RIE Equipment Control by Cross-sectional Trench Area Prediction-Xueting Wang

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1. Introduction

In semiconductor manufacturing, equipment control is important to maintain high yield. It is conventionally conducted by using SPC (Statistical Process Control) and QC (Quality Control). However, abnormality involving a combination of multiple parameters may not be detected. In order to solve this problem, we created a model to predict the processing shape determined from multiple parameters. This model is used for RIE (Reactive Ion Etching) equipment control. This is called predictive process control (PPC) (Fig. 1)[1)-2)]. In the manufacturing of a power device, such as super junction MOSFET[3)]. It is difficult to measure the trench shape in a non-destructive method or without making contact with the wafer. As we cannot measure the product wafer in manufacturing line and detect any abnormality of the equipment in real time, we developed a method for monitoring the change in equipment condition by using a predictive model. The trench is formed by RIE process. The number of parameters (equipment logs) indicating the equipment condition can be as many as 400 parameters. In this paper, we will introduce a method of choosing effective parameters, the predictive model creation, and an equipment control method that use the predictive model.

2. Approach and Results

(1) Data Preparation and Parameters Selection

Previous data was used to create the predictive model. The trench shape measured in equipment QC was set as the output factor. The etching mask CD (critical dimension) and equipment parameters were set as the input factors. As the trench shape can be represented by the cross-sectional area of the trench, as shown in Fig. 2, this area was used as the output factor. As there are approximately 400 parameters in RIE equipment logs, we chose the parameters which can affect the cross-sectional area in the following four steps: (1) Screening of outliers, (2) Multicollinearity analysis, (3) Single regression analysis, and (4) Multiple regression analysis by stepwise. Especially, multicollinearity analysis is necessary to choose important parameters in principle. Thus, in this step we chose the parameters not only by statistical analysis, but also from the viewpoint of a process of RIE. Next, we chose the parameters by Single regression analysis and Multiple regression analysis by stepwise. Finally, approximately 10 parameters were chosen (Table 1).

(2) Multiple Regression Modeling

Parameters chosen above were used to create a predictive model. The model was verified by checking the residual error (difference between actual value and predicted value). The target of residual error was less than ±2%. We used 80% of previous QC data as training data and the remainder of 20% was used as validating data to verify accuracy of the model. After verification, the worst residual error was 1.9%. The model with targeted accuracy (residual error is less than ±2%) was obtained (Fig. 3).

(3) Operation

This predictive model was applied to the RIE equipment control. By using this predictive model, we can now detect the change in the RIE equipment by monitoring the residual error. Since data under normal condition was used to create the predictive model, the control limit was set to ±2%. In our actual monitoring, a residual error larger than ±2% was obtained when equipment condition changed. Therefore, we can confirmed that the abnormalities in equipment are detectable. (Fig. 4).

3. Conclusions

We chose the parameters that were effective for equipment control from approximately 400 parameters in terms of statistical analysis and process analysis. Additionally, we used these parameters to create the predictive model. By monitoring the residual error of the predictive model, we can detect the change in equipment condition. This predictive model has already been implemented in our product line for equipment control. In the future, we plan to deploy this equipment control method to other trench power devices process.

4. References

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2) M. Kano, “Data-based Process Modeling” Journal of the Society of Instrument and Control Engineers, vol. 49(2), pp 101-106, 2010.

3) Syotaro Ono, “Development of 600V-class trench filling SJ-MOSFET with SSRM analysis technology” Proceedings of ISPSD2009, pp 303-306.

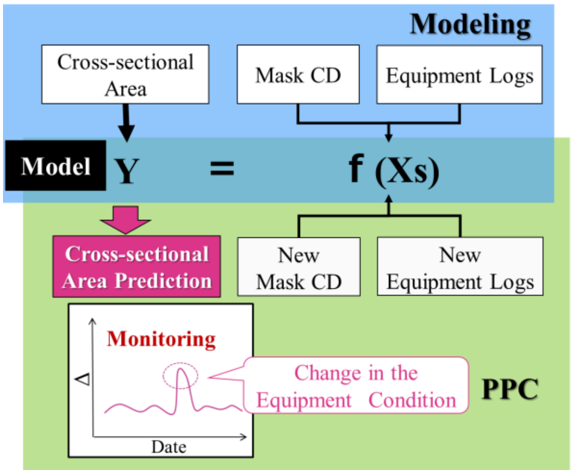

Fig. 1 The outline of PPC

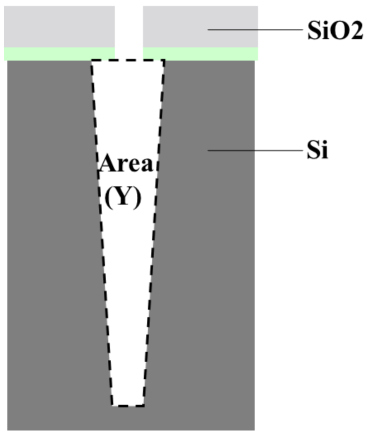

Fig. 2 Image of cross-sectional area of trench

Table 1 Input Factors of RIE equipment

Input Factors
Mask CD
StepX LineImpedence
StepY LineImpedence
StepZ LineImpedence
StepX Bias Power
StepY Bias Power
StepX Temperature
StepY Temperature
StepX Gas flow rate
StepX Etching Time

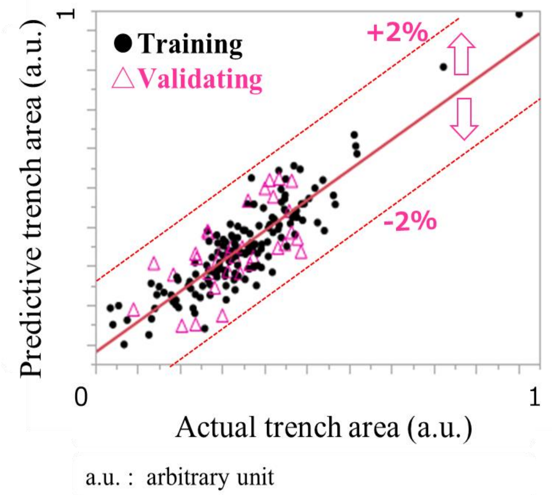

Fig. 3 The model accuracy

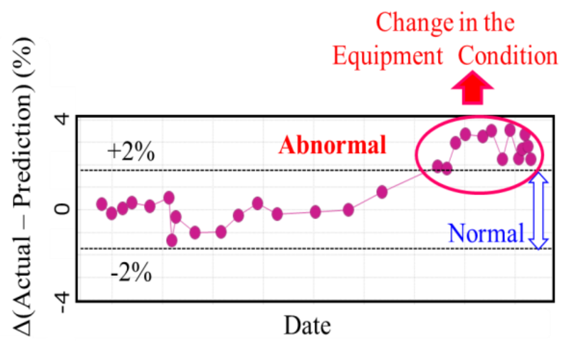

Fig. 4 Monitoring of equipment control by a predictive model