Development of Film Thickness Monitor Using Multiple Databases to Improve Robustness Against W2W Device Structure Fluctuation

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1. Introduction

To enable miniaturization in semiconductor manufacturing, precise control of critical dimensions is required. Plasma etching with high accuracy has been achieved by using end point detection [1], where in-situ film thickness monitoring (FTM) that detects the thickness of the remaining film of a wafer during etching on the basis of light spectra reflected from the wafer is widely utilized. One of the critical issues for FTM is the increase of error in estimated film thickness due to fluctuation of the device structure between wafers. In conventional FTM, film thickness is estimated by comparing the measured light spectra with spectra in a database (DB). However, in cases where the device structure of wafers is fluctuated, it is difficult to precisely estimate the wafer film thickness because the relationship between film thickness and the spectrum is changed for each wafer. In this study, we propose a new FTM that uses multiple DBs (multi-DB FTM) to improve robustness of film thickness estimation against the device structure fluctuation between wafers.

2. Experimental

Figure 1 shows the algorithm of the proposed multi-DB FTM. The spectral data obtained from wafers with various device structures are assigned to multiple DBs. A measured light spectrum is compared with the spectra in all DBs, and the film thickness is determined based on the error in spectrum matching. By using this algorithm, film thickness can be estimated using an optimal DB that is closest to the relationship between film thickness and spectra in the etched wafer. Here, the fluctuation range of the device structure in the multiple DBs should be almost the same as that in the target etching process. Figure 2 shows the algorithm to select multiple DBs from a number of wafer spectra data in the target etching process. All wafer spectra data are analyzed by manifold learning (Isomap: Isometric Mapping) and sorted based on the similarity of spectral change during etching. Multiple DBs are selected based on the similarity value. We evaluated the accuracy of the film thickness estimation using multi-DB FTM by using simulated data of wafer spectra. Figure 3 shows the etching process and device structure utilized in the simulation, where the etched film is Si_3N_4 and the parameter fluctuating the device structure between wafers is defined as the mask thickness.

3. Results

Figure 4 shows the simulated spectra of the wafers with mask thicknesses of 20, 30, and 40 nm. Although the Si_3N_4 thickness of all wafers was the same, the spectra differed from each other due to the difference in mask thickness of each wafer. Figure 5 shows the result of sorting the wafers according to the similarity value calculated by Isomap. The horizontal and vertical axes correspond to the similarity value and the mask thickness, respectively. It is confirmedthat there is a high correlation between the similarity value and the mask thickness. By selecting multiple DBs based on the similarity value, it is possible to ensure a wide fluctuation range of the device structure in the DBs. The film thickness of wafers with various mask thicknesses was estimated by multi-DB FTM using 11 DBs, as shown in the orange plot in Fig. 5. Figure 6 shows the error of the estimated film thickness for wafers with the Si_3N_4 thickness of 100 nm. The horizontal axis is the mask thickness of the wafers. We found that multi-DB FTM can estimate the film thickness with an error of 0.6 nm or less for all wafers with various mask thicknesses.

4. Summary

To achieve precise estimation of film thickness for wafers with device structure fluctuation, we proposed an FTM method using multiple DBs and an algorithm to select the optimal DBs using manifold learning. We demonstrated that the proposed FTM can detect the film thickness with an angstrom-order accuracy even when the device structure fluctuates between wafers. The proposed technique will be useful for applying FTM to the etching process of wafers with complex device structures.

References

1) I. Tepermeister *et al.*, Solid State Technol. **39**, 63 (1996).

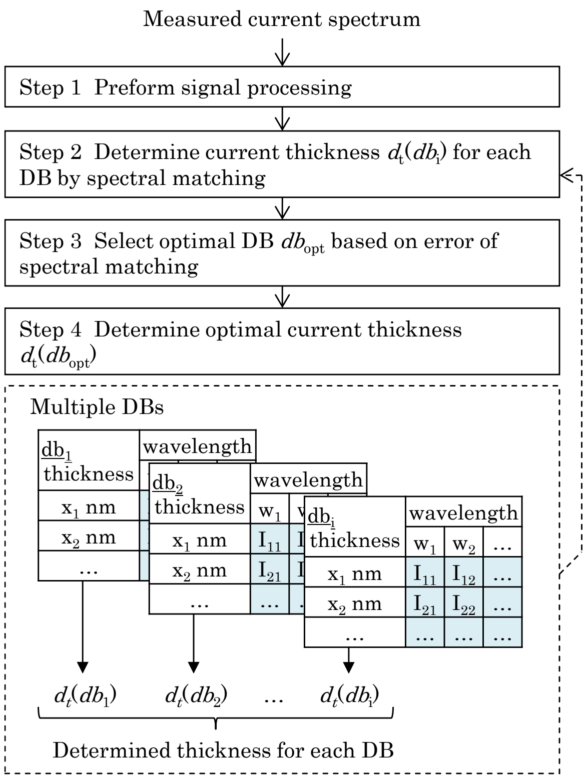

Figure 1 Flowchart of algorithm to estimate film thickness in multi-DB FTM.

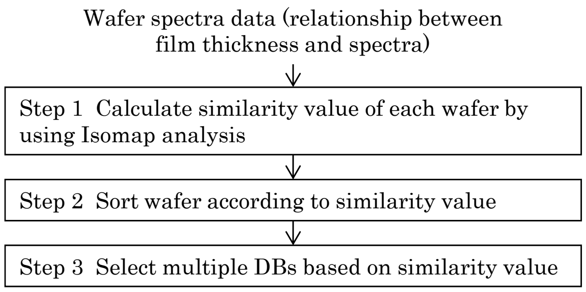

Figure 2 Procedure to select multiple DBs for multi-DB FTM.

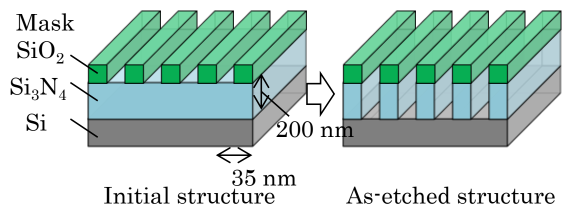

Figure 3 Etching process and device structure in the spectrum simulation.

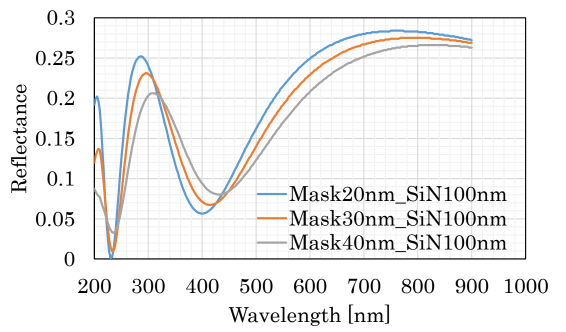

Figure 4 Simulated spectrum of wafers with mask thicknesses of 20, 30, and 40 nm.

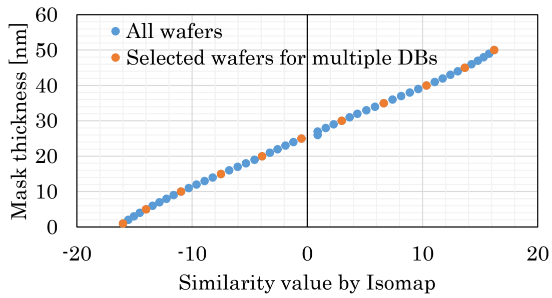

Figure 5 Relationship between similarity value calculated by Isomap and mask thickness.

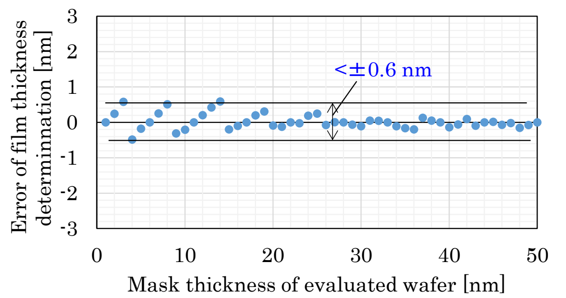

Figure 6 Error of estimated film thickness using multi-DB FTM for wafers with various mask thicknesses.