22P077-P

Gas-liquid plasma using nano-sec pulsed discharge and its application for sterilization

ナノ秒パルス放電を用いた気液混相プラズマ生成と滅菌への応用

Tatsuya Togashi, Ryutaro Shimokawa, Nozomi Tanaka and Akira Ando
富樫達也，下川龍太郎，田中のぞみ，安藤　晃

Graduate School of Engineering, Tohoku University
6-6-05, Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan
東北大学工学研究科　〒980-8579　仙台市青葉区荒巻字青葉6-6-05

Plasma discharge in gas-liquid mixed phase was investigated for water treatment applications. A bubbling type reactor and a high-voltage pulsed power supply were utilized to generate gas-liquid phase discharge. We applied this technique to sterilize spore-forming bacteria in water. Sterilization effects were examined in various kinds of working gases. Active species like ozone and OH radicals and UV rays generated in the discharge worked effectively in inactivation of bacteria.

1. Introduction

Water pollution is one of the most serious environmental problems. More then 8 million people cannot use safe water and are facing fatal problems all over the world. Water purification technology is urgent required for protection of water quality.

Recently, plasma discharge in water has attracted much attention for water treatments. Discharge in water enhances active species like ozone (O_3) and OH radicals, ultraviolet (UV) rays. Strong electrical field and shock waves are also generated in the discharge and they work effectively for water treatment [1].

In this study, we utilized gas-liquid phase discharge to sterilize spore-forming bacteria in water and measured the sterilization effect.

2. Experimental Setup

2.1 *High voltage pulsed power supply*

Figure 1 shows an electric circuit of the high-voltage pulsed power supply. The circuit consists of a capacitor C, a gap switch GS, an inductor L, and semiconductor opening switch (SOS) diodes. When the gap switch was shorted after the capacitor was charged by DC power supply (11 kV), current started to oscillate in the LC circuit. When the current was interrupted by the SOS diodes with delay of 100 ns, the sudden interruption of current resulted in the generation of high voltage pulse V_o with a short pulse width of 40ns typically [2]. The pulse repetition rate was variable and set at 30 Hz in this study.

2.2 *Gas-liquid plasma reactor*

Figure 2 shows the plasma reactor for gas-liquid mixed phase discharge. The upper part of the reactor was filled with water, and working gas was fed from the lower part through 25 holes of 1 mm in diameter. In this study, air, oxygen (O_2) and nitrogen (N_2) were used as working gas with the gas flow rate of 8.0 l/min. A thin stainless steel wire (ϕ = 0.3 mm) was placed below the holes and the pulsed high voltage was applied between the wire and a ground electrode set in the water. The discharge was formed between the wire electrode and surface of bubbles above the small holes in water.

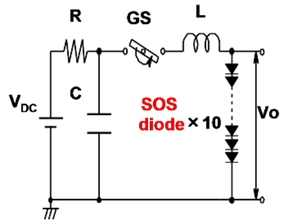

Fig.1. The electric circuit of the high-voltage pulse generator utilizing SOS diodes.

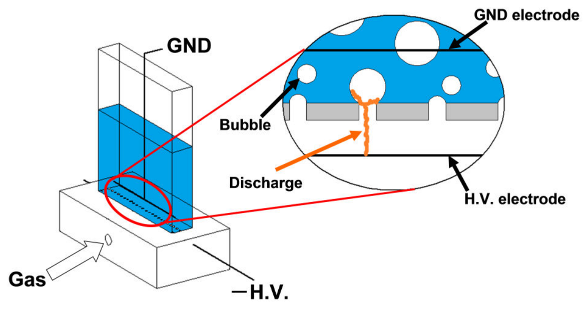

Fig.2. Schematic of the gas-liquid plasma reactor.

2.3 *Biological indicator*

In order to investigate the effect of sterilization, Spore-forming bacteria *Bacillus Subtillis* was used as biological indicator. The initial population of the bacteria was set at 10^5 in 50 ml solution. After treatment, samples were diluted appropriately and were put on Petri film. After incubation at 30 °C for 24 hours, colonies of the bacteria appeared as shown in Fig.3. Sterilization effect was measured by counting the number of the colonies and calculating survival ratio according to eq.(1).

$$Survival\ Ratio = \frac{Number\ of\ colonies}{Initial\ number\ of\ colonies} \qquad (1)$$

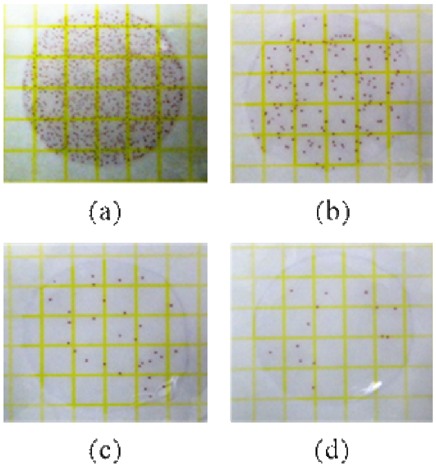

Fig.3. Sterilization effect on the number of the colonies (a) untreated, (b) 5 min, (c) 10 min and (d) 15 min.

3. Experimental results

3.1 *Gas-liquid plasma discharge*

Gas-liquid plasma discharge was observed in the plasma reactor as shown in Fig.4. Typical wave forms of pulsed high voltage and current at discharge are shown in Fig.5. When charging voltage V_{DC} was 11 kV, the pulsed voltage of about 20 kV can be applied with the pulse width of 30 – 40 ns. Averaged consumed energy was about 11 mJ per pulse.

Fig.4. Gas-liquid phase plasma discharge

3.2 *Sterilization effect*

Figure 6 shows that survival ratio as a function of time in various gas species. Sterilization effect was observed using various gas species. D-values (a time to decrease the number of bacteria to 1/10) in air, O_2 and N_2 gases were about 280 s, 370 s and 370 s respectively. Active species and UV generated with the discharge worked effectively for inactivation. Additionally, pH value decreased in the discharge with air gas and the solution became acidic. The pH value may contribute the sterilization.

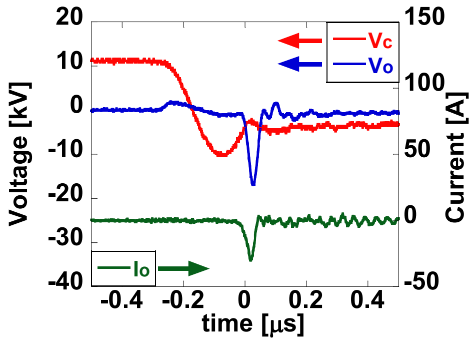

Fig.5. Wave forms of voltage and current at a pulsed discharge.

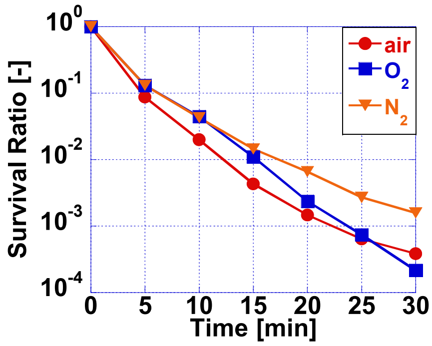

Fig.6. Survival Ratio as a function of time.

4. Summary

To sterilize bacteria in water, we utilized gas-liquid plasma discharge, which was generated by using a pulsed power supply and a plasma reactor. Sterilization effect was observed with various kinds of working gas. Active species and UV generated by the plasma discharge worked effectively for sterilization. Further experiments will be performed in order to study the effect of pH value in the solution.

References

[1] M. Sato: Plasma Source Sci. Technol. **17** (2008) 024021.

[2] K.Takaki, *et al*: IEEE Tran Die Ele Ins. **14** (2007) 834