Study of Wastewater Purification by Atmospheric Microplasma

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Introduction

In recent years, associated with industrial development, water pollution became a serious problem. Plasma could be used as water treatment technology such as decomposition of organic compound and sterilization of bacteria.

Conventional technologies requires expensive processes or the usage of chemicals for water treatment. Microplasma is an ecological and economical technology to be applied for water treatment due to the low cost and low discharge voltage.

Methods

Microplasma Electrode and Mechanism

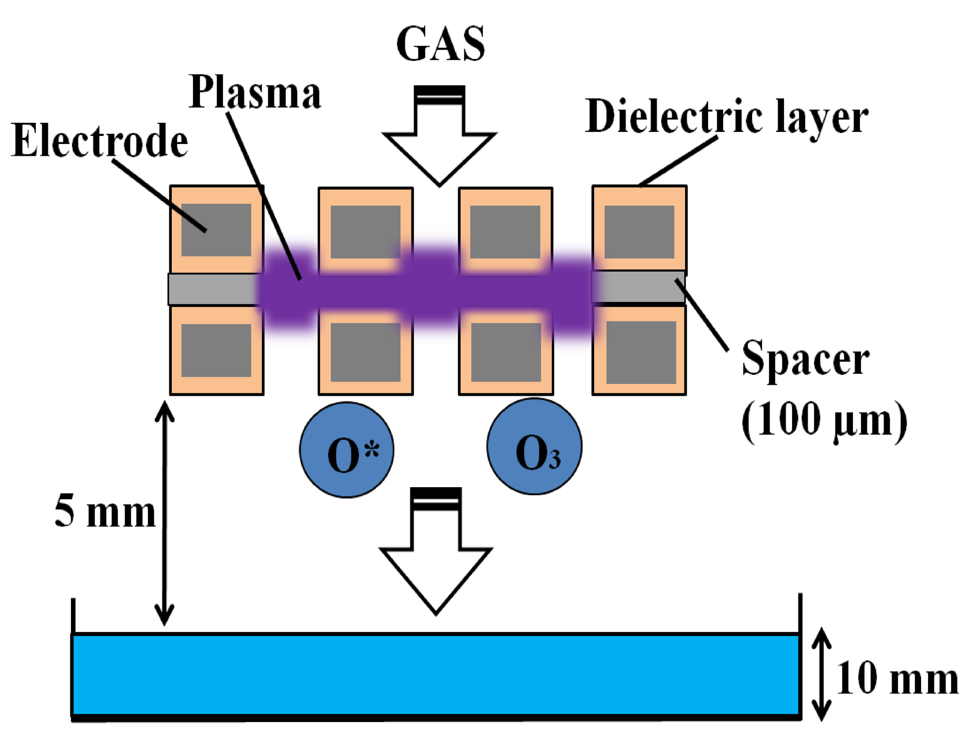

Fig. 1 Mechanism of water treatment by microplasma.

Microplasma electrodes are perforated metallic plates covered with a dielectric layer and faced together with a spacer of 100 μm as shown in Fig. 1.

Microplasma electrodes were placed at small distance above the water thus gas is flown towards the water surface to react with the target to be decomposed. Various active species such as ozone, OH radical etc. were generated by microplasma[1].

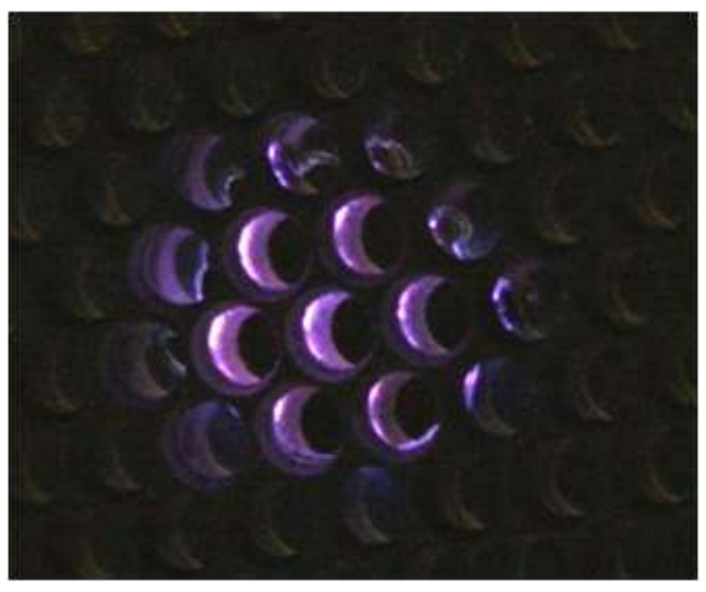

Fig. 2 The emission during discharge(Vd=1 kV).

Microplasma is a typical dielectric barrier discharge. The image of microplasma discharge is shown in Fig. 2.

Experimental Setup

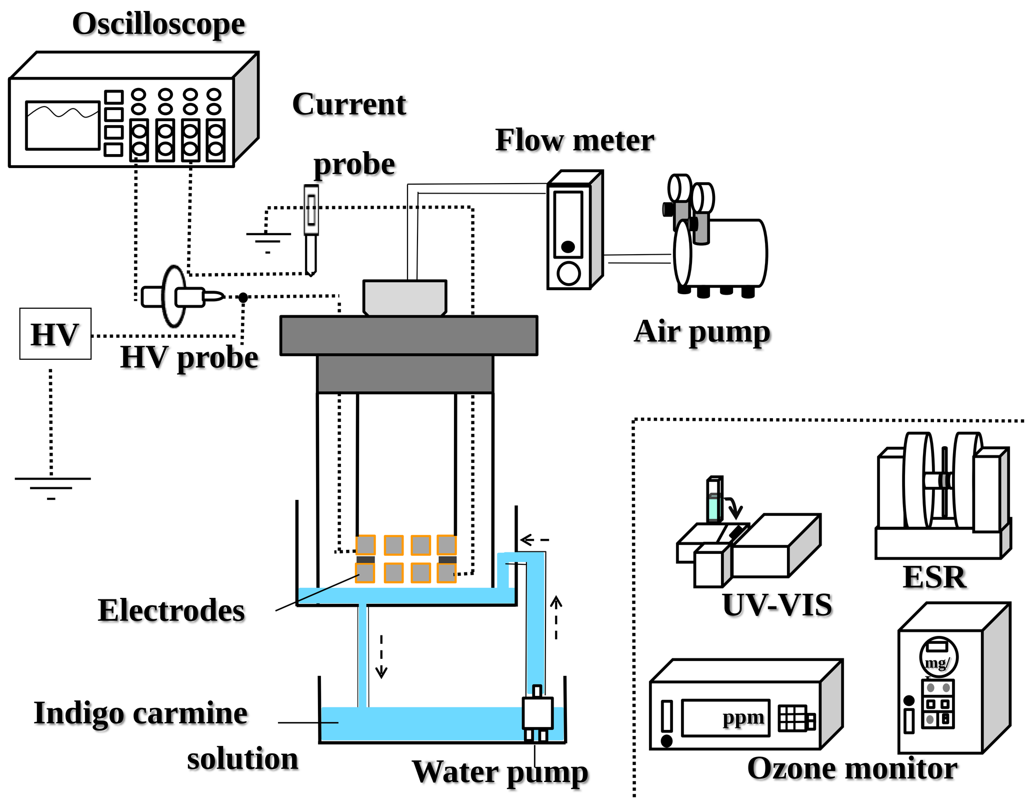

Fig. 3 An experimental setup.

Table.1 Experimental parameters.

Power supply	AC
Carrier gas	Air
Flow rate [L/min.]	10
Target	Indigo carmine
Concentration [mg/L]	10
Treatment volume [ml]	200

A neon transformer was used as the AC high voltage power supply. The carrier gases were supplied in case of the air from an air pump and in case of N_2, Ar and O_2 from gas cylinders. It flows above the reactor and pass through the holes of electrodes. Indigo carmine was used as the target to be decomposed. The treated sample was analyzed by UV-VIS, ozone monitor and ESR(Electron Spin Resonance).

Results

(1) Observation of indigo carmine absorbance

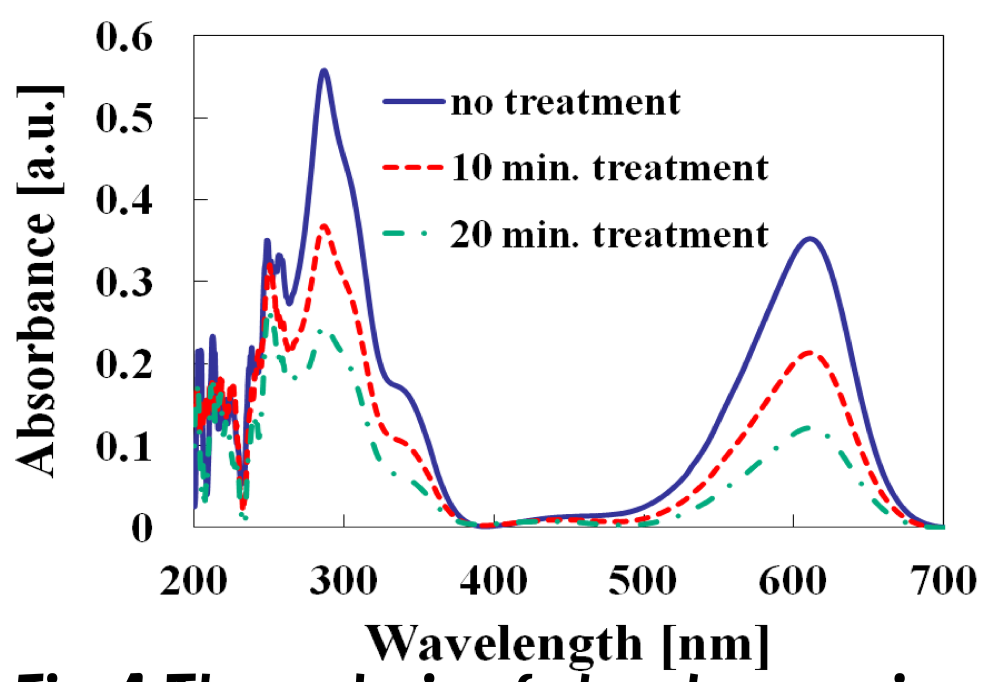

Fig. 4 The analysis of absorbance using spectrum photometer(Vd=1.0 kV).

The decrease of 610 nm and 300 nm peaks suggest that organic compounds contained in indigo carmine solution was decomposed during microplasma treatment.

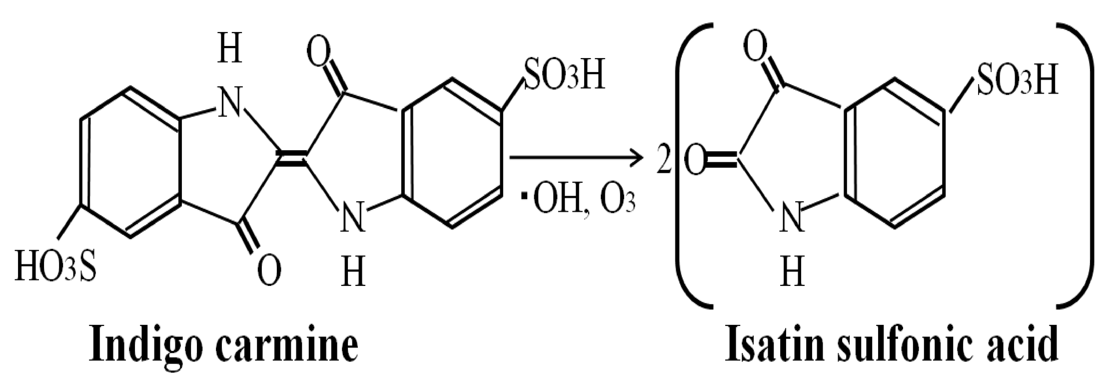

Fig. 5 Chemical reaction of indigo carmine by microplasma treatment.

Indigo carmine has the H type chromophoric group which gives the blue color. Double bond (C=C) was cut thus OH radicals and ozone presence lead to the formation of a new bond 2(C=O). As a result, Indigo carmine was decomposed to isatin sulfonic acid.

(2) Decomposition rate for various career gases

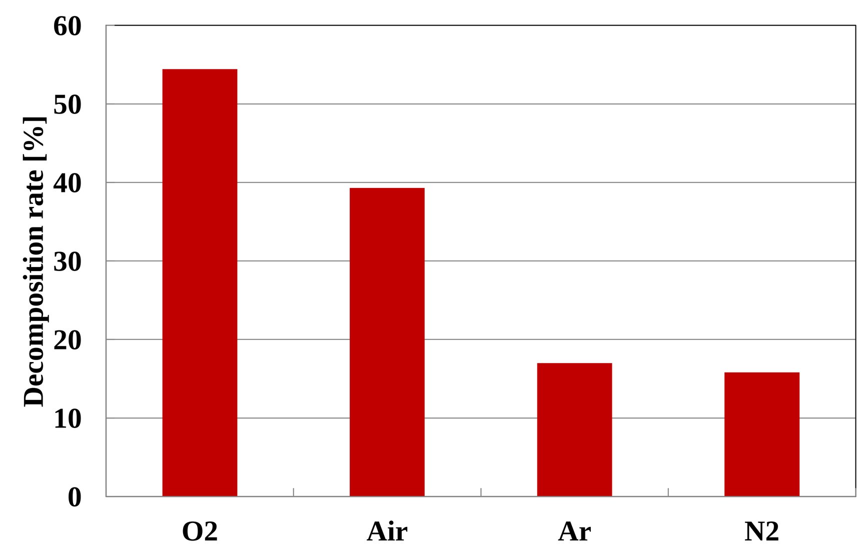

Fig. 6 The decomposition rate of indigo carmine for various career gas(Vd=1.00kV)

Fig. 6 shows the decomposition rate was calculated by the absorbance value. Air and oxygen were higher due to the active species of oxygen origin.

(3)Decomposition rate of indigo carmine

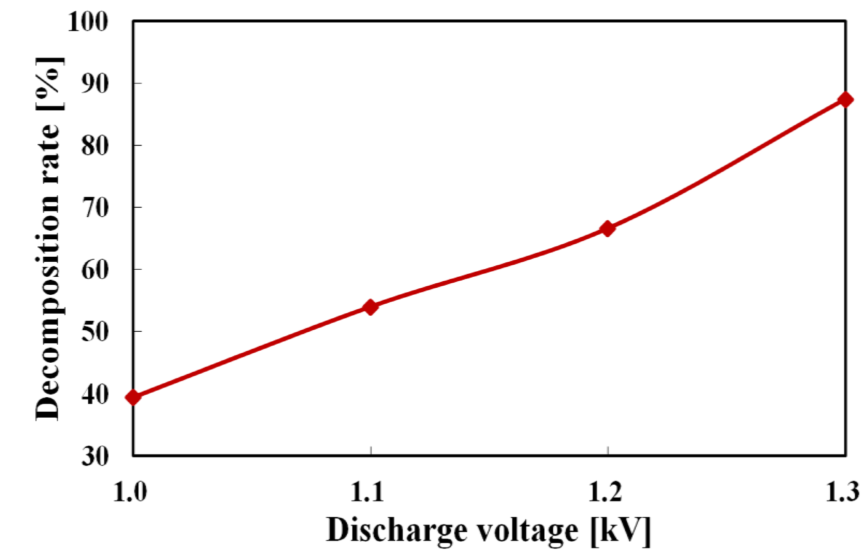

Fig. 7 Ozone concentration in gas phase.

The decomposition rate was higher than 40% at discharge voltages 1.0-1.3 kV.

(4)ozone concentration

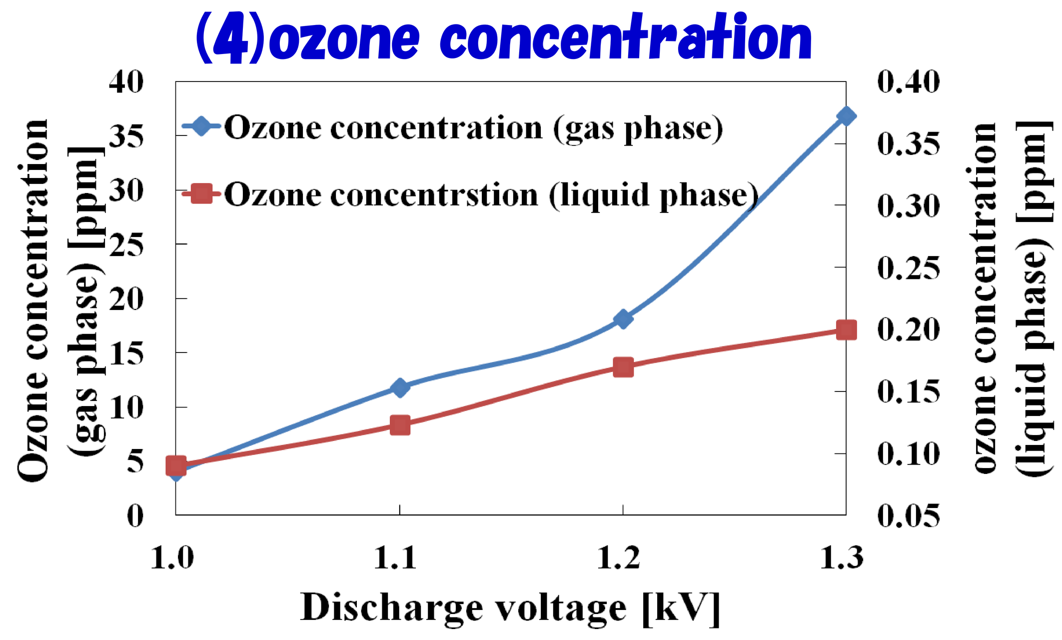

Fig. 8 Ozone concentration versus discharge voltage measured in gas phase and liquid phase by microplasma.

The ozone concentration increased with the increase of the discharge voltage. 0.5-2.2% of the total ozone generated in gas phase was dissolved in water.

(5)ESR analysis

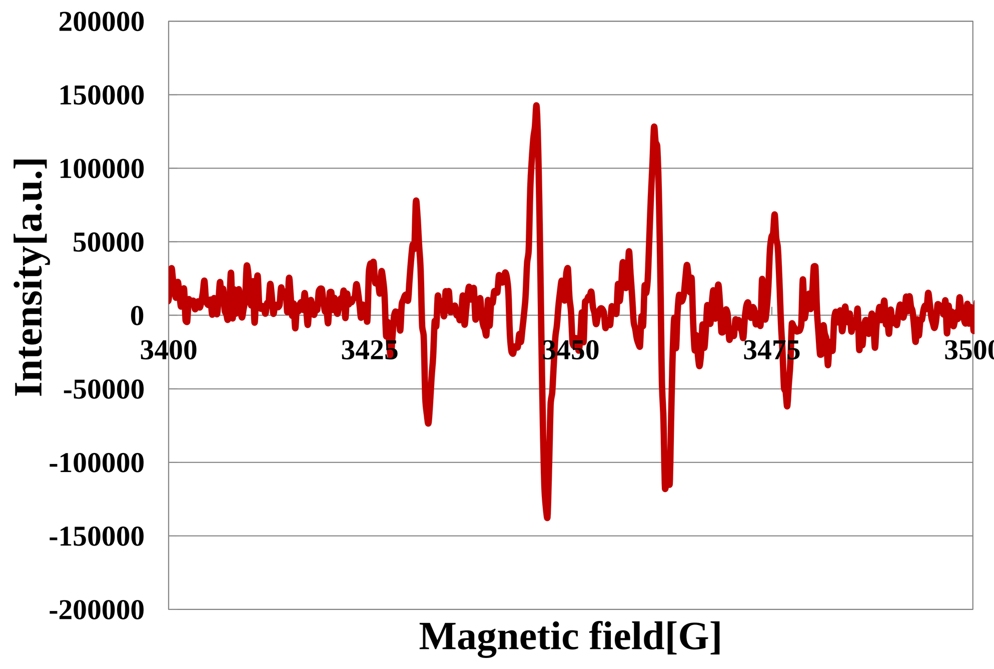

Fig. 9 OH signal detected by an ESR measurement

Spin trap agent 5,5-dimethyl-1-pyrroline N-oxide was used to perform ESR analysis. Generated OH radical by microplasma were observed at 3445, 3460, 3430, 3475 gauss.

Conclusions

Microplasma could be used as an ecological and economical technology. Water treatment using microplasma was carried out.

1. Indigo carmine was decomposed after microplasma treatment and decomposition rate increased with the treatment time and discharge voltage.
2. OH radical was one of the causes of indigo carmine decomposition. It was dissolved in the water as confirmed by using ESR.
3. 0.5-2.2% of the ozone generated in gas phase was dissolved in water.

Reference

[1] K. Takahashi, Y. Sasaki, S. Mukaigawa, K. Takaki, IEEE, Trans. on Plasma Sci. Vol. 38, pp. 2694-2699(2010).