Introducing a New Playbook for Process Control

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"AI and Big Data have the potential to transform every area of the economy and our lives. These inflections will also have a profound impact on the semiconductor industry."

Gary E. Dickerson
President and CEO, Applied Materials, Inc.

Today's Key Takeaways

1. Semiconductor complexity is increasing. Fab costs are soaring. Time to yield is worth billions in revenue and profitability.

2. The legacy approach to optical wafer inspection and process control is no longer economical. Rising cost per wafer scan is reducing inspection points, and defectivity issues are causing node delays.

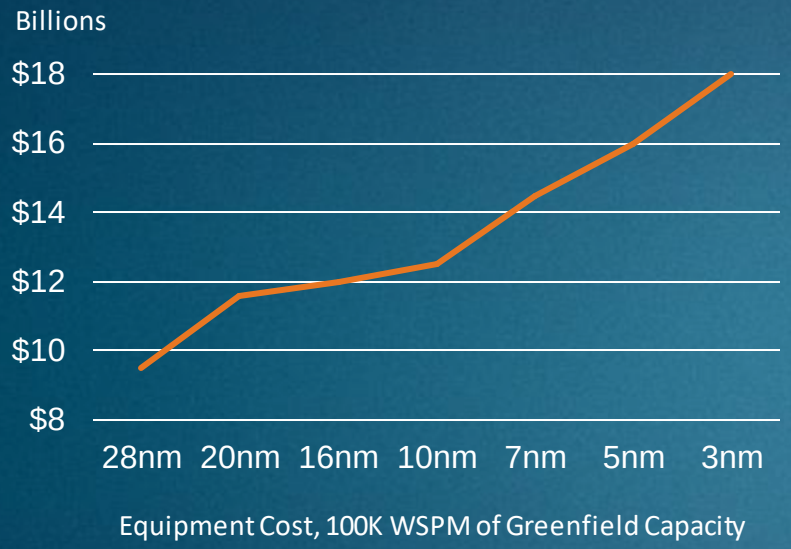
3. Applied Materials is introducing a new playbook for process control — in development since 2016 — based on Big Data and AI.

   - Big Data: Applied is introducing a brand new optical inspection system called **Enlight®** that combines industry-leading speed with new optics designed to capture more yield data.

   - AI: Enlight includes **ExtractAI™** technology that combines high-end optical inspection with the best eBeam imaging in the market to quickly classify yield-killing defects and remove noise. The Enlight system with ExtractAI technology gives customers more actionable data, faster than ever before, to accelerate yields and time to market.

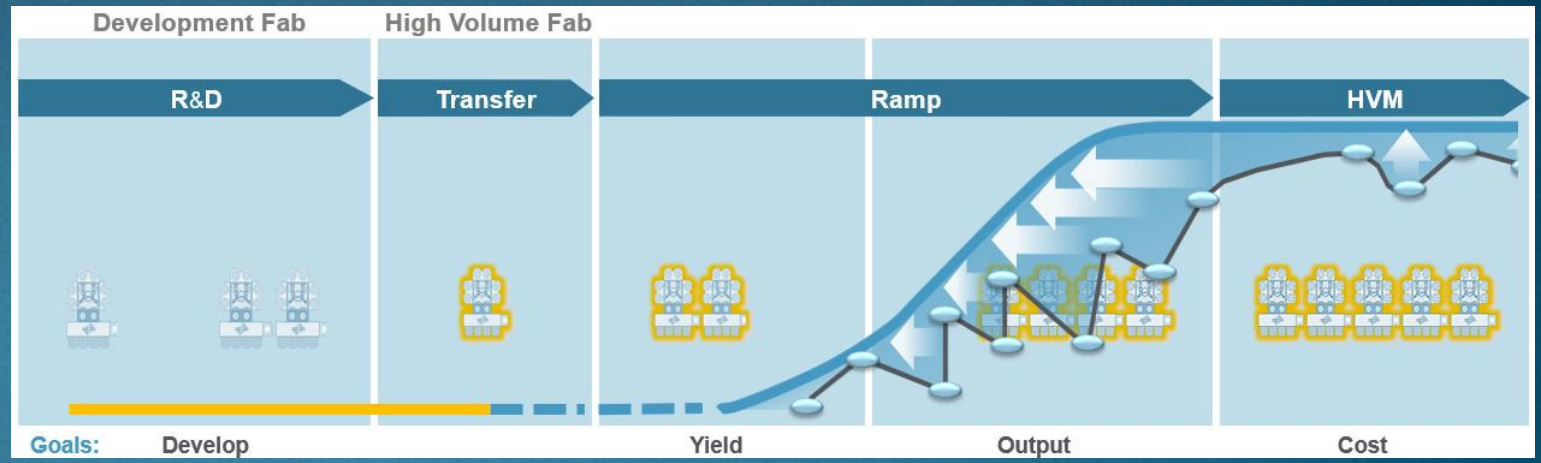
Semiconductor Industry Economic Challenges

Fab Cost is Increasing



Source: Applied Materials Internal Data

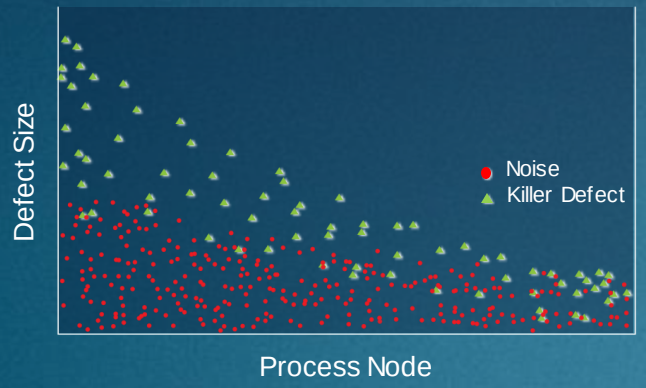
Speeding Time to Market, Reducing Area Under the Yield Curve is Worth Billions



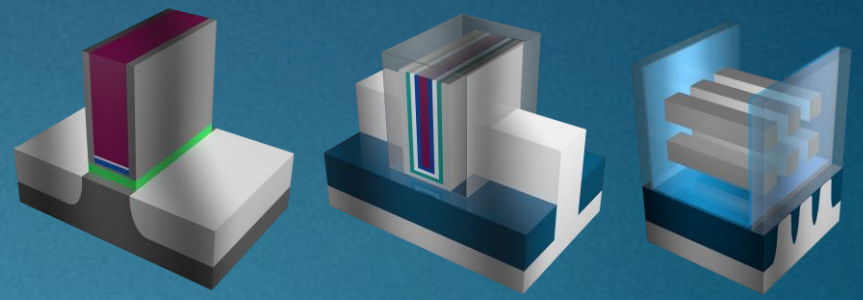
- Foundry/Logic: at 3nm, one week of downtime results in $25 million in unamortized depreciation cost.
- DRAM: one week of downtime costs 2% of annual revenue plus price erosion.

Semiconductor Industry Complexity Challenges

SMALLER LINE WIDTHS Smaller particles become yield-killing defects



3D STRUCTURES Increase process complexity

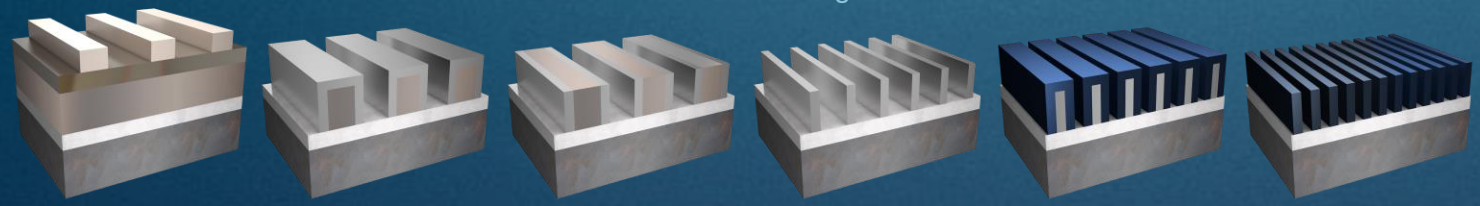


Planar Transistor FinFET Gate-All-Around

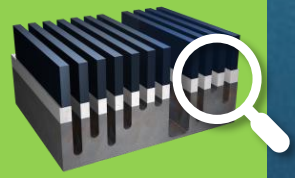
MULTI-PATTERNING Small variances accumulate to produce yield-killing defects

Multi-Patterning Inspection Points – SAQP Drives Inspection Adoption

Line Monitoring

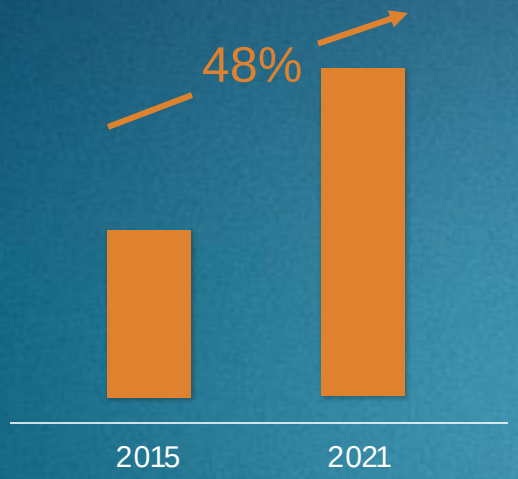


Final Check
Yield Critical

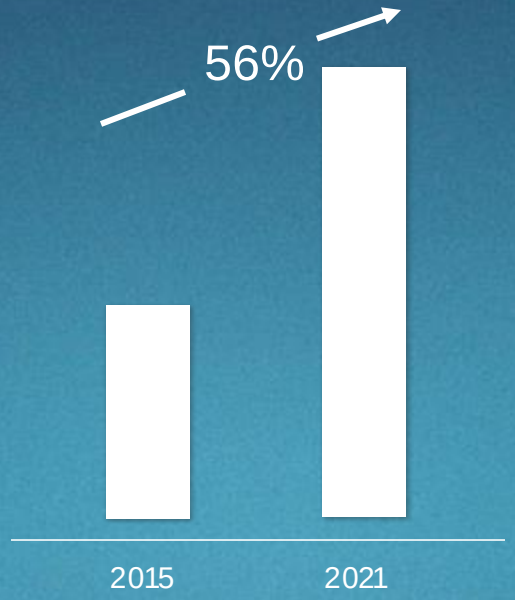


If you only inspect here, how do you know which step caused the defect?

Legacy Approach: Increasing Optical Inspection Complexity & Cost

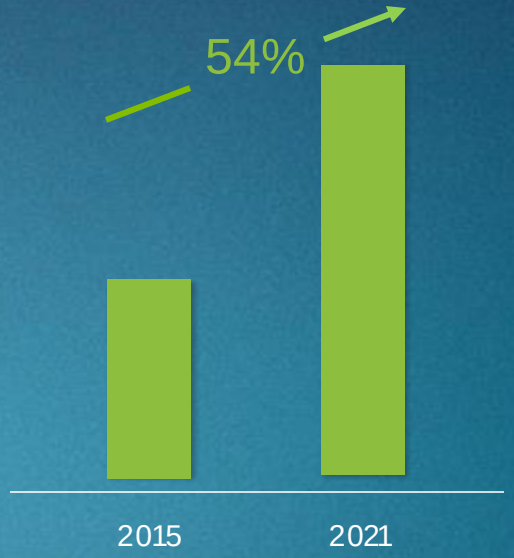


Process Steps



High-End Optical System Cost

*Average high-end systems cost



Cost Per Wafer Scan (High-End Inspector)

Source: Applied Materials internal data

Result: While rising complexity calls for more inspection, higher cost limits inspection points. “Little data.”

A New Playbook for Process Control

Breakthrough #1: Enlight® System

A. Industry's fastest high-end optical scanner
   - Up to 3X cost improvement in critical defect detection

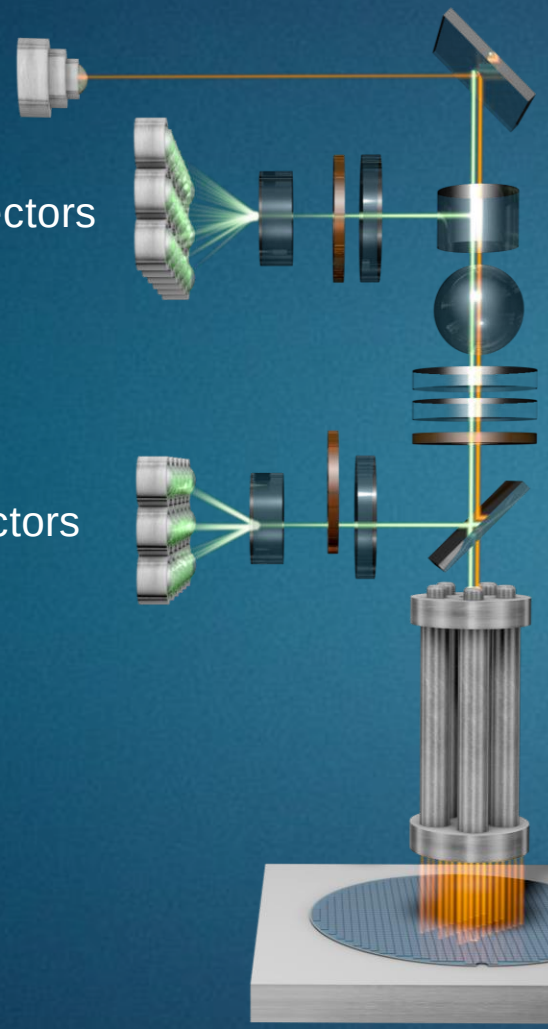
B. Industry's highest numerical aperture
   - For maximum resolution + higher sensitivity

C. Brightfield + Greyfield optics
   - To simultaneously collect more data per pass

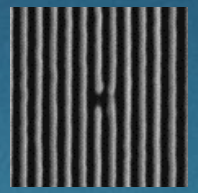
D. Tunable polarization
   - Maximize noise suppression

E. Flexible imaging and computing infrastructure
   - To support AI algorithms

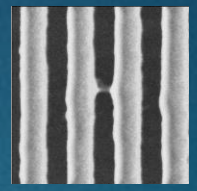
Enlight System: Optimized for Big Data Collection



High-End Sensitivity

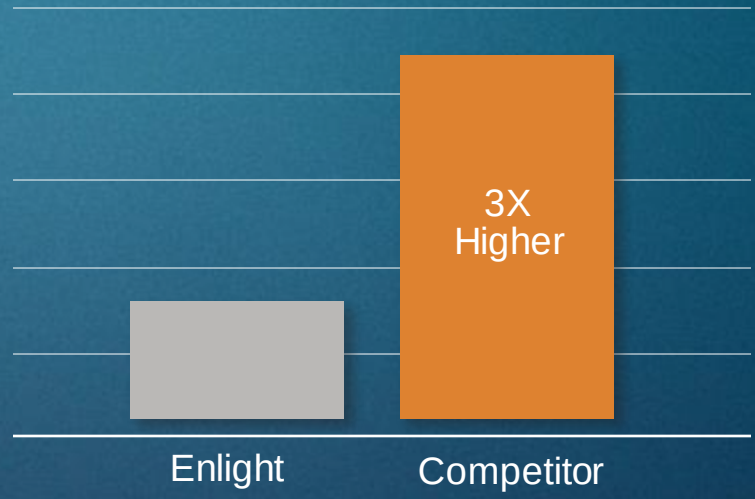


Highest numerical aperture available. Open circuit detected by Enlight, imaged by SEMVision eBeam review.



3D polarization control. Circuit short detected by Enlight, imaged by SEMVision eBeam review.

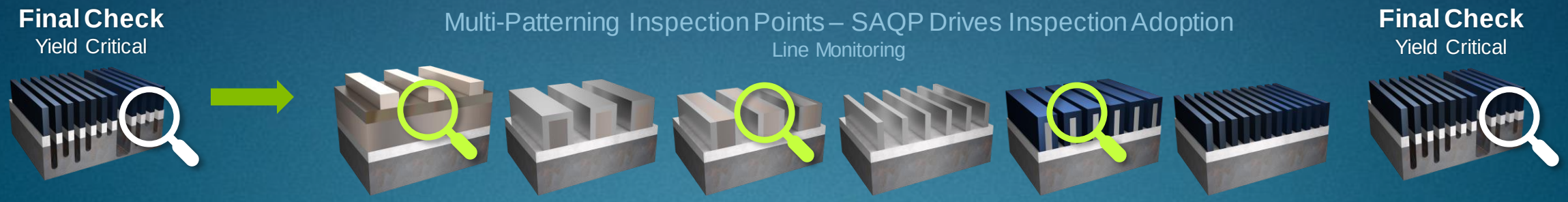
Lower Cost Per Wafer Scan (High-End Inspector)



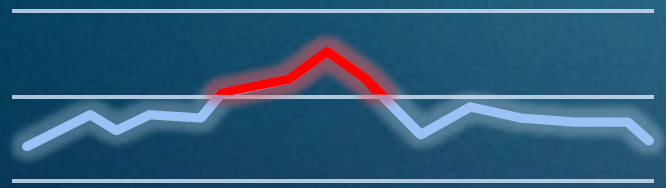
New Economic Model

Enlight System: Big Data = Faster and Better Yields

MULTI-PATTERNING More inspection points enables root cause traceback



LINE HEALTH MONITORING More inspection data enables excursion prediction and detection



Stop wafer processing as soon as an issue is identified

"The additional data obtained by line monitoring enables me to accelerate and manage yields in a way that I could never afford to do before."

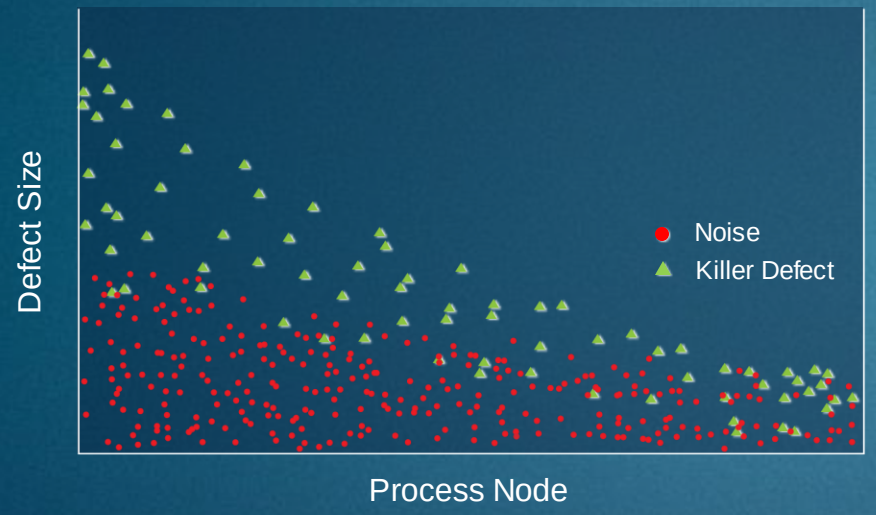
- Leading Customer, June 2020

A New Playbook for Process Control

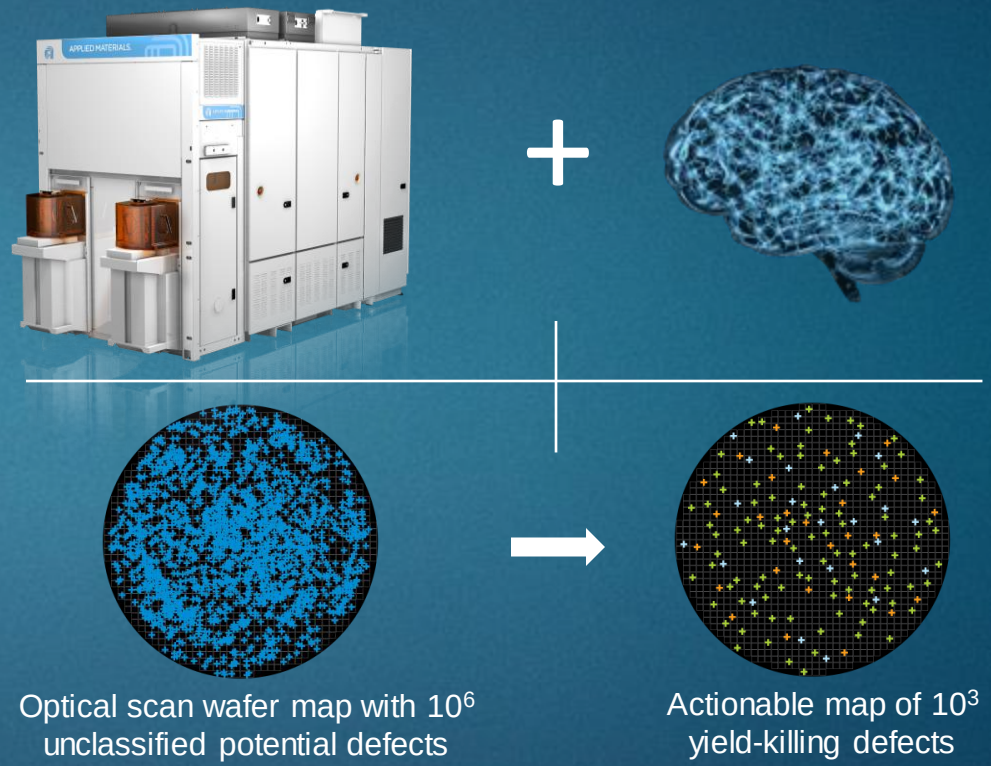
Breakthrough #2: Enlight System + ExtractAI™ Technology

PROBLEM

Distinguishing defects from “noise”



SOLUTION



Optical scan wafer map with 10^6 unclassified potential defects

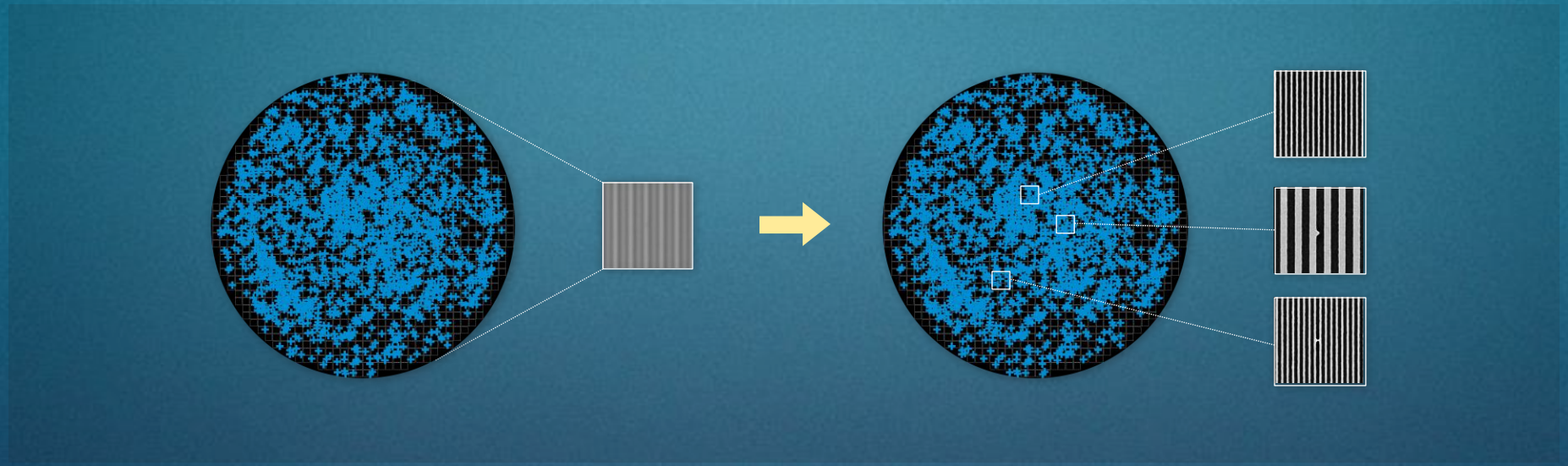
Actionable map of 10^3 yield-killing defects

Introducing AI Technology to Quickly Classify Defects, Remove Noise

Tutorial: Optical and eBeam - Complementary Technologies

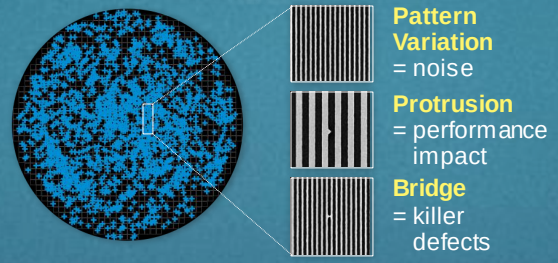
	Optical Data Capture	eBeam Data Classification
Wafer Coverage	FAST	SLOW
Pixel Resolution	LOW	HIGH
Classify Defects	LOW	HIGH
Defects vs. Noise	LOW	HIGH

Key attributes for data classification

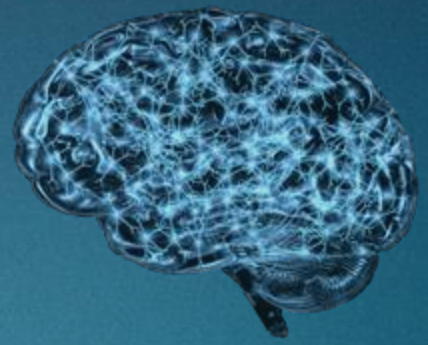


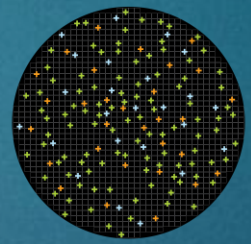
Applying Big Data + AI Strategy

1. Unclassified Data
Use Enlight system to quickly generate database of potential defects



2. Classification & Training
Use SEMVision system to train ExtractAI to classify defects and noise





3. Inferencing
Enlight with ExtractAI now automatically recognizes specific defects across the wafer map

Enlight with ExtractAI Solution: How It Works

Enlight System

ExtractAI Technology

SEMVision System


APPLIED MATERIALS


APPLIED MATERIALS

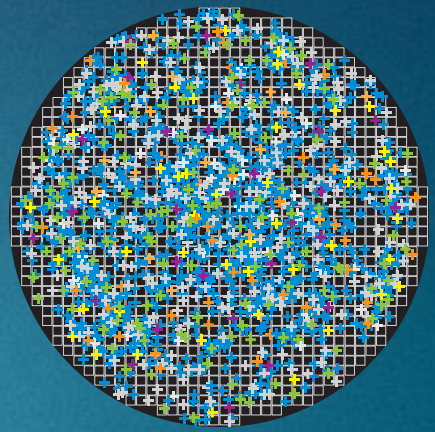
Enlight System

ExtractAI Technology

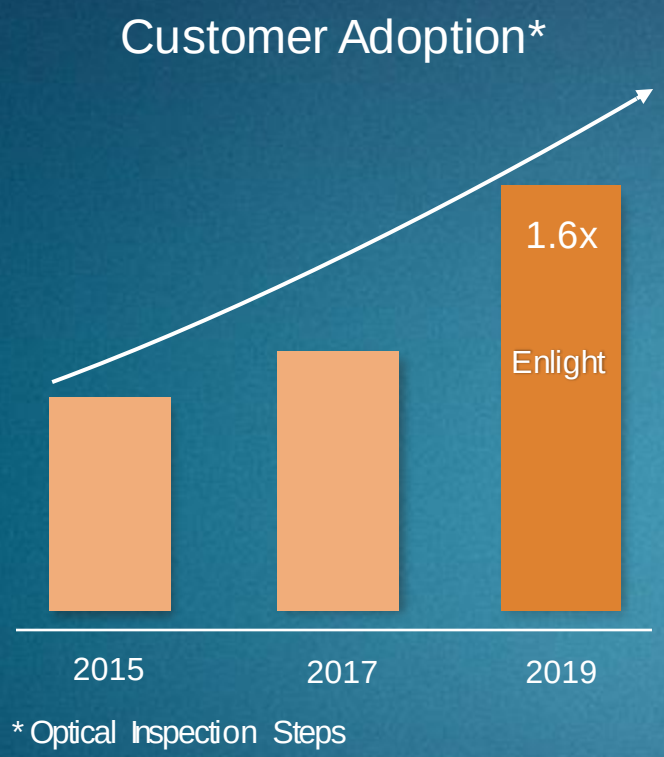
SEMVision System

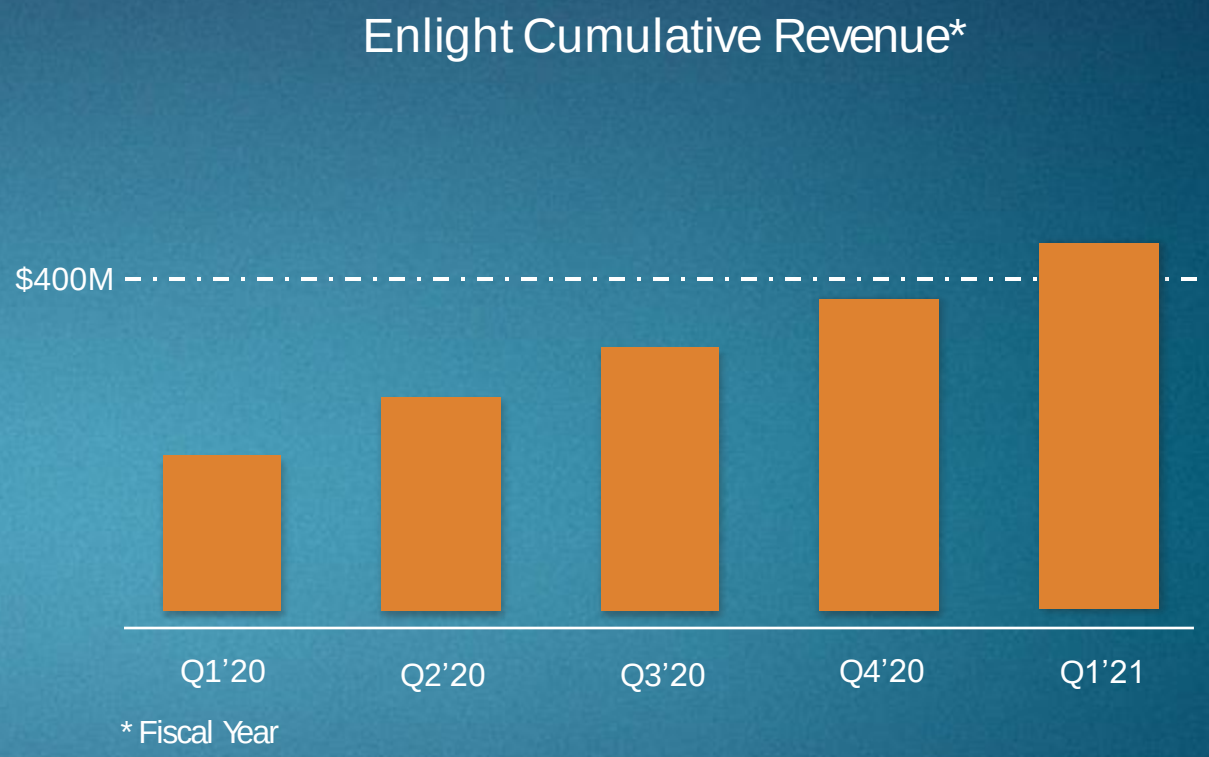
ExtractAI Technology

- Learns quickly with SEMVision, the industry's leading eBeam review system with the best-in-class imaging, enabling automatic defect classification
- The only real-time active learning using database-to-database connectivity to provide adaptive run-time classification of yield-killing defects and noise
- The most efficient solution: extracts all defects of interest after reviewing only 0.001% of the potential defects
- Provides an actionable defect map – 100% classified and noise free
- Delivers more accuracy and value as more wafers are scanned



Enlight with ExtractAI: Customer Momentum at Launch





- In development since 2016
- Fastest-ramping inspection system in Applied's history
- In production at all leading-edge foundry/logic customers worldwide

SEMVision® eBeam Review

Industry's leading eBeam review system for over 20 years

2021 New Product with Sub-1nm Resolution Enabled by Cold Field Emission

2020 SEMVision G7

2014 SEMVision G6+

2013 SEMVision G6

2011 SEMVision G5

2007 SEMVision G4

2005 SEMVision G3

2002 SEMVision G2

2001 SEMVision 300

1998 SEMVision Creates Automatic SEM Defect Review Segment

Cumulative System Shipments

>1,500 Systems at Customer Fabs

APPLIED MATERIALS

Enlight with ExtractAI: A New Playbook for Process Control

BIG DATA

Enlight system combines industry-leading speed with new optics designed to capture more yield data.

ARTIFICIAL INTELLIGENCE

ExtractAI technology learns to automatically classify yield-killing defects and distinguish defects from noise.

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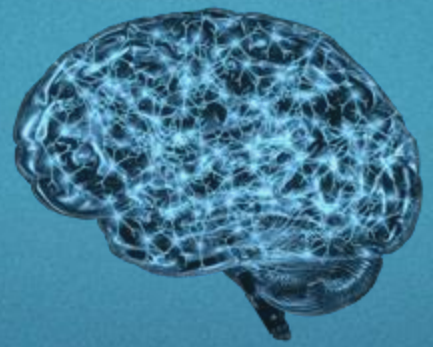

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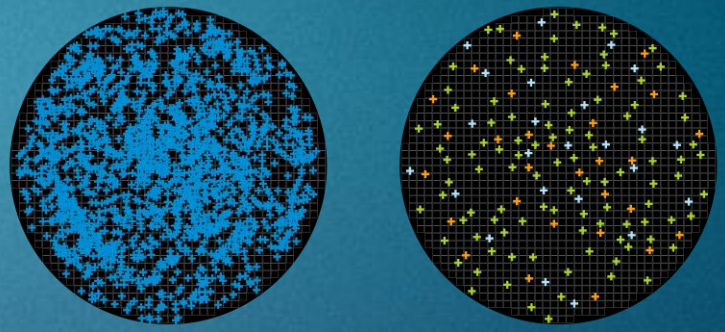
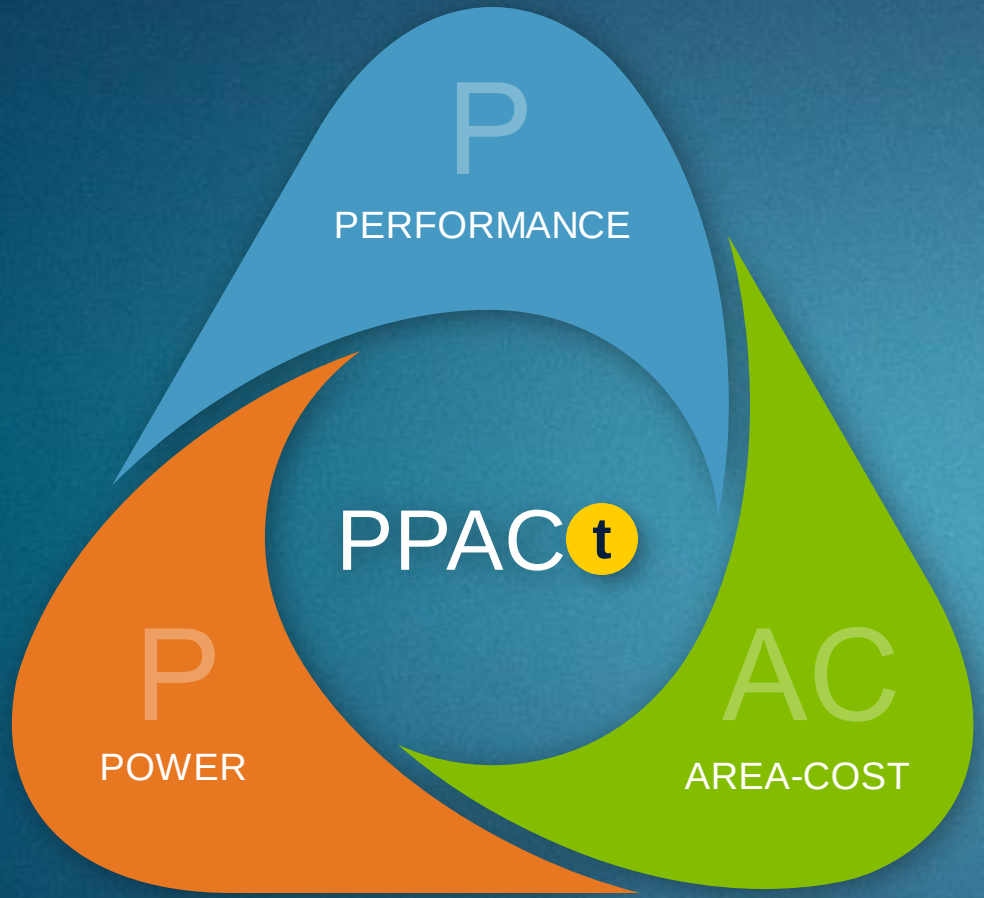


Delivering the “t” in Applied’s New Playbook for PPACt



ENABLED BY

- New **architectures**
- New **materials**
- New **structures / 3D**
- New ways to **shrink**
- Advanced **packaging**

Enlight with ExtractAI Accelerates Industry Time to Market

APPLIED MATERIALS®

make possible