Department of Industrial and Systems Engineering
IE3100 System Design Project

Wafer Profile Indicator

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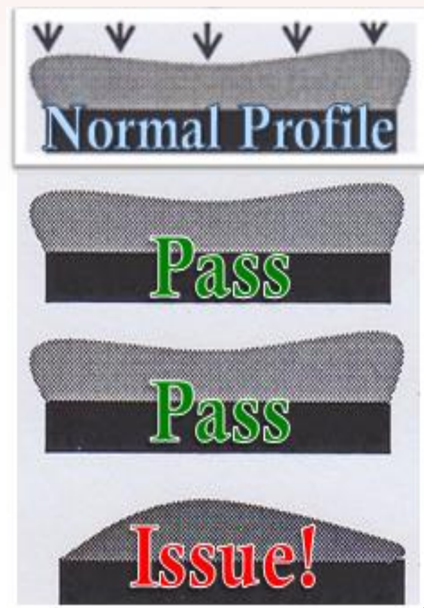
Problem Definition

Current process monitoring tools :

X-bar chart & Sigma Chart

- Detect abnormalities in the mean and the variance of a particular layer of the sample wafer in-line
- Unable to detect abnormalities in the profile of the layer in-line.
- Abnormalities only discovered near the end of the manufacturing process



Objectives

Improve performance of the process by introducing a profile indicator that

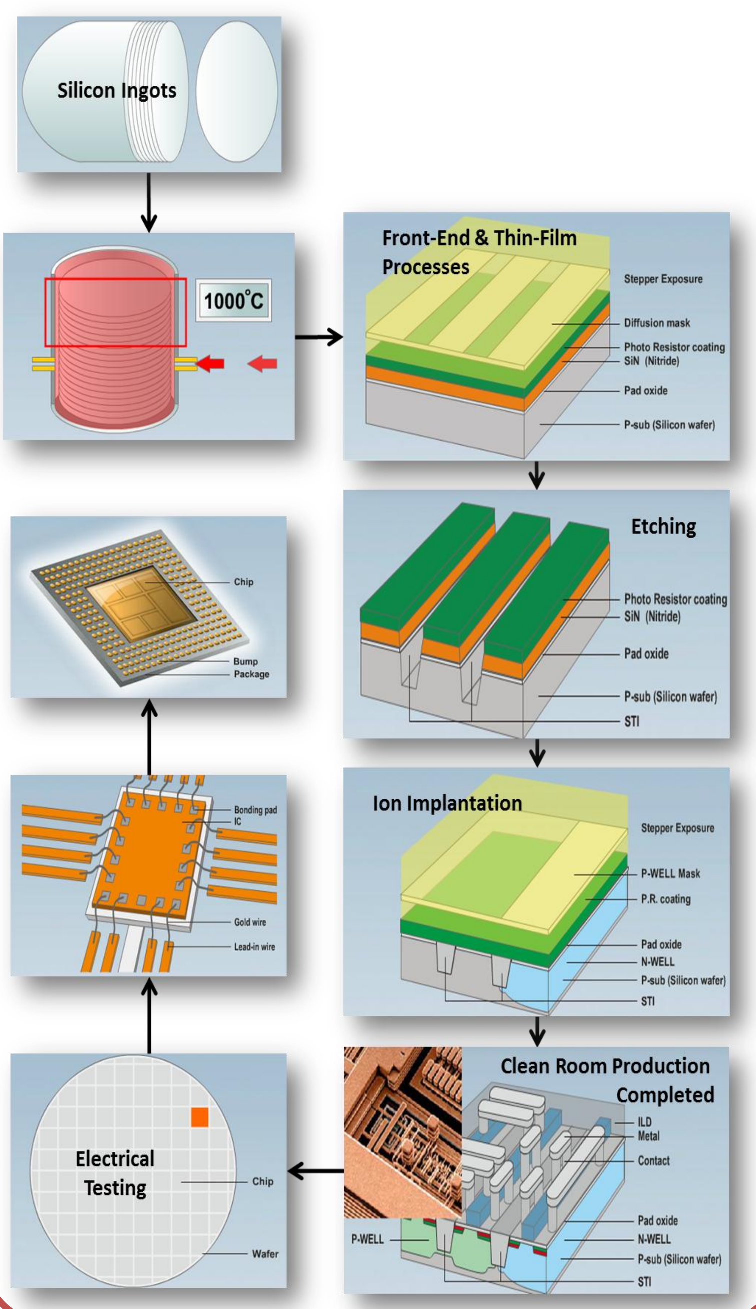
- Detects wafers with profile issue in-line
- Utilizes the readily available data
- Minimizes "false-alarm"

Approach

Wafer Profile Indicator → Define Problem & Objectives → Understand Wafer Fabrication → Generate Models (• Logistic Regression • Support Vectors Machine) → Validate Models (Stratified Cross Validation) → Implement the profile indicator (• Executable software • R Programming) → Conclusion

Process Flow

Wafer fabrication process takes 6 to 8 weeks. Wafers with profile issues are only detected late during the electrical test.



Methodology

Logistics Regression (LR)

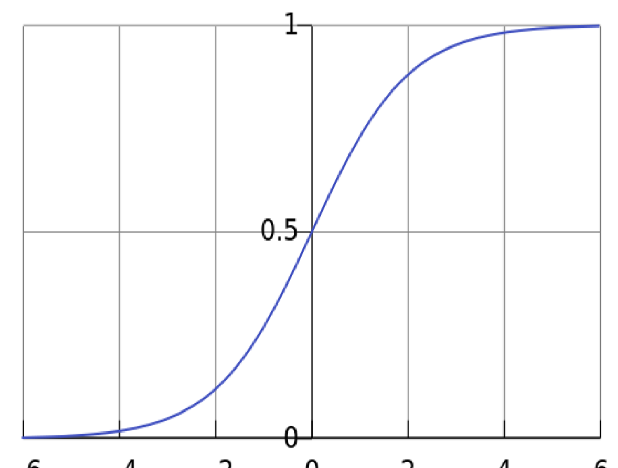
LR is a predictive statistical model that aims to construct a parametric curve which best fits the observations. LR transforms the dependent variable, i.e. the probability of a wafer having issue, to its logit function (Logit function is the inverse of the sigmoidal logistic function). A suitable threshold can be drawn, above which an "issue detected" alarm will be triggered.

Single Variable Logit Function

$$g(x) = \ln\frac{\pi(x)}{1-\pi(x)} = \beta_0 + \beta_1 x$$

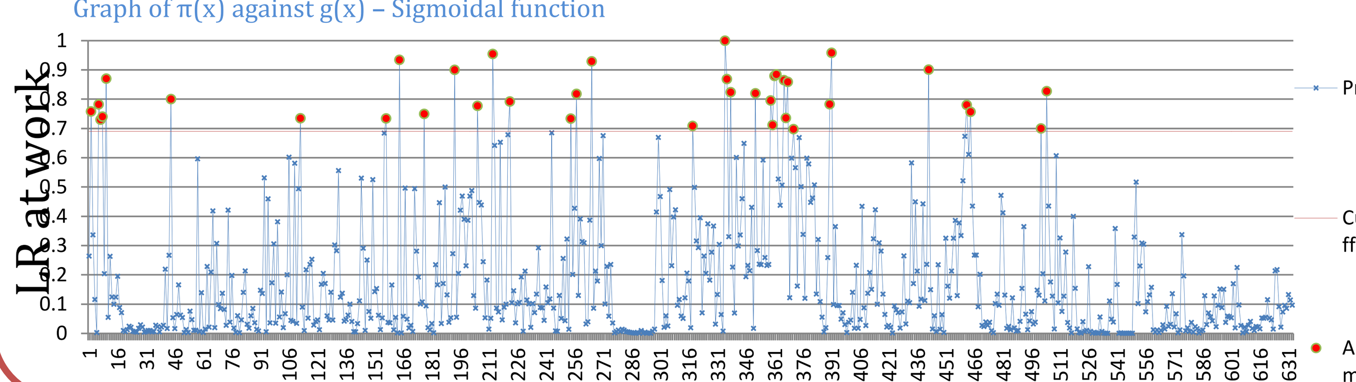
Multi-variate Logit Function

$$g(\tilde{x}) = \ln\frac{\pi(\tilde{x})}{1-\pi(\tilde{x})} = \beta_0 + \tilde{\beta}^T \cdot \tilde{x}$$



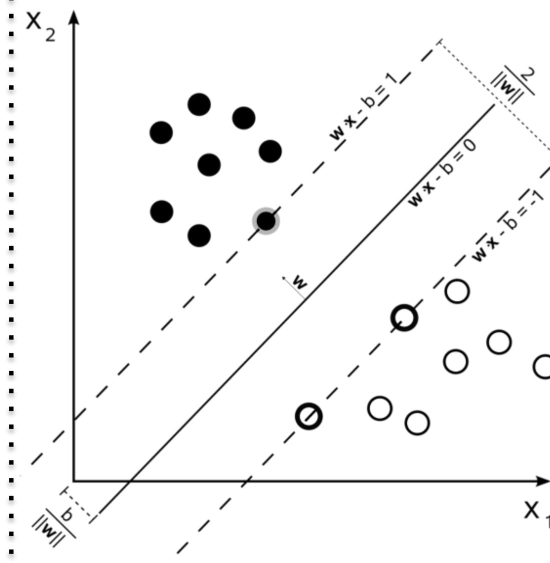
Graph of π(x) against g(x) – Sigmoidal function

$\pi(x)$ ranges from 0 to 1 and can be interpreted as the probability of detecting an issue. $g(x)$ takes all values and is therefore used to map to the linear product terms at the right hand side of the regression equation.



Support Vectors Machine (SVM)

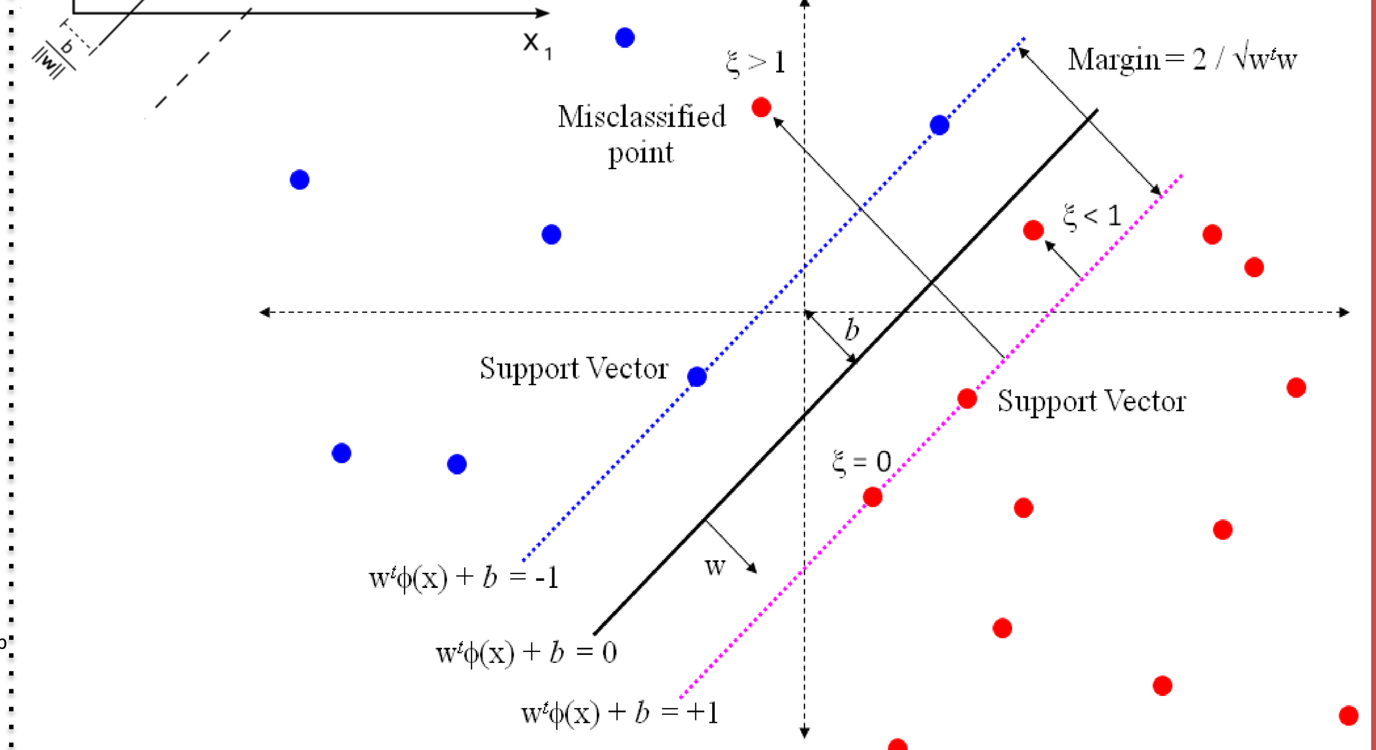
SVM classify the data by recognizing patterns and separating the defected units from the non-defect units.



A hyperplane is generated such that the distance between the hyperplane and the nearest data point on both sides is maximized.

$$\min \frac{1}{2}\|w\|^2 + C\sum_{i=1}^{L}\xi_i$$

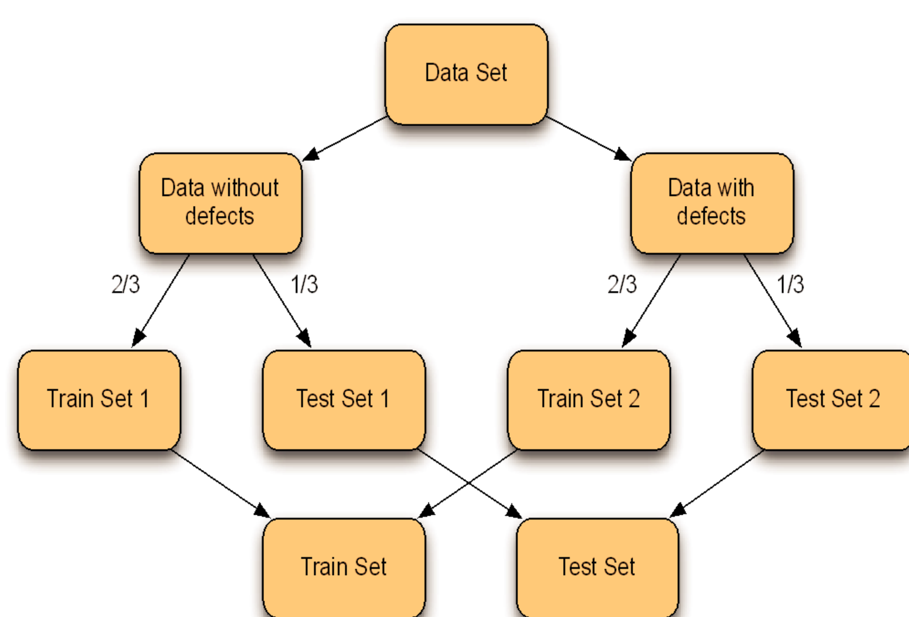
$$\text{s.t.} \quad y_i(x_i \cdot w + b) - 1 + \xi_i \geq 0 \quad \forall_i$$



Misclassification of points is inevitable. By adjusting both the degree of model separator and the cost constraint value, C, will affect the values of alpha- and beta-errors.

Validation

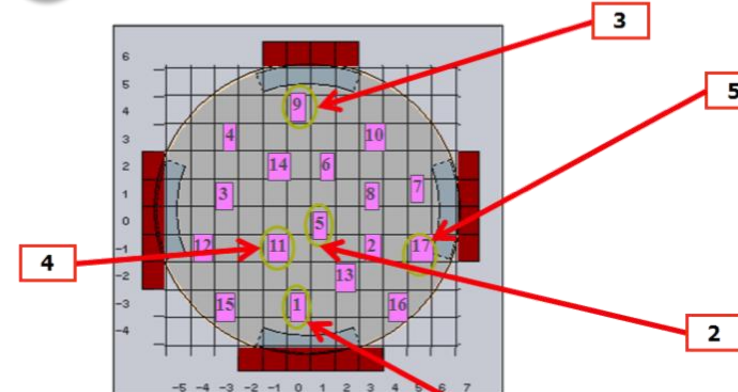
To ensure that (1) the model is able to detect the defects and (2) to achieve a low alpha-error with a reasonable beta-error, Stratified Cross-Validation is used to verify and validate the effectiveness of the model.



1. Due to the lack of faulty data points in, Stratified Sampling is applied to ensure there are sufficient defective units in the train set proportionally.
2. For both defective and non-defectives points, 2/3 of the data points are assigned to the train set, and 1/3 to the test.
3. Model generation is completed based on train set and then tested on the test set.

Implementation

1 Site Measurements

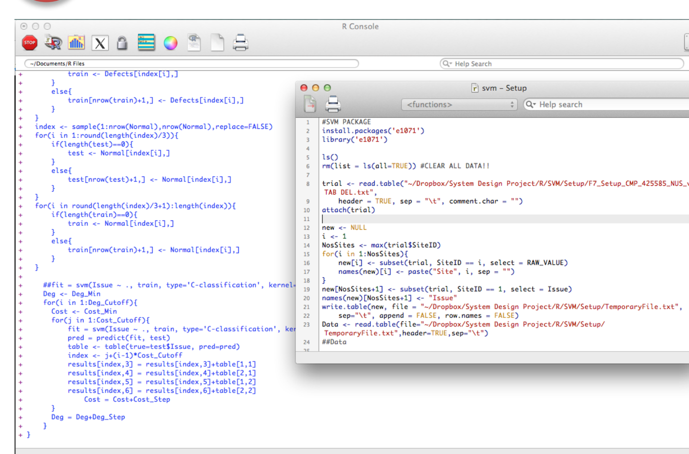


Thickness at 5 sites are measured.

2 Raw Data

Issue wafers are highlighted in red.

3 Execution



Programming language R is used to code and run LR and SVM models.

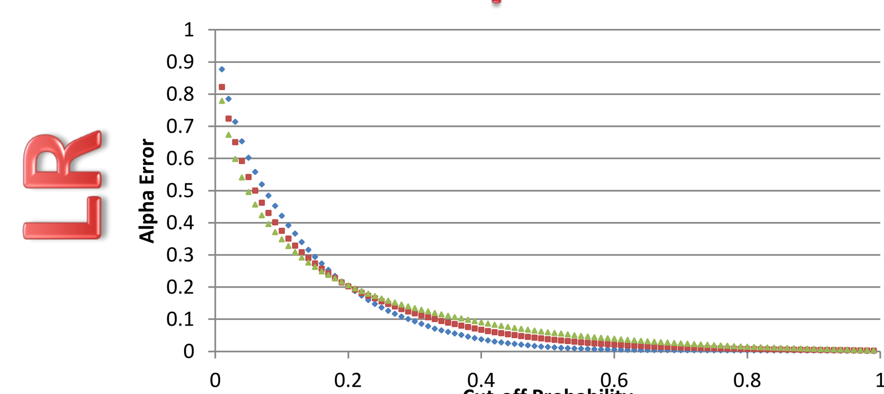
4 Output

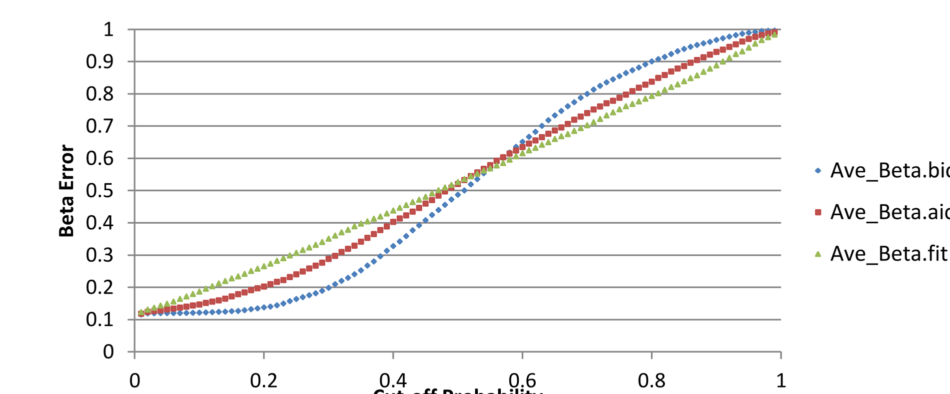
Output data are kept in .txt files for easy analysis later.

Results

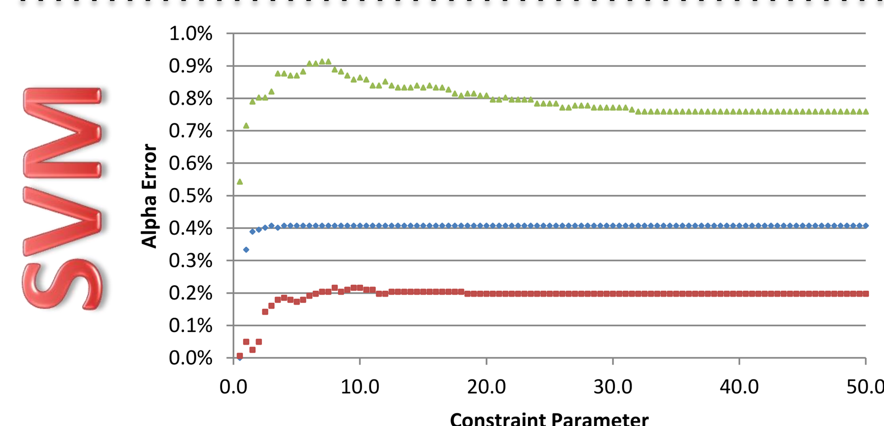
Alpha Error / Beta Error

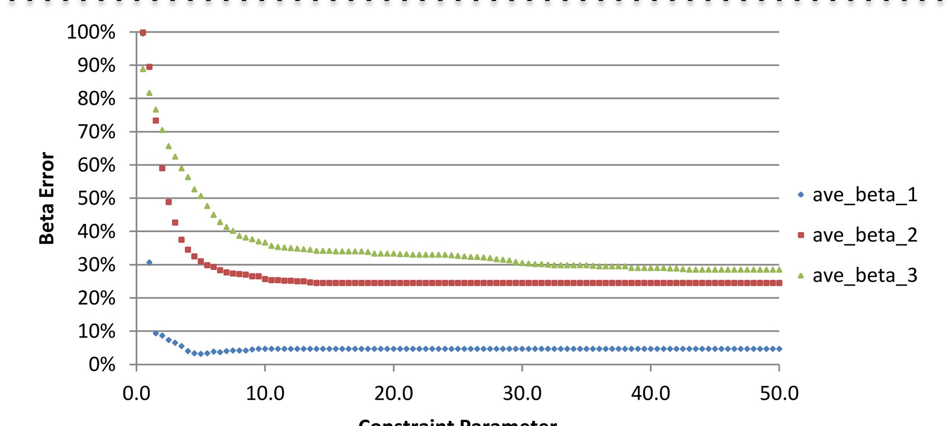
LR





SVM





Alpha error and beta error is inversely proportionate. Suitable cut-off probability (in LR) and separation parameters (in SVM) are to be selected for an acceptable error allowance.

Conclusion

LR and SVM methodology can be applied to processes in GlobalFoundries

- ✓ Using existing data
- ✓ Identify wafer profiles in line
- ✓ Minimize alpha error

Results show promising potential for implementation in GlobalFoundries.