Plamsa Filter Development for Bioairosol Disinfection in Air Circulating System

J.Y. Park[1], K. H. Baek[1], J.-H. Choi[2], S. Lee[1,*]

[1] *Depertmemt of Nano-Bio Convergence, Korea Institute of Material Science, Changwon, Korea*
[2] *Depertmemt of Functional Ceramics, Korea Institute of Material Science, Changwon, Korea*

Abstract: This paper represents a method for genering a constant concentration of ozone in air circulating system using dielectric filer discharge (DFD). Airborne bacteria (*E. coli*, *M. luteus*) in air circulating system are removed with 99.99% of efficacyThe pressure drop is maintained under 200 Pa at 1 m/s of flow speed. This performance was maintained over 200 hours showing its durability. Also SARS-Cov-2 virus penetrating plasma filter are removed by 99.8%.

Keywords: Filter discharge, Ozone, Disinfection, Bioaerosol, Airborne bacteria.

1. Introduction

In recent years, demand for bioaerosol disinfection has increased due to COVID-19 pendamic. Various methods, such as UV, HEPA filters, and photocatalysts, have been tried to remove airborne bacteria, but each has serious drawbacks. UV and HEPA filters are mainly used in combination with each other to remove airborne bacteria collected in the HEPA filter, but the disadvantage that the surface of the HEPA filter is hardened by UV and microplastics are generated is pointed out. Photocatalysts can also sterilize only airborne bacteria collected on the surface of the catalyst, but have a disadvantage in that the collection efficiency is low. Therefore, if the sterilization plasma filter and the ozone removal catalytic filter are used together, all bio-aerosol passing through the flow path is removed, and concern about ozone emission can be reduced. In this paper, we propose a durable square-shaped dielectric filter discharge (DFD) plasma source capable of producing a wide range of ozone for air circulating system. Its performance was verified thorugh following methods. While the existing HEPA filter shows a pressure loss of 166 Pa, the DFD module shows a pressure loss of less than 20 Pa, so it is judged that it can be compatible with existing air conditioning facilities without difficulty. In addition, the amount of ozone produced and discharged ozone was kept constant for 300 hours, and durability was also verified. Moreover, the sterilization effect was verified while evaluating the amount of bacteria attached to the surface of the HEPA filter.

2. Material

The overall picture of the plasma filter performance evaluation system is shown in Figure 2. 1.5 m of airflow duct with cross section of 10 × 10 cm^2 was prepared. DFD source was located in the middle of the duct. Bioaerosol generator (ABG-1771, ART Plus) was conncected to the duct. DFD source structure are consisted of 2.5 mm diameter beads (ZrO_2, Al_2O_3) and two pinched electrodes. One of the electrodes was connected to a resonant power supply with a 40 kHz, and the other was connected to the ground. Monolith typed ozone catalyst with 400 cpsi (channels per square inch) was installed 10 cm behind the DFD source, and airborne bacteria capture filter (HEPA, OA-AP003) is located between DFD and ozone catalyst. The flow speed of duct was controlled upto 1 m/s, and gas analyser (O_3, NOx) are connected through sampling port. The laboratory air condition was fixed near 25°C and 60% of relative humidity. Surface damage of HEPA filter due to ozone is investigated using FT-IR (IS10, Thermo Scientific). Bactericidal effect on HEPA filter was evaluated by dissolving into a 0.1 M phosphate-buffered saline solution. Also, virus sterilization effect using SARS-Cov-2 was conducted miniature model imitating this duct flow system.

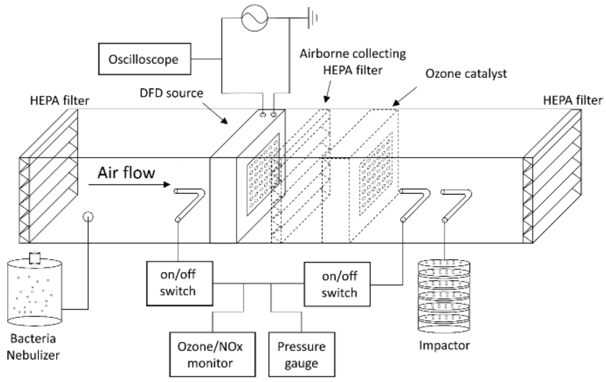

Fig. 1. Schematic of experimental setup

3. Results and discussion

The two type of DFD modules consist of ZrO_2 (ε_r=16.7) and Al_2O_3 (ε_r=9) beads have different amounts of ozone generation as much as their permittivity is different. In the case of ZrO_2, discharge breakdwon from about 2 kV, while Al_2O_3 breakdown from about 3.5 kV. However, the dissipated power was early saturated in ZrO_2 case. Thus , as shown in Figure 2, ZrO_2 DFD uniformly discharged at 2.5 kV, but in Al_2O_3, the discharge region is non-uniform even though 5 kV is connected.

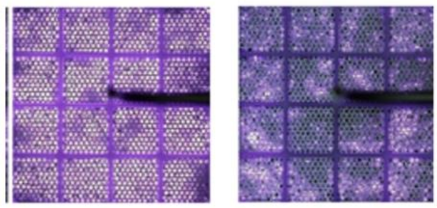

Fig. 2. Actual photograph of discharge pattern in ZrO_2 (left) and Al_2O_3 (right) DFD

If the power consumption is similar, the amount of ozone produced (obtained by the Lissajous diagram) is about twice as high as that of ZrO2 in alumina. This difference also greatly affects the amount of ozone produced. Contrary to expectations, the amount of ozone produced from Al_2O_3 is saturated at 3 ppm, which is three times higher than ZrO_2 which generates 1 ppm showing effective driving. In particular, these two cases have similar dissipated power ,7 W. Therefore, it is understood that this difference is a result of power density.

In addition, the concentration of ozone becomes saturated as soon as it reaches the maximum value, which is thought to be because the DFD surface temperature is formed very low due to the gas passing through the filter quickly, preventing the decomposition of ozone.

In order to use it in real life, the issue of ozone emission must also be verified. Therefore, when about 0.5 ppm of ozone was input, the ozone concentration discharged through the ozone catalyst was measured, which is shown in Fig. 3.

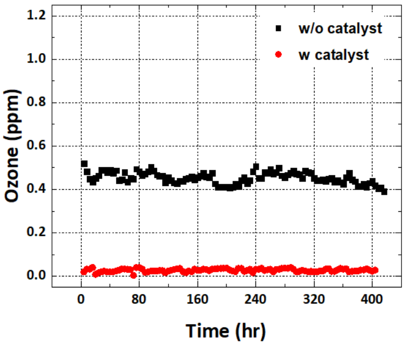

Fig. 3 Ozone generation durability until 400 hours with ozone removal catalyst

Ozone discharged through the catalyst maintains about 0.02 ppm, which satisfies the WHO standard, so it is expected that there will be no major problem.

The sterilization ability of this DFD was verified in the following method. The HEPA filter for floating bacteria capture are unified, and captured bacteria was exposed to the ozone. As varing exposure time, the bactericidal effect on the HEPA filter was examined. The removal of HEPA filter surface bacterai means that the utilization of DFD presupposes a unified product with HEPA filter.Thus the bactericidal effects also evaluated using HEPA filter and DFD together.

According to the Fig. 4, the bacteria removal effecicacy of the HEPA filter is shown to be about 4 Log CFU/cm^3 filter for both microorganism. The HEPA filter-attached *E. coli* was reduced by approximately 0.6 log CFU/cm^3 during plasma treatment. Moreover, more 10 min of DFD driving time after nebulizing showed a further bactericidal effect of approximately 1.13 log CFU/cm^3 filter. However, in case of *M. luteus*, it was reduced by 0.4 log CFU/cm^3 filter and 0.50 log CFU/cm^3 filter compared to those of control group during 10 min and 20 min of DFD plasma treatment, respectively. [1]

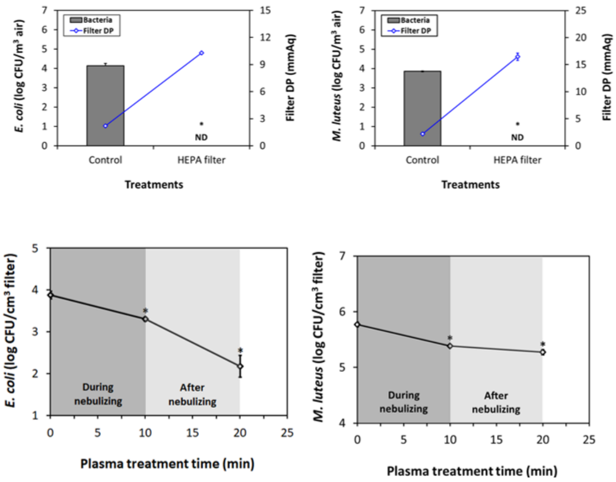

Fig. 4. Removal of attached bacteria (E. coli, M. Luteus)

Evaluation of sterilization effect using SARS-Cov-2 virus should be handled in Bio-safety lever 3. Thus, miniature of this duct flow system are prepared for SARS-Cov-2 experiment (Fig. 5). In this experiment, since the internal volume was small, the ozone concentration exceeded 0.5 ppm and was maintained at about 3 ppm. At that condition, the SARS-Cov-2 was removed by 1.94 Log PFU/cm^2.

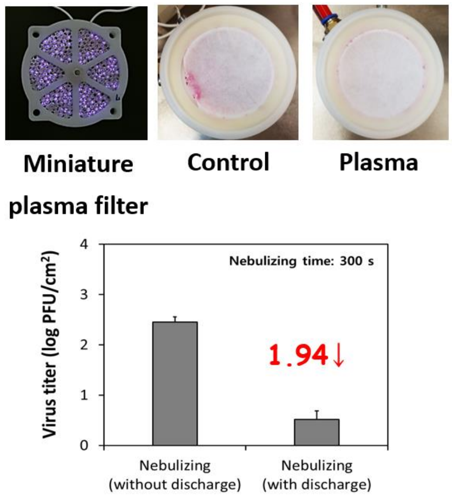

Fig. 5 SARS-Cov-2 bioaerosol disinfection removal ability.

4. Conclusion

The most important points in attempting air disinfection with plasma technology are (a) durability of ozone generation and its emission, and (b) compatibility with exsiting air flow duct, and (c) verification of floating bacteria sterilization performance. Durability was demonstrated by showing ozone generation in range from7 0.5 ppm to 3 ppm within about 10% error range for 400 hours. Also emission ozone concentration through ozone catalyst is controlled less than 0.02 ppm, which is safe level recommended by WHO. The pressure drop due to DFD (16 Pa), which is only 10% compared to the existing HEPA filter, is considered to be excellent in compatibility as it does not impose excessive pressure on the existing air flow duct. Continuous DFD plasma treatment showed effective sterilization against filter-attached bacteria including *E. coli* and *M. Luteus* in low level ozonge generation mode. In miniature air flow duct model, high level ozone generation mode was examined using SARS-Cov-2 virus, showing 1.94 Log PFU/cm^2 sterilization ability. According to above three characteristics, it is expected that it will be of great help to plasma technology and airborne quarantine in case of air purifiers development using this air duct.

5. References

[1] J. Y. Park, Current Applied Physics, **41**, 100-110 (2022).