Proactive Yield Management using Frequent Pattern Database

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Outline

• Overview
• Motivation
• Technology
• Benefits
• Methodology
• Operational Workflow
• Challenges
• Case Studies
• Conclusion & Future Work
• Acknowledgements
Overview

<table>
<thead>
<tr>
<th>GOOD</th>
<th>BETTER</th>
<th>BEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI based Spatial Pattern Recognition (SPR) system for inline wafer monitoring</td>
<td>Performing offline reactive root cause analysis for the detected spatial patterns</td>
<td>Proactive association of spatial patterns to WIP process step and equipment</td>
</tr>
</tbody>
</table>

Reactive to Proactive

INCREASED FAB YIELD & PRODUCTIVITY
Motivation

“Analyzing yield loss from both defect and wafer probe data led to the conclusion that solving systematic spatial pattern challenges in production is the missing link between inline tool control and yield improvement!”

- 29% of wafer starts have some form of spatial pattern
- 10% of wafers exhibit new UNKNOWN spatial pattern

Unknown Patterns
- Top3Pattern
- Top2Pattern
- Top3Pattern

Known Patterns
- No Pattern

No Pattern
Technology – Build Frequent Pattern Database

Yield limiting pattern on a wafer is a sign of a systematic issue due to process or tool marginalities!

<table>
<thead>
<tr>
<th>Rank</th>
<th>Failure Type</th>
<th>Wafer Map</th>
<th># of Wafers</th>
<th>Failure Rate</th>
<th>Route/Stage : Step</th>
<th>Process Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Edge Arc</td>
<td><img src="image" alt="Edge Arc" /></td>
<td>410</td>
<td>0.32</td>
<td>C-MET1ET : CE51B</td>
<td>CELRC01X</td>
</tr>
<tr>
<td>2</td>
<td>SP2</td>
<td><img src="image" alt="SP2" /></td>
<td>350</td>
<td>0.26</td>
<td>C-BCAPCLN : CA065</td>
<td>CAFS02X</td>
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<tr>
<td>3</td>
<td>Center Core</td>
<td><img src="image" alt="Center Core" /></td>
<td>100</td>
<td>0.10</td>
<td>C-YWDEP2 : CY311</td>
<td>CY310</td>
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</tbody>
</table>
Benefits

**Inline Monitoring & Lot/Wafer Disposition Strategy**
- Drive actions in production (OCAP)
  - Lot Hold, Tool Downs, Rework, Chamber Actions and Test wafer measurements
  - Interacting with SPC

**Learning from UNKNOWN**

**Yield & Productivity Improvement**
- Timely Root Cause
- Dashboards for High Impacting Route Step & Tools

**Quality Improvement**
- Proactive Die Binning
- Pattern Search
- Event Scope
Introduction / Methodology

Six months of AOI & Wafer Probe production data was used.
Discover Patterns Operational Workflow

Diagram showing the operational workflow with nodes for Prober, Metrology, STDF G55, CSV Flat File, Library, Recipe, Loader, SPR Engine, Alarm, Discover DB, Export/Notify, Data Load, Post Process SPR Engine, Update Frequent Pattern, OCAP - Reports & Notifications.
Learning from the “UNKNOWN”

• An UNKNOWN pattern is an identified spatial signature that does not match an existing pattern in the production database

Auto Discovery

Pattern Pareto based on hundreds of feature vectors

• Understand top-n high impacting new patterns that start to emerge & go unnoticed
• Efficiently maintain comprehensive Pattern Library
• Proactive response to production issues
Results of learning from the “UNKNOWN” Patterns

Pattern Pareto based on hundreds of feature vectors from UNKNOWN Patterns over 3 months

- Three key patterns were discovered: System Scratch, Small Cluster, and Ring Light.
- Analysis shows the potential for hundreds of wafers to be classified and correlated to yield limiting spatial issues.
Challenges with Scratch Detection

Additional post processing algorithm is dedicated to running image-based scratch detection instead of defect-based detection using dynamic threshold determination (based on density and distribution) to eliminate or reduce false positives.
Case Study #1: Pattern Search Technique Improves Quality

- Contributes to proactive analysis and build the Frequent Pattern Database
- Defect edge band pattern was used as reference to pull top 50 similar wafer probe patterns
- This powerful tool explicitly defines inline to EOL pattern commonalities and can be used to obtain accurate kill ratios
Case Study #2: SPR Identifies Root Cause Tool in CMP Excursion

Yield excursion linked to a recurring scratch formation in the CMP process.
Production limitations & low defect density impacts quality & contributes to scrap

Integration of this signature into the Frequent Pattern Database quickly highlights the root cause tool and event timeline.

- Equipment Data Monitored
  - Platen Temp, Rotation Speed, Motor Amps
  - Spindle Head Speed, Vacuum/Pressure, Down force and Motor Amps
  - Slurry Dispense
  - Wafer Chuck Placement/Retry
  - Conditioner Sweep Speed, Motor Amps and Arm Force
  - Processing time (by platen)
  - Wet Idle Time
  - DI Water Flow
  - ...
Case Study #3: Killer Pattern Excursions by Process Tool & Date

- Chemical dispersion challenges at a strip step cause semi-circular ring like pattern
- Application of real-time alarm monitoring will notify the engineer and maintenance staff of this yield-impacting defect pattern, allowing for quick reaction times
- This known failure mode requires timely detection so wafer can be reworked to avoid scrap

Trend split by Tool & Pattern, helps to find signal which would have been missed otherwise
Yield Improvement / Line Control

Yield Optimizer

• Analyze the relationships between in-process data and End-of-Line test or output results
• Recommend changes to the in-process targets to optimize the yield/output parameters

In-process tool data

Inline Metrology/output data

Frequent Patterns

Use NN to learn the relationship

Neural Network(s)

Predicted Metrology / Performance

Optimizer

Recommended Input Targets

Current process targets

Future Work
Engineering productivity improves ~25% by linking Pattern based Equipment Study with AOI data

Daily Pass Down Report to production highlights process tools that contribute to yield limiting alarm conditions
Conclusions & Future Work

**AI based Frequent Patterns Implementation**

- **Good:** Key application
  - Shutdown faulty tools
  - Outline excursion scope
- **Better:** Reactive Analysis
  - Expedient association of wafer spatial signatures to process step & tool
- **Best:** Proactive Yield Management
  - Build Frequent Pattern Database
  - Avenue for proactive process control, yield enhancement & fab productivity

**Continuous Improvement**

- Discover Patterns on Metrology Data
- Whole wafer image-based Pattern Classification
- Frequent Patterns input to Yield Optimizer for Process Optimization
Acknowledgements

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Thank You

谢谢 | 謝謝
ありがとうございました
감사합니다

Danke

Obrigado

Merci

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