Chamber matching of etching rate in HDP-CVD equipment - Yoshiyuki Nakao

Koichiro Ohira/Takahiro Tsuchiya/Kazuhide Abe
nakao.yoshiyuki@jp.fujitsu.com - ohira.koichiro@jp.fujitsu.com - t.tsuchiya@jp.fujitsu.com - kazuhide.abe@jp.fujitsu.com
Mie Fujitsu Semiconductor Limited
2000, Mizono, Tado-cho, Kuwana-shi, Mie-ken, 511-0118, Japan
Phone: +81 -594-24-9160 Fax: +81-594-24-9143

1. Background

The device isolation structure that is called STI(Shallow Trench Isolation) is adopted along with fabricating of the semiconductor device. A general process to form STI is as follows. First, trenches are etched on the semiconductor substrate. Next, trenches are filled in the insulation film. And extra insulation film on the semiconductor substrate is removed. It is a method filled in the trench with silicon dioxide film by HDP(High Density Plasma)-CVD.

Figure 1 shows the flow of the silicon dioxide film filled by HDP-CVD. In the HDP-CVD chamber, the silicon dioxide film is deposited by HDP that uses SiH4 and O2. Next, the overhang in the trench opening is etched with the NF3 plasma. The silicon dioxide film can be filled by repeating deposition-etching several times, inhibiting the void in the film by the overhang. Because the void in the film causes unwanted electric current leakage and yield loss, it is necessary to obstruct the void generation.

It is feared the generation of the void in the film by the overhang when the etching rate of the NF3 plasma decreases. When the etching rates were compared by seven chambers of HDP-CVD, it was clarified that it tended to be 6.6% two chambers (F and G) lower than five another chambers as shown in Figure 2. Then, we investigated the equipment parameter with a large influence on the etching rate, and we report on the investigation result of the difference between chambers.

2. Method

Two major parameters (1) characteristic of deposited film and (2) etching ability are thought to affect the etch rate because the deposition and the etching doing in the same chamber. It is reported that the relation between characteristic of film evaluated with Refractive Index and the source gas ratio as O2/SiH4 flow, then Virtual Sensor of Gas_ratio (=O2/SiH4 ratio) decided to be used as a physical model.

2.1. Relation to etching rate (PLS)

We forecast the etching rate by PLS regression by using 11 parameters carefully selected from process engineer's finding, and have extracted the parameter with a large influence on the etching rate by VIP score.

2.2. Parameter with great difference between chambers (Random Forest)

We did the discrimination of two bad chambers with low etching rate and five other good chambers by Random Forest, and we determined the Conditional variable importance [1].

3. Result and Discussion

3.1. PLS-VIP

We obtained an excellent predicted result, R^2 of leave one out cross-validation was 0.78. The parameter with large VIP score was Bias power and the time of the Etch step (Figure 3). Bias power was divided by the step time and it was assumed Virtual Sensor named Bias_Power_Rate. Figure 4 shows that the etching rate is low when Bias_Power_Rate is low.

3.2. Random Forest

The classification error rate was 0.8% in the discrimination of Good and Bad chamber by Random Forest. Moreover, the “variable importance to discrimination” of Bias_Power_Rate and Gas_ratio were high (Figure 5), and guessed that the influence on the difference was large between Good and Bad. By the scatter plot of the etching rate and Gas_ratio (Figure 6), it shows that there is a different correlation in Good and Bad. The source gas of the Bad chamber is O2 rich. Then, the improvement of the etching rate is expected by lowering the O2/SiH4 ratio.

4. Summary

The difference of Bias_Power_Rate in the Etch step and the difference of the O2/SiH4 ratio of the Depo step were extracted as a cause of the difference between chambers of the etching rate in HDP-CVD. We have improved the difference between chambers of the etching rate by correction of O2/SiH4 ratio and calibration of Bias Power in the Bad chamber. In addition, the real time etching rate monitoring system using the PLS model (Figure 7) was constructed.

References
[1] C. Strobl et al., BMC Bioinformatics, 9, 307. (2008)

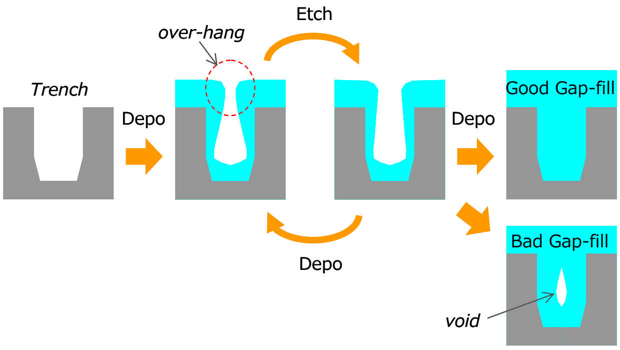

Fig. 1 STI process flow by HDP-CVD

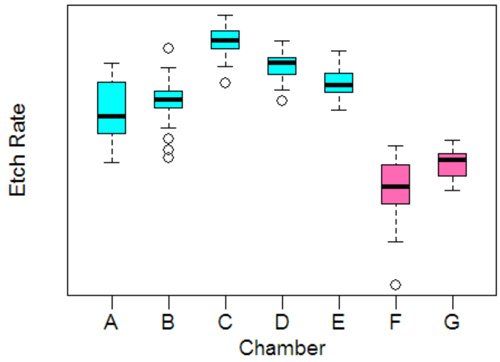

Fig. 2 Difference between chambers of etching rate

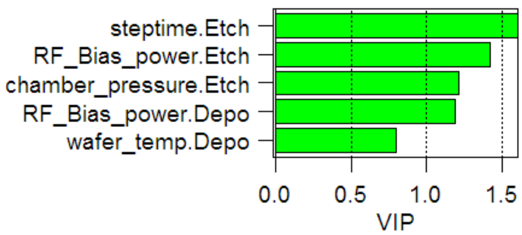

Fig. 3 VIP of PLS Regression (Top 5)

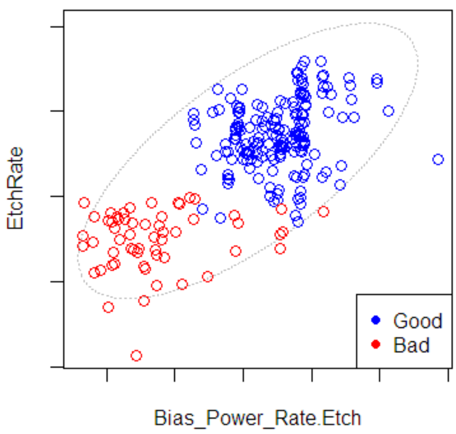

Fig. 4 Scatter Plot of etching rate and Bias Power Rate

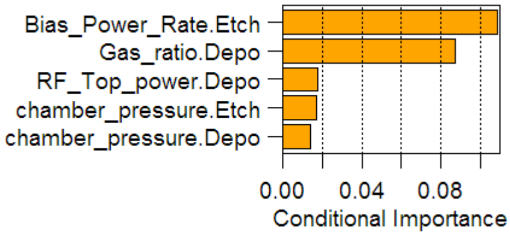

Fig. 5 Variable importance by Random Forest (Top 5)

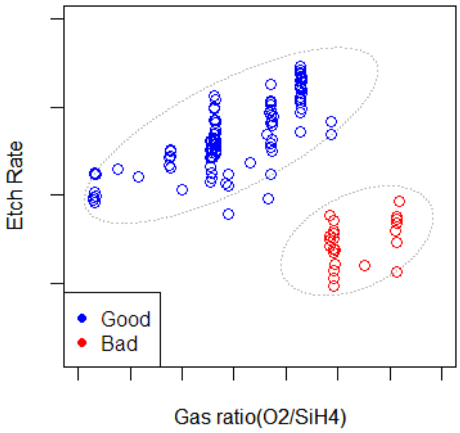

Fig. 6 Scatter Plot of etching rate and source gas ratio as O_2/SiH_4 flow

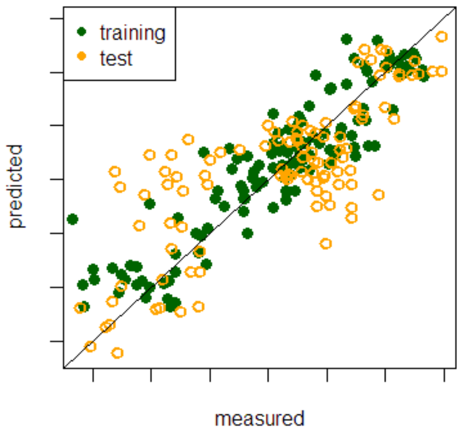

Fig. 7 result of PLS model to monitor etching rate