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Application of Microwave Plasma to Medical Sterilization
マイクロ波プラズマの滅菌応用

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In this paper, we present recent experimental results on low-temperature sterilization using surface-wave plasma (SWP) and volume-wave plasma (VWP). Characteristics of plasma sterilization were presented for both the cases of SWP and VWP. In the SWP sterilization, the sterilization of 10^6 spores was confirmed for 3 min oxygen discharge. We also investigated the internal sterilization using microwave-excited VWP for application to the sterilization of the medical instruments wrapped with perforated plastic materials. The spores of population of 10^6 were irradiated during 10 min plasma discharge of He and O_2 mixture gas. The preliminary results showed a successful sterilization for 10 min. plasma treatment at a relatively low temperature of 70 °C.

1. Introduction

Recently it has been noticed to utilize the plasma discharges driven by DC[1-2], RF[3] or microwave[4-6] in the sterilization of medical instruments or in disinfect of food or drink packages. Conventionally, sterilization of medical instruments has been performed using a dry-heat or hot-steam technique for heat-resistant materials, or the ethylene-oxide gas (EOG) for heat-sensitive materials. In the former method, however, sterilized materials are limited to the metal or glass usable under high-temperature circumstances. Furthermore, in the latter case, there remains a big issue of handling the dangerous ethylene-oxide gas in the sterilization procedure. Recently, it is believed that EOG itself is referred to as carcinogen, and its toxicity and serious effects on environment are concerned. In the EOG sterilization, it might be also a big problem that it takes one week or more to reduce the toxic ethylene-oxide residuals to the safety level after the EOG sterilization procedure. Therefore, the novel sterilization method, which can be done safely, environmentally friendly and rapidly at low temperature, is strongly demanded.

Hence, we have been aiming at developing the low-temperature plasma sterilization technique using SWP and VWP. So far, we have shown that rapid sterilization could be accomplished for 3 min. oxygen SWP discharges[6]. Furthermore, in order to sterilize inside the materials, such as catheter wrapped with perforated plastic packing, we proposed the novel technique using VWP for the internal sterilization.

2. Experiment

Illustrations for production schemes of SWP and VWP are shown in Fig. 1. In the SWP, plasma was locally produced with the strong microwave launched from the microwave launcher, especially below the quartz window. Then plasma diffuses downward toward the medical equipment, so that it simply leads to the surface sterilization.

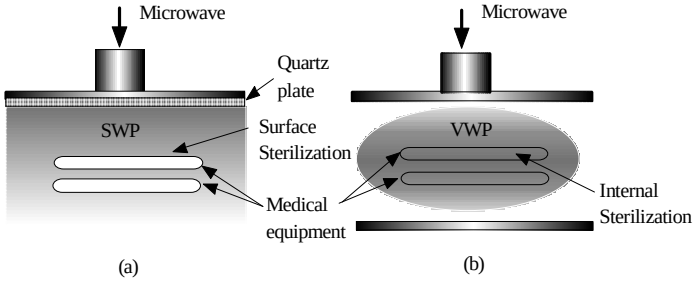


Fig. 1 Illustrations of (a)SWP and (b)VWP in the sterilization experiments.

On the other hand, in the case of VWP, the plasma was produced in the region having stronger fields distributed inside the chamber. We employed the 40 cm-diam. SWP device and 25 cm-diam. VWP device in the present experiments. The details of the experimental setups are described in ref. [6,7].

3. Results and discussion

In the SWP sterilization experiments, we have found that the spores with a population of 1.5×10^6 *Bacillus stearothermophilus* were killed by irradiation during 3 minutes of oxygen plasma due to the etching effect by oxygen radicals[6]. In addition to oxygen gas, we tested the sterilization experiments using the other gases, such as Ar and hydrogen. Figure 2 show the results of survival curves of spores by counting the numbers of colony forming units after incubation procedure.

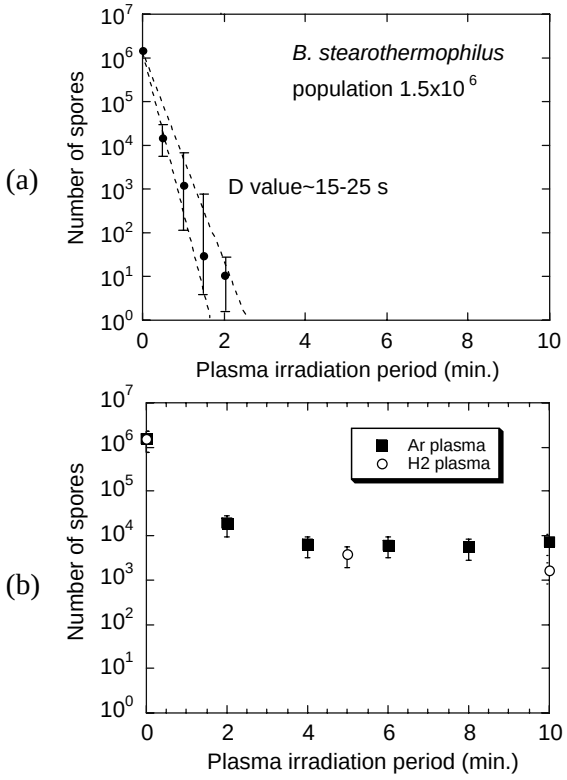
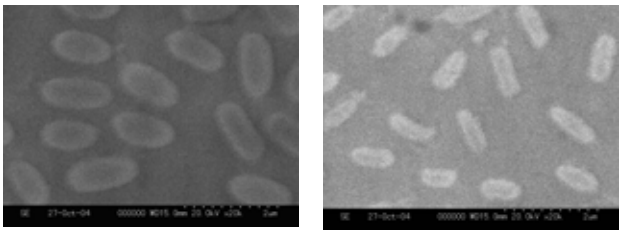


Fig. 2 Survival curves of spores by counting the numbers of colony forming units in the cases of (a) oxygen and (b) Ar and hydrogen plasma.

In the case of oxygen plasma, we found roughly linear reduction of spore numbers with a D-value of roughly D=15~25 sec, as shown in Fig. 2(a). However, when Ar or hydrogen gas was used, sterilization was not confirmed even for 10 min plasma discharges. Next, by increasing the cw incident power, we found the sterilization can be accomplished more rapidly. When the incident power was Pi=700W, 1 kW or 1.5 kW, sterilization could be confirmed for oxygen plasma during 180 sec, 50 sec or 40 sec, respectively.

In the VWP sterilization, we aimed at confirming the internal sterilization, so that we used the biological indicators without unpacking sample from the glassine envelope. We changed the plasma irradiation period up to 10 min. After incubation procedure, we confirmed that B.I. having spores of 10^5 and 10^6 were sterilized for 10 min He/O_2 mixture gas plasma. From the measurement using thermal label, it was found that temperature of Petri dish was about 70°C or less.



(a) (b)

Fig.3 SEM images of the spores irradiated by the oxygen plasmas for (a) 2 min (not sterilized) and (b) 8min. (sterilized).

Figure 3 shows the SEM images of spores treated for 2 min- and 8 min -oxygen plasmas discharges. It is apparently seen that the spore sizes after 8 min plasma irradiation are significantly reduced due to the chemical etching by oxygen plasma sterilization, similarly to the previous results using oxygen surface-wave plasma[6].

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