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Mechanisms for medical sterilization and sterilization for the development of high-frequency low-pressure by air plasma

低圧高周波空気プラズマを用いた医療用滅菌法の開発と滅菌機序

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Characteristics of medical sterilization method using the RF air plasma generated by two types antenna under low pressure were investigated. The meandering wire antennas of semicircular and encircling shapes were adopted to produce plasmas, and their sterilization abilities are compared. Oxygen radicals generated by RF discharge sterilized bacillus in biological indicator during 2-4 hours.

1. Introduction

The sterilization of medical devices is needed to prevent infection. Two major methods has been used for sterilization in the medical field. One is high-pressure steam heat sterilization method (autoclave). Another one is sterilization of the gas with ethylene oxide gas (EOG). However, two methods have problem that deterioration of heat and harmful toxic gases.

Recently plasma sterilization has attracted much attentions. Plasma sterilization has advantages such as low temperature and low humidity and low toxicity. In this experiment, air plasma sterilization changing the form of the antenna is performed to evaluate the medical sterilization performance.

2. Experimental procedure

Figure.1 shows experimental apparatus with the semicircular type antenna. Pressure in the chamber set at 30-60Pa by vacuum pump. The CCP type antenna used in the experiment has the wavy form for effective and spatially uniform generation of oxygen radicals. When the RF power (13.56MHz) is applied to antenna, the grow discharge plasma with high uniformity is produced below the antenna.

In order to investigate the dependence of the antenna geometry on the sterilization characteristics, two types of RF antenna are adopted in this experiment. In the case of the semicircular antenna, the antenna is placed around the upper half wall of the chamber. The air discharge occurs at upper region of chamber. The encircling type antenna has a wavy form all around along the chamber inner wall. In this case oxygen radicals would be generated by the air-plasma and dispersed all around of the chamber. Sterilization experiments using above two types of antenna were carried out.

In order to evaluate the performance of air-plasma sterilization, the generation of oxygen radicals in the chamber in measured by the emission spectroscopy and chemical indicator (CI) method. After treatment with air plasma, biological indicators (BI) with the bacillus were cultivated for 24h, and the color of pigment in the culture media (successful: purple, failure: yellow) indicates the successful of the

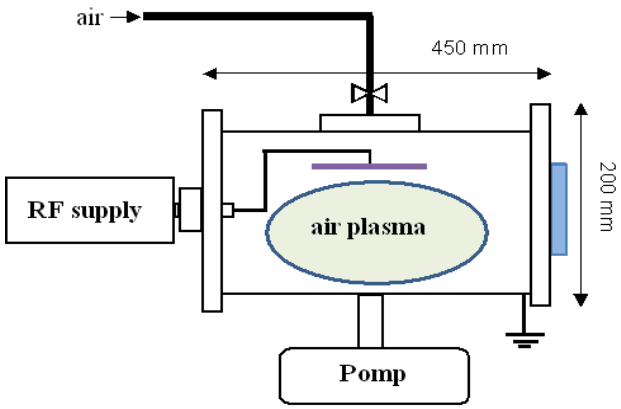

Fig.1 : Schematics of experimental apparatus with semicircular type antenna.

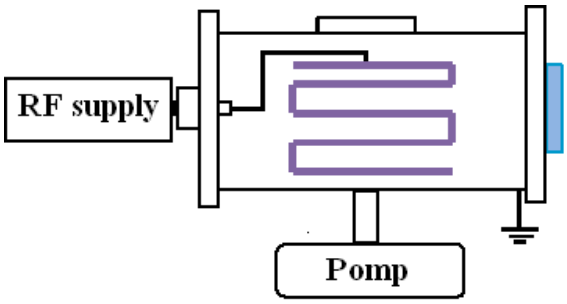

Fig.2 : Schematics of experimental apparatus with encircling type antenna.

treatment.

The uniformity of the generated plasma using different types antenna is confirmed using the Langmuir probe method. Obtained uniformity of electron densities around the axis of the chamber have the fluctuation of several ten % within 150mm of radical direction in the case of the encircling type antenna, which are acceptable for the practical use. While that of the semicircular type antenna is approximately 15%, therefore, oxygen radicals generated in the air plasma using the semicircular type antenna would have enough uniformity for medical sterilization.

3. Experimental results and discussion

3.1 *Sterilization characteristics using semicircular type antenna*

The OES spectra of the air plasma indicate the generation of active oxygen in the whole of the treatment region even when the semicircular type antenna is used. Also, the chemical indicator confirms that the active oxygen is produced at bottom and center of the chamber. Production of the active oxygen is larger around the center axis of the chamber than that in the bottom region of the chamber.

Table 1 shows results of sterilization experiment in air plasma using semicircular type antenna. Sterilization is successful for the treatment period of the 300 min in the bottom of the chamber. In the center of axis, sterilization is successful for 150 min using a BI with sterilization bag, and is successful for it 120 min without sterilization bag.

Treatment period (min) position & pressure	90	120	150	180	240	300
30 Pa at bottom	××	××	×	×	×	○
60 Pa at bottom	××	×	×	×	×	○
30 Pa at center (sterilization bag)	××	○×	○	○	○	○
60 Pa at center (sterilization bag)	××	○	○	○	○	○
30 Pa at center (w/o sterilization bag)	○×	○○	○	○	○	○
60 Pa at center (w/o sterilization bag)	×					

Table 1 : BI sterilization in air plasma with semicircular type antenna.

Treatment period (min) position & pressure	150	180	240	300
50 Pa at center (sterilization bag)		××	○×	
50 Pa at center (w/o sterilization bag)		××	○○	

Table.2 : BI sterilization in air plasma with encircling type antenna.

3.2 *Sterilization characteristics using encircling type antenna*

In order to enhance the oxygen radical generation and inactivation ability of bacillus, we created the encircling type antenna. Langmuir probe indicates that the electron density in the treatment region except the antenna survives has the fluctuation below 70%. Using this result of an electrostatic probe method, the most efficient plasma condition is determined.

When the RF power of 50 W and the air pressure of 50 Pa, the higher and uniform electron density is obtained. Sterilization experiments run under above condition. Table 2 shows result of sterilization experiment in air plasma with encircling type antenna. Sterilization is not successful for 180 min, and is successful for 240 min without sterilization bag. Therefore, the encircling type antenna is not effective for the sterilization comparing with semicircular type antenna. This result would be due to the decrease of the diffusion region area that is necessary for the radical generation.

4. Conclusion

Remarkable difference of sterilizing performance between the semicircular type and encircling type antennas is observed. Sterilizing ability is better in the case of semicircular type antenna than the encircling type antenna. In both cases, oxygen radicals produced from the air are considered to be a sterilization factor.

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