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Effect of Bubble Formation on Water Treatment Using Gas-Liquid Plasma
気液混相プラズマ生成時における気泡形成と水処理への効果

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Recently, much attention has been paid to water treatment utilizing a discharge in bubbling water and various methods were studied extensively. Radicals with short lifetimes are generated by the discharge and effective for water purification and sterilization. We have studied gas-liquid mixed phase discharge by using pulsed high-voltage with several tens of nanoseconds in a duration. The voltage and current characteristics of a discharge in bubbling water were measured. The shape of bubbles and discharge in a bubble were observed in various gas flow rates and hole diameters. We have investigated decolorization of indigo solution for water treatment. The relation of the contact area between the plasma and water was studied for a higher efficient of water treatment.

1. Introduction

Commercially used water treatments such as chlorine treatment process, ozone treatment process, and activated sludge process have various problems in safety issues for human bodies and environment. Water treatment techniques using plasma discharges have attracted much attention for next generation water treatment because it is expected that this process does not have such problems and has ability to decompose persistent organics.

Ultraviolet exposure, ozone, shock wave, and various radicals are generated by using a discharge in or on water and various methods were studied extensively [1-3]. Radicals and ions with short lifetime are generated by the discharge, which are effective for water purification or sterilization. OH radicals have strong oxidation ability and produced in the discharge in water. They are expected to decompose contaminated materials and persistent organics and to remove compounds in water.

We have investigated the effect of water treatment by using pulsed high voltage discharge and evaluated decolorization effect in water using indigo carmine (blue dye liquid) [4]. The reaction rate depends on contact area between the plasma and water. In order to improve the efficiency of water treatment, discharge in bubbles were examined with various working gases.

2. Experimental apparatus

Figure 1 shows the electric circuit of a high voltage pulse generator used in the experiments. The circuit consists of capacitor C, gap switch GS, inductor L, and semiconductor opening switch (SOS) diodes. When the GS is closed, current starts to oscillate in the LC circuit. When the current direction reverses, the reverse current was interrupted by the SOS diodes with the delay of 100 ns. The sudden interruption of the current resulted in the generation of high voltage pulse V_o with a short pulse duration of 40 nanoseconds.

The plasma reactor for water treatment is also shown in Fig.1. A wire electrode was placed in the gas section (lower part of the reactor) and a grounded electrode was immersed in the water section (upper part). When the pulsed high voltage with negative polarity was applied to the wire electrode, a streamer-like discharge was observed in elongated bubbles above each hole of the separator.

The diameter and number of holes were changed (0.3, 0.5, 0.8, 1.0 mm and 5, 10, 15, 20, 25 holes) in order to vary the contact area between the plasma

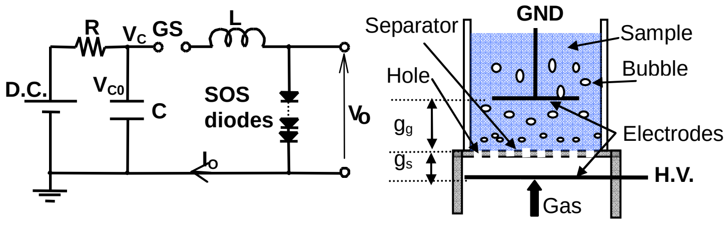


Fig.1. Schematic diagram of the pulsed high voltage circuit and a plasma reactor with bubbling water.

and water. The discharge characteristics and the effect of water treatment were measured by changing the gas flow rate. To evaluate the effect of water treatment, the decolorization ratio of indigo solution were used.

3. Experimental results and Discussions

Figure 2 and 3 show the decolorization rate and efficiency with various gas flow rates and hole diameters. According to previous study, ozone and oxygen radicals have selectivity for reactions and react easily with C=C double bond that shows the blue color of indigo carmine [7]. Treatment time is 20 sec with the pulse repletion rate of 30 Hz. These values increased with the gas flow rate but did not change with hole diameter.

The decolorization ratio depends on the contact area between the plasma and water. Figure 4 shows photographs of bubbles and discharges occurred in the bubbles. The shape of the bubbles was different with different gas flow rates and hole diameters. Larger bubbles appeared with larger flow rate and larger hole diameter. With a constant flow rate the number of bubbles decreased and total area seemed to be constant. The decolorization rate and efficiency were also evaluated in different number of holes.

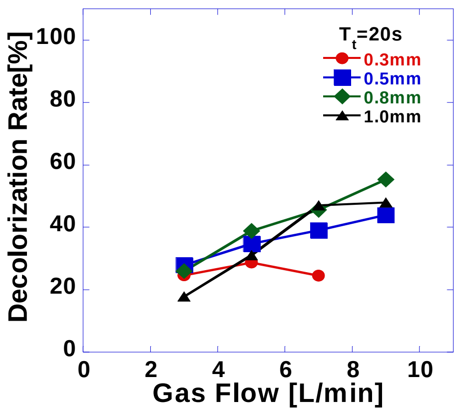


Fig. 2. The energy consumption as a function of the gas flow rate and the hole diameter.

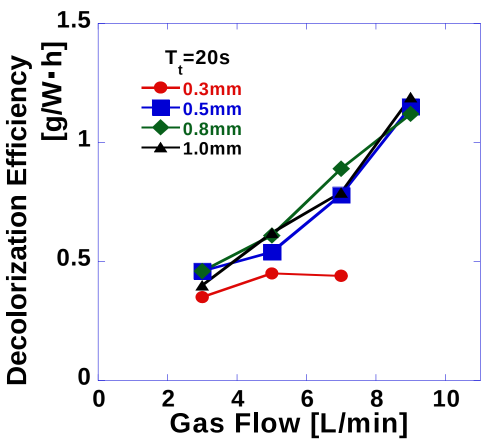
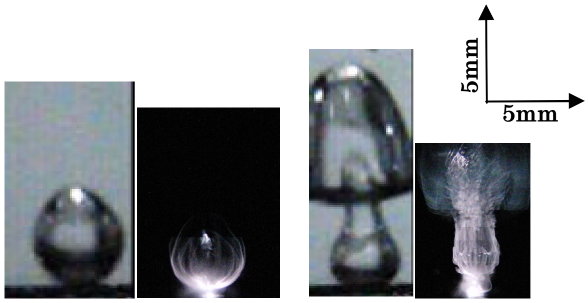


Fig. 3. Decolorization efficiency as a function ofthe gas flow rate and the hole diameter.



(a)Gas flow was small (0.1L/min for single hole) (b) Gas flow was large (0.5L/min for single hole)

Fig. 4. Photographs of the bubble and the discharge from a single hole of 1mm in diameter. (left: bubble without discharge. right: with discharge).

4. Conclusions

Pulsed high voltage with several tens of nano-seconds was generated by using SOS diodes. The discharge in water with bubbling gas was studied and applied for the decolorization of the indigo solution.

The shape of bubbles and discharge in a bubble were observed in various gas flow rate and hole diameters. The decolorization rate and efficiency of the indigo solution were improved by increasing the gas flow rate. To enable higher efficiency of water treatment, the relation of the contact area between plasma and water to the efficiency should be clarified further.

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