Proactive Yield Management using Frequent Pattern Database

Alan Fan | Metrology Engineer, Seagate Technology

Prasad Bachiraju | Director, Sales & Customer Solutions

OCT 4TH, 2021

Outline

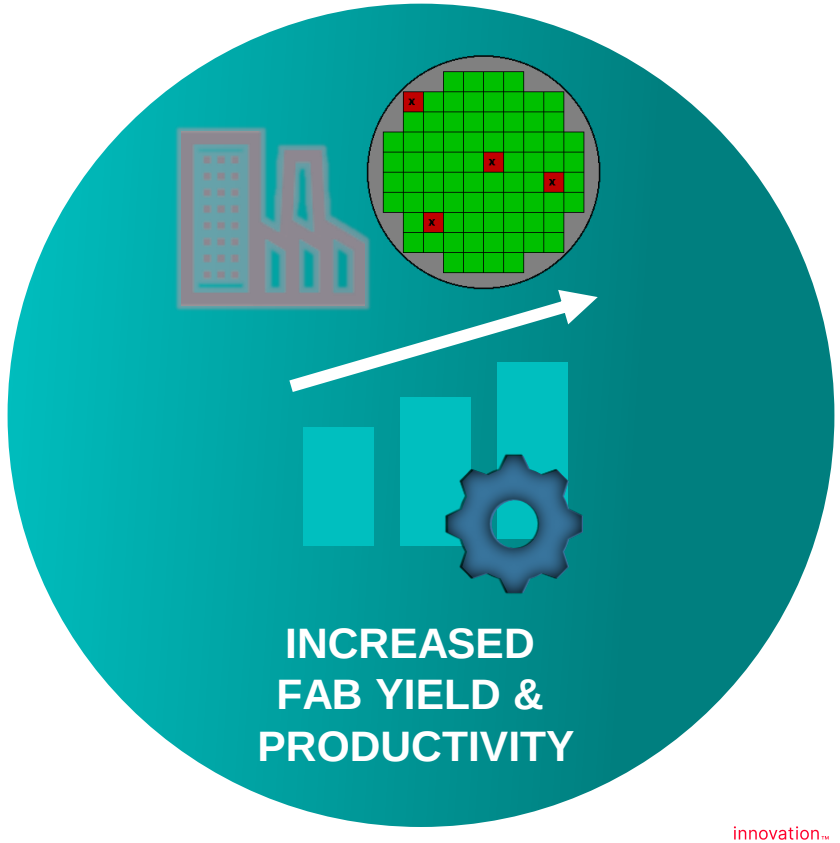
- Overview
- Motivation
- Technology
- Benefits
- Methodology
- Operational Workflow
- Challenges
- Case Studies
- Conclusion & Future Work
- Acknowledgements

Proactive Yield Management using Frequent Pattern Database

Overview

GOOD	BETTER	BEST
AI based Spatial Pattern Recognition (SPR) system for inline wafer monitoring	**Performing offline reactive root cause analysis for the detected spatial patterns**	**Proactive association of spatial patterns to WIP process step and equipment**

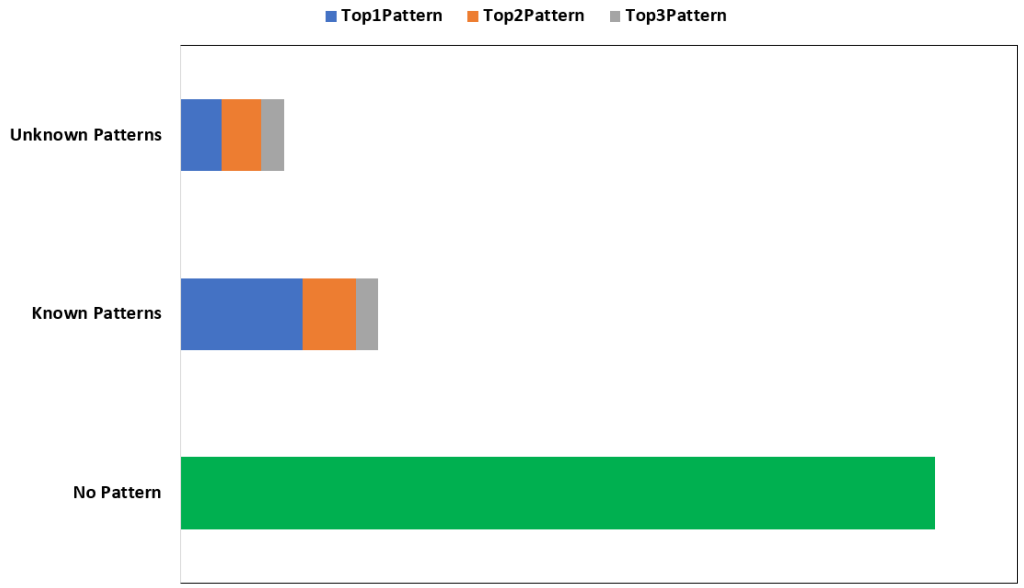
Reactive to Proactive



SEAGATE

onto innovation

Motivation



29% of wafer starts have some form of spatial pattern

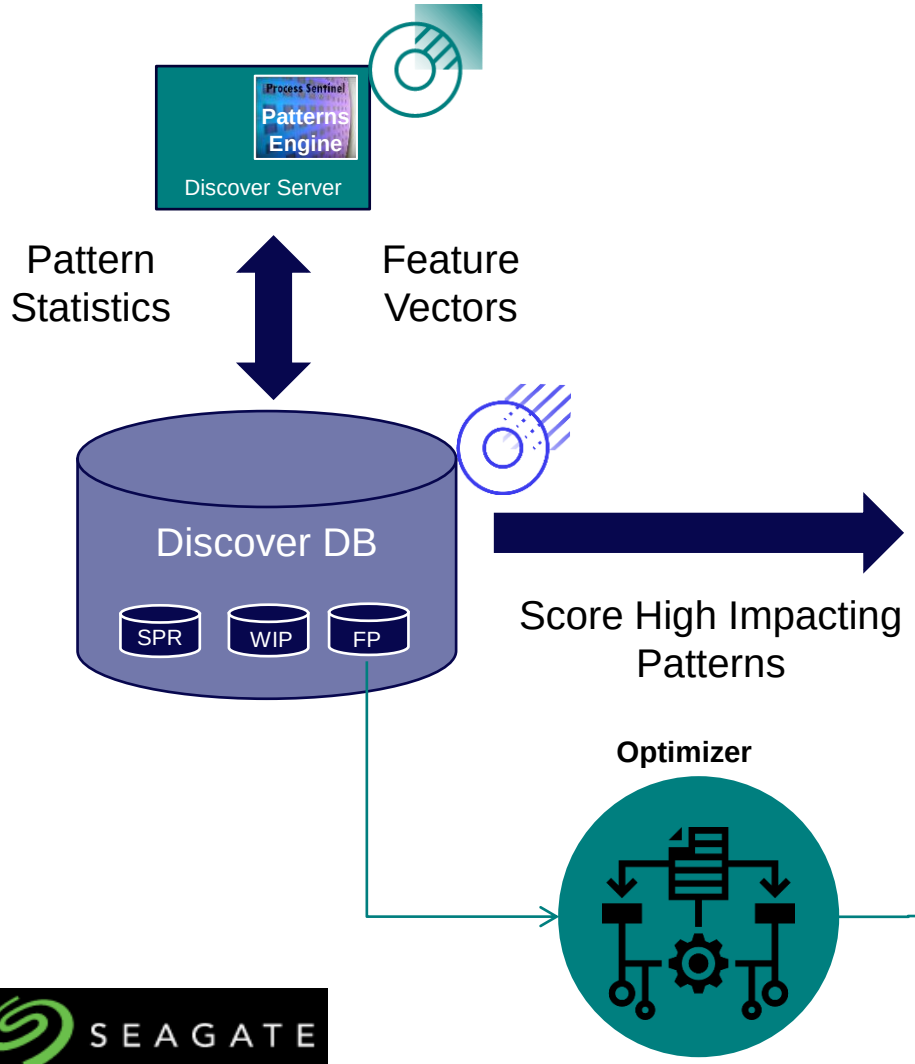
↳ **10%** of wafers exhibit new UNKNOWN spatial pattern

"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!"

SEAGATE

onto innovation™

Technology – Build Frequent Pattern Database



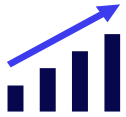
Yield limiting pattern on a wafer is a sign of a systematic issue due to process or tool marginalities!

Rank	Failure Type	Wafer Map	# of Wafers	Failure Rate	Route/Stage : Step	Process Tool
1	Edge Arc		410	0.32	C-MET1ET : CE51B	CELRC01X
2	SP2		350	0.28	C-BCAPCLN : CA085	CAFSI02X
3	Center Core		100	0.10	C-YWDEP2 : CY311	CY310

Benefits

Inline Monitoring &
Lot/Wafer Disposition Strategy

Learning from UNKNOWN



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

Drive actions in production (OCAP)
- Lot Hold, Tool Downs, Rework, Chamber Actions and Test wafer measurements
- Interacting with SPC

Quality Improvement
- Proactive Die Binning
- Pattern Search
- Event Scope

SEAGATE

innovation™ onto

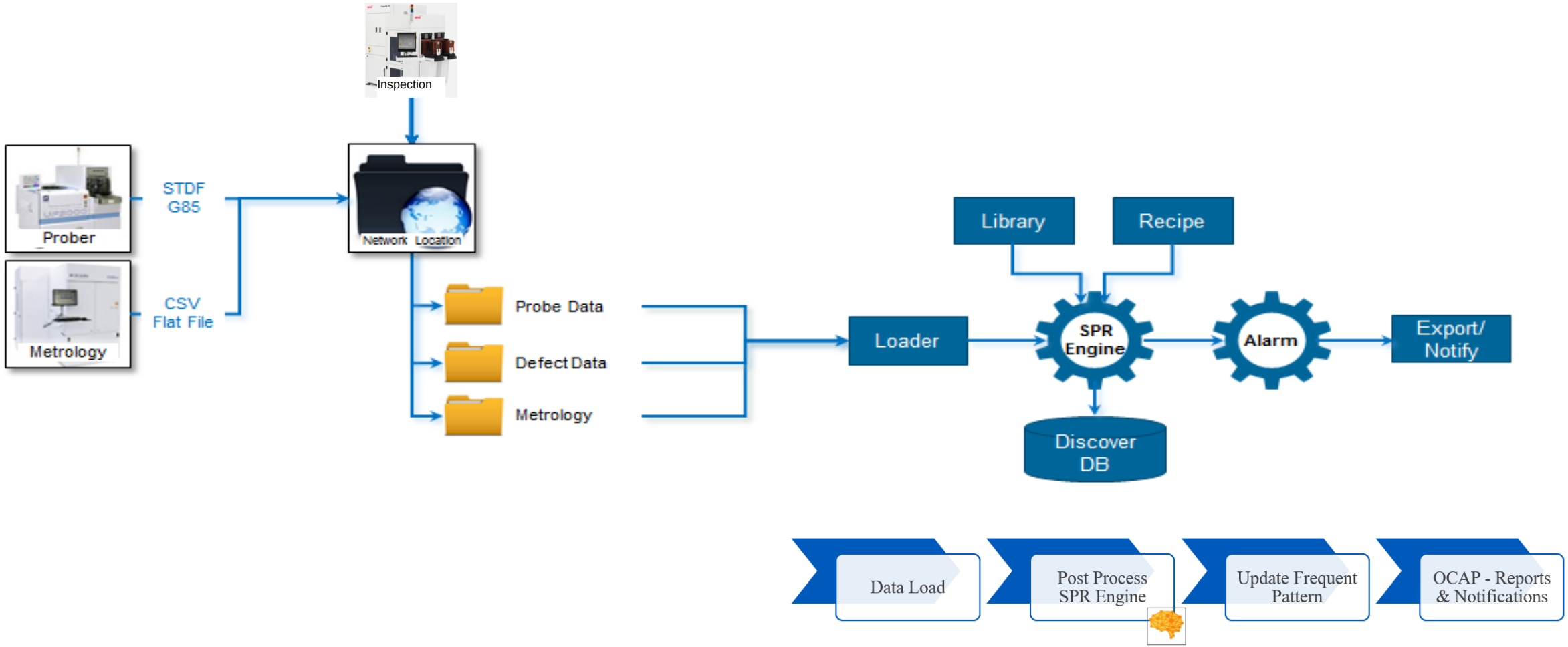
Introduction / Methodology

Six months of AOI & Wafer Probe production data was used.

SEAGATE

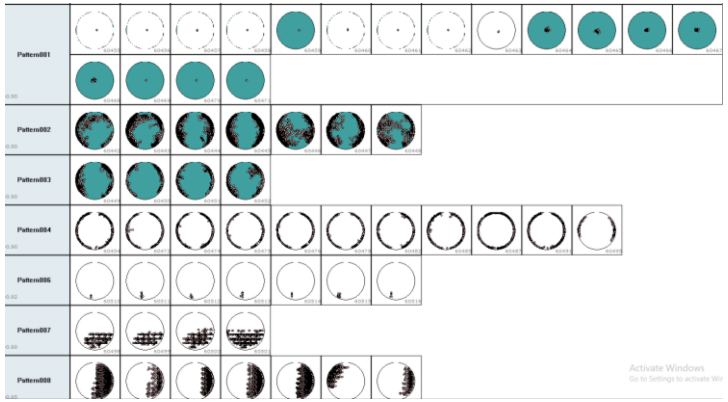
onto innovation

Discover Patterns Operational Workflow



Learning from the “UNKNOWN”

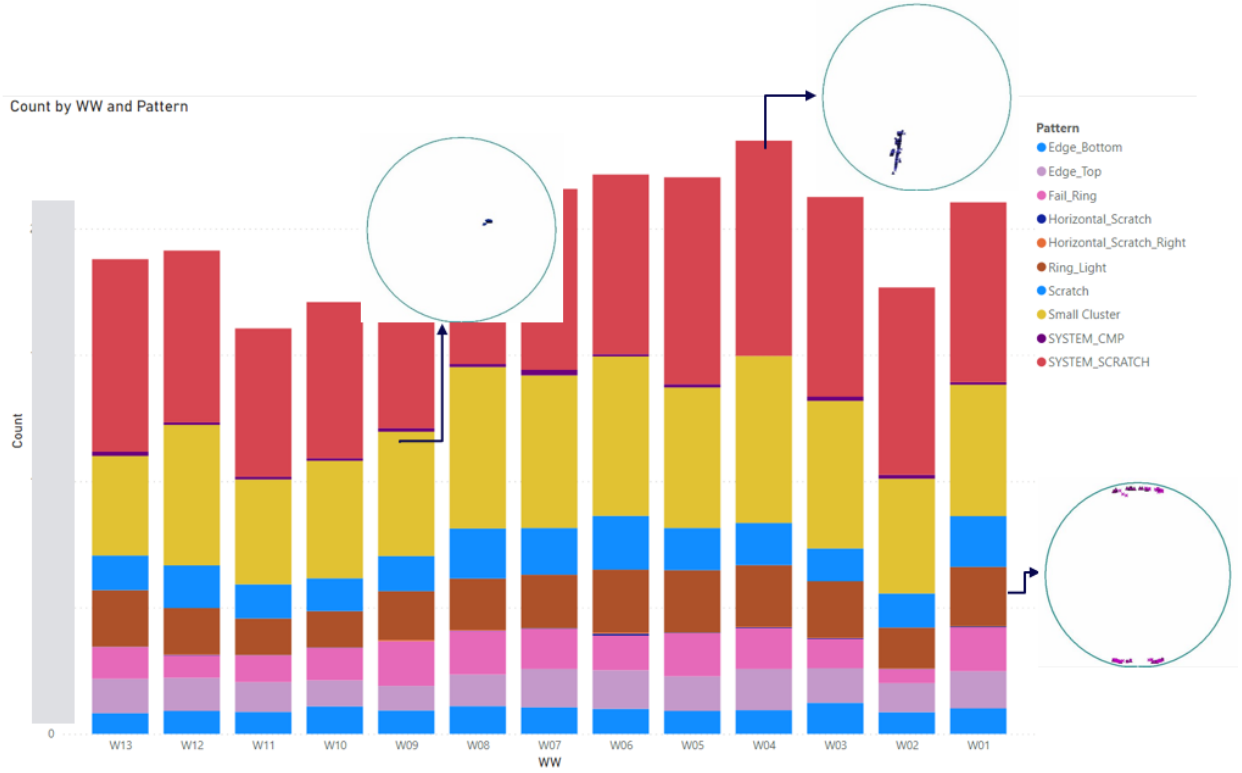
- An UNKNOWN pattern is an identified spatial signature that does not match an existing pattern in the production database



- Understand top-n high impacting new patterns that start to emerge & go unnoticed
- Efficiently maintain comprehensive Pattern Library
- Proactive response to production issues

Pattern Pareto based on hundreds of feature vectors

Results of learning from the “UNKNOWN” Patterns



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

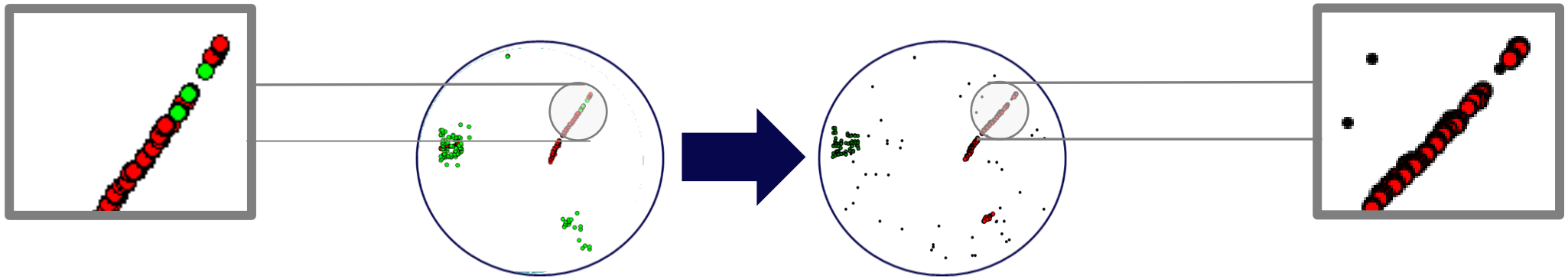
UNKNOWN Patterns tracked weekly

- 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.

SEAGATE

innovation™ onto

Challenges with Scratch Detection



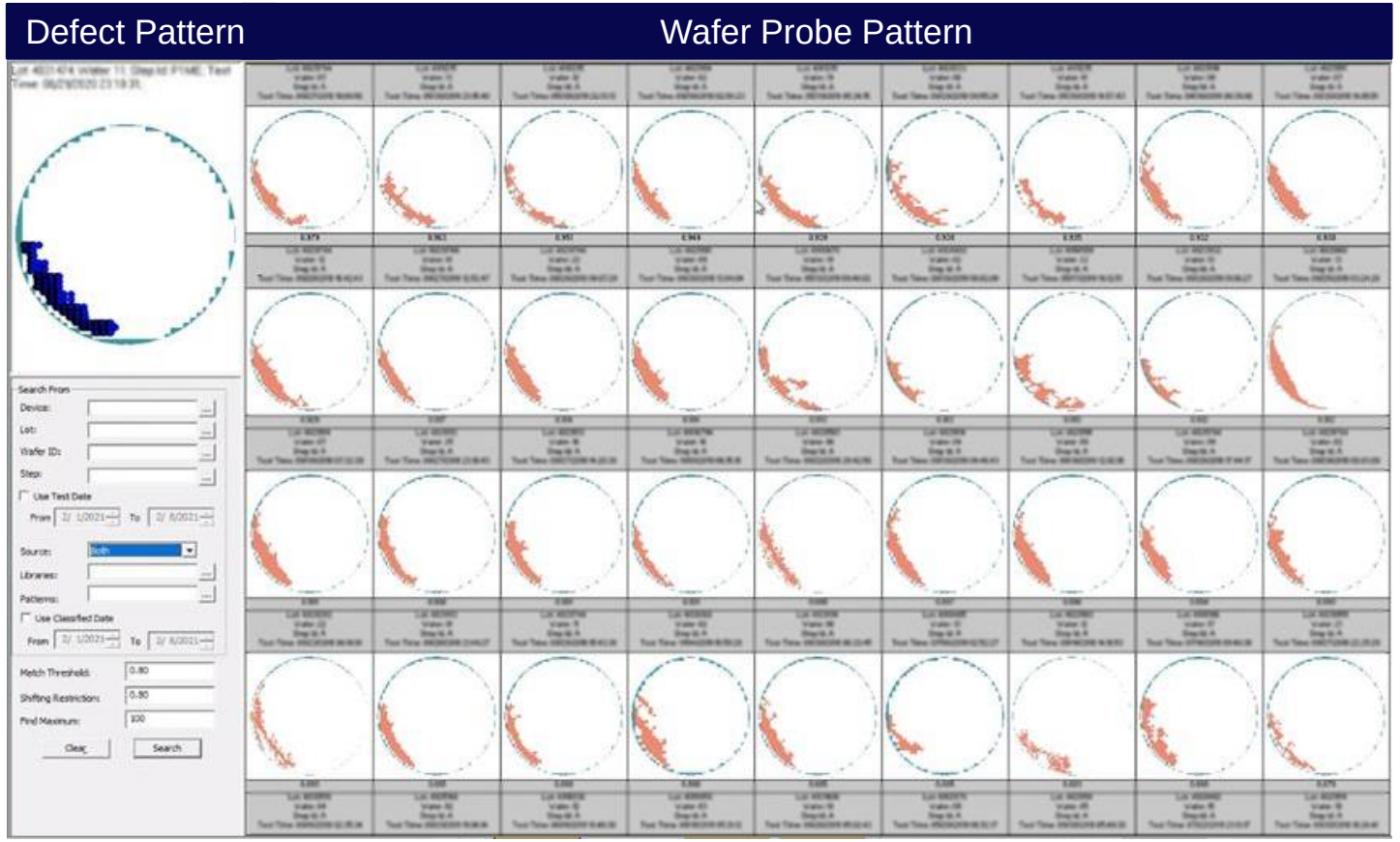
Additional post processing algorithm is dedicated to running image-based scratch detection instead of defect-based detection using dynamic threshold determination (based on density and distribution) to eliminate or reduce false positives.

SEAGATE

innovation™ onto

Case Study #1: Pattern Search Technique Improves Quality

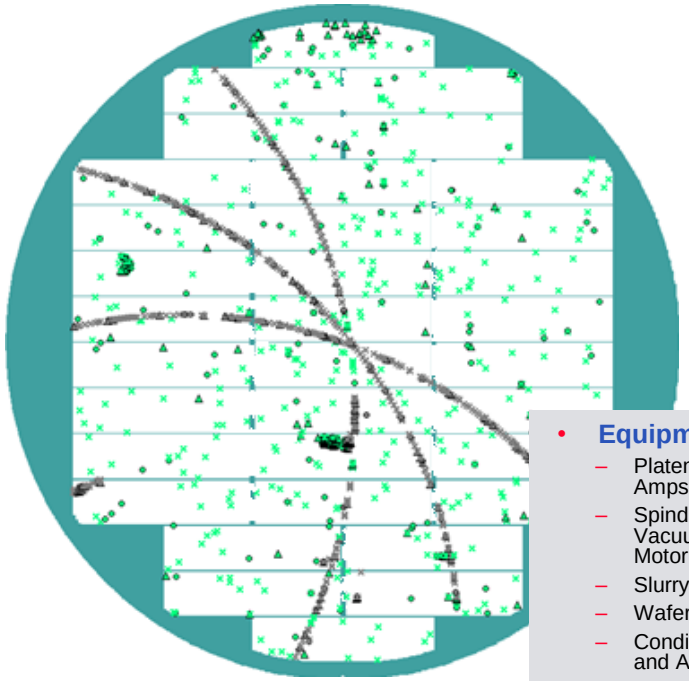
- Contributes to proactive analysis and build the Frequent Pattern Database
- Defect edge band pattern was used as reference to pull top 50 similar wafer probe patterns
- This powerful tool explicitly defines inline to EOL pattern commonalities and can be used to obtain accurate kill ratios



Case Study #2: SPR Identifies Root Cause Tool in CMP Excursion

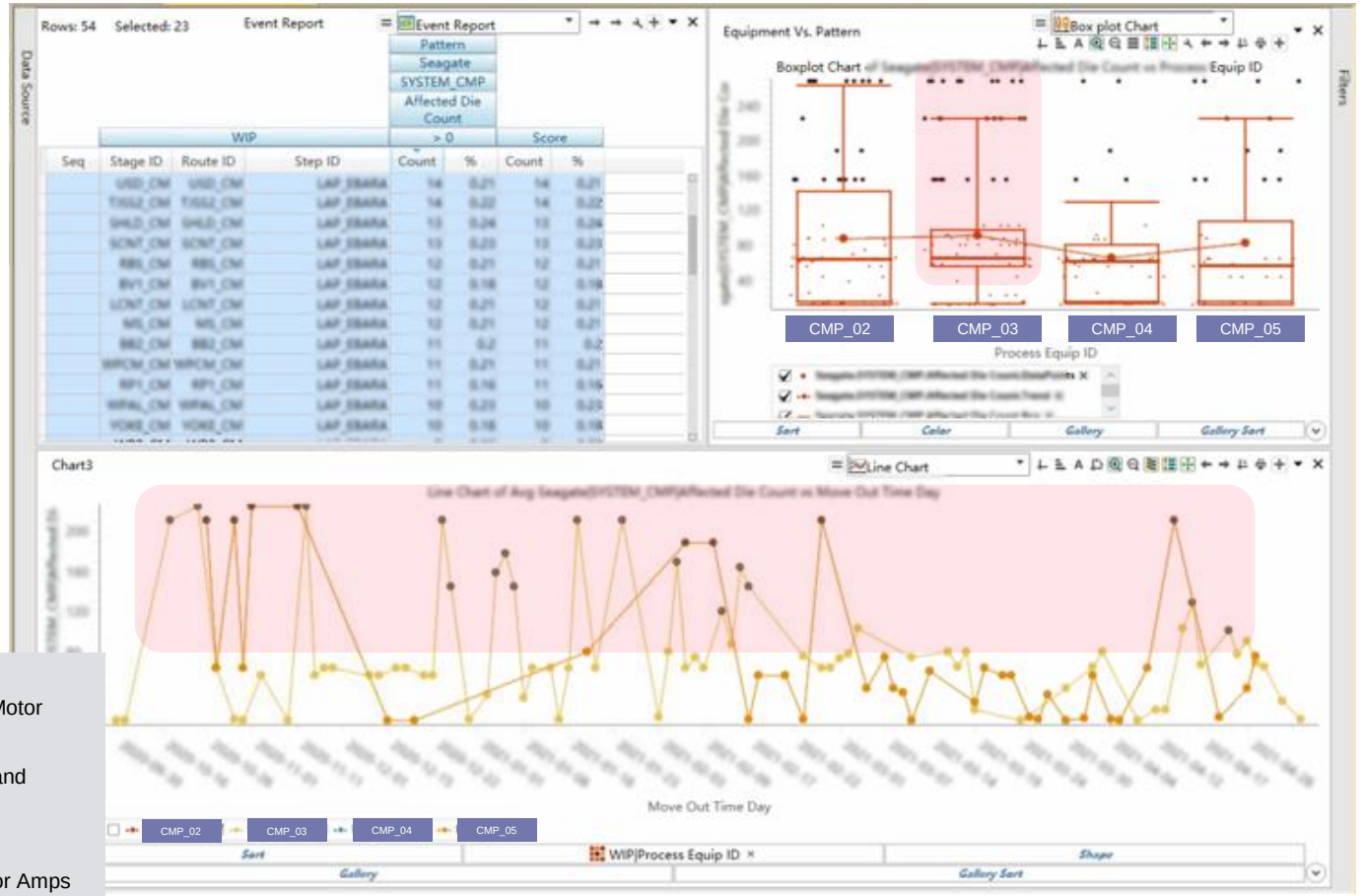
Yield excursion linked to a recurring scratch formation in the CMP process.

Production limitations & low defect density impacts quality & contributes to scrap



CMP SCRATCH EXAMPLE

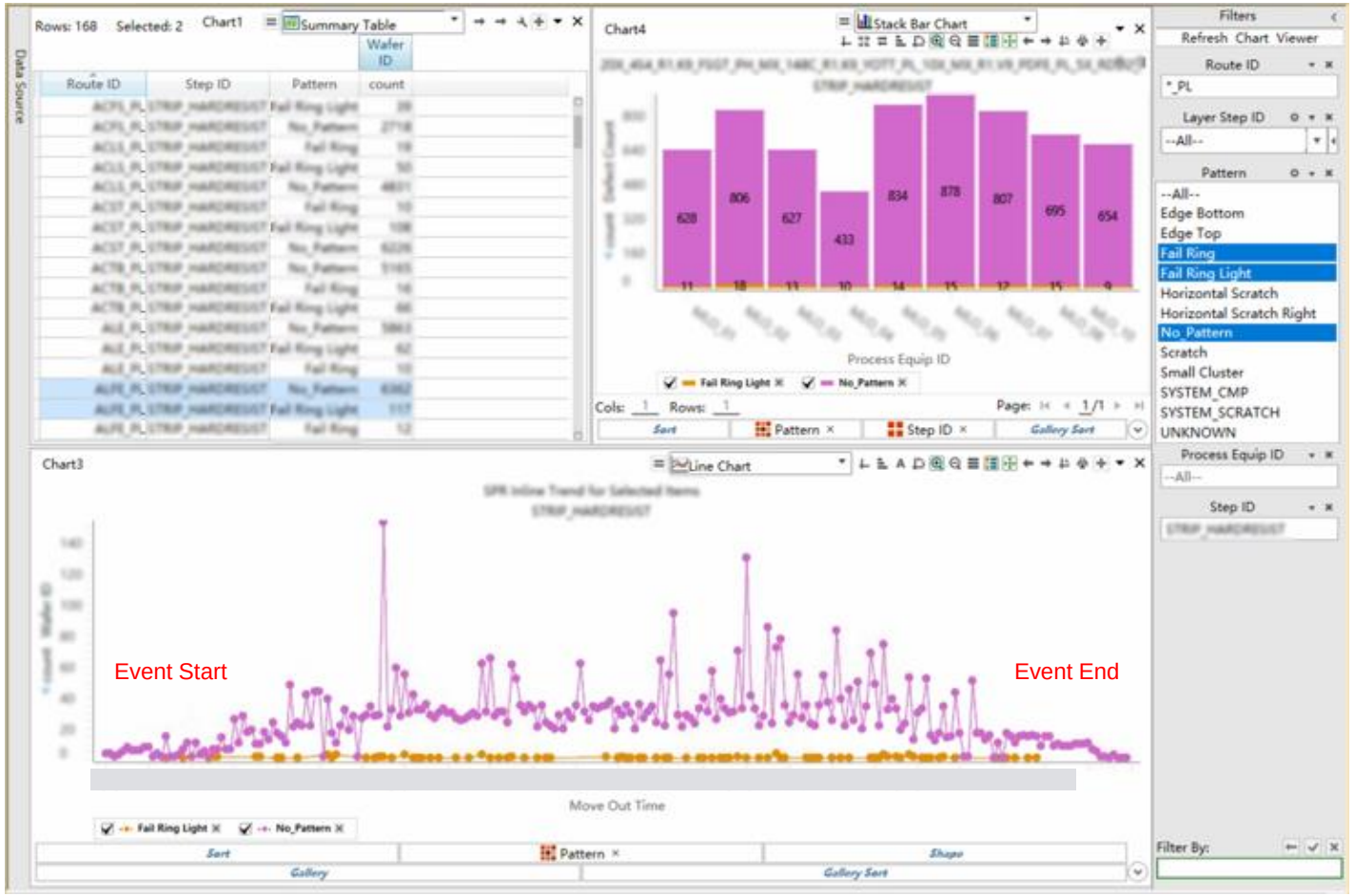
- **Equipment Data Monitored**
  - Platen Temp, Rotation Speed, Motor Amps
  - Spindle Head Speed, Vacuum/Pressure, Down force and Motor Amps
  - Slurry Dispense
  - Wafer Chuck Placement/Retry
  - Conditioner Sweep Speed, Motor Amps and Arm Force
  - Processing time (by platen)
  - Wet Idle Time
  - DI Water Flow
  - …



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

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

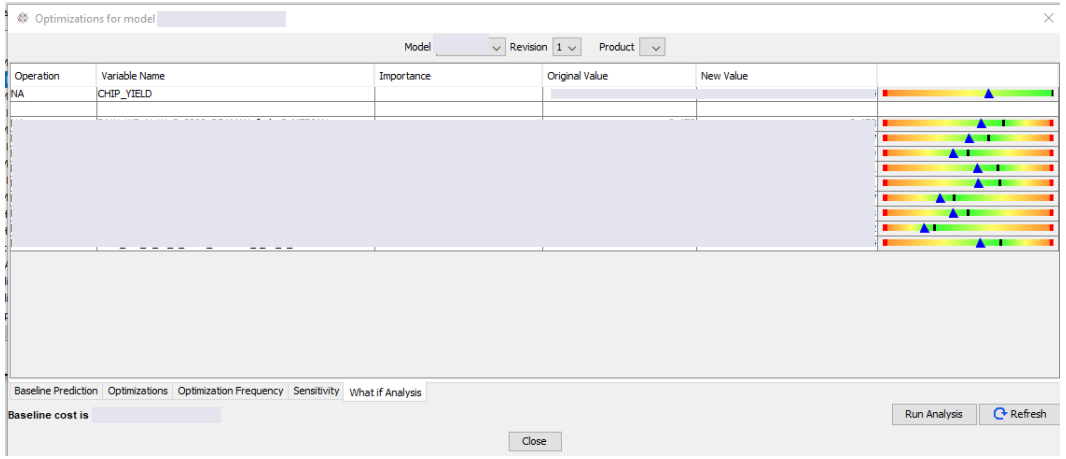


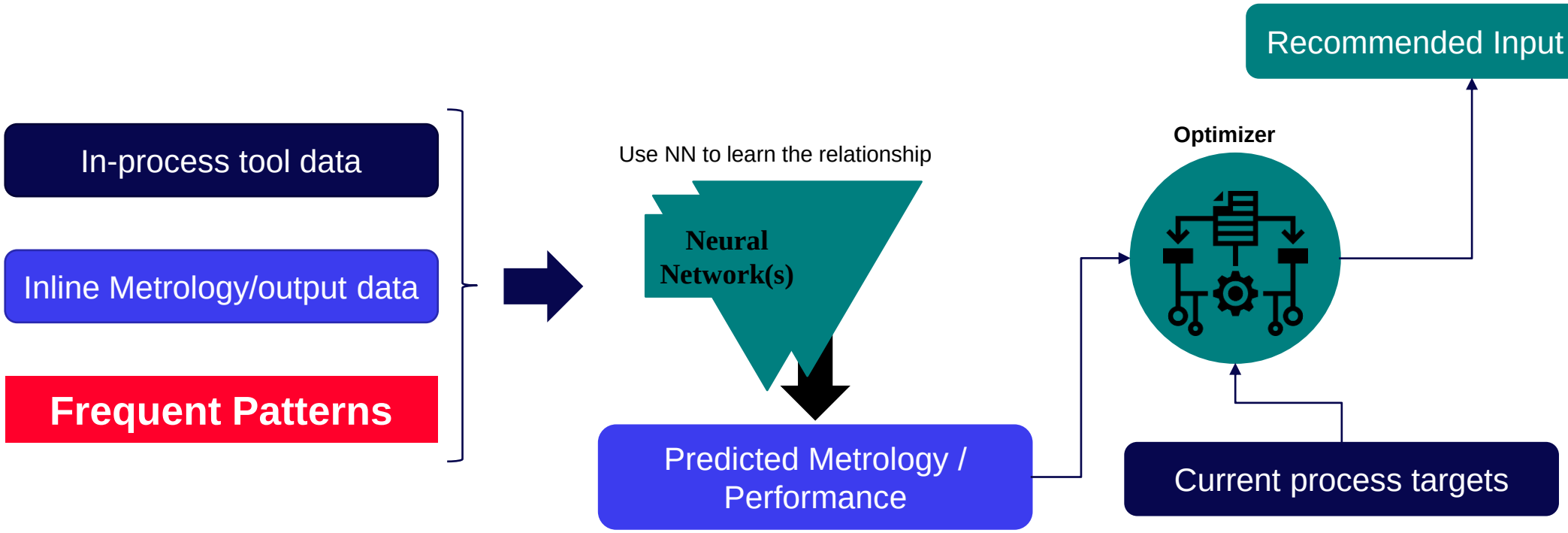
Trend split by Tool & Pattern, helps to find signal which would have been missed otherwise

Yield Improvement / Line Control

Yield Optimizer

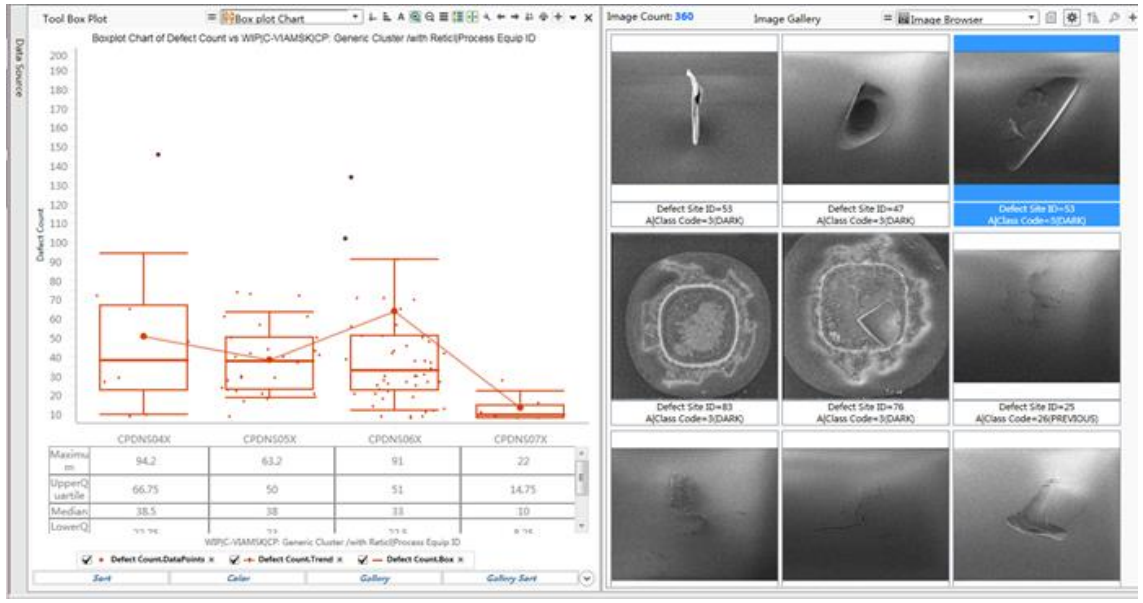
- Analyze the relationships between in-process data and End-of-Line test or output results
- Recommend changes to the in-process targets to optimize the yield/output parameters





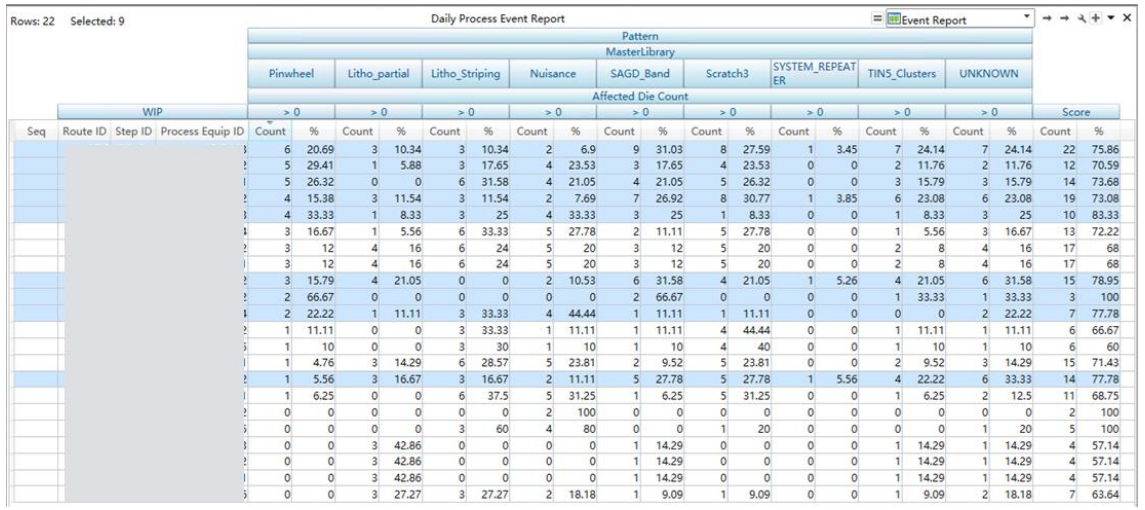
Improve Production Efficiency – React Faster & Reduce Scrap

Monitoring Dashboards



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

Process Event Reports



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

SEAGATE

innovation™ onto

Acknowledgements

Prasad Bachiraju

Alan Fan

Authors would like to thank

- Karen Terry, Senior Engineering Manager, Seagate Technology for her guidance and support.
- Jeff Zia & Gil Cooper from Onto Innovations Inc for their contributions towards Reprocessing & Dashboards rollout.
- David Gross, Senior Director & Katherine Gramling, Senior Defect Engineer from SkyWater for inspiring discussions on Discover Patterns and its application in fabs

Thank You

谢谢 | 謝謝	ありがとう	Obrigado
Danke	감사합니다	Merci

info@ontoinnovation.com
www.ontoinnovation.com

innovation™
onto