Basic Study on Simulated Indoor Air Treatment by Atmospheric Microplasma

大気圧マイクロプラズマを用いた模擬室内空気の浄化の基礎研究

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1. INTRODUCTION

Microplasma has advantages of reducing the power and downsizing the entire plasma system, compared to other atmospheric plasmas. It is generated in atmospheric pressure at only around 1.0 kV since its discharge gap is especially small.

We investigated capability of whether microplasma can removed volatile organic compounds (VOCs).

2. ATMOSPHERIC MICROPLASMA REACTOR

The microplasma reactor is shown in Fig. 1. A pair of punching metal plates covered with dielectric layer are used as microplasma electrodes.

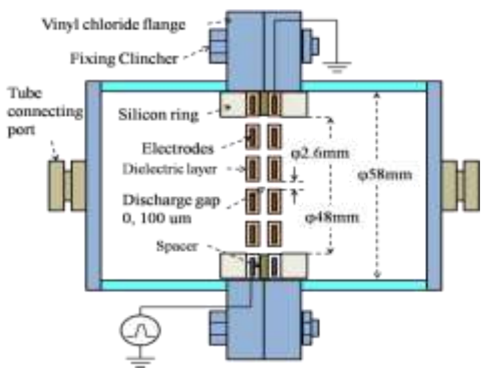

Fig. 1 Schematic image of microplasma reactor.

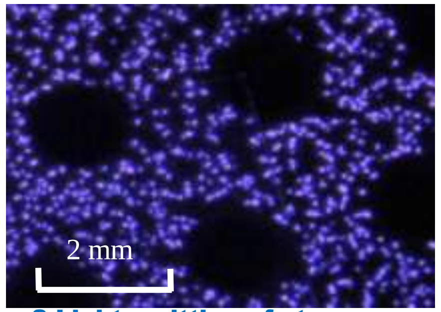

Fig. 2 Light emitting of streamers on microplasma electrode (680 V).

Microplasma is a typical dielectric barrier discharge. The image of Light emitting of streamers is shown in Fig. 2.

3. EXPERIMENTAL SETUP

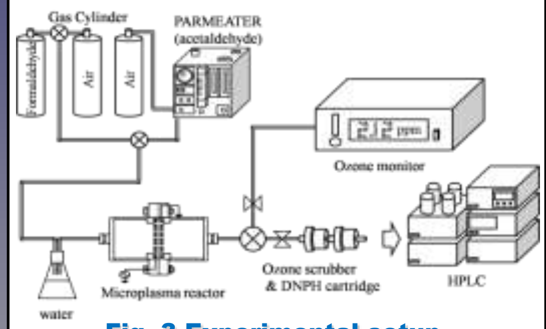

Fig. 3 Experimental setup.

Formaldehyde (HCHO) and acetaldehyde (CH_3CHO) are the target as the typical VOCs gas.

Table 1 Parameters of experiments.

CH_3CHO gas flow rate [L/min.]	2.35
HCHO gas flow rate [L/min.]	5.00
CH_3CHO and HCHO Analysis method	DNPH-HPLC method
Ozone Analysis	Ozone monitor

4. Results and discussion

4.1 Treatment of CH_3CHO

Table 2 Experimental parameters.

Power supply	Neon transformer
Discharge gap [um]	0
Initial concentration of CH_3CHO [ppm]	0.48
Humidity [%]	55

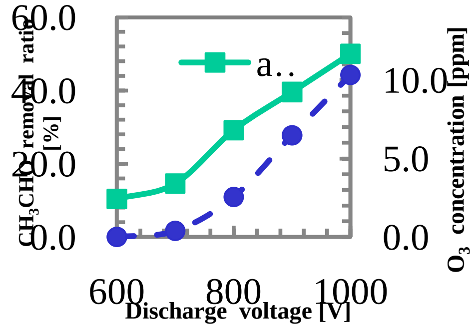

Fig. 4 Removal ratio of CH_3CHO and O_3 concentration at 0 um.

Table 3 Experimental results of CH_3CHO treatment.

Maximum removal ratio [%]	50
Discharge voltage of maximum treatment ratio [kV]	1

Even at low discharge voltage (600 V, 700 V) with very small amount of ozone production (0 ppm ~ 0.39 ppm), the removal ratio was 10.4 % to 14.6 %, the removal amount of 0.05 ppm to 0.07 ppm was obtained.

4.2 Treatment of HCHO

Table 4 Experimental parameters.

Power supply	Pulse generator and High Voltage Amplifier
Discharge gap [um]	100
Initial concentration of HCHO concentration [ppm]	The value at 800 V
Humidity [%]	0 and 55

Indoor concentration of HCHO is regulated to 0.08 ppm by MHLW.

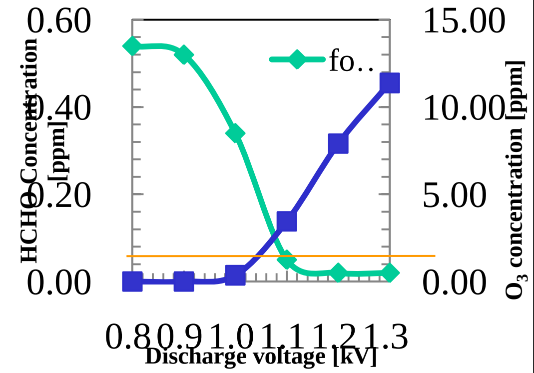

Fig. 5 HCHO and O_3 concentration. at Humidity of 0 %

HCHO was treated with low concentration of ozone without humidity.

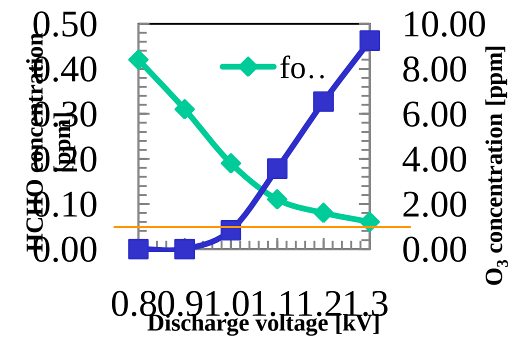

Fig. 6 HCHO and O_3 concentration at Humidity of 55 %.

Removal of HCHO was slightly lower compared to without humidity.

Table 5 Experimental results of HCHO treatment.

Discharge voltage which HCHO decrease under 0.08 ppm [kV]	1.1 (Hum. 0%)
	1.2 (Hum. 55 %)

4.3 Analysis of chemical reaction

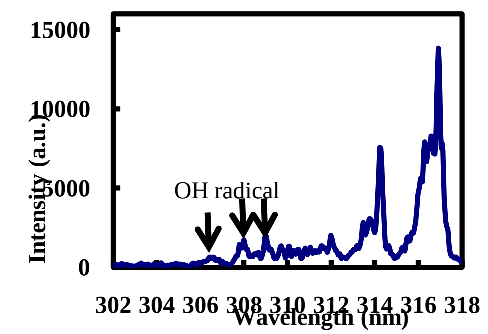

Fig. 7 OH radical peak measured by ICCD camera.

CH_3CHO and HCHO was treated with various radicals (N*, O*, OH*, etc) which were produced by microplasma. The peak of OH radical it is shown in Fig.7.

The chemical reaction process which treat CH_3CHO and HCHO are defined by the following chemical formula.

The process of product O_3 and OH radical [1]

$$O_2 + e \rightarrow O + O + e \qquad H_2O + e \rightarrow OH + H + e$$

$$O + O_2 + M \rightarrow O_3 + M \qquad O + H_2O \rightarrow 2OH$$

The process of treatment CH_3COOH and HCHO by O_3 and OH radical [2, 3]

$$CH_3CHO + OH \rightarrow CH_3CO + H_2O$$

$$CH_3CO + O_2 + M \rightarrow CH_3C(O)OO + M$$

$$CH_3C(O)OO + NO_2 + M \rightarrow CH_3C(O)OONO_2 + M$$

$$HCHO + O \rightarrow HCO + OH$$

$$HCHO + OH \rightarrow HCO + H_2O$$

$$HCO + O \rightarrow CO_2 + H$$

$$HCO + O \rightarrow CO + OH$$

$$HCO + OH \rightarrow H_2O + CO$$

$$HCO + O_3 \rightarrow H + O_2 + CO_2$$

5. CONCLUSIONS

(1) CH_3CHO was decomposed by atmospheric microplasma within a range of discharge voltage from 600 V to 1000 V at 0um discharge gap . CH_3CHO removal ratio at 600 V was almost 10 % without ozone production, and at 1000 V reached 50 %.

(2) HCHO was decomposed by atmospheric microplasma. The HCHO concentration was decreased below 0.08 ppm at 1.1 kV without humidity. And HCHO was decreased below 0.08 ppm at 1.2 kV with humidity at 100 um discharge gap.

(3) Atmospheric microplasma technology could treat CH_3CHo and HCHO which are typical VOCs gases with the various radicals. In this study, the efficiency of microplasma was shown.

REFERENCES

[1] E.Uhde, T. Salthammer, Atmospheric Environment, Vol. 41, pp. 3111-3128, (2007)

[2] H. Ding, A. Zhu etc, Journal of phisics D: Applied physics, vol. 38, pp. 462-467, (2005)

[3] D. Storch, M. Krushner, Journal of Applied Physics, vol. 73, No.1, pp.51-55, (1993)