Sterilization of bacteria at low discharge voltage by using microplasma

Kazuo SHIMIZU, Yuuki KOMURO, and Marius BLAJAN
Innovation and Joint Research Center, Shizuoka University, Jyouhoku, Hamamatsu, 432-8561, Japan
E-mail: shimizu@e.shizuoka.ac.jp

INTRODUCTION

In recent years, infectious diseases such as new influenza caused by pathogenic organisms were spread worldwide. It is expected that alternatives to chemical sterilization methods such as new safety sterilizing process using nonthermal plasma to be developed.

We have investigated sterilization effect of bacteria at low voltage by using atmospheric microplasma.

METHODS

(1) Microplasma Electrodes

Dielectric layer
Metallic electrode

Pair of metal plates covered with dielectric materials is used as a dielectric barrier electrode.

Fig. 1 Microplasma electrode

The image of microplasma electrodes during discharge at discharge voltage of 1 kV.

Fig. 2 Electrode surface

The image of microplasma electrodes during discharge at low discharge voltage by using atmospheric microplasma.

(2) Experimental Setup

Gas flow rate 0.5 L/min
Gas flow rate 5.0 L/min

Fig. 4 Experimental setup

The liquid culture medium was introduced in the microplasma reactor and sprayed at a gas flow rate of 0.5 L/min through the electrode against a petri dish with culture medium. Total gas flow rate was 5.0 L/min. Sprayed bacteria with liquid culture medium was sterilized between microplasma electrodes. Discharge voltage and discharge current were measured by a digital oscilloscope.

Table 1 Experimental condition

<table>
<thead>
<tr>
<th>Discharge voltage</th>
<th>1.4 kV</th>
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</thead>
<tbody>
<tr>
<td>Gas flow rate</td>
<td>0.5 L/min</td>
</tr>
<tr>
<td>Carrier gas</td>
<td>Air, N₂</td>
</tr>
<tr>
<td>Target bacteria</td>
<td>E.coli, B.subtilis</td>
</tr>
</tbody>
</table>

(3) Emission spectrum of microplasma

Fig. 7 shows the emission spectrum of microplasma.

(4) Rate of sterilization

Without discharge.

VD=1.4 kV.

Fig. 8 Images of the E. subtilis treated samples by air-plasma.

With discharge.

VD=1.4 kV.

Fig. 9 Images of the B. subtilis treated samples by nitrogen-plasma.

RESULTS

(1) Electric Characteristics

Spike-like currents occurred at the steepest slope of the discharge voltage. This is a typical waveform of dielectric barrier discharge. The microplasma reactor can generate atmospheric plasma at about 1 kV, since its discharge gap is narrow (about 50 to 100 μm).

Fig. 5 current-voltage characteristic

(2) Ozone Generation

Generated ozone concentration by microplasma can be controlled by discharge voltage. It was observed that sprayed distilled water was lower than that with only air.

Fig. 6 Ozone concentration

(3) Emission spectrum of microplasma

Fig. 7 Emission spectrum of microplasma

(4) Rate of sterilization

Fig. 8 Images of the E. subtilis treated samples by air-plasma.

Fig. 9 Images of the B. subtilis treated samples by nitrogen-plasma.

Fig. 10 Sterilization rate of E.coli

Sterilization rate of E. coli with pulsed microplasma.

Fig. 11 Sterilization rate of B.subtilis

Similar sterilization rates of B. subtilis were obtained for air as carrier gas. Sterilization rate by nitrogen plasma was lower compared to the rate of E. coli. The thickness of the cell wall could be considered the sterilization effect between E. coli and B. subtilis.

Fig. 12 Sterilization rate of E. coli with pulsed microplasma.

Sterilization rate by pulsed was lower than by neon transformer. It is expected sterilization rate could be improved by treatment in more than one pass.

Fig. 13 SEM images of B. subtilis before(left) and after(right) the microplasma.

CONCLUSIONS

In this study, the following conclusions were obtained.

1) Sterilization by microplasma was confirmed at a relatively low discharge voltage of 1.0 kV for both carrier gases: air and nitrogen.

2) The sterilization rate by air plasma was higher than that of nitrogen plasma. It could be considered by the combination effect of high electric field, UV radiation and other radicals.

3) The sterilization rate of E. coli was higher than the results for B. subtilis due to the characteristics of the cell walls, which are different in thickness and chemical composition.