Anomaly detection of semiconductor manufacturing equipment by cluster analysis

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1. Introduction

The processing accuracy required for semiconductor manufacturing equipment is becoming higher. Equipment monitoring technologies such as statistical process control (SPC) have been used to meet this requirement and stabilize the equipment. If the signals acquired from the equipment are out of the control range, the equipment condition would be anomalous and defects may occur.

Semiconductor manufacturing equipment has many signals; it is difficult to control all of them. Thus, development of a method to easily detect anomalous equipment is required.

2. Anomaly detection method

We propose a method for detecting anomalous equipment by using the number of clusters that are derived through principal component analysis (PCA) and cluster analysis (CA) of multiple signals from the equipment.

After PCA, k-means cluster analysis is performed with the number of clusters from 1 to 20. At the same time, ccc1) is also calculated and the number of clusters with the largest ccc is selected.

The results of PCA and CA are shown in Figure 1; (a) is a normal equipment whose signal behavior is within control limits, and (b) is an anomalous equipment whose behavior is not. Signals from normal equipment were classified into two clusters and signals from anomalous equipment into one cluster. These results suggest that the number of clusters is useful to classify normal and anomalous equipment.

The basic concept was reported in the previous work2). In this work, the proposed method was further investigated and evaluation results are shown.

3. Results

We applied the proposed anomaly detection method to three equipment.

The results of PCA and CA are shown in Figure 2. The equipment in (a) had one cluster, (b) had nine, and (c) had 19. Table 1 shows the quality measurements of wafers processed by each equipment, where equipment with a value of less than 10 is acceptable; (a) and (b) are anomalous equipment, and (c) is acceptable equipment. Here, the measurements and the number of clusters were negatively correlated. It has been confirmed that the number of clusters represents the equipment performance.

4. Conclusion

In order to easily and accurately detect anomalous equipment, we proposed a detection method using principal component analysis and cluster analysis and confirmed that the number of clusters is a useful indicator for anomaly detection.

5. References

1) SAS (R) Technical Report A-108, Cubic Clustering Criterion January 1, 1992, SAS Inst Paperback in English.
2) Toshiya Hirai, Manabu Kano : Anomaly detection of semiconductor manufacturing equipment using cluster analysis, The 10th SICE

Multi-Symposium on Control Systems, 2023.

Table 1. Comparison of quality measurements of equipment and the number of clusters

equipment	quality	# clusters
a	16.8 anomalous	1
b	13.6 anomalous	9
c	4.5 acceptable	19

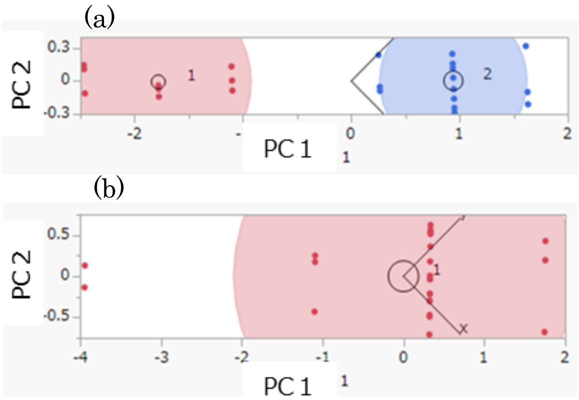

Figure 1. Cluster analysis results for the signals acquired from (a) the normal equipment and (b) the anomalous equipment

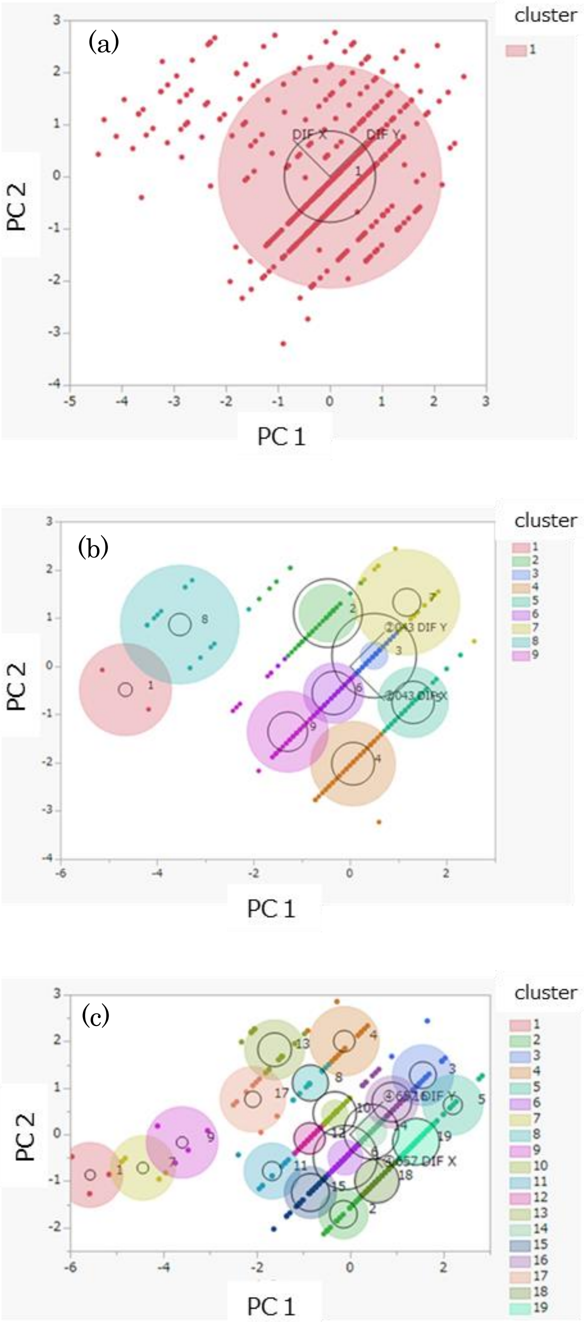

Figure 2. Principal component analysis and cluster analysis results: (a) anomalous equipment (quality=16.8), (b) anomalous equipment (quality=13.6), (c) acceptable equipment (quality=4.5)