Improvement of Thickness variation and Productivity in LP-CVD process by APC system – Masaki Ueda

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1. Introduction

In the manufacturing of advanced NAND Flash Memories, the balance management between film thickness variations and productivity is very important for LP-CVD process.

Generally, LP-CVD SiN has serious particle issues caused by film abrasion from the inner wall of quartz reactor. And a root cause of film peeling is high SiN stress (as shown in Fig.1 bottom), therefore process operation with low accumulate film thickness by frequent dry cleaning is effective to prevent particle issues.

However, such a frequent periodic cleanings cause the SiN thickness variation (film growth rate (G/R) variation). We consider that the reason of the thickness variation is due to micro cracks on the reactor inner wall surface which are caused by the dry cleanings. Since the micro cracks are filled with deposited SiN film, the area of a reactor surface decreases. And this decreasing of the surface area increases deposition gas consumption on the reactor surface. From a result of this mechanism, the G/R of SiN film strongly depends on the accumulated thickness. To improve SiN thickness variation, lower accumulation thickness operation with frequent dry cleaning is needed, and it results in a reduction of productivity of LP-CVD tool.

In this paper, we discuss about the application for run-to-run (R2R) thickness control by using Advanced Process Control (APC) system into LP-CVD process for suppression of the accumulated thickness dependence of the G/R and the improvement examples.

2. APC System

Figure 2 shows the relationship between the G/R calculated from the SiN film thickness average on Si wafers in the reactor and the accumulated thickness. We experimentally find that the relationship fit the power function shown by $Z = A(X + C)^B$, where Z is the G/R, X is the accumulated thickness, A and B are fitting parameters, and C is constant. A and B are automatically updated to the optimum values every time when the SiN film thickness is measured by least-square method.

Thus, in our APC system, the R2R thickness is controlled by calculating optimum deposition time from the fitting function.

3. Results of introducing APC system

Figure 3 shows the result of the APC system evaluation by a piece of equipment. It reduces the R2R SiN thickness variation and adjusts the SiN film thickness to target value that the APC system corrects a deposition time against the accumulated thickness dependence of the G/R. In addition, with the reduction of the variation, it becomes possible to extend the limits of accumulated thickness within not peeling off SiN films. It shows the possibility of increasing the productivity by reducing dry cleaning frequency.

Figure 4 shows the thickness in each piece of equipment introduced APC system. Before introducing the APC system, the thickness was not adjusted enough to target value in each piece of equipment because operators adjusted the process condition. After introducing the APC system, the equipment-to-equipment (E2E) thickness variation was greatly reduced. It shows that the introduction of APC system into LP-CVD process is highly effective in a large scale factory which has lots of equipment.

Finally, figure 5 shows the electrical property and the defective rate which are sensitive to the SiN thickness are improved by the introducing APC system. It shows the reduction of the thickness variation improve the electrical property and the defective rate. From now on, the more the thickness margin against semiconductor devices is narrow, the more the strict thickness control by APC system becomes important.

4. Summary

We demonstrated that an introduction of APC system minimizes R2R and E2E thickness variation for the LP-CVD SiN process. Thus, APC system is very productive for high volume manufacturing of LP-CVD process by removing the sensitivity of thickness variation with the accumulated thickness.

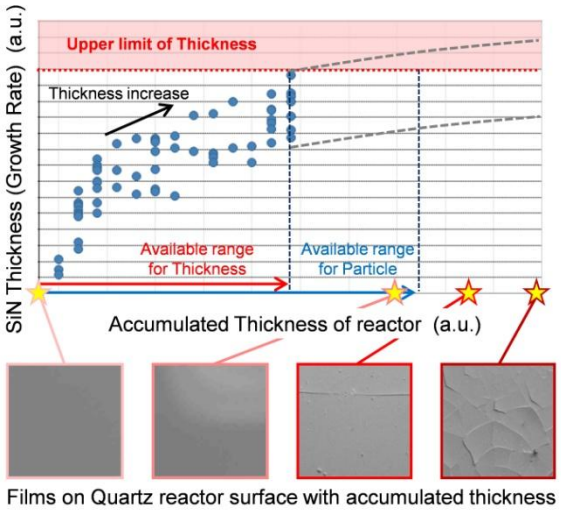

Fig. 1. The accumulated thickness dependence of SiN thickness (G/R of SiN film) and pictures of quartz reactor inner wall surface

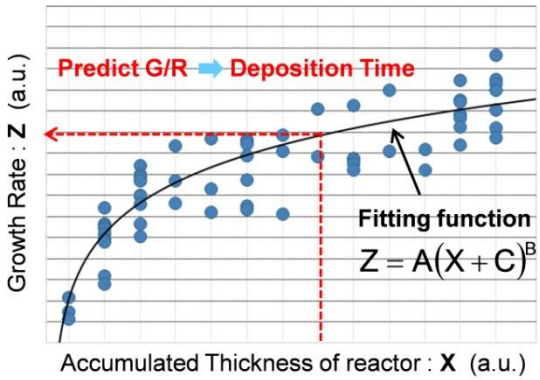

Fig. 2. The relationship between the G/R and the accumulated thickness fitting to the power function

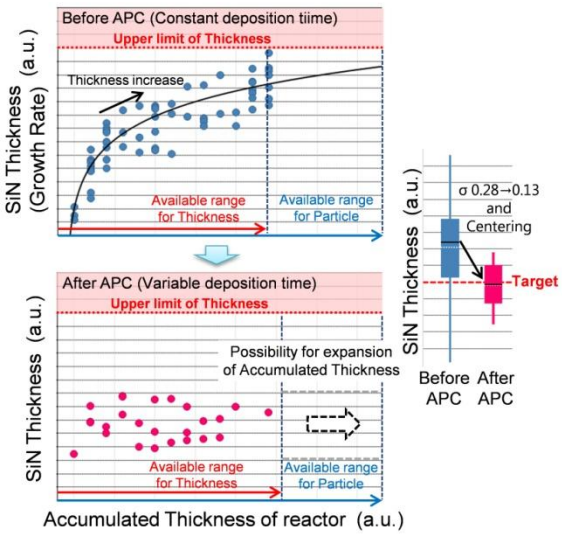

Fig. 3. The relationship between the SiN thickness and the accumulated thickness before or after introducing APC system

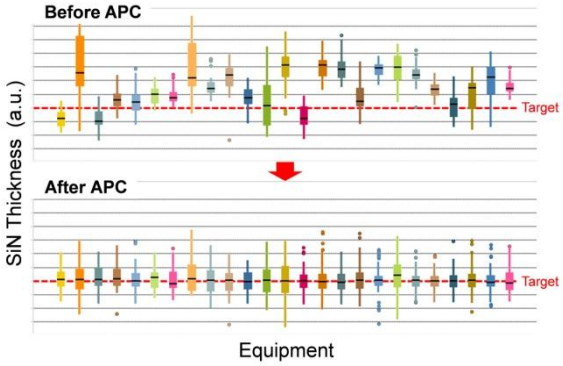

Fig. 4. The SiN thickness in each piece of equipment before or after introducing APC system

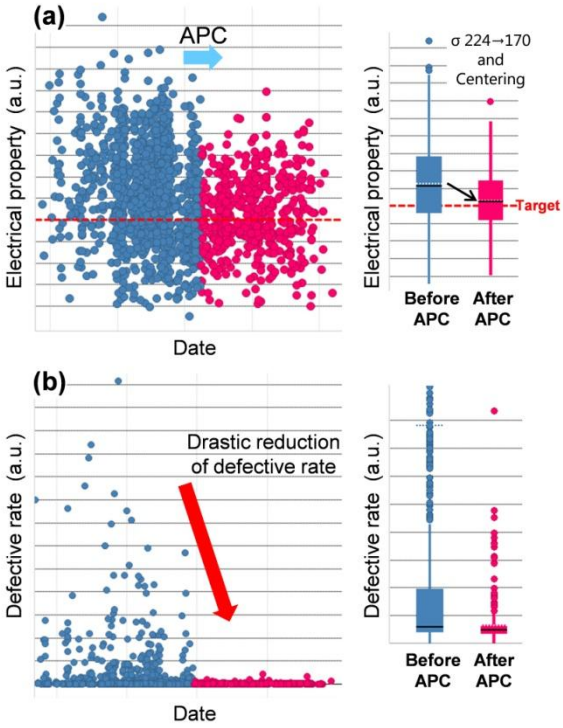

Fig. 5. The improvement of the electrical property (a) and the defective rate (b) before or after introducing APC system