Comparison of Plasma Spectral Characteristics Using a Plasma-Based Ion Implantation

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Plasma-based ion implantation is a recently developed technique used to modify the surface of materials by immersion in plasma coupled with the application of a negative bias voltage.

In this study, we compare the properties of the plasma spectrum with respect to the change in applied voltage as well as the difference in the plasma generation method used.

Spectra of 428 nm and 656 nm show the generation of Ar ions.[1] In addition, the strength of a spectrum emitted by the ion is proportional to the number of the generation of the ion. Comparisons of these spectra suggest that the number of ions increases in line with an increase in voltage. Moreover, our findings suggest that the number of ions increase for a combination of RF burst plasma and self-ignition plasma compared with the number of ions for only self-ignition plasma.

It was shown that we could estimate the property of the plasma ion by emission spectrum.

Сравнение на спектралните характеристики при използване на базирана на плазма йонна имплантация (Х. Ногучи, Н. Фужимура, К. Шимоно, Х. Тойота, Й. Шираи, Т. Танака). *Базираната на плазма йонна имплантация е техника, разработена в последно време, която се използва за модификация повърхността на материалите чрез потапяне в плазма и съединение на отрицателен потенциал. В това изследване ние сравняваме особеностите на плазмения спектър, при промяна на приложеното напрежение, както и на начина на генериране на плазмата. При 428 nm и при 656 nm спектъра показва наличие на Ar йони. В допълнение, силата на емитирания спектър от йоните е пропорционален на числото генерирани йони. Сравнението на спектрите показва, че числото йони нараства линейно с увеличение на напрежението. Нещо повече, ние намерихме, че броят йони расте за комбинация от ВЧ разрядна плазма и само-запалваща се плазма сравнено с броя йони само за само-запалваща се плазма. Показано е, че оценка на свойствата на плазмените йони от емисионния спектър.*

Introduction

The gas-sterilization methods currently used at hospitals include ethylene oxide gas sterilization and hydrogen peroxide gas sterilization. However, residual traces of chemical substances that have an adverse affect on the human body remain a problem with ethylene oxide sterilization.[2] In the case of hydrogen peroxide sterilization, there is a problem in that the process takes around 90 minutes. In addition, the sterilization of items such as fiber gauze, cotton, artificial blood vessels, and felt is difficult, and hydrogen peroxide—an expendable supply in the process—is expensive.

As a substitute sterilization method, the plasma-based ion implantation (PBII) method is tried. In the PBII method, an ion and a radical are produced by applying a negative high-pressure pulse voltage to an item and the reaction by it inactivates bacteria spore. In this study, the methods of generating plasma suitable for sterilization using the PBII method was evaluated use emission spectroscopy.

Experimental

A schematic of the experimental setup is shown in Fig. 1. The chamber measures 450 mm in height, 590 mm in width, 470 mm in depth. The RF antenna (manufactured by American North Star Inc.) is a copper coil with five windings, and a diameter of approximately 250 mm. The RF antenna is electrically insulated from the chamber by glass, and this coiled

RF antenna produces the RF voltage (222 kHz) by an induction electric field.

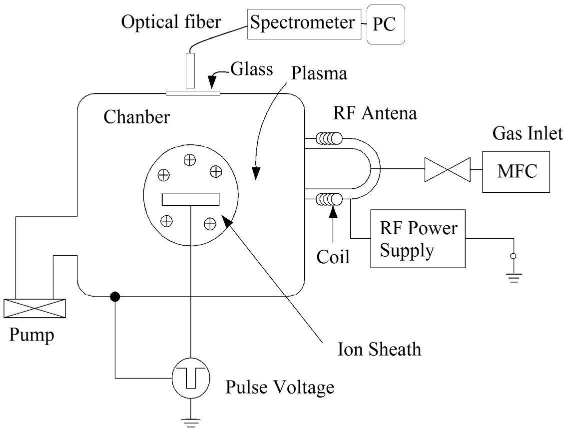

Fig. 1. Experimental setup

The target electrode, made of SUS, is 140 mm in diameter, 18 mm thick, and it is insulated by a grounded chamber, and it is installed in the center of the chamber. The high-pressure pulse modulator (manufactured by KURITA Seisakusho CO.) can generate a frequency up to 1000 pps, a capacity of up to 8A and can irradiate a target with a negative pulse voltage of a maximum of 15 kV in a pulse width of 2 – 30 μs. The high-pressure pulse voltage is controlled by a computer control system (Fotgen2) running Windows 98. We installed extra boards in the expansion slots of the PC and used light as a control signal output through an optical fiber.

The vacuum exhaust used mass flow together with a rotary pump and a mechanical booster pump, and the chamber was filled with gas to a density of 99.9999%.

We measured the spectrum through the glass top of the target electrode. We used a USB2000 spectroscope and saved the data using spectroscope control software Overture running on Windows 7.

We measured RF burst plasma, self-ignition plasma, and a combination of RF burst plasma and self-ignition plasma with the chamber pressure maintained at 2 – 5 Pa.

Result and discussion

1) Change according to the plasma generation method of the spectrum

In this subsection, we show the results from the observation in the change of the spectrum by plasma generation method. In addition, we pay attention to the spectrum of 428 nm and 656 nm indicating the generation of Ar ions, and suppose a change in the number of ions of produced plasma.

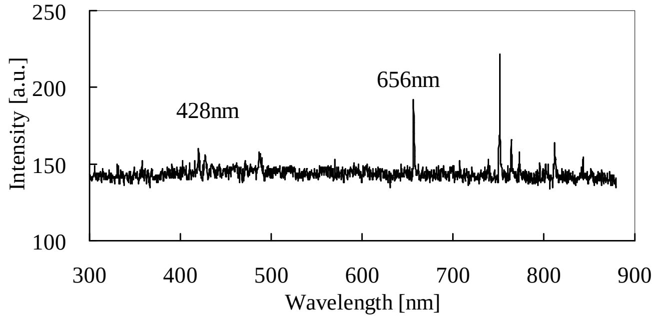

Fig. 2. Self-ignition plasma only

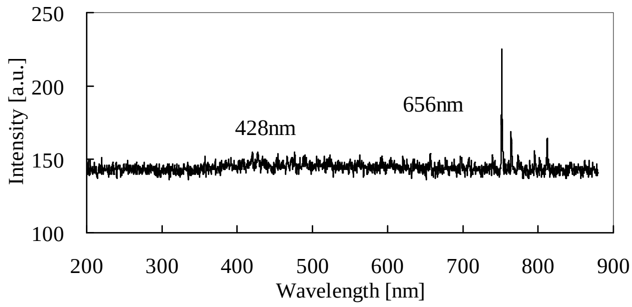

Fig. 3. RF burst plasma only

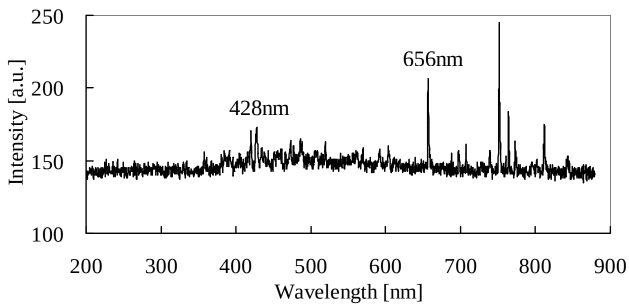

Fig. 4. Combination of RF burst plasma and self-ignition plasma

The spectrum when only self-ignition plasma is used is shown in Fig. 2, that for only RF burst plasma is shown in Fig. 3, and a combination of RF burst plasma and self-ignition plasma is shown in Fig. 4.

Fig.2 shows the typical emission spectrum in self-ignition plasma. Spectra of 428 nm and 656 nm show the generation of Ar ions.

It suggests that the self-ignition plasma generates ions contributing to sterilization.

It suggests that a sterilization effect enhances during increase the number of the generation of the ion.

Therefore we consider combination of RF burst plasma and self-ignition plasma as a method to increase the number of the ions.

Fig3 shows the typical emission spectrum in the RF burst plasma. As shown in Fig.3, it was found that spectra of 428 nm and 656 nm appeared in only RF burst plasma.

Fig.4 shows the typical emission spectrum in combination of RF burst plasma and self-ignition plasma.

Comparing with Fig. 4 and Fig. 2, the spectrum intensity of combination of RF burst plasma and self-ignition plasma is larger than that of the self-ignition plasma.

Because of this, it suggests that the number of ions contributing to sterilization become larger in the case of combination of RF burst plasma and self-ignition plasma.

2) Target voltage dependence of the spectrum

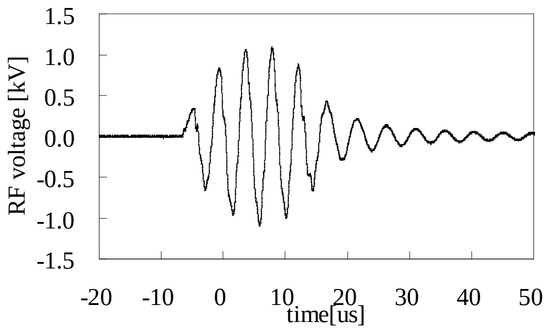

Fig. 5. RF power supply voltage

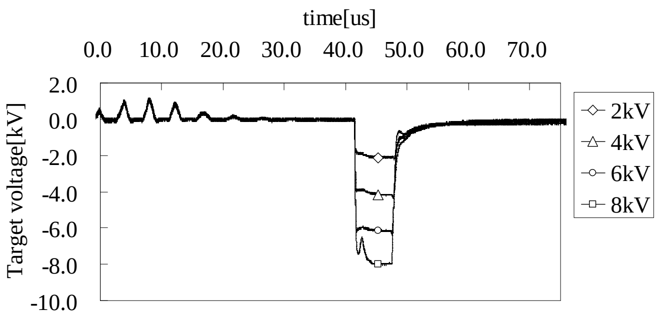

Fig. 6. Target power supply voltage

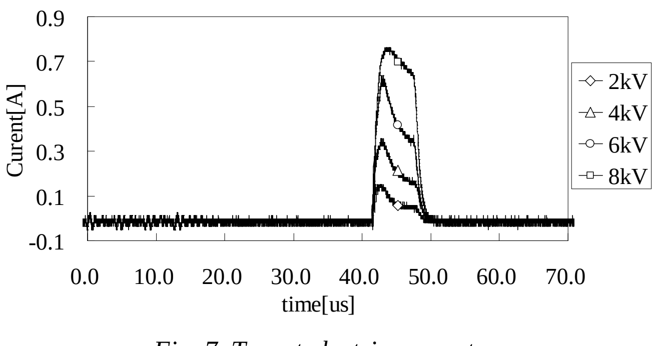

Fig. 7. Target electric current

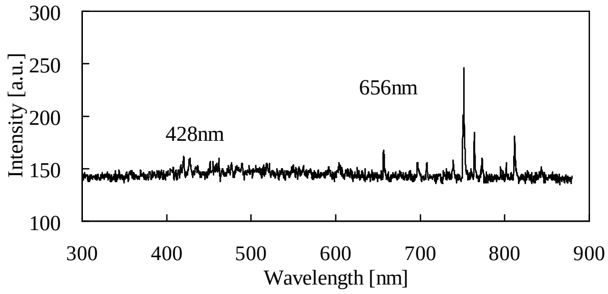

Fig. 8. Combination of RF burst plasma (60 V) and self-ignition plasma (2 kV)

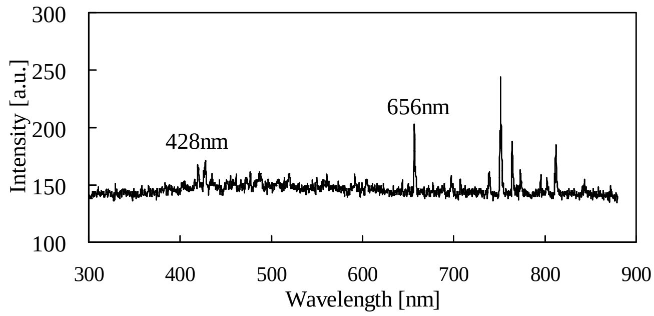

Fig. 9. Combination of RF burst plasma (60 V) and self-ignition plasma (4 kV)

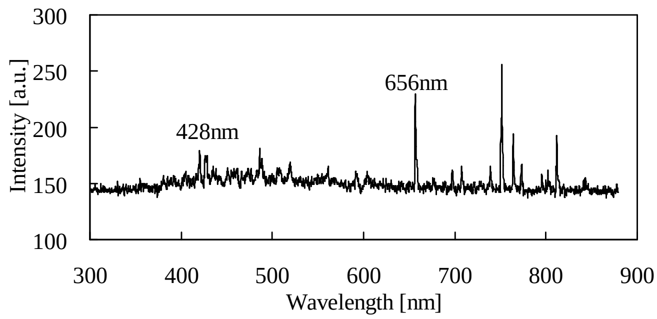

Fig. 10. Combination of RF burst plasma (60 V) and self-ignition plasma (6 kV)

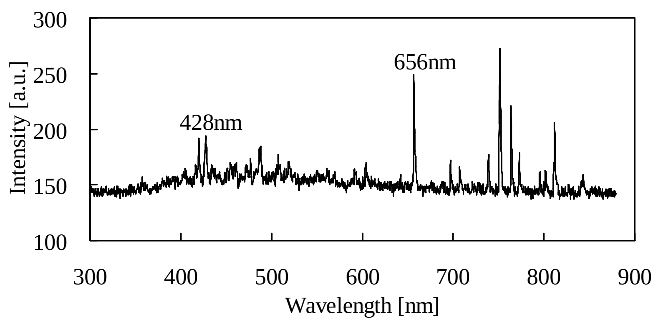

Fig. 11. Combination of RF burst plasma (60 V) and self-ignition plasma (8 kV)

In this subsection, we show the result observed for the change of the spectrum by the change of the target power supply voltage when we set the RF power supply voltage to 60 V and when we used RF burst plasma together with self-ignition plasma. In addition, we pay attention to the spectrum of 428 nm and 656 nm indicating the generation of Ar ions, and suppose a change in the number of ions of the produced plasma.

The RF power supply voltage is shown in Fig. 5, the target power supply voltage in Fig. 6, the target electric current in Fig. 7, and the spectrum when we used an RF power supply voltage of 60 V and a target voltage of 2 kV in Fig. 8, an RF power supply voltage of 60 V and a target voltage of 4 kV in Fig. 9, an RF power supply voltage of 60 V and a target voltage of 6 kV in Fig. 10, and an RF power supply voltage of 60 V and a target voltage of 8 kV in Fig. 11.

It suggests that the strength of the general spectrum increases with an increase in the target power supply voltage from a comparison of Figs. 8 - 11. Spectrum intensity of 428nm and 656nm becomes strong during increase of the power supply voltage. From these results, it is found that the number of the Ar ions increases with the power supply voltage.

Conclusion

It was observed that the spectrum changed by changing the plasma generation method and the target voltage. For the plasma generation method that we used in this paper, it is suggested that the combination of RF burst plasma and self-ignition plasma is the most suitable to sterilization. With respect to the target voltage, each spectrum strength became stronger by increasing the voltage.

In particular, as for the extreme change of these spectra, the number of Ar ions generated supposes that we have equilateral correlation when we pay attention to a spectrum of 428 nm and 65 nm. Thus, it is supposed by the change of the spectrum of 428 nm and 656 nm that the number of Ar ions generated changes by changing the plasma generation method and the target voltage. In other words, it is supposed that it is combination of RF burst plasma and self-ignition plasma that produces the most ions, followed by only self-ignition plasma, and only RF burst plasma in order.

From the above, the possibility of examining a method of generating plasma suitable for sterilization using the PBII method was suggested by measuring the light emissions of produced plasma using a spectroscope.

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[2] T. Tanaka, T. Hironaka, S. Hayashi, and I. Koyama : Elektrotechnica & Elektronica E+E, **47** (2012) 268.

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