The Detection of Process Variation Synchronous within Wafer Variation Pattern – Masanobu HIGASHIDE

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In CMP process which is one of principal process of semiconductor manufacturing processes, a part of thin film which should be removed remain sometimes. This film residual has occurred by variation of polishing amount with-in wafer. In this paper, we apply logistic regression model to the film residual defect occurred in CMP process and with-in wafer variation of polishing rate on CMP process. Then we focus two-valued variable with or without film residual and polishing rate, and apply logistic regression model. We can monitor CMP process by this index and analyze mechanism of film residual occurrence.

The polishing rates with or without film residual in CMP process are shown in Table 1. The average and range with film residual are small.

Table 1. Polishing Rate

film residual	Wafer Average(1)	Wafer Range(2)	n
Without	100	10	101
With	83.8	8.8	27

(1) Wafer average of polishing late without film residual is converted to 100.

(2) Wafer range of polishing late without film residual is converted to 10.

Distribution of polishing rate with or without film residual in CMP process are shown Fig.1. The polishing rate distribution with film residual is relatively flat contrary to expectation.

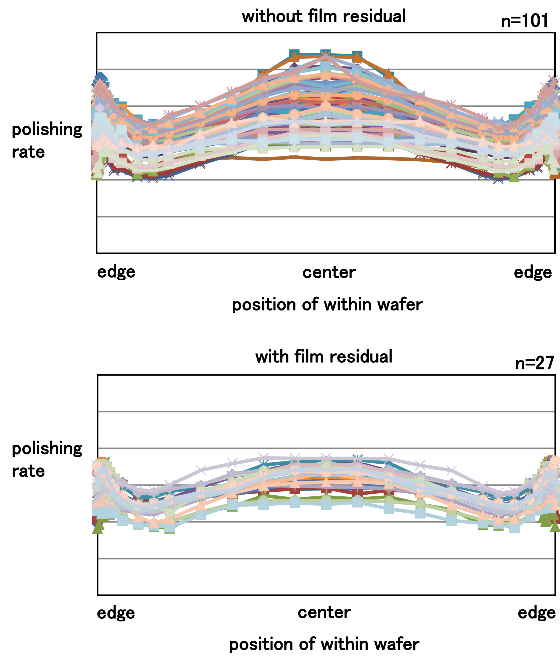

Fig.1 Distribution of polishing rate in CMP

To monitor variation of with-in wafer, T^2-Q control chart based on a multivariate control chart has been proposed. However we can't apply T^2-Q control chart for monitoring this problem, because of the variation with-in wafer in term with film residual occurrence is smaller than the variation with-in wafer in term without film residual occurrence.

We apply logistic regression model to the film residual defect and polishing rate to calculate the prediction probability of film

residual. The logistic regression model is shown in Equation (1).

$$logit\,(\,p_i\,) = ln(\frac{p_i}{1 - p_i}) = \alpha + \beta_1 x_{1i} + \Lambda + \beta_p x_{p,j} \qquad (1)$$

We evaluate statistical model based on stepwise procedure by maximum-likelihood method. We get model formula shown in Equation (2).

$$\log\text{it}(\hat{\text{p}}) = 15.776 - 0.0164\text{x}_\text{a} - 0.0656\text{x}_\text{b} - 0.1576\text{x}_\text{c} + 0.1822\text{x}_\text{d} \qquad (2)$$

Here, $\text{x}_\text{a}, \text{x}_\text{b}, \text{x}_\text{c}, \text{x}_\text{d}$ are polishing rates on measurement points *a,b,c,d*. The prediction probability and actual film residual in CMP process are compared in Fig. 2.

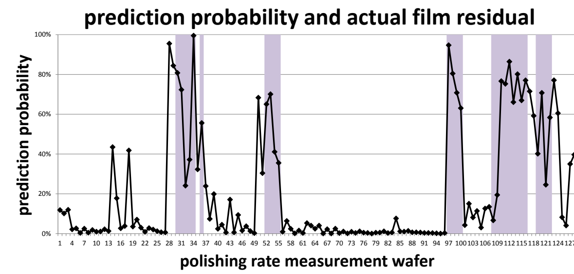

Fig. 2 Comparison prediction probability and actual film residual

The polygonal line shows prediction probability based on Equation (2) and hatching areas show the term of actual film residual occurrence in CMP process. The prediction probability and actual film residual agree well if threshold is 50%.

CMP equipment consists of 4 heads that mean polishing stage. The above study was evaluated by only 1 head result. So, we evaluate reproducible and validity. Evaluation index is *Dev* calculated from Equation(3). *Dev* value follows χ^2 distribution asymptotically.

$$Dev = \sum_{i=1}^{n} D_i \qquad (3)$$

$$D_i = \begin{cases} -2\ln(1-\hat{p}_i) & (p_i = 0) \\ -2\ln(\hat{p}_i) & (p_i = 1) \end{cases}$$

Dev and *P* value are shown in Table 2.

Table 2 *Dev* and *P* value (n=128)

	head1	head2	head3	head4
Dev	67.49	58.26	70.51	79.55
P	0.99999	1.00000	0.99996	0.99916

Next, prediction probability for head2 and actual film residual in CMP process are compared in Fig. 3. The prediction probability for head2 is calculated from Equation2 based on head1 data and polishing rate data of head2.

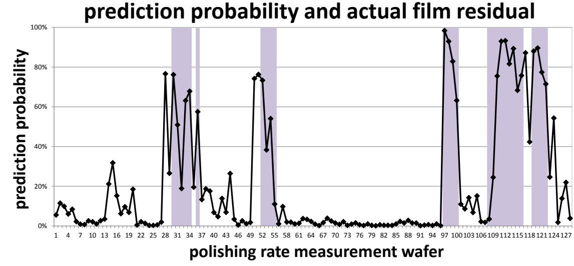

Fig. 3 Comparison prediction probability and actual film residual (head2)

The hatching areas in Fig.3 means the term of actual film residual occurrence in CMP process, and the prediction probability and actual film residual agree well the same as head1 case. The reproducible and validity are confirmed from the above results.

In this study, we can't apply usual control chart, because of the variation with-in wafer in term with film residual occurrence is smaller than the variation with-in wafer in term without film residual occurrence. So, we focus two-valued variable with or without film residual and polishing rate, and apply logistic regression model.

Acknowledgment

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