Introduction and Application of Microplasma

Yuki KOMURO, Hodaka FUKUNAGA, Shigeki TATEMATSU,

Marius BLAJAN and Kazuo SHIMIZU

Innovation and Joint Research Center, Shizuoka University, Jouhoku, Hamamatsu, 432-8561, Japan

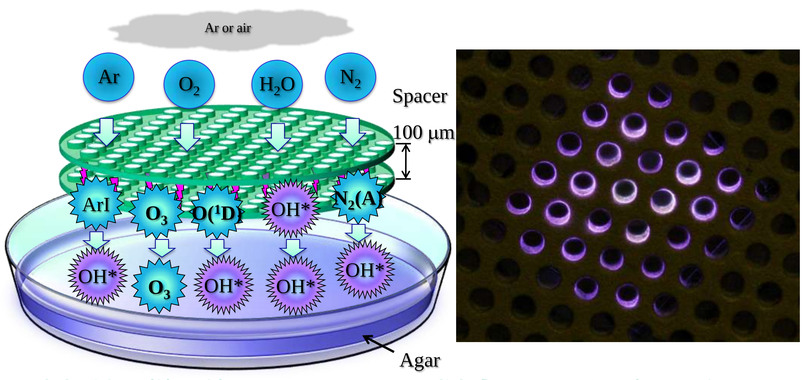
E-mail : shimizu@cjr.shizuoka.ac.jp

INTRODUCTION

Microplasma can be generated only around 1 kV at atmospheric pressure. It has possibilities of replacement technology of traditional one and has been intensively studied for various application fields, since this technology. 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

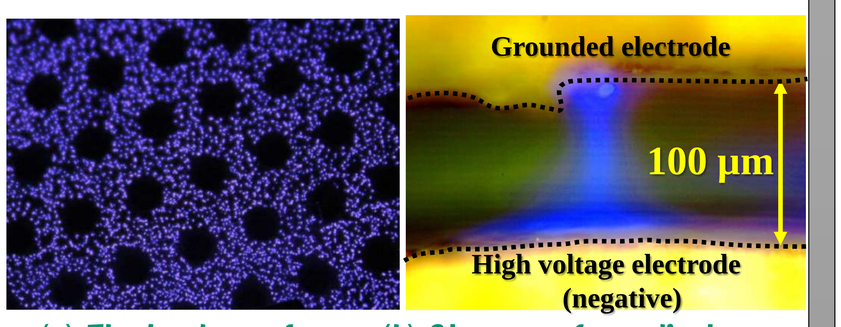


(a) Sterilization process (b) Image of microplasma

Fig. 1 Sterilization process 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.

(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

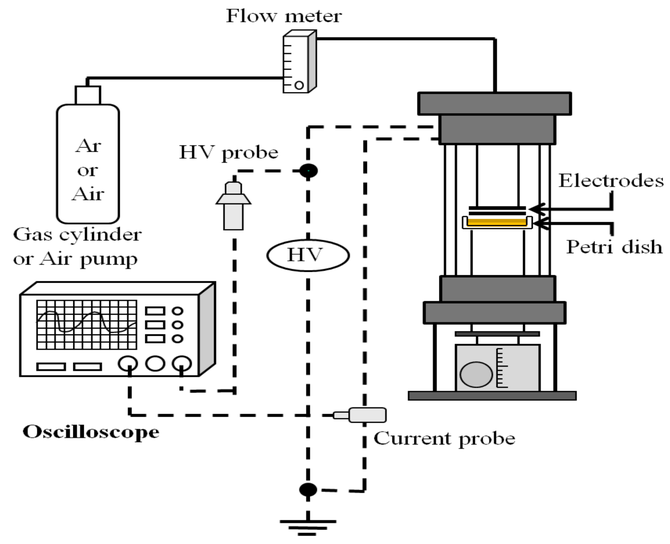


Fig. 3 Experimental setup [○]

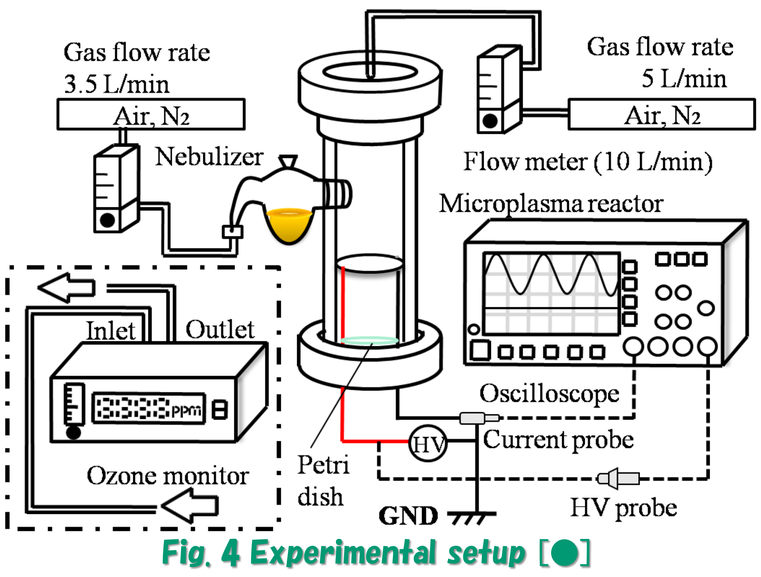


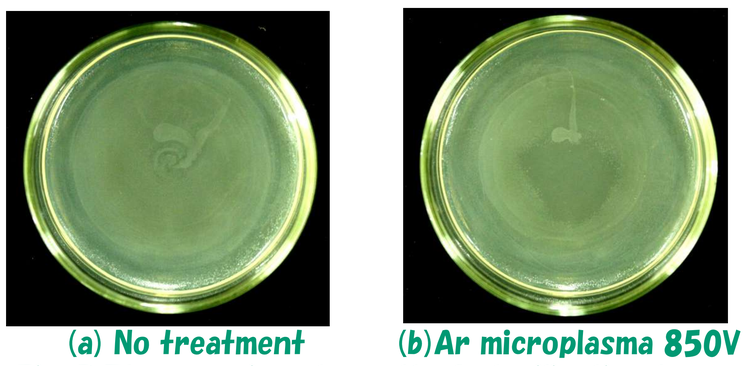
Fig. 4 Experimental setup [●]

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.

Fig. 4 shows experimental setup for sterilization of *E.coli* and B. *subtilis*. The liquid culture medium was introduced in the microplasma reactor and sprayed at a gas flow rate of 3.5 L/min, through the electrode against a petri dish with culture medium. Total gas flow rate was 8.5 L/min. Sprayed bacteria with liquid culture medium was sterilized between microplasma electrodes.

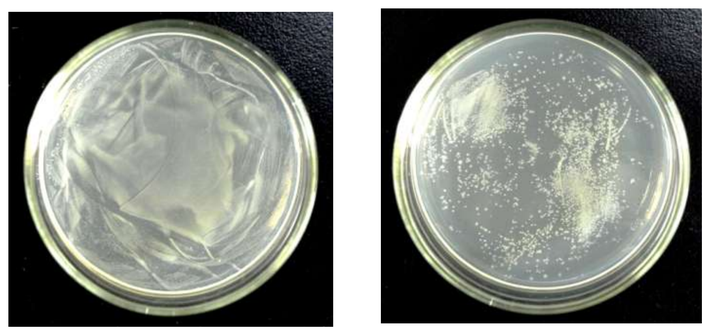
RESULTS

(1) Sterilization result [○]



(a) No treatment (b)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.

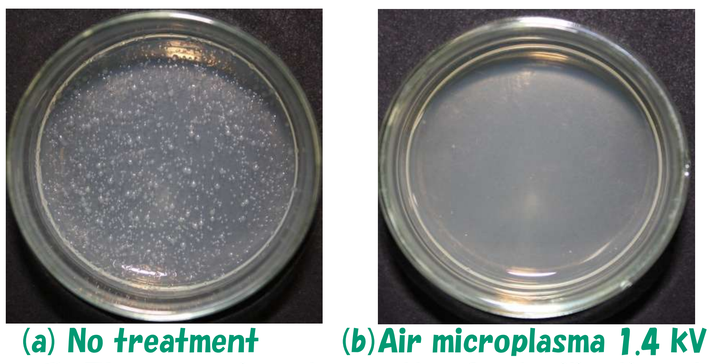


(a) No treatment (b)Air microplasma 1.5 kV

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.

(2) Sterilization result [●]



(a) No treatment (b)Air microplasma 1.4 kV

Fig. 7 The experiment result of sterilization by using air microplasma (*B. subtilis*).

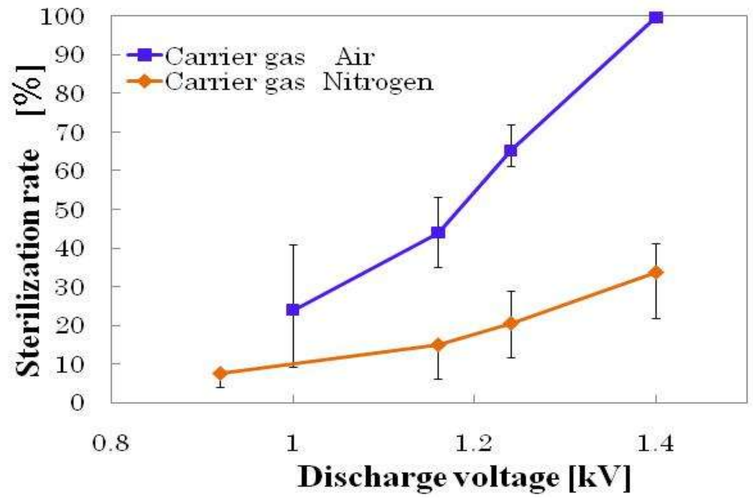
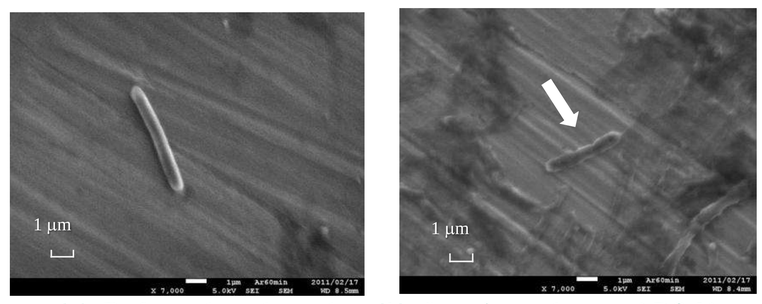


Fig. 8 The experiment result of sterilization by using air and nitrogen microplasma (*B. subtilis*).

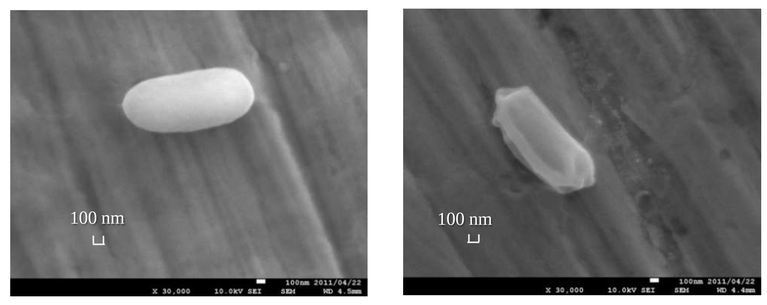
Sterilization rate by nitrogen plasma was lower compared to the rate of Air plasma.
The sterilization process according with this results, could be considered synergetic effect of UV radiation, high electric field, (not only oxidative) radicals, and ozone.

(3) FE-SEM images of bacteria



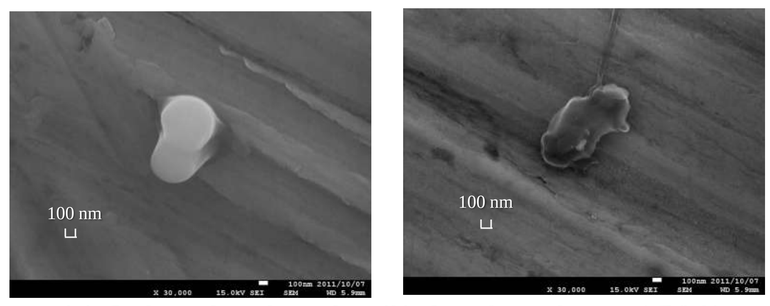
(a) Before treatment (b) Ar microplasma 650 V

Fig. 9 Image of *E. coli* before and after Ar microplasma treatment(x7,000).



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

Fig. 10 Image of *Alicyclobacillus* before and after Ar microplasma treatment(x30,000).



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

Fig. 11 Image of *B. subtilis* before and after Air microplasma treatment(x30,000).

Fig. 9 shows the image of *E. coli* which was the nursing cell state and Fig. 10 shows the image of gram-positive bacteria *Alicyclobatillus acidoterrestris* was spore state taken by SEM. Fig. 11 shows the image of *B. subtilis* spore *E. coli* and *Alicyclobatillus* were physically damaged by applying microplasma as shown in Figs. 9, 10 and Fig. 11 (right).

(4) Effect on the living body by microplasma

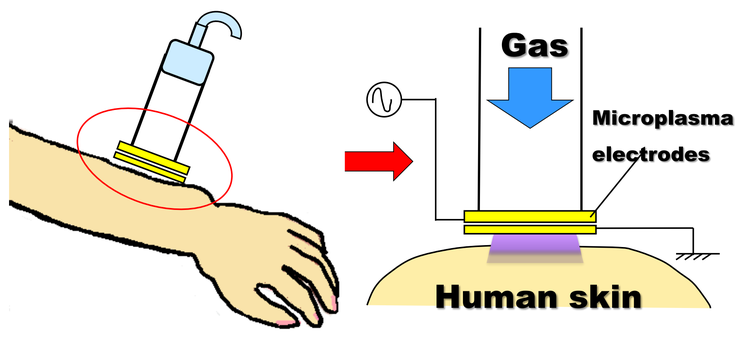
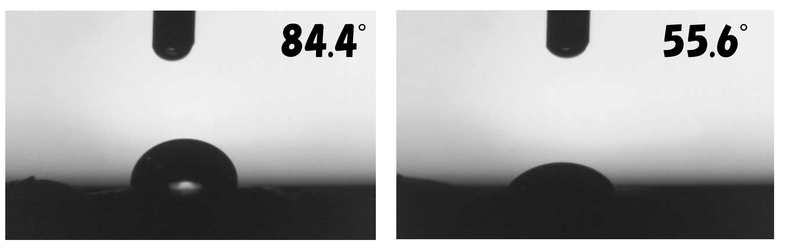


Fig. 12 Image of Microplasma exposure to human skin.

Various active spices generated by microplasma such as ions, and metastable molecules has been treated to the human skin as shown in Fig. 12.



(a) Before treatment (b) After treatment

Fig. 13 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. 13 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.

Conclusion

In this study, we are presenting the introduction and application of microplasma. 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.