Low stress TEOS-SiO_2 films deposited by PECVD using a low frequency

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Abstract: As a technique for low-temperature deposition using PECVD, TEOS-SiO2 was deposited at 100°C using 400 kHz. The residual stress, refractive index and wafer temperature were evaluated, respectively. By adjustment of the RF power, dense films with low compressive stress were obtained while keeping the substrate temperature.

Keywords: PECVD, TEOS, Low temperature, Low frequency

1. Introduction

In recent years, diversification of substrate materials has increased the demand for insulating film formation on materials with low heat resistance temperatures. SiO2 is also effective as an insulating film when insulating Si and electrodes for samples bonded to a support substrate, such as TSV.SiO_2 deposition using PECVD is promising as a method that enables formation even at low temperatures. SiH_4 is commonly used as a raw material gas for SiO_2 in plasma CVD, but it is explosive and toxic, and sparse films are easily formed when depositing films at low temperatures.

We have been developing plasma CVD deposition using liquid precursor materials (LS-CVD®) [1], where tetraethyl orthosilicate(TEOS) is used as a precursor of SiO_2, which is effective for step coverage due to its large molecular and low adhesion coefficient. [2]

In the case of SiO_2 deposition using TEOS, its molecular size makes it difficult for the reaction to proceed, and the film tends to contain a large amount of hydrogen. The film stress after deposition tends to be tensile stress, which changes to compressive stress over time when the film is left in the air. This is thought to be caused by the film being in a sparse state and moisture in the atmosphere being contained in the film [3]. If the film is under compressive stress after deposition, the change over time is slight, suggesting that the film is dense.

We have investigated in this study the use of low frequency as a possible method for the deposition of compressive stress. It is known that compressive stress can be easily obtained by CVD using plasma at low frequencies. [4] The low frequency allows the ions generated in the plasma to follow the frequency, and the ion impact accelerates the deposition reaction.

We have performed TEOS-SiO_2 deposition by plasma CVD using a power supply frequency of 400 kHz and evaluated the stress and refractive index. We also evaluated the substrate temperature rise due to ion bombardment.

2. Experimental

Figure 1 shows the schematic view of the experimental apparatus. TEOS and O_2 are introduced through a shower plate into a vacuum-exhausted reaction chamber, the pressure is kept constant, and 400 kHz is applied to generate plasma for SiO_2 film deposition. The deposition parameters were TEOS flow rate at 5 sccm, O_2 flow rate at 195 sccm, pressure at 40 Pa, and stage temperature at 100°C. The RF power was varied from 50 W to 200 W, evaluating stress and refractive index. To measure substrate temperature, Thermo Color Sensor (Asey Industries Corp.) was attached to a small piece of Si and evaluated during deposition.

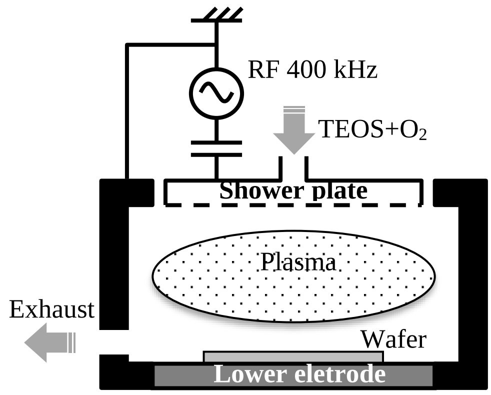

Fig. 1. Schematic view of PECVD.

3. Results and Discussion

Figure 2 shows the change in stress versus 400 kHz power: the tensile stress was about 30 MPa at 50 W, the compressive stress was -110 MPa at 100 W, and the compressive stress was about -170 MPa at 150 W and 200 W. The stress after one day of standing in the air showed -190 MPa at 50 W, and the stress showed a change of around -10 MPa at 100 W and above from immediately after the film was deposited. It has been reported that the stress changes to compressive stress in relation to moisture in the air [3], and the film at 50W was considered to be in a sparse state that easily contained moisture; at 100W or higher, the film is considered to be in a dense state because the stress change is small.

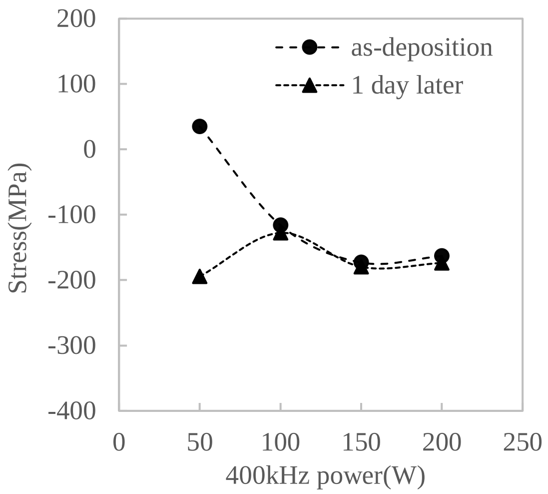

Fig. 2. Variation of Stress as a function of 400kHz power.

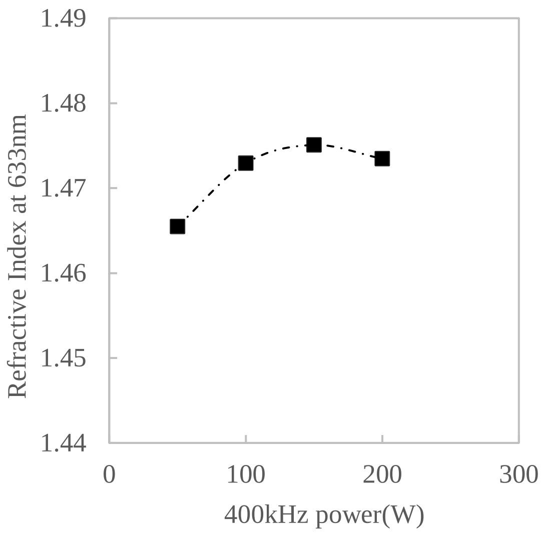

Fig. 3. Variation of refractive index as a function of 400kHz power.

Figure 3 shows the change in refractive index versus 400 kHz power: at 50 W it is about 1.465, and above 100 W it exceeds 1.47. The slightly smaller refractive index at 50 W also suggests that the film is sparse.

Figure 4 shows the variation of substrate temperature with 400 kHz power. The substrate temperature rises gradually with increasing power, with an increase of about 1.5°C/W from the stage temperature of 100°C. Although the effect of ion impact at 400 kHz is considered to be present to some extent, the increase is gradual.

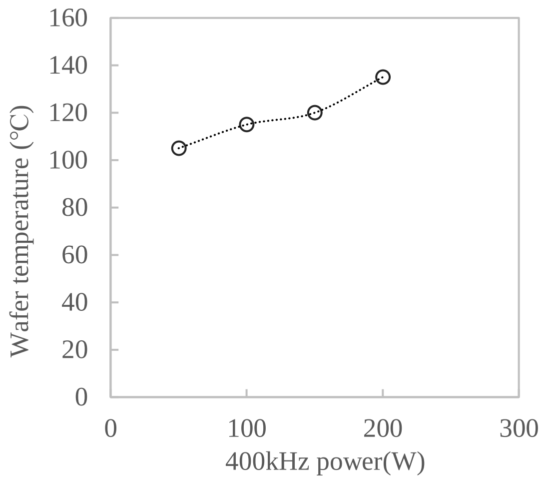

Fig. 4. Variation of wafer temperature as a function of 400kHz power.

4. Conclusion

These results suggest that even at a low deposition temperature of 100°C, the use of plasma at 400 kHz makes it possible to deposit dense films while minimizing the increase in substrate temperature.

By depositing TEOS-SiO2 films at 400 kHz, SiO2 with good refractive index and stress could be deposited while controlling the substrate temperature rise by adjusting the RF power. This is expected to enable high-quality SiO2 deposition on plastics and other materials with low heat resistance.

5. References

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