Large volume treatment of formaldehyde using atomospheric microplasma

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1.Introduction

Recently, Indoor Air Quality (IAQ) is recognized as an important factor of houses and buildings. This point of view emerged since Sick-building syndrome (SBS) has become a worldwide issue.

In this paper, decompositon of HCHO was carried out by using atmospheric microplasma at high volume flow rate in order to confirm the effectiveness of microplasma for large volume treatment.

2. Atmospheric microplasma

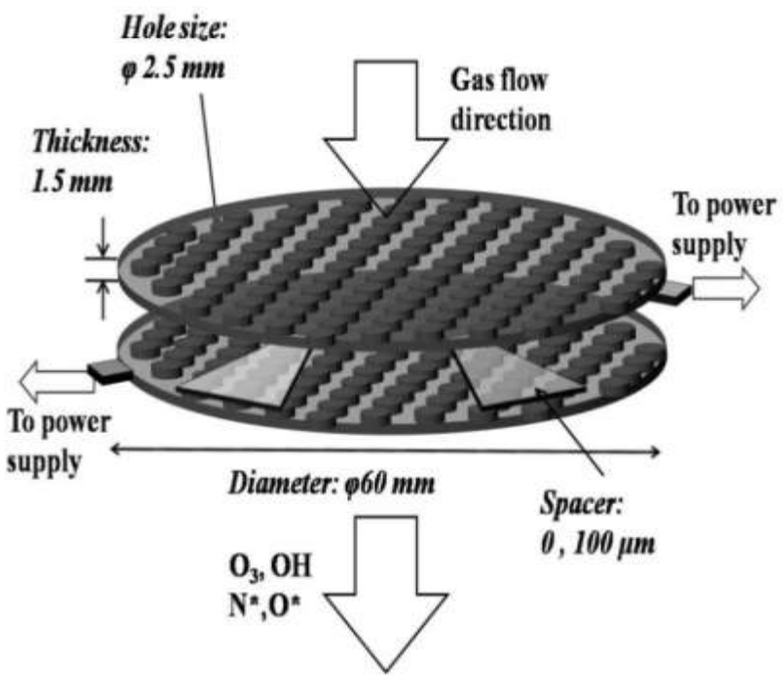

Fig.1 Schematic image of microplasma electrode.

Atmospheric microplasma is a kind of dielectric barrier discharge which has a discharge gap in the order of micro meters. A schematic image of the miroplasma electrode is presented in Fig.1.

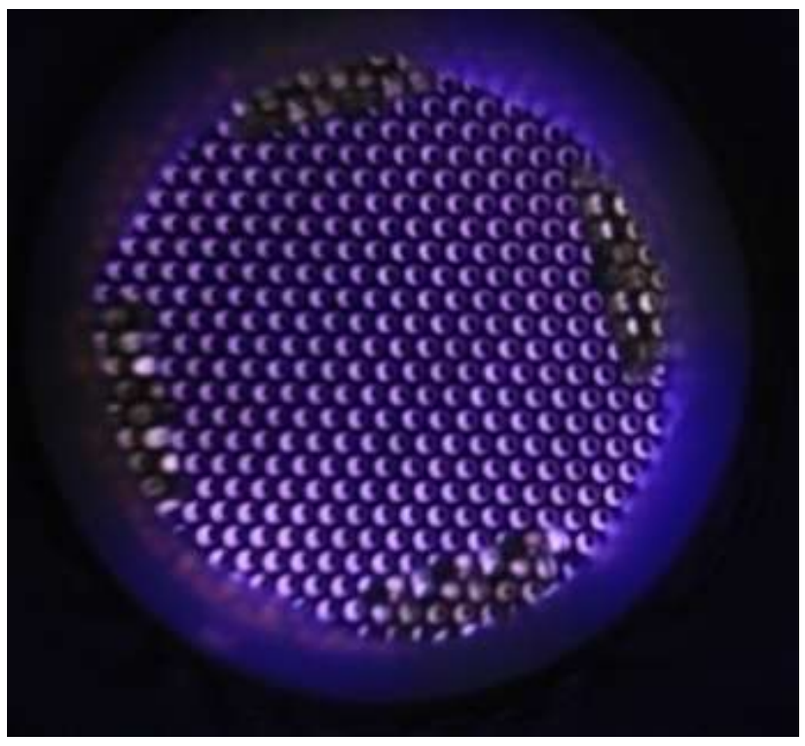

Fig.2 Image of microplasma during discharge.

Two metal circular plates covered with dielectric materials are placed together with a spacer in between. By applying an alternative voltage, streamers generate to form glow-like plasma (Fig.2).

3. Experimental setup

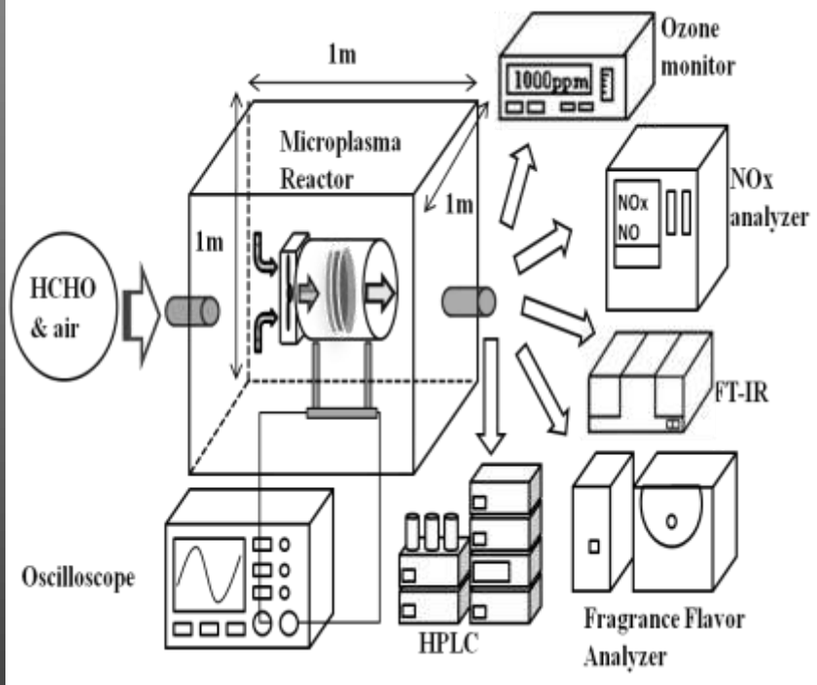

Fig.3 Experimental setup

Fig.3 shows the experimental setup. This microplasma reactor is placed inside a 1 m^3 acrylic cube. The fan flows the surrounding air through the electrode at a flow rate of 0.1~0.5 m^3/min. A neon transformer was used as the power source for microplasma. Its maximum output voltage was 1.3 kV at a frequency of 25 kHz.

4. Results and discussion

4. 1 Formaldehyde decomposition

The concentration of HCHO was estimated by the DNPH method using the HPLC. The initial HCHO concentration was set to about 1.25 mg/m^3(1 ppm) which is about 10 times higher than the regulated value in Japan.

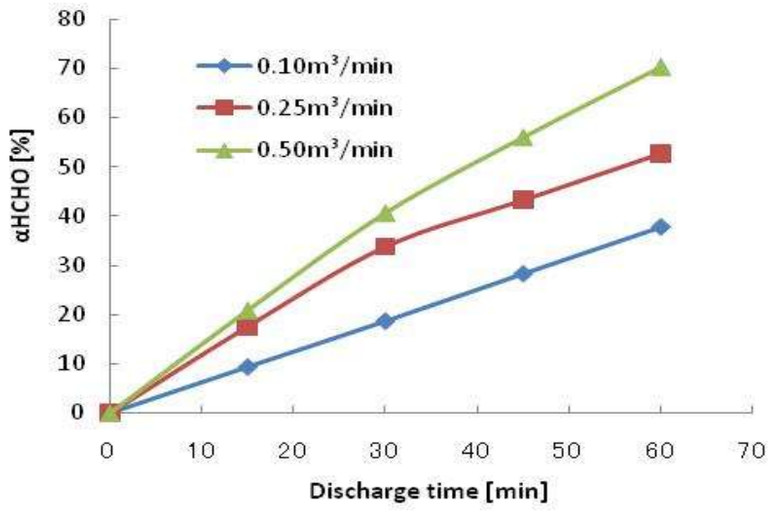

Fig.4 HCHO removal ratio versus discharge time for various gas flow rates.

Fig.4 shows the results of the HCHO decomposition using microplasma. Removal ratio of HCHO (αHCHO) was calculated by the equation below.

$$\alpha HCHO\,[\%] = \frac{\Delta HCHO\,[\mu g/m^3]}{\text{Initial HCHO}\,[\mu g/m^3]} \times 100$$

(ΔHCHO: Decreased amout of HCHO per 15 minutes.)

In order to compare the effectiveness with the same condition, the decomposed amount of HCHO per 1m^3 of circulated air (ηHCHO) was calculated by the equation below.

$$\eta HCHO\,[\mu g/m^3] = \Delta HCHO[\mu g/m^3] \times \frac{1[m^3]}{\Delta Q[m^3]}$$

(⊿Q: Circulated volume of air per 15

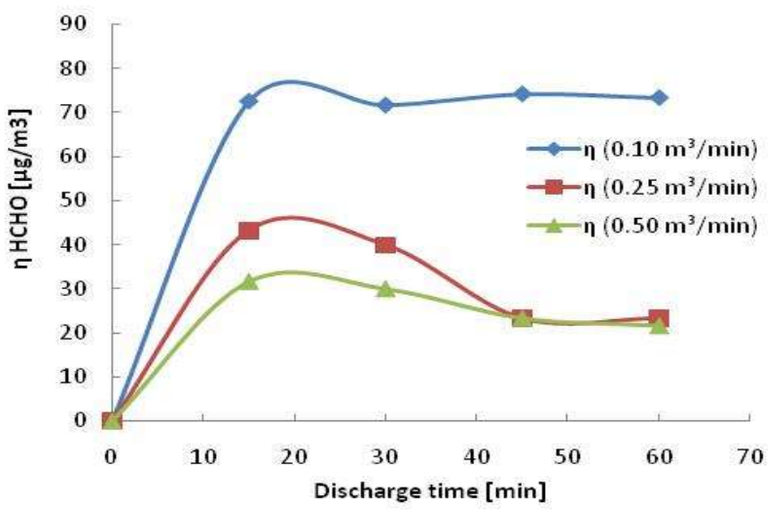

Fig.5 HCHO removal amount per 1 m^3 versus discharge time for various gas flow rates.

Fig.5 shows ηHCHO during with the discharge time. ηHCHO were higher with lower gas flow rates since the exposure time in plasma decrease at higher flow rates.

4.2 Byproduct Analysis

A byproduct analysis is carried out by the FT-IR. For this analysis, the initial concentration of HCHO is set to about 10 ppm, in order to make the spectrums larger for identification. The gas flow rate was set to 2 L/min, and the humidity was set to 60%. The discharge voltage was change between 0.6 ~ 1.0 kV.

Figs.6 and 7 show the analysis results at different wavenumber ranges.

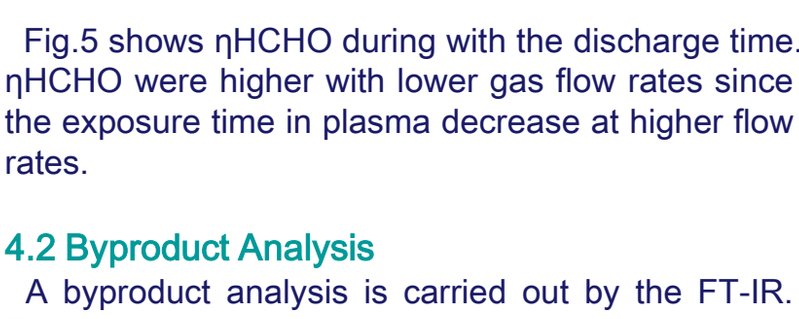

Fig.6 Byproduct analysis by the FT-IR (wavenumber: 2080-2300 [cm^{-1}])

From the analysis results, carbon dioxide, carbon monoxide, and nitrous oxide were discovered as byproducts without humidity.

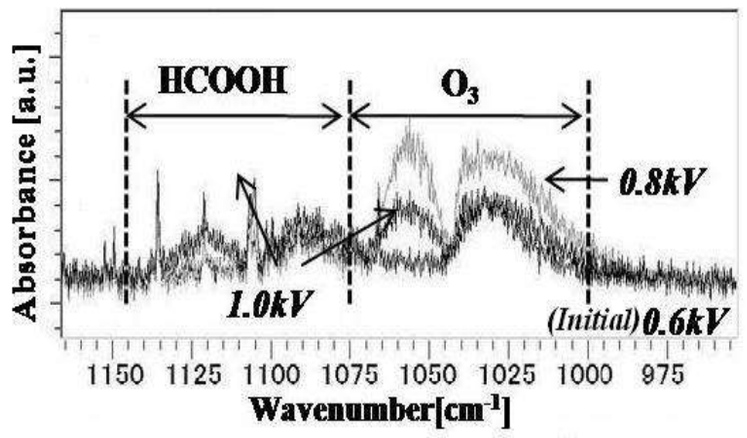

Fig.7 Byproduct analysis by the FT-IR (wavenumber: 950-1200 [cm^{-1}]).

Table.1 Byproduct concentration.

V_D [kV]	NOx [ppm]	N_2O [ppm]	CO [ppm]
0.6	0.6	0.6	1.2
0.8	7.4	2.4	8.2
1.0	24.0	9.1	10.5

Table.1 shows the byproduct concentrations. Byproduct concentrations increase with the increase of discharge voltage. CO concentration exceeded 10 ppm. This could be because some CO_2 was dissociated by electron collision. CO derives mostly from the decomposition of HCHO.

4.3 Smell Analysis

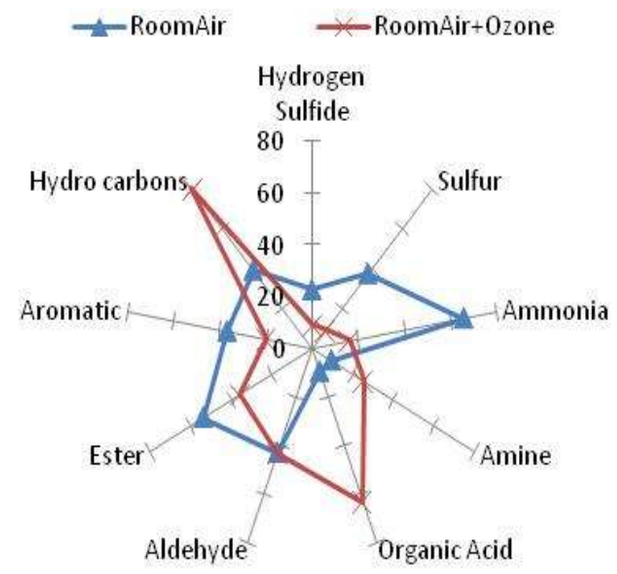

Fig.8 Smell similarity analysis of room air and ozone by Fragrance Flavor Analyzer.

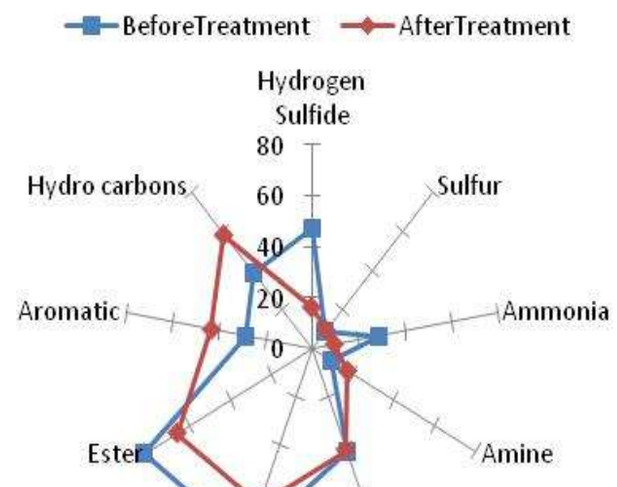

Fig.9 Smell similarity nalysis of HCHO before and after microplasma Treatment.

The smell similarity of room air and ozone is presented in Fig. 8, and the similarity of HCHO before and after microplasma treatment is shown in Fig. 9.

5. Conclusion

In this study, treatment of 1 ppm of formaldehyde in a 1m^3 cube with large volume flow rate (0.10 ~ 0.50 m^3/min) was confirmed by atmospheric microplasma. The following conclusions were obtained by the series of experiments.

(1) A removal ratio of 70% was achieve at a discharge voltage of 1.0 kV, discharge power 20W, gas flow rate 0.50 m^3/min and discharge time of 60 min.

(2) Removed amount of formaldehyde per 1 m^3 was calculated for various gas flow rates. About 70 μg/m^3 was obtained for gas flow rate of 0.10 m^3/min.

(3) Byproduct analysis was carried out with the FT-IR. N_2O, CO, and HCOOH were found as byproducts, when initial concentration of HCHO was set to 10 ppm.

(4)Smell analysis was carried out with the Fragrance Flavor Analyzer. Smell similarity has changed after microplasma treatment, and it is mainly the smell of remaining ozone.