PWS: Potential Wafermap Scratch Defect Pattern Recognition with Machine Learning Techniques

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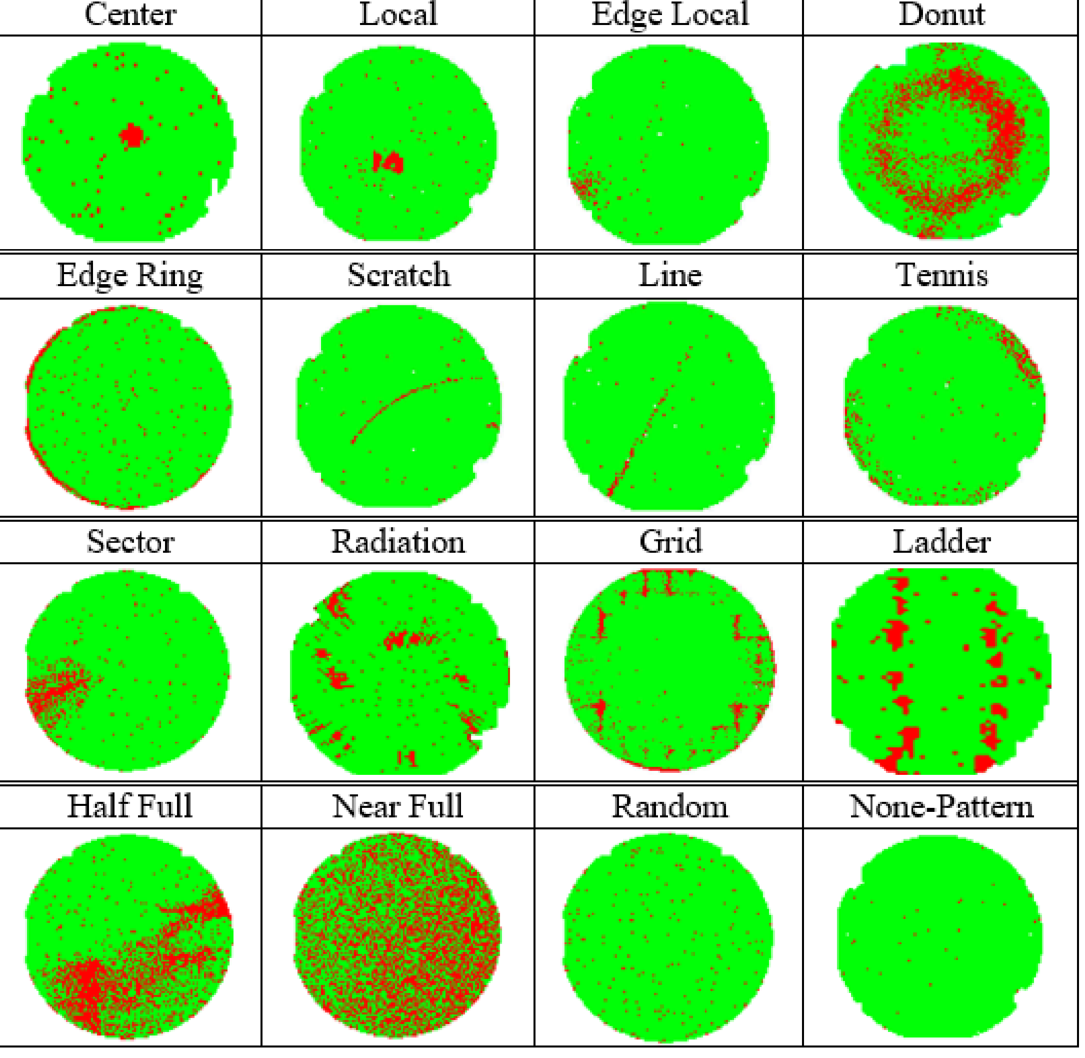
Abstract

- Introduction
- Problem Definition
- Methods
- Experiment Results
- Conclusion

Introduction

- Wafer Defect Maps in wafer test show defects in fabrication process and test process
- Wafer defect patterns are the result of various problems in the manufacturing and wafer test process
- The Defect Patterns and Failure Modes of defects in a wafer are highly correlated to the Root Causes
- Through Wafer defect pattern recognition we can conduct Root Cause Analysis to identify possible problems in the fabrication and wafer test process

Introduction



Problem Definition

- The potential defect are the discontinuity in spatial defect patterns corresponds to dies passing wafer test, they are caused by variation of mechanical force
- Since they fall inside a given defect pattern, it implies that such dies may suffer from the same cause that is responsible for the defect pattern

WDD	Local	Scratch	Line	Special: Matrix
Conventional WDD				
Potential WDD				

Problem Definition

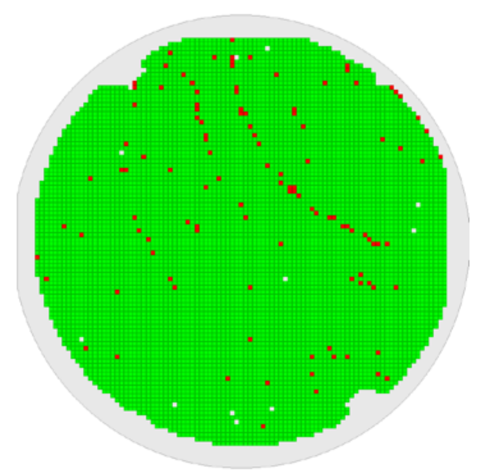
- Scratch and Line types of wafer patterns are often the most obscure
- Potential Wafer Scratch pattern recognition system
- Identify incomplete scratch pattern
- Reduce the classification effectiveness in wafer defect diagnosis
- Improve the prediction/classification accuracy

Methods

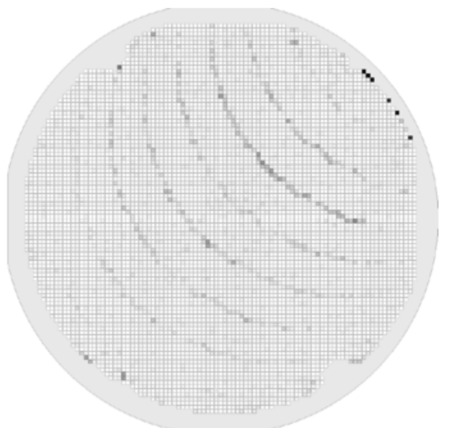
- Phase I: Wafer Lot Test
- Phase II: Wafer Clustering
- Phase III: Intra-Cluster Point Filling
- Phase IV: Inter-Cluster Point Filling
- Phase V: Machine Learning Based Classification

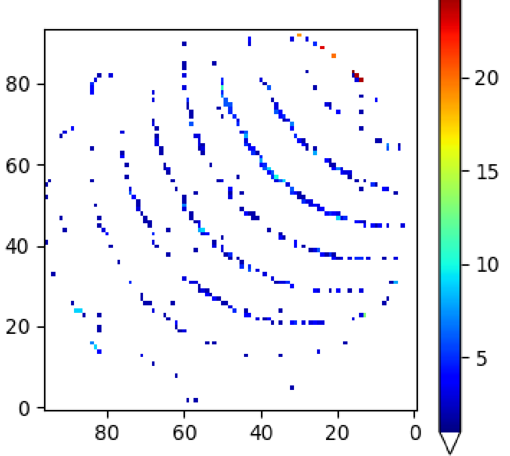
Wafer Lot Test

- Wafers are processed in batches of wafer lots in manufacturing process
- Search for potential scratch pattern in wafer maps per lot
- Stack all wafers in same lot into one lot wafer map



Single wafer





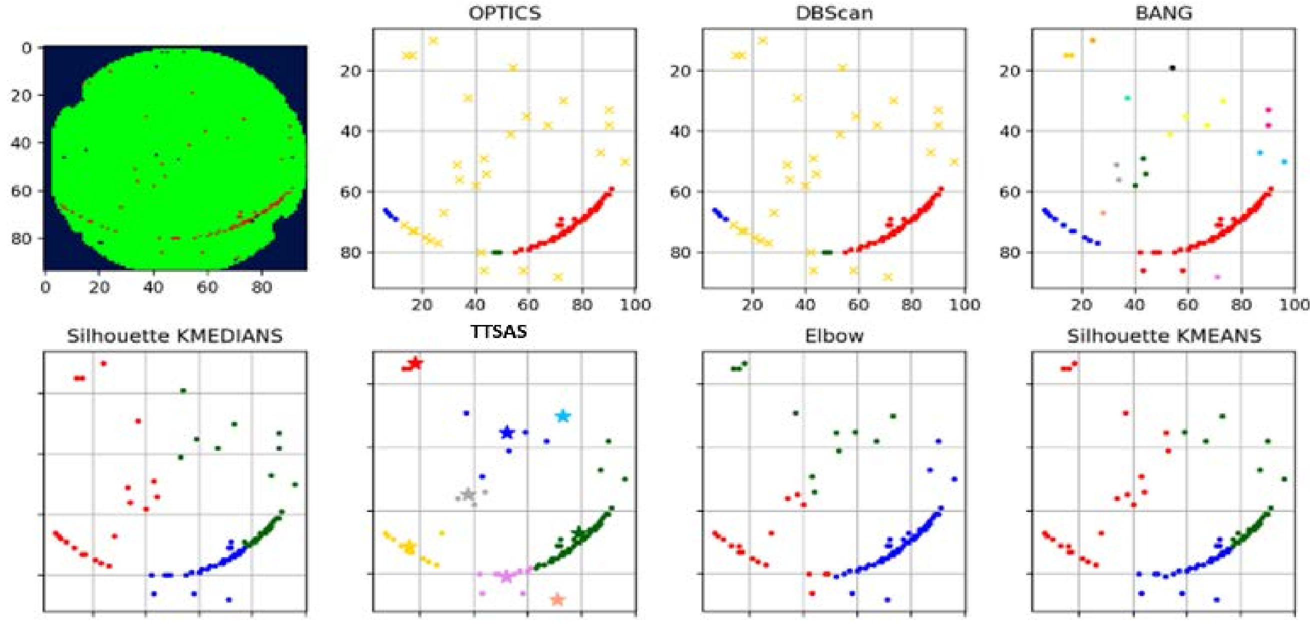
Lot wafers

Wafer Clustering

- Defective dies in a wafer may be caused by various problems, and defects caused by the same problem tend to form a local cluster
- Clustering algorithms
  - OPTICS (Ordering Points To Identify the Clustering Structure)
  - DBSCAN (Density-based spatial clustering of applications with noise)
  - TTSA (Two-Threshold Sequential Algorithm)
  - Elbow
  - BANG
  - K-Medians
  - K-Means

Wafer Clustering

- Rand Index (RI)
  - $RI = \frac{\#TP + \#TN}{\#TP + \#FP + \#FN + \#TN}$

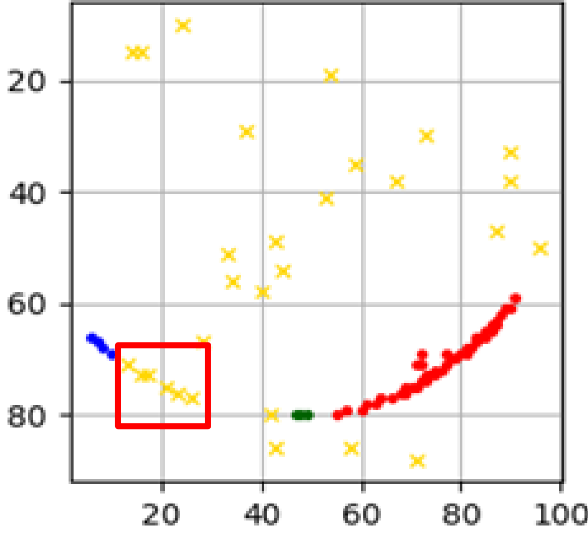


Wafer Clustering

- OPTICS
  - Based on defect density to cluster defective dies of a defect type
  - A generalization of DBSCAN, and can solve one of DBSCAN’s major shortcomings: effective clustering over density-variant data set
  - Robust against variation of shapes and sizes in Scratch pattern

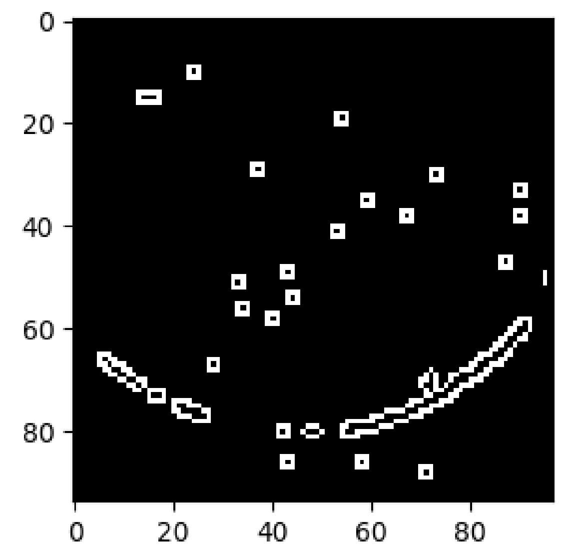
Intra-Cluster Point Filling

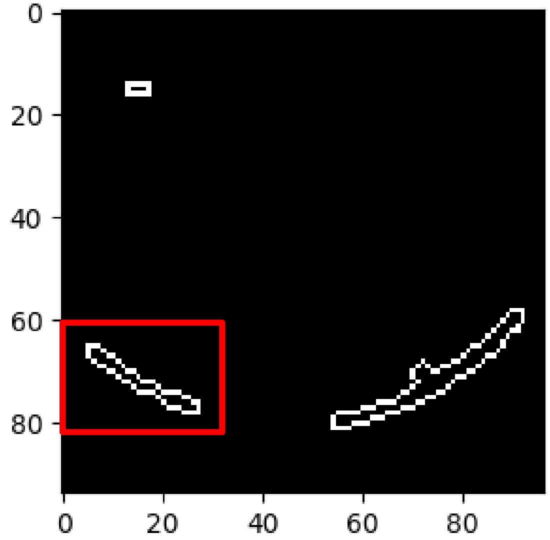
- The clustering process removes the random defect dies not in the pattern, but sometimes can also remove die that belong to the pattern but not obvious
- Scattered points are not put in any cluster as the defect density around these points is lower than the threshold.



Intra-Cluster Point Filling

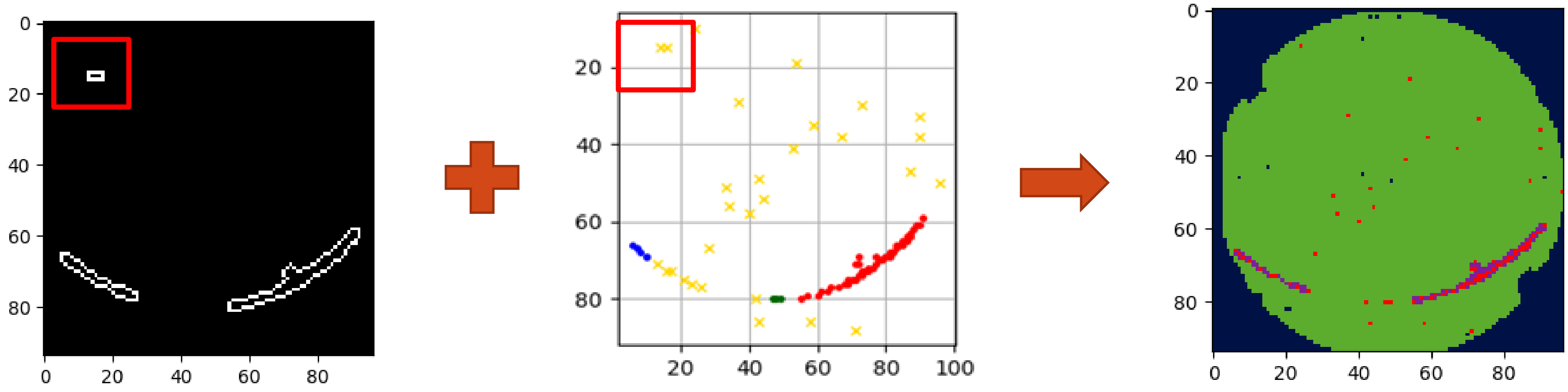
- Canny Edge Detection
- Region Labeling & Filtering
- Image closing operation





Intra-Cluster Point Filling

- Combine the cluster result and the image process result
- Flood Fill Algorithm

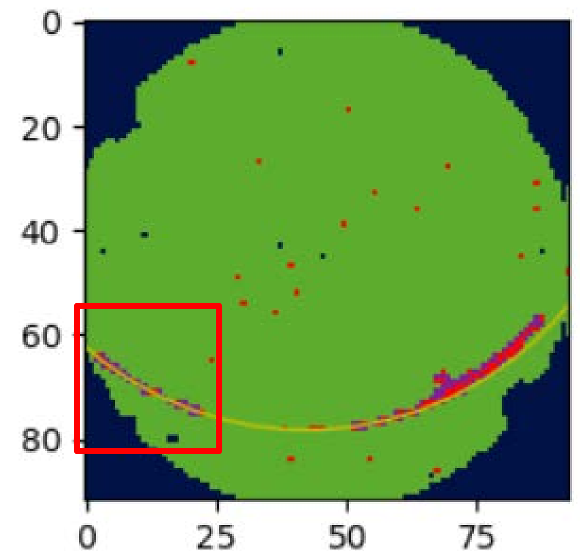


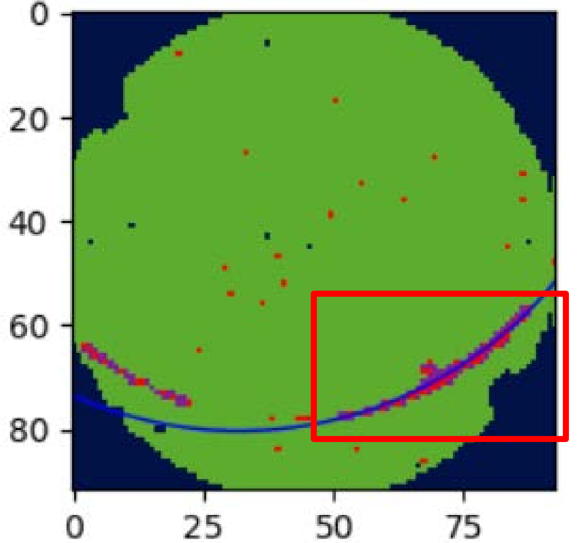
Inter-Cluster Point Filling

- For different clusters with potential Scratch, we need to judge:
  - 1. **Integrated** Scratch:
    - There are disconnected points in Scratch, but with the same arc shape.
  - 2. **Individual** Scratch:
    - Due to different arc shapes, they belongs to individual scratches with their own features

Inter-Cluster Point Filling

- Scratch Generation
  - Generate circle that matches the shape of each cluster

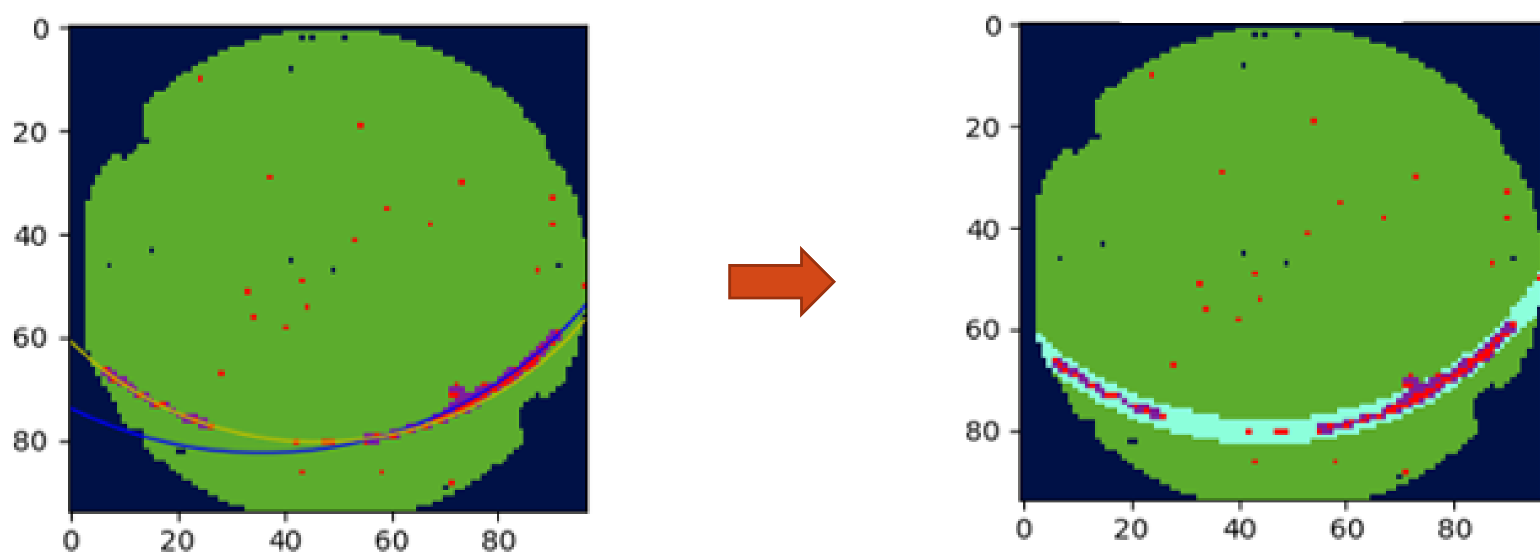




Inter-Cluster Point Filling

- Integrated *vs.* individual Scratches
  - Judge whether the intersection of individual scratches exists
  - Jaccard Index (Jaccard similarity coefficient) is used to compare similarity between two arc shape

$$JI(A,B) = \frac{|A \cap B|}{|A \cup B|} = \frac{|A \cap B|}{|A| + |B| - |A \cap B|}$$

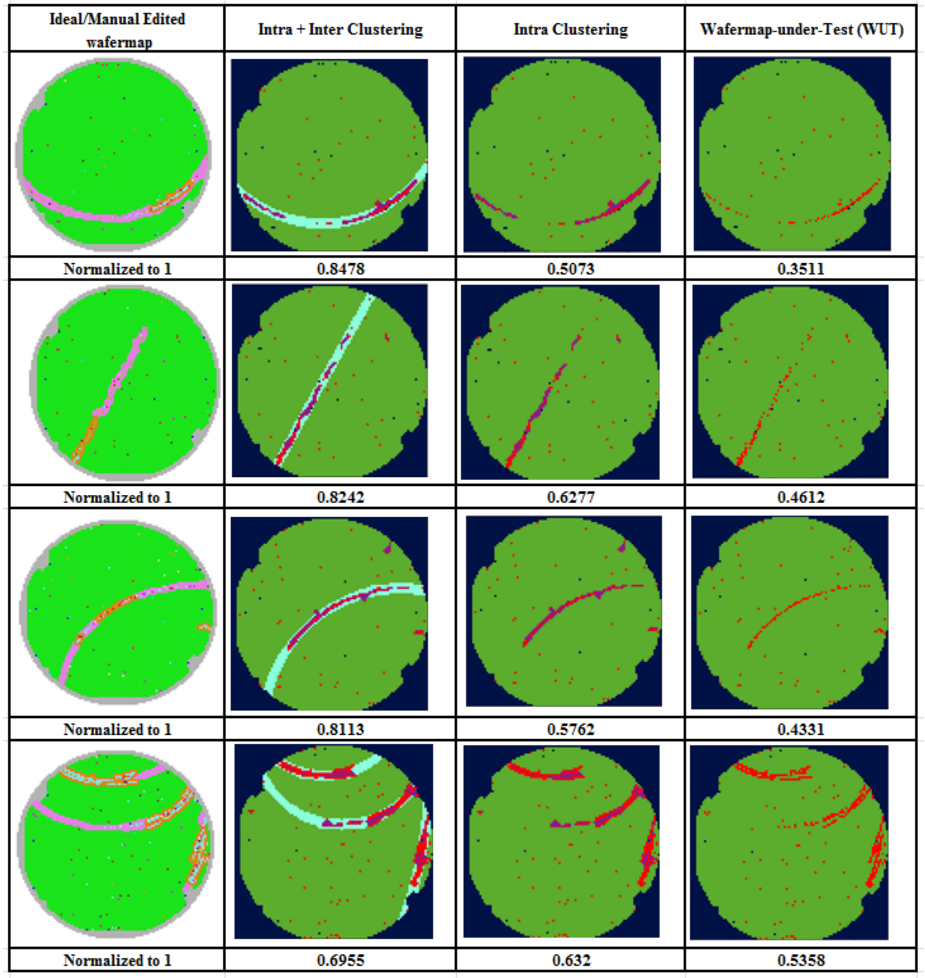


Machine Learning Based Classification

- Ada Boost and Decision Tree method
  - Spatial Feature
  - Geometry-based Feature
  - Density-based Feature
  - Radon-based Feature

Experiment Results

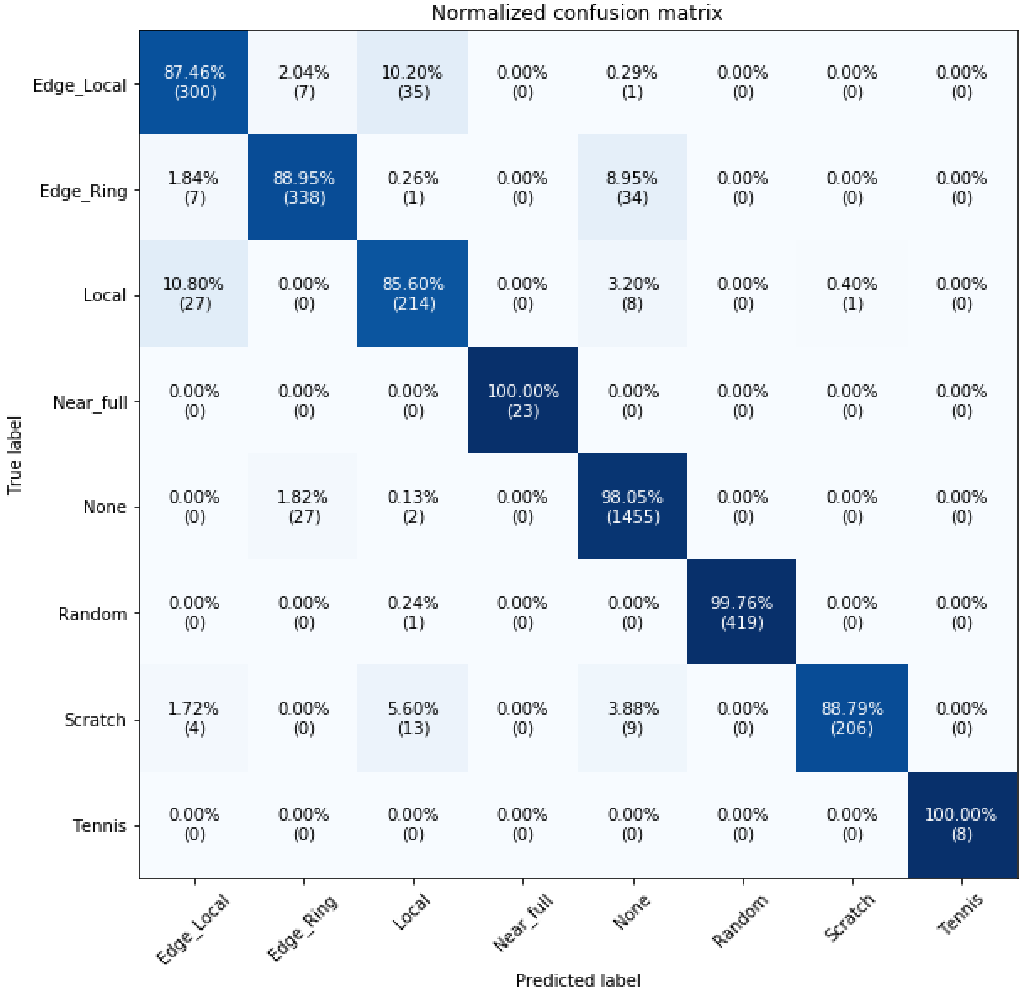
- Similarity ranking



Ideal/Manual Edited wafermap	Intra + Inter Clustering	Intra Clustering	Wafermap-under-Test (WUT)
Normalized to 1	0.8478	0.5073	0.3511
Normalized to 1	0.8242	0.6277	0.4612
Normalized to 1	0.8113	0.5762	0.4331
Normalized to 1	0.6955	0.632	0.5358

Experiment Results

- 8 Defect patterns
- Total 3140 wafers
- 80% training, 20% test



Conclusion

- An automatic defect pattern recognition system demonstrated to search for potential scratch/line defect types
- Experimental results show the proposed method can achieve more than 89% prediction accuracy for scratch/line types, and higher than 94% for all common wafer defect types
- The quality and reliability of products can be significantly improved and cost of final test can be reduced.

THANK YOU