IE3100R Systems Design Project, Dept. of Industrial & Systems Engineering

Enhancement of SPC through Multivariate Charting Technique

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PROBLEM DEFINITION

GlobalFoundries manufactures silicon chips for many companies. For every product, they promise to do a quality check on every wafer produced. Each wafer will undergo testing of 100 to 500 electrical testing parameters.

Problem

1. These data is monitored on univariate SPC charts, thus there are 100-500 individual charts for engineers to monitor weekly
2. Univariate charts still miss some readings near to the control limit

OBJECTIVES

A solution that

1. Reduces total number of charts that engineers monitor
2. Detection of several simultaneous signals close to control limit

APPROACH

1) Reduce the number of parameters
2) Multivariate Control Chart
3) Diagnostics of Multivariate Control Chart
4) Evaluation

RESULTS

1) Clustering

Rationale

Reduce 100-500 parameters into clusters of <20 for easier handling, at the same time preserving covariance structure

Method

Generate correlation matrix (Minitab)

Rank correlation coefficients

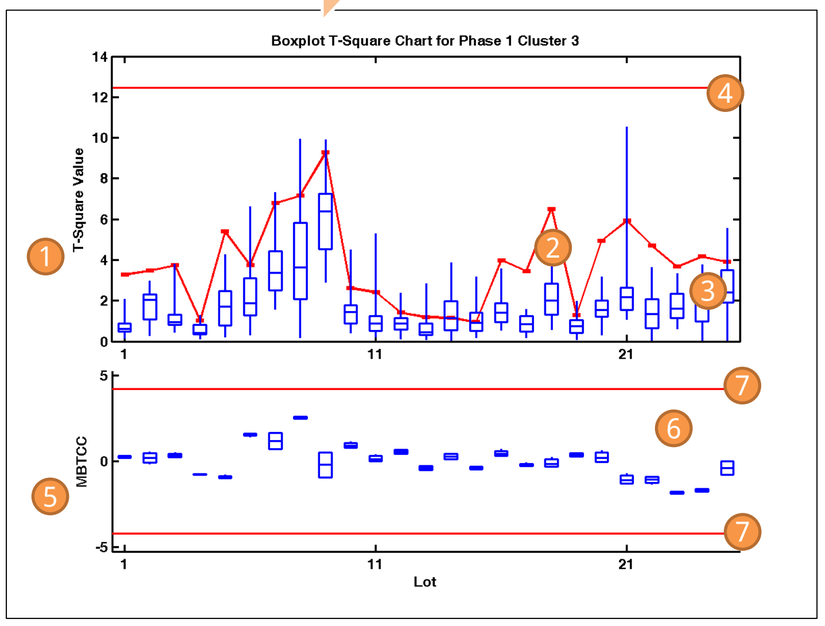
From largest coeffcient, cluster parameters together

Repeat previous step till all parameters clustered

Results

Cluster	Number of parameters
1	7
2	12
3	4
4	16
5	16
6	14
7	12
8	16

2) Hotelling's T^2 Chart



Why Hotelling's T^2 control chart?

The T^2 chart is

- Directionally invariant
- Capable of detecting abnormal correlation between monitored parameters
- Has reliable method of decomposing T^2 values

Hotelling's T^2 formula

$$T^2 = (X - \bar{X})' S^{-1} (X - \bar{X})$$

Features of Proposed Chart

1. **T-Square Chart**
Main component of chart. Contains graphs of lot level T^2 values, as well as wafer level box plots if desired.
2. **Lot level T^2 plot**
T^2 values calculated from parameter lot averages. Coloured red to distinguish from wafer level plots.
3. **Wafer level T^2 Box plot**
Wafer level T^2 are grouped according to lots and displayed as a box plot. Compresses graph length and makes it easy to differentiate lots.
4. **Wafer level UCL**
UCL for wafer level T^2 chart, coloured blue to avoid confusion with lot level UCL.
5. **MBTCC chart**
Supplementary chart used to help display intra-lot variation. Placed as a separate sub-graph to avoid confusion with wafer level boxplot.
6. **MBTCC**
Parameter lot standardized averages for each lot displayed as a box plot.
7. **MBTCC CL**
Standardized Control Limits for MBTCC.

3a) MYT Decomposition Method

Decomposition: process of identifying the parameter/set of parameters responsible for the out of control signal.

In the **MYT method**, the T statistic can be broken down into different forms and each form consists of unconditional and conditional components.

Decomposition form	1st order interaction (unconditional)	2nd order interaction (conditional)	3rd order interaction (conditional)
1	T1	T2|1	T3|1,2
2	T1	T3|1	T2|1,3
3	T2	T1|2	T3|1,2
4	T2	T3|2	T1|2,3
5	T3	T1|3	T2|1,3
6	T3	T2|3	T1|2,3

The simplified MYT method can

- identify large deviation from the mean
- provide information on covariance

In general, the simplified MYT works better than univariate control chart at interpreting out of control signals.

3b) MBTCC - Multi-variate boxplot – T^2 Control Chart

MBTCC : a boxplot constructed for each lot by plotting standardized wafer averages for all parameters within a cluster.

When an out-of-control signal occurs in the univariate control chart, it will also be reflected by the boxplot. Any part of the box plot exceeding the control limit will be displayed in bold.

The MBTCC is very efficient in monitoring large variations in individual parameters. At the same time, it also gives an overall impression of the behavior of all the parameters in the same cluster

4) EVALUATION

Our proposed methodology is developed in Matlab and is evaluated using the following 3 criteria:

1. **Outlier Detection**
   ➔ Successfully detect univariate SPC OOC points
2. **T^2 Decomposition**
   ➔ Decomposition method effectively identifies cause
3. **Correlation**
   ➔ Successfully detect OOC points due to change in correlation between parameters

CONCLUSION

- Used Hotelling's T^2 approach
- Approach is verified with theoretical data and practical data provided by client
- Signals may be easily decomposed and interpreted

1. 90% reduction in number of charts
2. Manage to catch almost OOC points

CONTRIBUTIONS

1. Time savings
2. Systematic analysis procedure of handling multivariate data
3. Pinpoint possible assignable causes of OOC status

FURTHER EXTENSIONS

1. Better design of Corrective Action System (CAS) at GlobalFoundries
2. Usage in module testing