Fluid Characteristics of Surface Wave Plasma from the Viewpoint of Material Surface Modification

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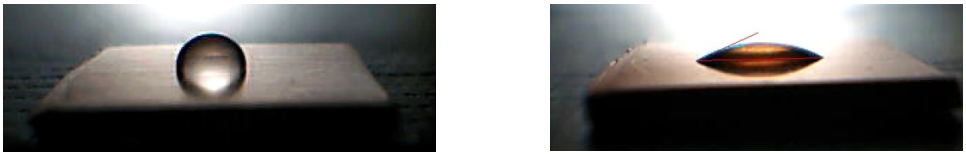
Abstract Low temperature plasma can be utilized for material development because of its less plasma damage to material. However it has not achieved to generate and control plasma satisfactorily. In this paper, we examined the effect of plasma process on the copper plate surface by the use of surface wave plasma (SWP). Figure 1 shows a status of the water droplet on the copper plate before and after treatment by SWP. As a result, we found the certain relationship between a contact angle of a water droplet on the copper plate surface and process gas components and location in the process chamber. It suggests the importance and possibility of controlling the plasma flow in the process chamber.



Before plasma treatment After plasma treatment

Fig.1 Water droplet on the copper plate

1. Introduction

Dry process with plasma has been applied in earnest to industry since the 1980's [1]. Especially for the semiconductor manufacturing process, the importance of plasma process has been increasing every year and now it is introduced into over 60% of the whole process [2]. Considering the extension of application fields of the low temperature plasma process such as further miniaturized semiconductor devices, medical and biological technology, it is clear that such the plasma for material process et al. should be controlled precisely [3]. In

this study, we aimed to research the relationship between surface wettability of a copper plate and a low temperature plasma flow in a process chamber and the plasma characteristics by surface wave plasma (SWP), which is low temperature plasma.

2. Principle and theory

A 2.45GHz microwave released from the magnetron reaches the slot antenna located at the end of the waveguide and standing wave (surface wave) is generated on the surface of the quartz glass as shown in Fig.2. Electrons are accelerated by the surface wave and the surface wave plasma is generated continuously [4]. Wettability is a term that represents the interface phenomenon between solid surface and fluid. As shown in Fig.3, the angle θ is called "contact angle" and stands for an index of wettability.

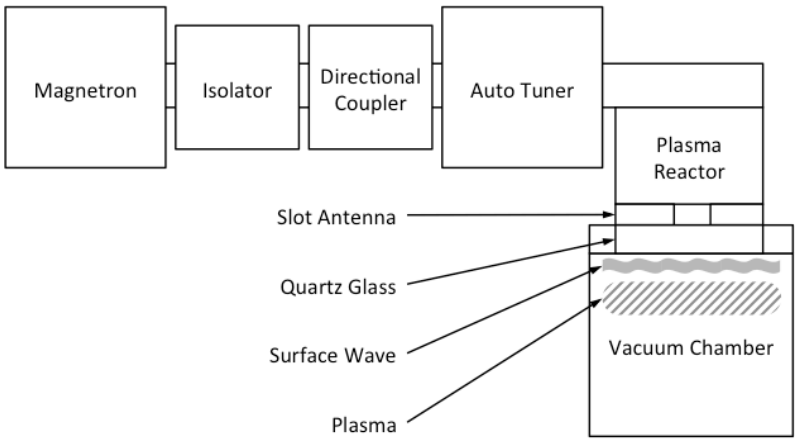


Fig.2 Excitation of surface wave plasma

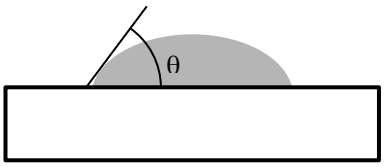


Fig.3 Contact angle θ

3. Experiment

Figures 4 and 5 shows the schematic diagrams of the experimental apparatus and the chamber viewed from the top. We placed copper plates at four points shown in Fig.5.

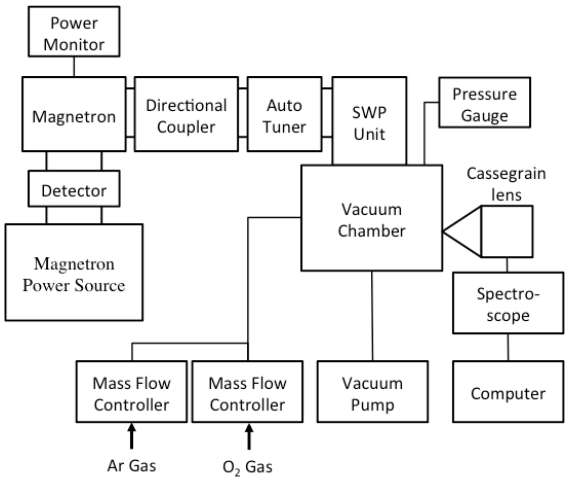


Fig.4 Experimental apparatus

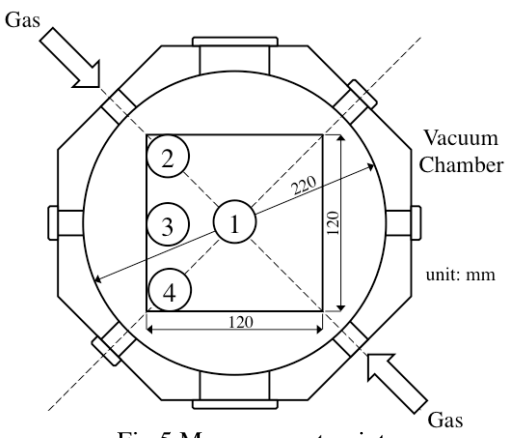


Fig.5 Measurement point

About the behavior of the plasma flow in the chamber, we analyze it by numerical simulation. Table 1 shows the experimental conditions.

Table 1 Experimental conditions

Input power (W)	500
Gas flow Ar:O_2 (sccm)	Condition 1 350:50
	Condition 2 300:100
	Condition 3 200:200
	Condition 4 100:300
	Condition 5 50:350
Exposure time (sec)	15, 30, 60, 120

4. Experimental results and considerations

Figure 6 shows the change of the contact angle in each condition. From this result, it can be seen that the contact angle at each measurement point is substantially reduced as the plasma exposure time increases. However for the conditions that the flow rates of argon to oxygen being comparable such as the condition 3, the contact angle has increased at the exposure time of 60 seconds at the location ③, ④.

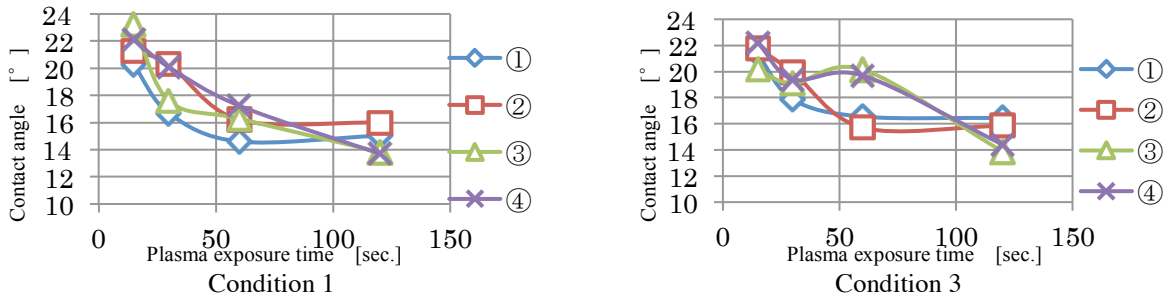


Fig.6 Relation between a contact angle and plasma exposure time

Figures 7 and 8 show the change of the contact angle for each measurement point and the distribution of the product of gas density and vertical downward velocity just above the stage, that is mass flow rate. The result of the numerical simulation for gas flow in the chamber is shown in Fig.9.

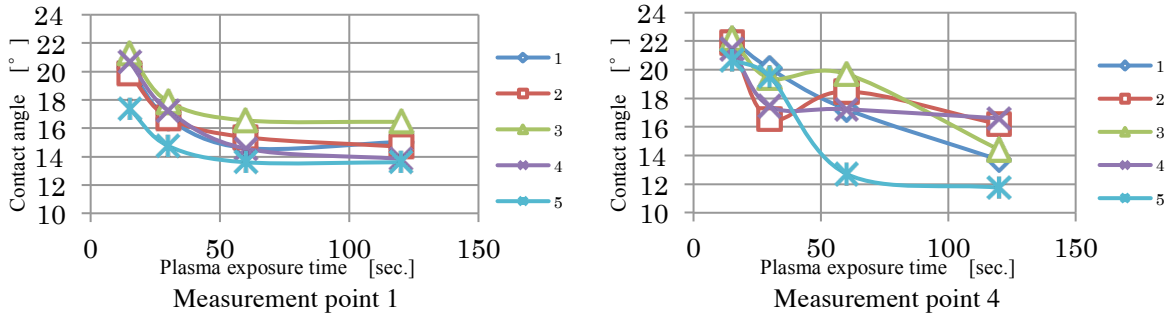


Fig.7 The contact angle for each measurement point

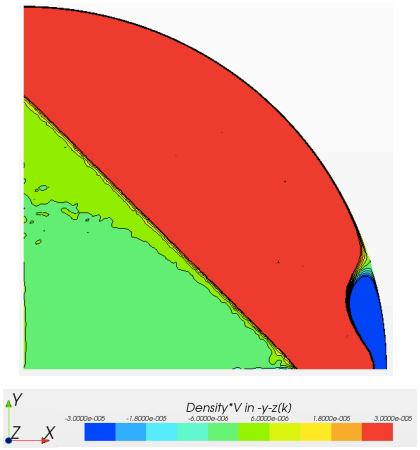


Fig.8 Distribution of the product of gas density and vertical downward velocity

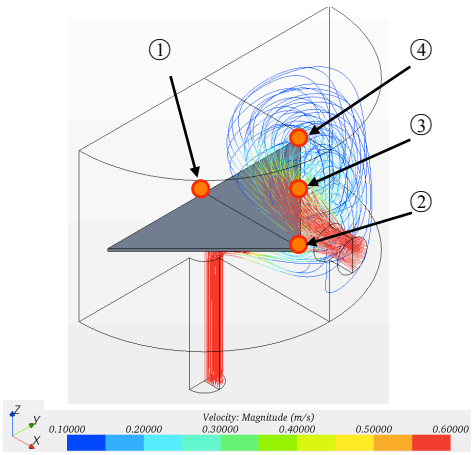


Fig.9 Stream lines of gas flow in the chamber

These results show that in the condition that the difference of argon and oxygen flows is relatively small, the contact angle is reduced by oxygen plasma at the beginning of plasma exposure, and then, the contact angle increases with a sputtering effect of argon plasma, and after that the contact angle decreases again.

5. Conclusion

In this study we evaluated the effect of plasma process by SWP with a mixture gas of argon and oxygen using a contact angle. As the result of the investigation about the change of contact angle on the copper plate by varying the flow ratio of argon/oxygen, the contact angle becomes smaller with plasma exposure time in the both cases of argon rich and oxygen rich conditions and experimental results show that the effect of plasma treatment on the surface of a copper plate changes according to not only the kind of gas but also the flow in the chamber. Therefore, this might be the reason of the above-mentioned increase and decrease of the contact angle. It was also found that only the effect of oxygen plasma appears at the center of the stage and there is a certain relationship between the behavior of the gas flow pattern just close to the stage and the result of plasma process.

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