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Selective Area Deposition of Insulating Films by Laser CVD and its Characterization

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Abstract

Selective area deposition of SiN and SiON films is achieved by Laser CVD method. This technique is noticeable as film deposition can be done easily and directly on a localized area of the substrate at low temperature and with less damage. An ArF excimer laser with a wave length of 193nm is used to excite and dissociate reactant gases. FT-IR(Fourier Transform Infrared Spectrometer) analysis are carried out to evaluate the bonding structure of the deposited films. In addtion, area selectivity(pattern size/deposition area) of the films are investigated with respect to substrate temperature and chamber pressure which are the film deposition conditions.

1. INTRODUCTION

In thin film deposition, the deposits are often produced over a large area of the substrate but in some applications it becomes important to confine deposition to a spatially selected area. Conventionally, localized or patterned thin films are obtained by a photo-lithography process. But this requires many steps and a more simplified process becomes desirable on many occasions. One of the methods proposed recently to satisfy this desire is photo-chemically deposited insulating films by Laser CVD [1-2]. This makes it possible to deposit thin films on localized areas of the substrate without the photo-lithography process. There are two methods of depositing thin films on localized areas of the substrate by Laser CVD; the laser direct writing method [3-4] and the mask process method [5-6]. In the former method, the laser beam is focused on the substrate through a lens without a mask, and makes patterned films directly by moving the laser beam or the substrate. The mask process is divided into two deposition methods, that is parallel and perpendicular to the substrate surface, according to the direction of irradiation. In this paper, after deposited SiN and SiON films by mask process with parallel irradiation of the laser beam, bonding structure and area selectivity of the deposited films are evaluated.

2. EXPERIMENTAL

SiN and SiON films were deposited on P-type Si(100) wafer substrate with a resistivity of 4.5-6 Ω·cm. Before film deposition, an RCA standard cleaning process was applied. Fig.1 shows the schematic diagram of the Laser CVD system arrangement. An ArF excimer laser with a wave length of 193nm was irradiated parallel to the substrate surface. The distance between the beam and the substrate was fixed to about 0.3mm. A mask with a hole diameter of 500㎛ was located above the substrate surface. Table 1 shows the deposition conditions for SiN and SiON films. After film deposition, thickness of the films were measured by an α-step and the bonding structure was evaluated by FT-IR analysis. Area selectivity was investigated by an optical micro-photograph equipment.

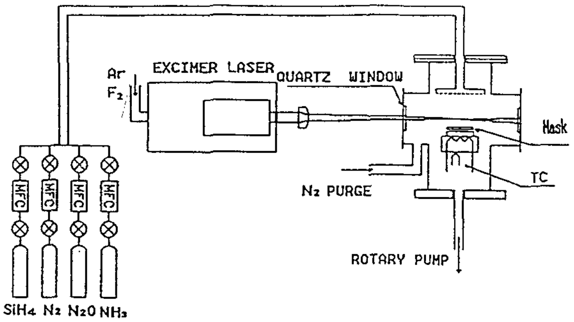

Figure 1. A schematic diagram of the Laser CVD system arrangement.

Table 1
Deposition conditions of SiN and SiON films.

	SiN	SiON
SiH_4 Flow Rate	20 SCCM	20 SCCM
N_2O Flow Rate		80 SCCM
NH_3 Flow Rate	80 SCCM	80 SCCM
N_2 Flow Rate	100 SCCM	100 SCCM
Substrate Temperature	100℃ - 300℃	100℃ - 300℃
Chamber Pressure	0.5 - 2.5 Torr	0.5 - 2.5 Torr
Laser Power	6.4 Watt	6.4 Watt

3. RESULTS AND DISCUSSION

3-1. FT-IR Analysis

Fig.2 shows the FT-IR absorption spectrum of SiN film deposited under the condition of 300℃, 2 Torr. Weak absorption peaks appear at 3350 cm^{-1} (N-H bond), 2200 cm^{-1} (Si-H bond), and 450 cm^{-1} (Si-O bond) respectively, and a strong absorption peak appears at 900 cm^{-1} which indicates a Si-N bond. This represents that Laser CVD SiN film is mainly composed of Si-N bond although there is a little shift compared with FT-IR spectrum of conventional PECVD SiN film [7]. Fig.3 shows the FT-IR absorption spectrum of SiON film deposited under the condition of 300℃, 2 Torr.

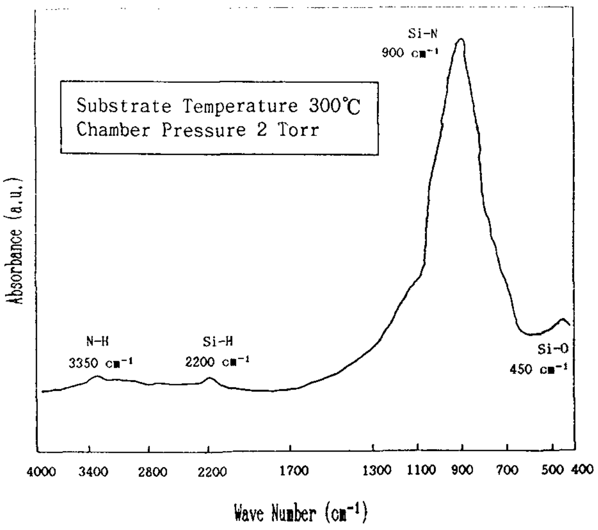

Figure 2. FT-IR absorption spectrum of SiN film.

Absorption peaks show the presence of N-H bond (3350 cm^{-1}), Si-H bond (2200 cm^{-1}), Si-N bond (900 cm^{-1}), and Si-O bond (1150 cm^{-1} and 450 cm^{-1}) in the film. As mentioned above, the film is supposed to be SiON.

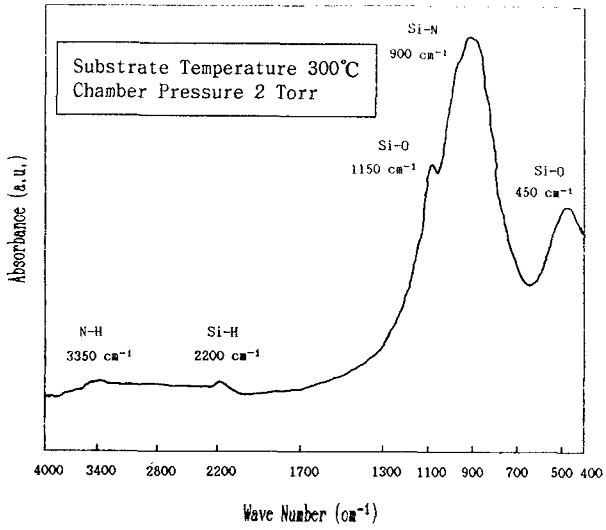

Figure 3. FT-IR absorption spectrum of SiON film.

3-2. Evaluation of area selectivity as a function of substrate temperature

Fig.4 shows the area selectivity of SiN film as a function of substrate temperature. Area selectivity degraded as substrate temperature increased. Fig.5 shows the area selectivity of a SiON film as a function of substrate temperature which shows a similar trend to SiN film. This phenomena can be explained by two factors. First, the mean free path of excited radicals which are reactive gas molecules excited by the laser beam increase, as substrate temperature is increased. Second, surface migration length of excited radicals and its intermediates on the substrate surface increase, as substrate temperature is increased. As mentioned above, increasing the mean free path of excited radicals by increasing the substrate temperature can broaden the deposited area size, which reduces area selectivity. And also, surface migration length of excited radicals increases to a few micrometer order by increasing substrate temperature from 100℃ to 300℃, which increases the deposited area size and reduces area selectivity.

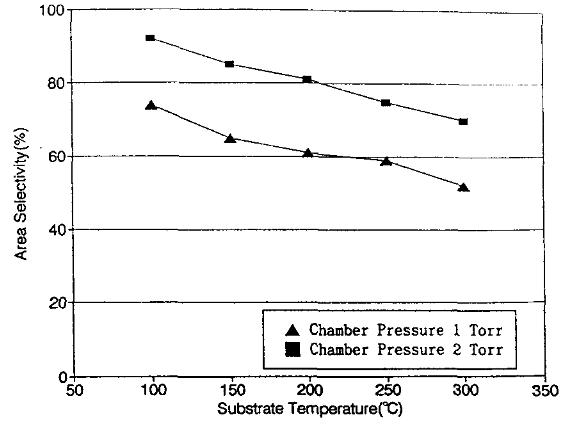

Figure 4. Area selectivity of SiN film as a function of substrate temperature.

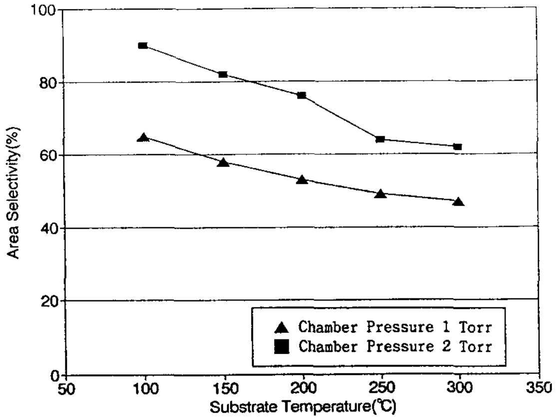

Figure 5. Area selectivity of SiON film as a function of substrate temperature.

3-3. Evaluation of area selectivity as a function of chamber pressure.

Fig.6 and 7 shows area selectivity of SiN and SiON films, respectively as a function of chamber pressure. Chamber pressure was controlled by adjusting the throttle valve in the chamber. Area selectivity improved considerably as chamber pressure increased. With increasing chamber pressure, the mean free path of excited radicals decreases due to more collisions. This reduces the deposited area size and improves area selectivity. Fig.8 shows the optical microscope image of SiON film deposited under the condition of 300℃, 2 Torr.

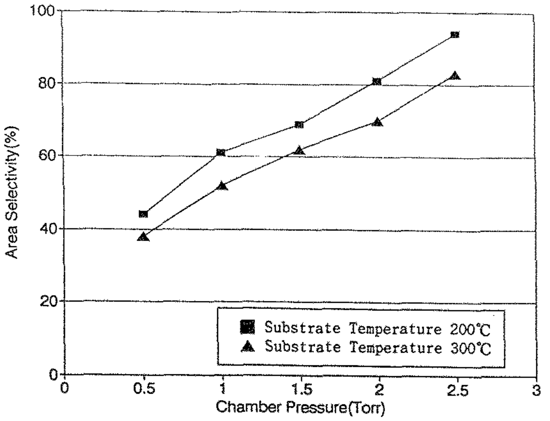

Figure 6. Area selectivity of SiN film as a function of chamber pressure.

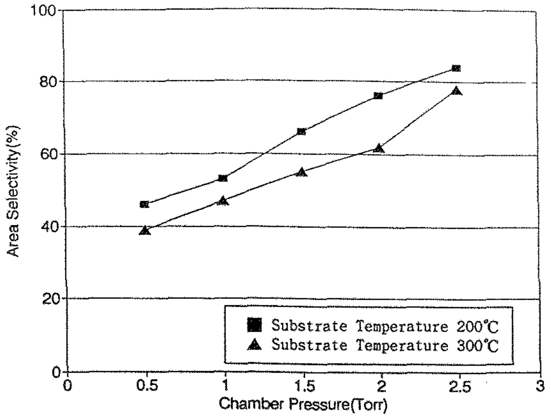

Figure 7. Area selectivity of SiON film as a function of chamber pressure.

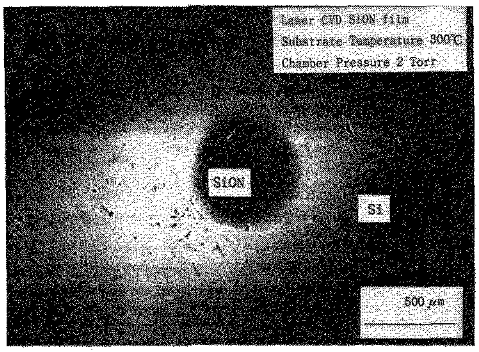

Figure 8. Optical micro-scope image of SiON film.

4. CONCLUSION

The following are the results:

1. The bonding structure of the deposited films is stable from the FT-IR analysis.
2. Area selectivity of SiN and SiON films is improved as substrate temperature is decreased.
3. Area selectivity of SiN and SiON films is improved as chamber pressure is increased.

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