Precise In-situ Detection of Wafer Film Thickness by Tilting Light Irradiation

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1. Introduction

Precise control of critical dimensions has been required towards miniaturization in semiconductor manufacturing. Plasma etching with high accuracy has been realized by using end point detection.1) In end point detection, *in-situ* film thickness monitoring (FTM) which detects the thickness of remaining film of a wafer during etching on the basis of light reflected from the wafer has been widely used. One of the critical issues for FTM is the deterioration of the signal to noise ratio in the case of a wafer with thin film or a low open area, where the dependence of reflectance on the film thickness is small. To improve the ratio, a light source that reduces the noise caused by light fluctuation and utilizes light with a wide wavelength range has been introduced.2) However, stray light generated from the source reduces the signal intensity from a wafer. In this work, we propose an optical system for removing the stray light and investigate the accuracy of FTM in that system.

2. Experimental

The proposed optical system for FTM is shown in Fig. 1. Two light ports are attached above the quartz plate of a chamber for a microwave electron cyclotron resonance (M-ECR) etcher. One is for irradiating light to a wafer in the chamber, and the other is for monitoring reflected light with a spectrometer. These two ports are tilted toward each other so that the paths of light reflected by a wafer match. Stray light is generated as a result of the reflection of irradiating light at the quartz plate. In this optical system, the dependence of both the amount of stray light and the reflectance in each film thickness on the angle of the two ports were investigated, and the accuracy of FTM for Si_3N_4 was evaluated.

The accuracy of determining film thickness was evaluated by comparing the thickness estimated by FTM to the actual thickness measured by *ex-situ* reflectometry. Our algorithm for FTM is shown in Fig. 2. The film thickness at each measuring time is determined by utilizing a database where the relationship between the spectra and the film thicknesses are determined in advance.

3. Results

Figure 3 shows the results of calculating the dependence of an amount of stray light on the angle of the irradiating port. It is clear that the stray light was completely removed when the angle exceeded 6 degrees. Figure 4 shows the dependence of the reflectance difference per 1-nm change for each Si_3N_4 film thickness when the angle of the monitoring port was varied. The reflectance difference, which directly corresponds to the signal intensity from a wafer, decreased in the case of an angle of over 20 degrees. The reduction was due to the shortened difference in the light path between the reflected light from the top surface of the film and that from the bottom surface. From these results, it was clarified that the angle of the two ports should be in the range of 6 to 20 degrees. Figure 5 shows a comparison of light intensities measured during Si_3N_4 etching. The amplitude at an angle of 20 degrees became twice larger than that of 0 degrees due to the removal of stray light. The errors in thickness as estimated by FTM for each Si_3N_4 thickness are shown in Fig. 6. The errors at 20 degrees were clearly less than those at 0 degrees. Note that detection with an angstrom-order accuracy was achieved even for film thicknesses of less than 100 nm.

4. Summary

An optical system, in which ports for light irradiation and monitoring are tilted to remove stray light, was proposed for FTM. It was clarified that the removal of stray light improves the signal to noise ratio of FTM and expands the range of detectable film thicknesses with an angstrom-order accuracy. This technique is expected to improve the accuracy of FTM even for wafers with a low open area.

References

1) I. Tepermeister *et al.*, Solid State Technol. **39**, 63 (1996)
2) N. Layardi *et al.*, J. Vac. Sci. Technol. B **17**, 2630 (1999)

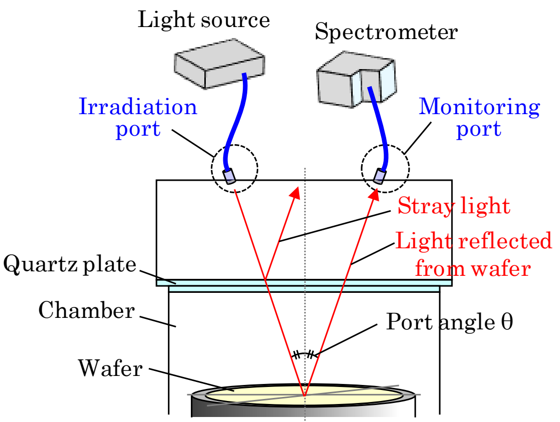

Figure 1 Schematic illustration of proposed optical system for film thickness monitoring in plasma etcher.

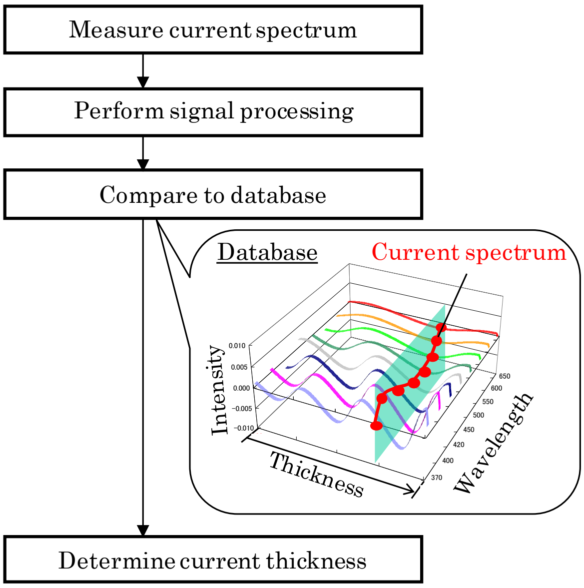

Figure 2 Algorithm for determining film thickness.

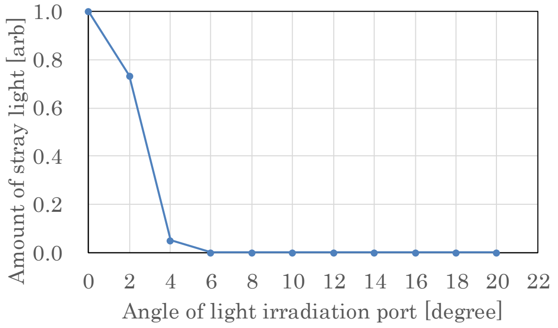

Figure 3 Relationship between angle of irradiating port (perpendicular irradiation: 0 degrees) and amount of stray light detected at monitoring port.

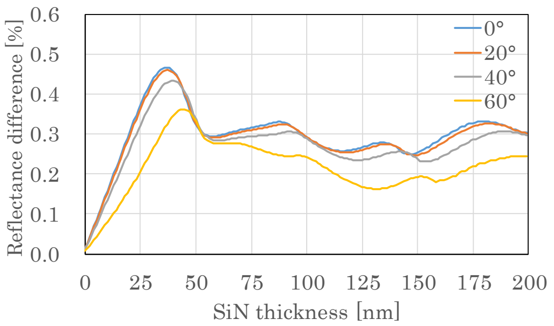

Figure 4 Average value (400–700 nm) of reflectance difference per 1-nm change for each Si_3N_4 thickness when angles of monitoring port were 0, 20, 40 and 60 degrees.

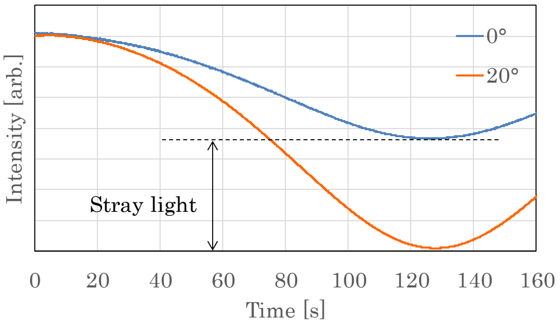

Figure 5 Light intensity variation (λ = 450 nm) during Si_3N_4 etching when angles of monitoring port were 0 and 20 degrees.

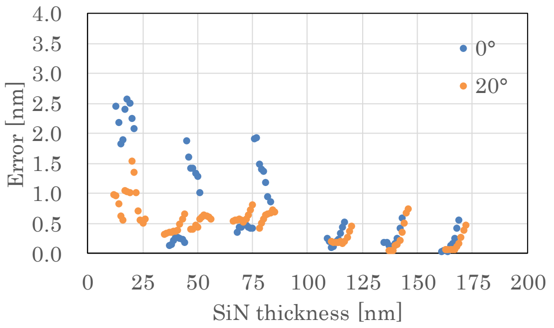

Figure 6 Errors in thickness estimated by FTM for each Si_3N_4 thickness when angles of two ports were 0 and 20 degrees. Here, error is defined as standard deviations of difference between determined and actual thickness.