

[Use of Graphical Model to Analyze Cause of Faults in Plasma Processes - Takehisa Iwakoshi]

Masaru Izawa

[\takehisa.iwakoshi.dj@hitachi.com - [masaru.izawa.qt@hitachi.com\]](mailto:masaru.izawa.qt@hitachi.com)

[Hitachi, Ltd., Central Research Laboratory]

[1-280, Higashi-koigakubo, Kokubunji-shi, Tokyo 185-8601, Japan]

Phone: +[81]-[42-323-1111 (ext.2143)] Fax: +[81]-[42-327-7708]

1. Introduction

The ISMI has described how unexpected troubles or unknown causes cause long delays in mass fabrication line [1]. To reduce these delays, the cause of troubles needs to be systematically analyzed. Graphical models can be used to visualize causalities between sensory data obtained from process equipment [2]. We applied graphical modeling to the analysis of sensor data causality and fault classification in plasma etching.

2. Analysis

Sensor data in our plasma equipment were recorded in a data server. We used about 4500 pieces of data, which included various process conditions to construct a graphical modeling. We assumed that each sensor datum obeys a first-order linear approximation expressed by Eq. (1).

$$X(m) = B_0(m) + \sum_{m' \neq m} X(m') B(m, m') \dots (1)$$

Here, $X(m)$ is sensor data of item m . In this model, arbitral sensor data are dependent on other sensor data. We determined $B_0(m)$ and $B(m, m')$ using multivariate analysis and principal component regression. If $B(m, m')$ satisfied the following condition A or B, we determined that $B(m, m') = 0$.

A: p -value of $B(m, m')$ is greater than 0.05

B: $|B(m, m') \times (\max. X(m') - \min. X(m'))| < 3\sigma_{\text{model}}$

Here, $(\max. X(m') - \min. X(m'))$ indicates the dynamic range of $X(m')$, and σ_{model} indicates the standard deviation of experimental data from the model described by equation (1). If the sensor data $X(m)$ depend on certain $X(a)$ while $X(a)$ is independent of $X(m)$, we draw a direct line from $X(a)$ to $X(m)$, which means $X(a)$ is the cause of $X(m)$. In this way, we visualized the sensor causality.

When a fault in the equipment occurs, the experimental sensor values fluctuate from model Eq. (1). To analyze the cause of the fault, we calculated

its probability and visualized which sensor data fluctuate from model equations.

3. Results and Discussion

The visualized causality is shown in Fig. 1. Sensor values at the roots of directed lines are causes of changes in sensor values at the tips of direct lines. We then analyzed the case when we had an error that had occurred as a result of time out of Turbo Molecular Pump (TMP) exhaustion of the plasma reactor, as an example.

The sensor values that had fluctuated from the model equations expressed by Eq. (1) is shown in Fig. 2 with gray boxes. If the causalities are correct, wrong values should propagate in the direction of the lines. Thus, we picked up sensors that all had tips with fluctuating values. These sensors are indicated with black lines and black letters as shown in Fig. 2. The exhaust pressure of the TMP, the penning gauge, wafer bias Pr (reflected power), and some mass flow controllers are expected to have problems. We posit from this result that there are problems with the TMP and/or penning gauge, which affect the plasmas resulting in change of plasma and cause a change in wafer RF Pr. There is a possibility that mass flow controllers have problems (Fig. 2). However, they were regularly calibrated, thus, this indicates errors possibly depends on process gasses. We can conclude that the cause of error is most likely to be problems with the TMP exhaust pressure or penning gauge.

4. Summary

We applied graphical modeling to analyze the cause of an error in turbo molecular pumping. Our model picked up some sensors as possible causes, and this suggests that the cause of the error is likely to be problems with the turbo molecular pump exhaustion or with the penning gauge.

References

- [1] ISMI Predictive & Preventive Maintenance Workshop, (2008-07)
- [2] Masami Miyakawa: Toukeiteki Innga Suiron (Statistical Causality Analysis) (Asakura-shoten, Tokyo, 2004) [in Japanese]

Fig.1 The visualized causality using graphical modeling

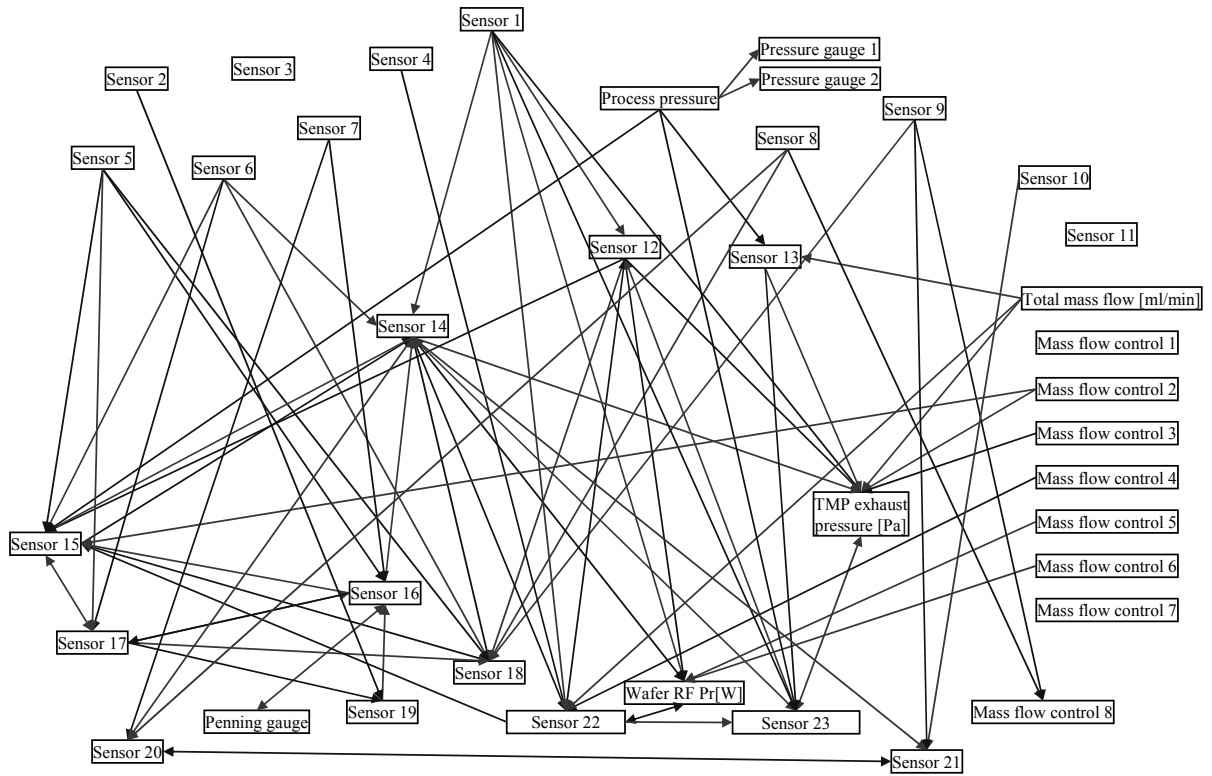


Fig. 2 The visualized probable cause of a time out error of turbo molecular pumping

