ozone monitor (106-M, 2B Technologies, USA) with measurement errors of $\pm$ 0.01 and $\pm$ 0.05 NTU, respectively.

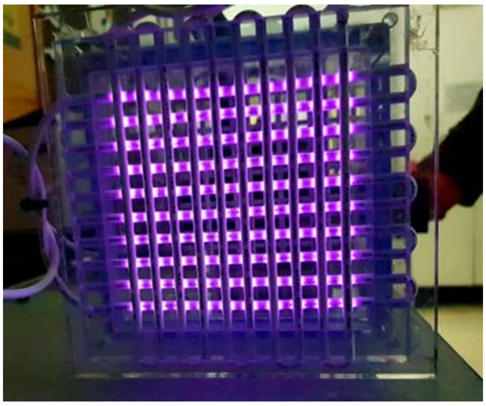

Fig. 2. Photograph of the flexible electrode DBD

## 3. Results and discussion

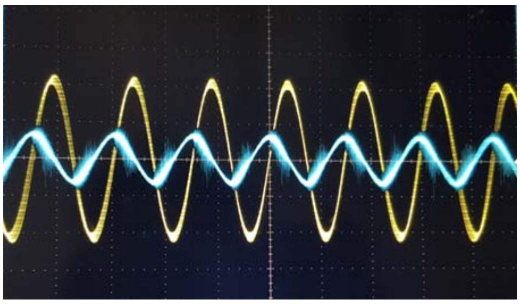

Fig. 3. Voltage and current waveform of the flexible electrode DBD

For the electrical analysis of the plasma, the DBD plasma using a flexible electrode wire was measured using an oscilloscope. Recorded voltage and current waveforms presented in Fig. 3 show that the discharge operates in a filamentary mode [10,11]. Amplitudes of the sinusoidal voltage of DBD at atmospheric pressure were $V_{rms}$ = 3.99 kV. Each half cycle is characterized by few tens of sub-microsecond current peaks. The measured current was $A_{rms}$ = 22.6 mA. These are expected features of such DBD discharge. As shown in Fig. 3, the power consumption was 90.174 W. The analysis result confirmed that the DBD plasma operated at a low power is stably discharged and maintained.

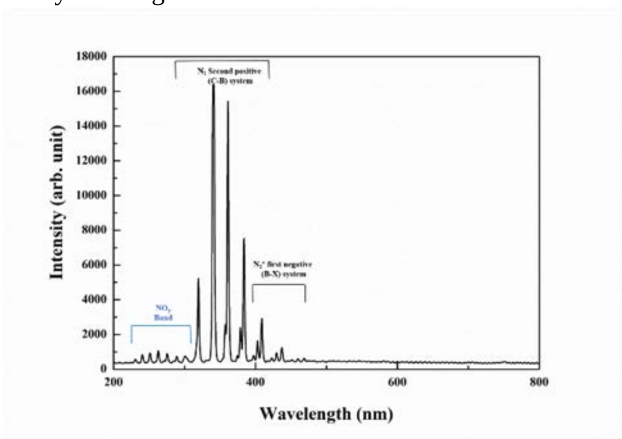


Fig. 4. Optical emission spectra of the flexible electrode DBD

Optical analysis of the DBD plasma was analysed through emission spectroscopy. Emission spectra for DBD in range of 200-900 nm are presented in Fig. 4. It is well known that the spectra of light emitted by DBD are dominated by emission bands originating from excited states of the $N_2$ molecules and $N_2^+$ ion. Fig. 4. Shows that spectral emissions are mainly visible in the 300-400 nm regions and most of the total light intensity is attributed to the nitrogen second positive system. The excited species of nitrogen and oxygen are expected in the DBD plasma [12,13,14]. However, only the $N_2$ second positive system and $N_2^+$ first negative system were found. The concentration of ozone generated from DBD was analysed by a potable ozone analyser, measured in real-time. The averaged concentration of ozone generated from stable DBD was 400-500 ppm. It is expected that ozone can be increased by adjusting the flow-rate of small fan or power.

Fig. 5 Show the treatment rate of mixed odor gas passing through the odor reduction system according to ozone treatment time. Odor decreased by about 70% after 20 min of exposure to the radicals generated in the plasma. The results confirm that ozone treatment of odor reduction system by DBD is effective for odor reduction.

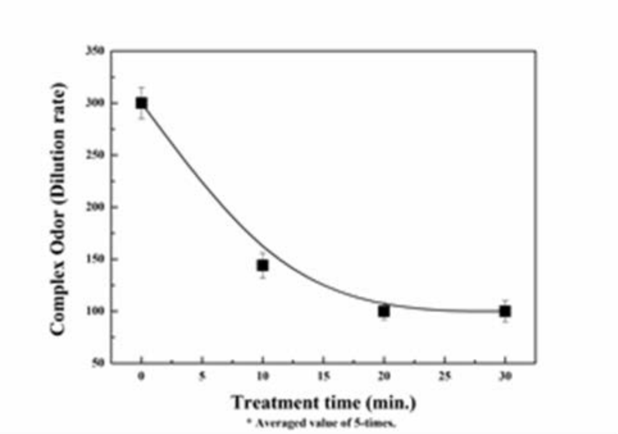

Fig. 5. Time dependent dilution rate of complex odor from 200A duct in a factory located in Daejeon, South Korea measured using the air dilution olfactory method

## 4. Conclusion

We developed an odor reduction system using flexible electrode DBD plasma in which a high concentration of ozone could be stably generated. In addition, the flexible electrode DBD has advantages of low installation cost, simple operation, installation anywhere. Electrical and optical characterization were conducted to analyze the developed DBD. As a result, the DBD plasma using a flexible electrode wire confirmed the generation of various ozone and active species at a low power consumption. We conclude that ozone treatment using DBD is effective method for reducing odor gas. In order to treat high concentration of odorous gases, we aim to develop odor reduction system of a high performance with improvement of electrode structure and reactor.

## 5. References

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