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Air Modification Apparatus by Using a UV Lamp and Corona Discharge

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ABSTRACT: An air modification apparatus was developed by using a UV lamp and two sets of corona discharge electrode pairs (UV2C). This apparatus works with no fan, and decomposes volatile organic compounds in air where the concentration of exhausted ozone is very low. The apparatus generates nitrogen oxide and collects dust in the air. The modification of air increases the quality of human daily life. The decontamination to the air was performed by using a simple atmospheric discharge system.

KEY WORDS: atmosphere; air modification; VOC; ozone; nitrogen oxide; particulate matter

I. INTRODUCTION

Air pollution is hazardous for human life. Particulate matters smaller than 2.5 μm (PM2.5)[1] and volatile organic compounds (VOC)[2] are important factors in indoor air pollution. Thus, reduction techniques for VOC and PM2.5 from the air are intensively studied.

For reduction of PM2.5, high-efficiency particulate air (HEPA) filters are effective.[3] Sucking air with fans and adsorbing small particulates on filters are effective, and these apparatuses are used in semiconductor factories and mycology laboratories. These apparatuses and techniques are expensive and they consume electricity and require maintenance.

It is well known that corona discharge reduces dust and allergens in the air.[4] The corona discharge technique is not expensive; however, it generates high-density ozone. In the case of indoor use, ozone generation is hazardous.

In this study, we developed an apparatus for reduction of PM2.5 and VOC with less ozone production by using simple techniques. Neither fan nor filter is required. The purpose of this study is air modification to increase the quality of human daily life. The apparatus cleans air by collection of dust, decomposes VOCs, and generates NOx without generating ozone. Decontamination of air was performed by using a simple atmospheric discharge system.

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II. STRUCTURE OF APPARATUS

This air modification apparatus consists of a UV lamp and two sets of corona discharge electrode pairs (UV2C).[5] The structure of UV2C is shown in Fig. 1. A set of corona discharge electrode pairs is situated at the upstream section of a wind tunnel. In this electrode pair, –10 kV is applied to the negative electrode. The negative electrode is situated in the 3-cm upper stream to the ground electrode. The anion generated with the negative electrode is accelerated toward a ground electrode. Ion wind occurs thereby and air flows to the lower stream in the wind tunnel. A UV lamp using discharge of mercury (wavelength: 254 nm) is installed in the central portion of the wind tunnel. By this, ozone is formed. The ozone formed here is carried by the ion wind to the second corona discharge electrode pair, which is located in the flow next to the UV lamp. In the second corona discharge electrode pair, electrons are emitted, ozone is decomposed, and reactive oxygen species are formed. The half-life of ozone is as long as 30 min or more,[6] and reaction time for the ozone in the wind tube is short. Ozone that was not reacted was exhausted to the atmosphere. The residual ozone is hazardous to a human body. However, when this ozone changes to reactive oxygen species, they can be short-lived and can decompose the organic compounds in the air more effectively. Ozone concentration becomes low, as a result the safety to a human body is secured. Change of the ozone concentration at the time of operating within a 48-L container is shown in Fig. 2. In this case, even if it made it operate, it did not exceed 1 ppm for a long time. When operation of this apparatus is performed in a room bigger than 1 m^3, it turns out that ozone concentration does not exceed 0.05 ppm. The regulation for limiting ozone emission from indoor air cleaning devices by California State is 0.05 ppm.[7] Therefore, the ozone concentration is low enough for human life.

The aperture of the wind tunnel was 10 cm^2, and wind velocity was 3 cm/s. In Fig. 2, nitrogen oxide is also observed. It seems that it was formed since the ozone collapsed

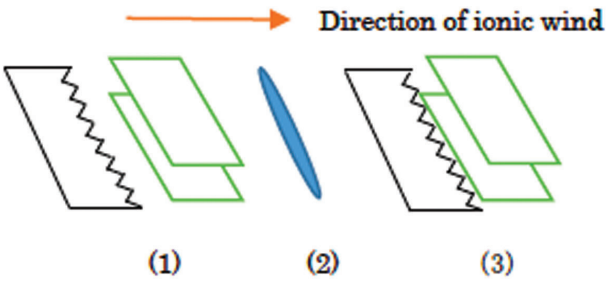

FIG. 1: Schematic illustration of the air modification apparatus using a UV lamp and two sets of corona discharge electrode pairs (UV2C). These are set in the wind tube. (1) Corona discharge electrodes. Ionic wind is generated. (2) UV lamp generates ozone. (3) Corona discharge electrodes emit electrons. The ozone is destroyed to form oxygen radicals

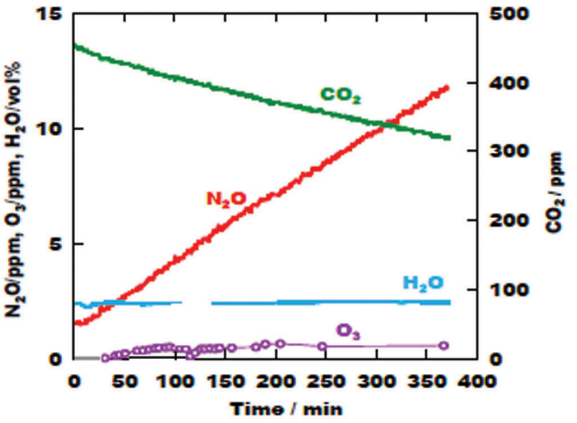

FIG. 2: Measurement of exhaust of UV2C. Ozone concentration is lower than the regulation of indoor air. Nitrogen oxide is also produced

to reactive oxygen species and reacted to molecular nitrogen. Tsutsui et al. reported that nitrogen oxide, absorbed by mammals, caused the peripheral vasodilation and a reduction in blood pressure.[8]

III. DECOMPOSITION OF ORGANIC COMPOUNDS

Reactive oxygen species are generated by a UV lamp and two sets of corona discharge electrode pairs, and are emitted by the ion wind from the exit of a wind tunnel. In order to investigate the effect of reactive oxygen species generated, the UV2C was operated in a 48-L PMMA chamber with semiconductor sensors and electrochemical sensors. For this investigation, ethylene, acetaldehyde, hydrogen sulfide, and methyl mercaptan were introduced into the chamber. These organic compounds are known as volatile organic compounds (VOCs), and they are hazardous for humans.

These introduced gases were decomposed by UV2C in the PMMA chamber, and the concentration of each gas was monitored by the sensors. The results of decomposition are shown in Fig. 3. When UV2C does not work, the concentration of VOCs was not reduced. However, the VOCs were reduced when UV2C worked. These results revealed that UV2C is effective for the decomposition of VOCs.

IV. DUST COLLECTION

Since the UV2C has corona discharge electrode pairs, dust collection is possible. The dust collection from air was examined by a particle counter KR-12A (RION Co. Ltd)

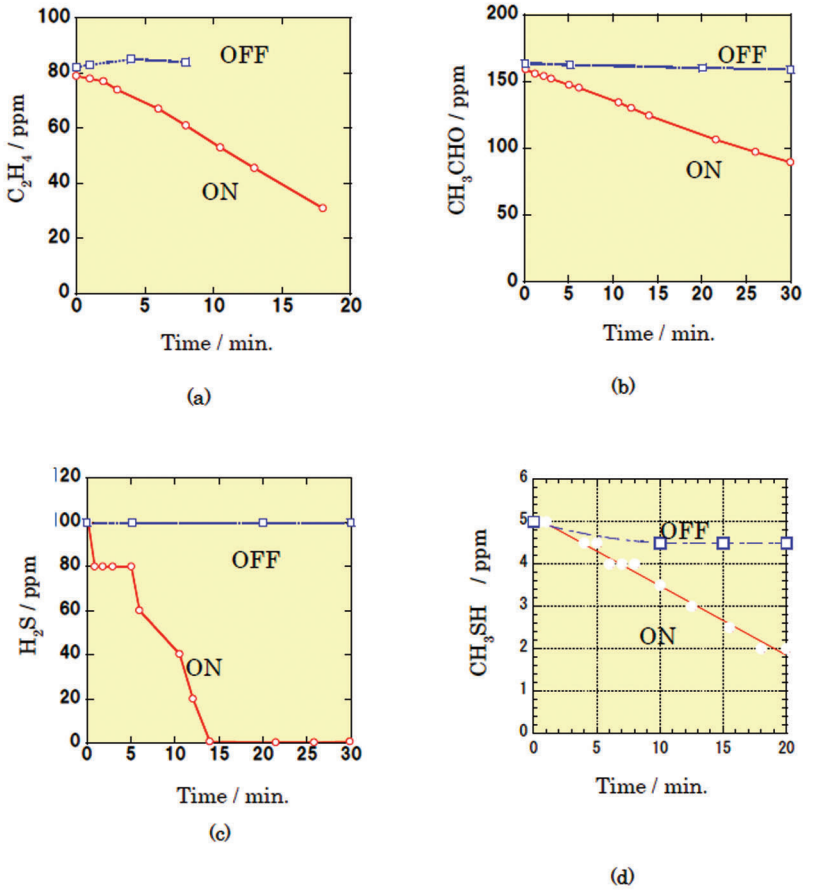

FIG. 3: Reduction of organics (a) C_2H_4, (b) CH_3CHO, (c) H_2S, and (d) CH_3SH by using the UV2C. "ON" represents UV2C working, and "OFF" represents UV2C not working for comparison

TABLE 1: Reduction of particulate matter by the UV2C

Class of particulate matter/μm	Number of PM in atmosphere/L	Number of PM in exhaust/L	Reduced rate
>0.3	82034	16564	0.8
>0.5	5435	807	0.85
>0.7	1516	160	0.89
>1	761	57	0.93
>2	296	10	0.97
>5	46	0	1

in a factory at AIST-Kansai Campus, Osaka, Japan. The measurement was performed in every class divided by the particle size. The measured results are shown in Table 1. Reduction rates of dust for each class were calculated by the reduced dust amount in the exhaust of the UV2C divided by the dust amount in the air. While the efficiency of dust reduction depends on the particle size, the merit of this technique is clear.

V. CONCLUSION

An air modification apparatus by using a UV lamp and two sets of corona discharge electrode pairs (UV2C) was developed. Operation of this UV2C reduces volatile organic compounds and particulate matter in the air. The reduction effect is higher for larger dust. Ozone concentration generated by this system is lower than the limit set by the regulations. Neither fan nor filter is required. This technology is simple and has practical advantages.

REFERENCES

1. Wichmann J, Lind T, Nilsson MA-M, Bellander T. Atmos Environ. 2010;44:4536–44.
2. Sakai K, Norbäck D, Mi Y, Shibata E, Kamijima M, Yamada T, Takeuchi Y. Environ Res. 2004;94:75–85.
3. Eggleston PA, Butz A, Rand C, Swartz L, Callahan K, Curtin-Brosnan J, Merriman B, Huffman M, Breysse P, Buckley T, Diette G, Krishnan J, Kanchanaraksa S. J Allergy Clin Immunol. 2004;113:S179.
4. Goodman N, Hughes JF. J Electrostat. 2004;60:69–91.
5. Kiuchi M, Matsutani T, Sakurai H, Tokuda K. PCT/JP2004/002283.
6. McClurkina JD, Maierb DE, Ileleji KE. J. Stored Prod Res. 2013;55:41–47.
7. Regulation for limiting ozone emissions from indoor air cleaning devices. Available from: http://www.arb.ca.gov/research/indoor/aircleaners/air-cleaner-regulation.pdf.
8. Tsutsui C, Lee M, Takahashi G, Murata S, Hirata T, Kanai T, Mori A. Jpn J Appl Phys. 2014;53:060309.