Introduction and Application of Microplasma

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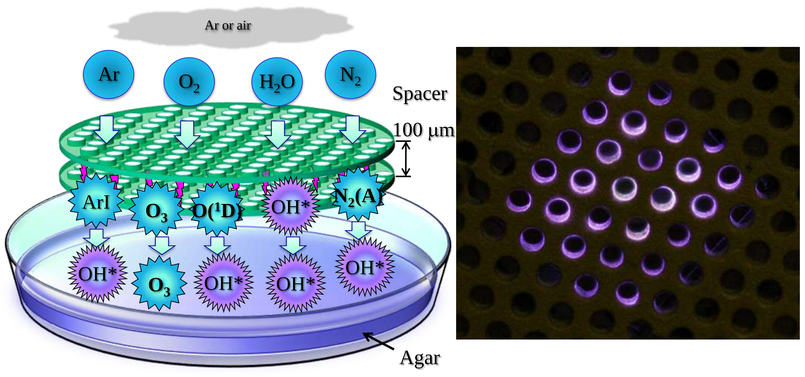
INTRODUCTION

Microplasma can be generated only around 1 kV at atmospheric pressure. It has the possibility to replace traditional technologies and has been intensively studied for various application fields. One bio/medical application of microplasma is "sterilization". The sterilization process was carried out with active species generated between the electrodes. Surface treatment with long life active species for glass, polymer and other materials could be also possible.

METHODS

(1)Sterilization process and electrodes



(a) Sterilization process (b) Image of microplasma

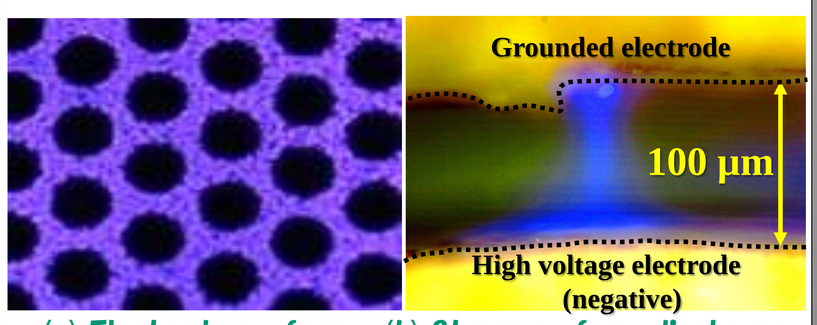
Fig. 1 Sterilization process for *E. coli* and image of microplasma during discharge.

Fig. 1 shows the electrodes and sterilization process. Electrodes are perforated metal plates covered with a dielectric layer and faced together. Microplasma was generated between the electrodes by the applied voltage thus active species and radicals were produced according to gas composition. Table 1 shows the detail of electrodes.

Table 1 The detail of electrodes.

Diameter	45 mm
Hole diameter	1.6 mm
Aperture ratio	30%
Discharge gap	100 μm
Discharge area	100 mm^2
Gas flow rate	10 L/min

(2) Image of streamer of discharge



(a) Electrode surface (b) Streamer from discharge

Fig. 2 Image of a streamer from microplasma discharge.

Microplasma is typically dielectric barrier discharge. The image of emitting of streamer is shown in fig. 2. Streamer diameter is thinner than previously reported.

(3) Experimental Setup

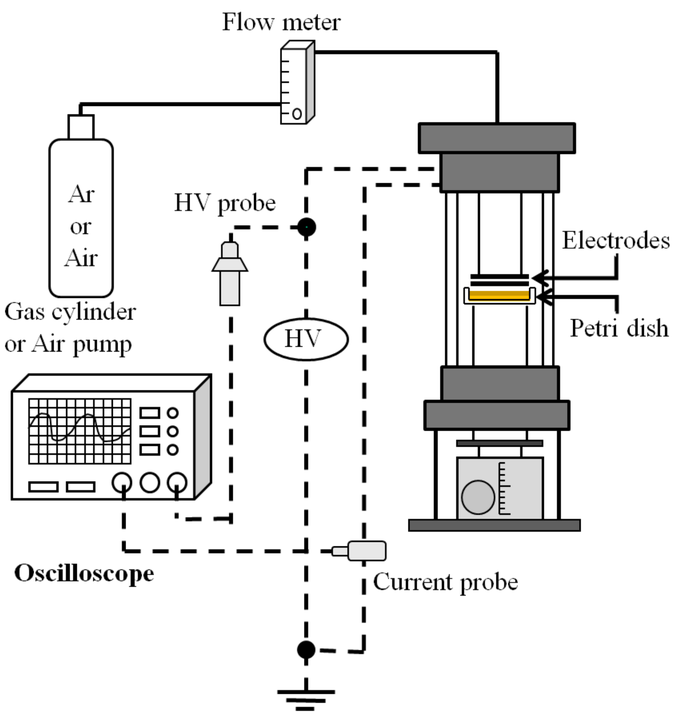
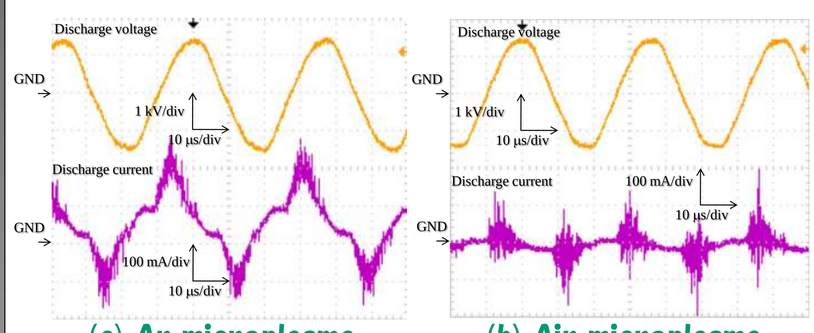


Fig. 3 Experimental setup

Fig. 3 shows experimental setup for sterilization of *E. coli*. *E. coli* was diluted in the liquid medium and the culture medium was applied on the agar medium. Then the agar medium was inserted in the microplasma reactor and exposed to remote microplasma. The distance between agar medium and electrodes could be adjusted by Z-axis stage.

RESULTS

(1) Electric Characteristics

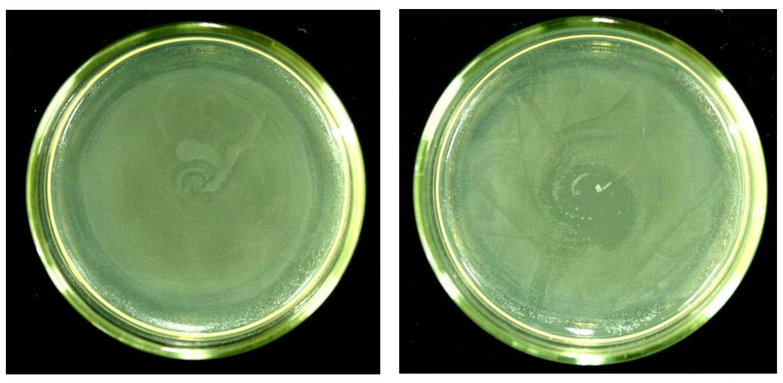


(a) Ar microplasma (b) Air microplasma

Fig. 4 current-voltage characteristic

Spike-like currents occurred at the steepest slopes of the discharge voltage. This is a typical waveform of dielectric barrier discharge.

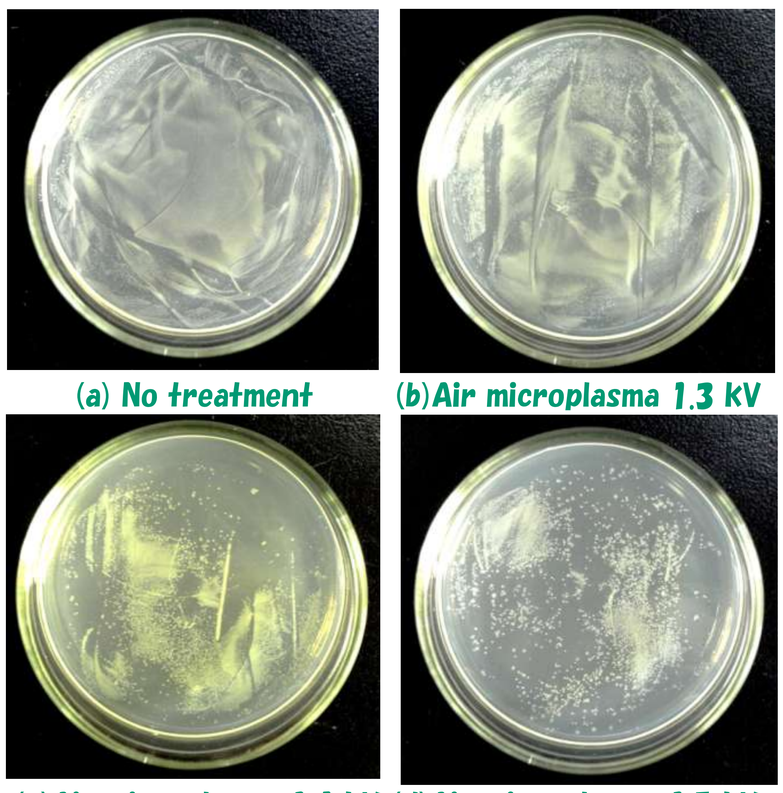
(2) Sterilization result



(a) No treatment (b)Ar microplasma 650V

(c)Ar microplasma 750V (d)Ar microplasma 850V

Fig. 5 The experiment result of sterilization by using Ar microplasma. Treatment time was 60 s, distance between electrodes and *E. coli* was 2 mm.

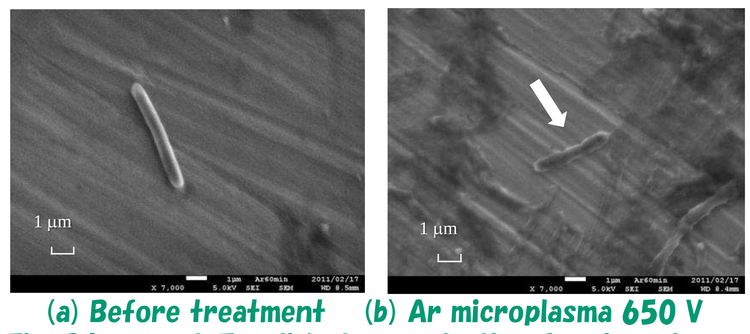


(a) No treatment (b)Air microplasma 1.3 kV

(c)Air microplasma 1.4 kV (d)Air microplasma 1.5 kV

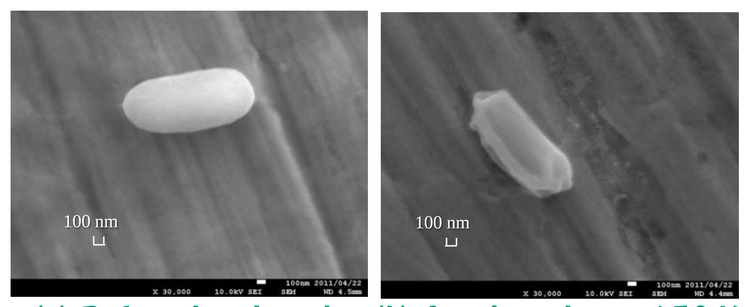
Fig. 6 The experiment result of sterilization by using air microplasma. Treatment time was 60 s, distance between electrodes and *E. coli* was 2 mm.

Figs. 5 and 6 show the sterilization result of *E. coli*. Ar microplasma treatment could sterilize near the center of Petri dish. However, air microplasma treatment could sterilize more widely area than Ar one. This could be due to the long lifetime active species derived from O_2.



(a) Before treatment (b) Ar microplasma 650 V

Fig. 7 Image of *E. coli* before and after Ar microplasma treatment(x7,000, treatment time 60 s).



(a) Before treatment (b) Ar microplasma 650 V

Fig. 8 Image of *Alicyclobacillus* before and after Ar microplasma treatment(x30,000, treatment time 60 s).

Fig. 7 shows the image of *E. coli* which was the nursing cell state and Fig. 8 shows the image of gram-positive bacteria *Alicyclobatillus acidoterrestris* was spore state taken by SEM. *E. coli* and *Alicyclobatillus* were physically damaged by applying microplasma as shown in Figs. 7 and 8 (right).

(3) Surface treatment by microplasma

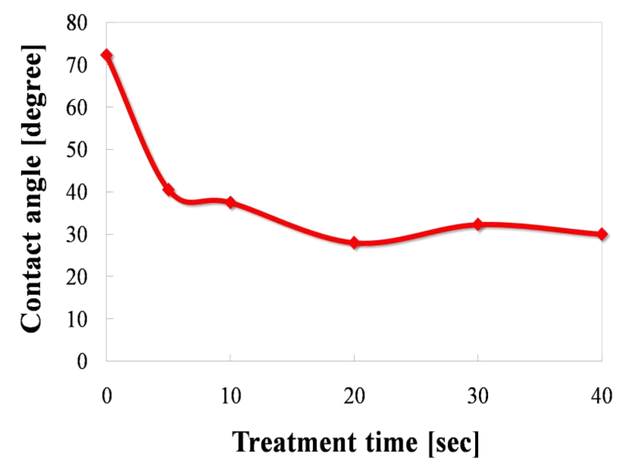
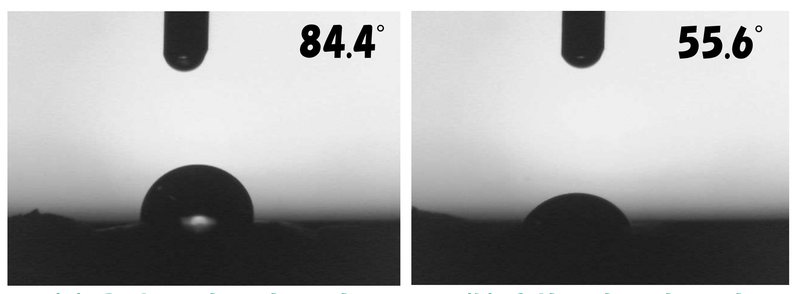


Fig.9 Relationship between treatment time and contact angle. (Discharge voltage -1.3 kV, distance between electrodes and PEN film1 mm, gas flow rate 5 L/min)

Fig. 9 shows characteristics between treatment time and contact angle. Marx generator circuit was used as power supply and it can generate pulse high voltage. Initial contact angle of PEN film was about 73° . The minimum contact angle of about 30° was obtained at treatment time of 20 sec.

(4) Effect on the living body by microplasma



(a) Before treatment (b) After treatment

Fig. 10 Contact angle of water droplet on the human skin before(left)and after the microplasma treatment(right). (Ar gas, V_d=650 V, treatment time: 30 s).

Fig. 10 shows surface treatment for human skin by microplasma treatment. Human skin' s contact angle was decreased. Electrical damage to sample could not be considered because the electric field was closed between electrodes.

In this study, we are presenting the introduction and application of microplasma. Characteristics of microplasma is similar to that of the other non thermal plasma except streamer diameter. Various application could be considered to the many fields i. e. sterilization process surface treatment and for plasma medicine. We will try to develop useful and safety microplasma process.