Convolution Neural Network Based Diagnosis for Temperature Sensing Modules

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1. Introduction

A temperature sensing module embedded in a hot plate of a bake module is used to control temperature uniformity during wafer heating for semiconductor lithography process. The sensing module consists of resistance temperature detectors (RTDs), which measure the temperature at separated zones on a hotplate. RTD measures the temperature based on the resistance change of sensor material affected by temperature. During the hot plate operation, the sensor can be oxidized by high temperature environmental conditions, resulting in sensor failure, such as measurement error due to unexpected resistance change. While the measurement error degrades the temperature uniformity due to partial overheating, heat transfer induced by overheating can prevent from detecting the amount and the location of faulty sensors within the sensing module.

This paper proposes a method to diagnose the temperature sensing module by capturing the heat transfer between the separated zones of a hot plate. A bake module was employed to measure temperatures using a healthy sensing module and a faulty module. The temperature measurement data was transformed to 2D image features. A convolution neural network was used as a 2D image feature to analyze simultaneous temperature change across a wafer. The proposed method detected not only the amount of failure but also the failure locations within the sensing module.

2. Background

The hotplate of interest uses a 3-wire RTD, which adds a wire to cancel out wire resistance for precise measurement. The RTD usually consists of two parts: sensor and wires. The sensor part is made by a material, such as platinum of which resistance increases linearly depending on temperature increase. The sensor in this study is made by Pt100, which is 100 Ω at 0 °C with increase of 0.00385 Ω per 1 °C. The wire part, usually made by copper and nickel, is used to transmit electrical signals for measured resistance from the sensor part to an instrument for calculation to avoid heat. 2 wires connected at each end of the sensor part is usually used for common sensors. In the case of the 3-wire RTD, an additional wire for measuring output voltage affected by the sensor resistance is connected to one end of the sensor part to prevent the measurement error induced from resistance of the 2 wire for signal transmission. The adding wire cancels the wire resistance using an electrical circuit called the wheatstone bridge.

3. Method

Temperature data simultaneously measured from 15 sensors can be used for the proposed method. Since the measured data only have information for sensor measurements, it may be difficult to consider heat transfer of the hotplate. Simultaneous analysis between the sensors are required to capture heat transfer in the hotplate. Since heat is transmitted through the flat hotplate, a 2-dimensional image, such as a heat map, may effectively work to observe the temperature change. Therefore, the proposed method used an image-based feature which can handle the temperature measurements of each sensor and heat transfer between the zones of the hot plate.

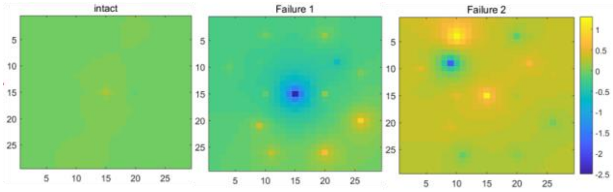
4. Experiment

An actual bake module was used for a test rig which usually uses to heat semiconductor wafer to 400 °C in this study. The hotplate in the module had 15 RTDs with 15 separated zones. The bake module was controlled by an instrumental control program. The temperature data from the sensors was measured every second, and transmitted to a computer using RS232 port.

Test #	Failure initiated sensor	Added Resistance	Target Temperature
Normal	None	None	400°C
Failure 1	Sensor 8	1.1 Ω	
Failure 2	Sensor 4	0.4 Ω	

5. Results

The image-based feature was created using the valley values. The temperature under estimation can be detected qualitatively by color of the feature. Additionally, the extent of the failure can be also detected qualitatively by color of the feature similar with a heatmap image. 50 cycles of the feature were used for the test. The CNN classified the features with 100% accuracy. As a result, the proposed method can diagnose the temperature sensor failure when the training data is existed.



6. Conclusions

A method was developed to diagnose a temperature sensing module embedded in a hotplate. Although continuous heat transfer may impede failure detection, an image-based feature based on layout of the hotplate was created to capture the heat transfer. A convolution neural network was used to classify normal and failure-initiated modules with 100% accuracy by analyzing the image-based feature.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2017R1D1A1B03028604).