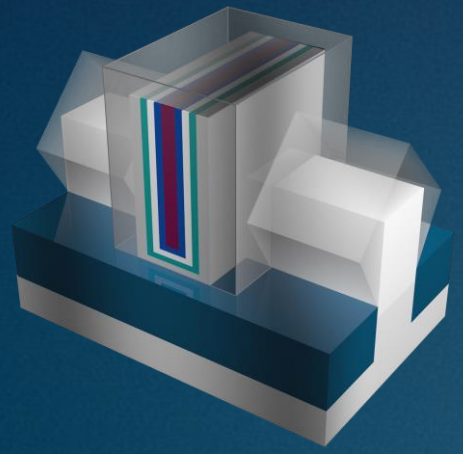
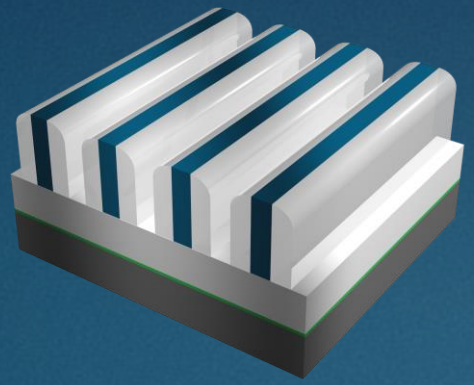
eBeam at Light Speed *for* the EPE Metrology Era

Ofer Adan
Director, Metrology and Process Control
Process Diagnostics and Control Group

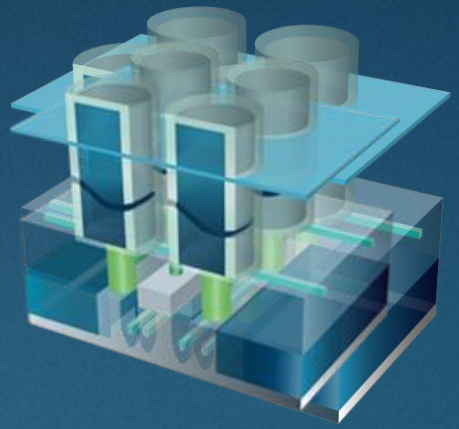
Inflections Creating New Metrology and Inspection Challenges



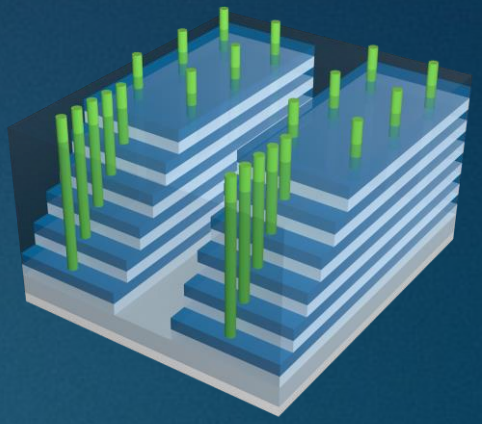
FinFET



Multi-Patterning



DRAM

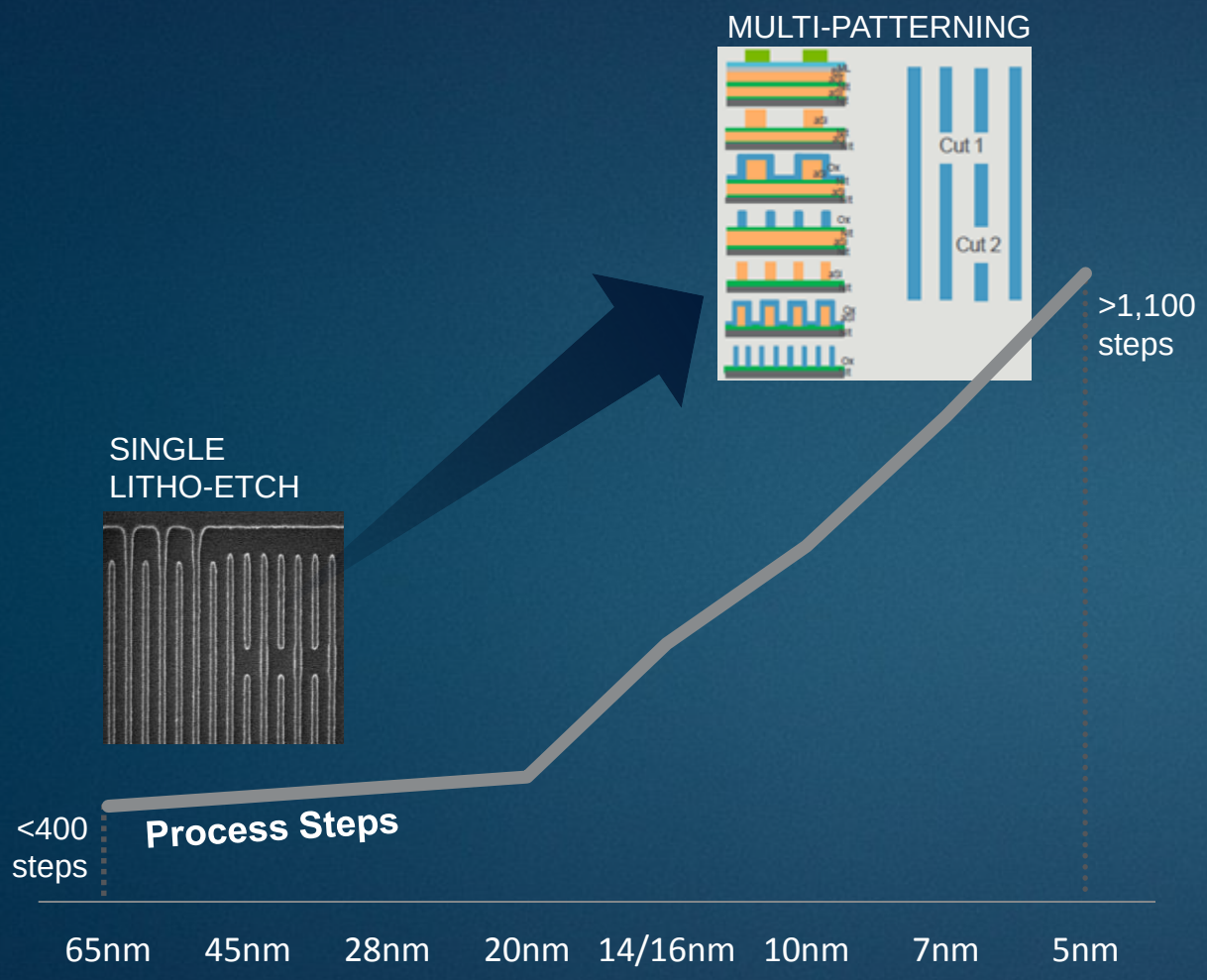


3D NAND

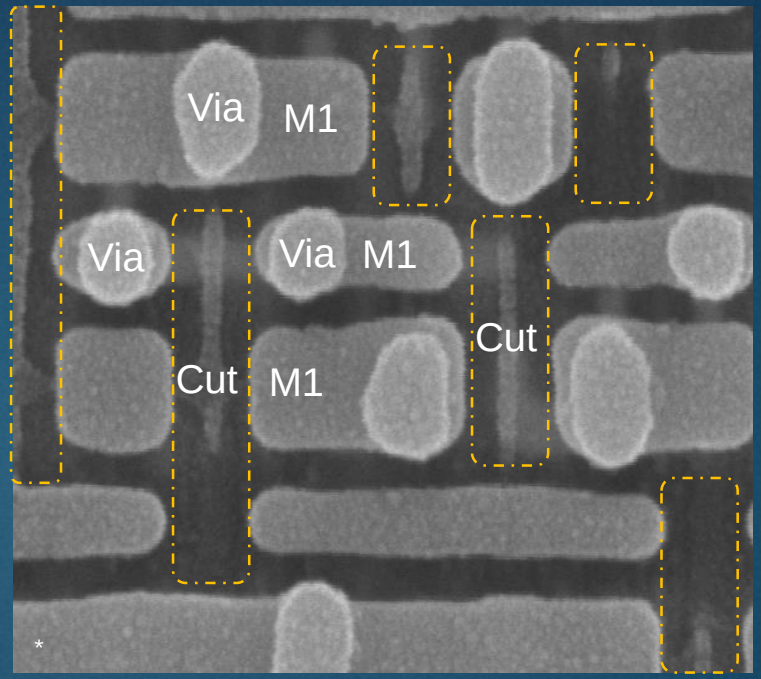
- Structures and defects are too small for optical resolution
- Multi-patterning triggers need for massive measurements
- 3D architectures limit ability to detect and measure

More Advanced Inspection Technologies Required

Major Market Inflection: Multi-Patterning



Edge Placement Error (EPE)



ERROR SOURCES

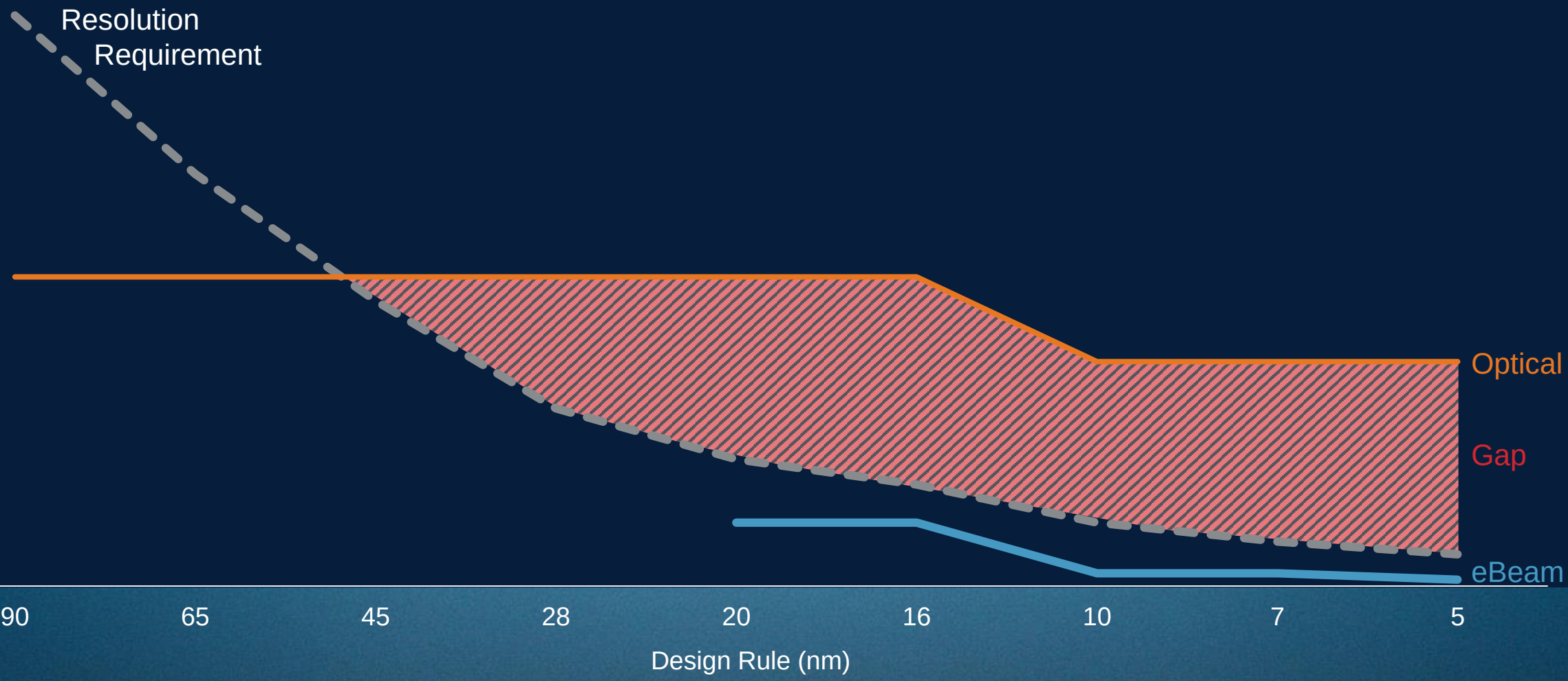
- Overlay/Alignment
- CD Uniformity lines
- CD Uniformity cuts
- Line roughness
- Pitch walking

EPE error = $\sqrt{(\Delta\text{overlay})^2 + (\Delta CDU_{lines})^2 + (\Delta CDU_{cuts})^2 + (\Delta LWR_{lines})^2 + (\Delta LWR_{cuts})^2}$

More Sources to Yield Loss

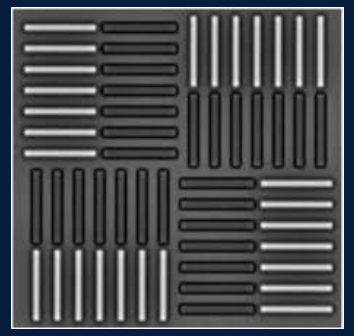
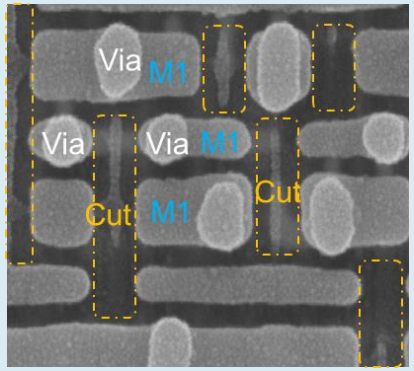
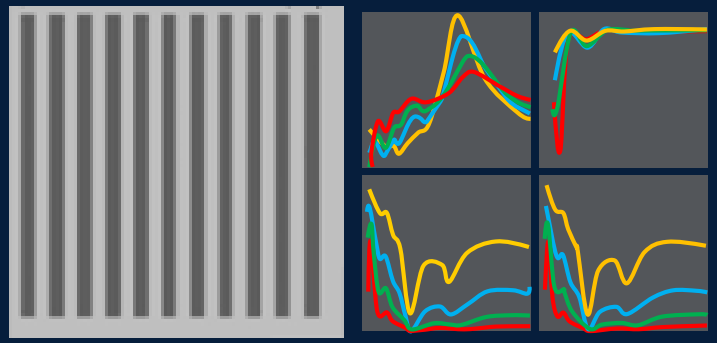
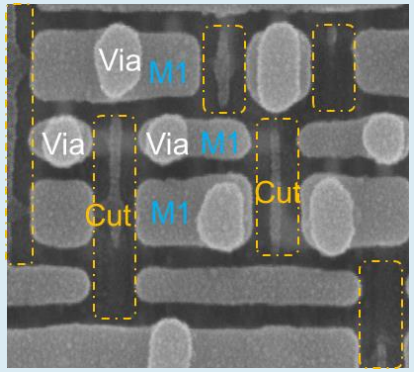
* Source: Chipworks

Inspection: eBeam Resolution Required to Detect Smallest Yield Limiting Defects



Source: Applied Materials internal simulation

Metrology: eBeam Addressing Growing Optical Gaps

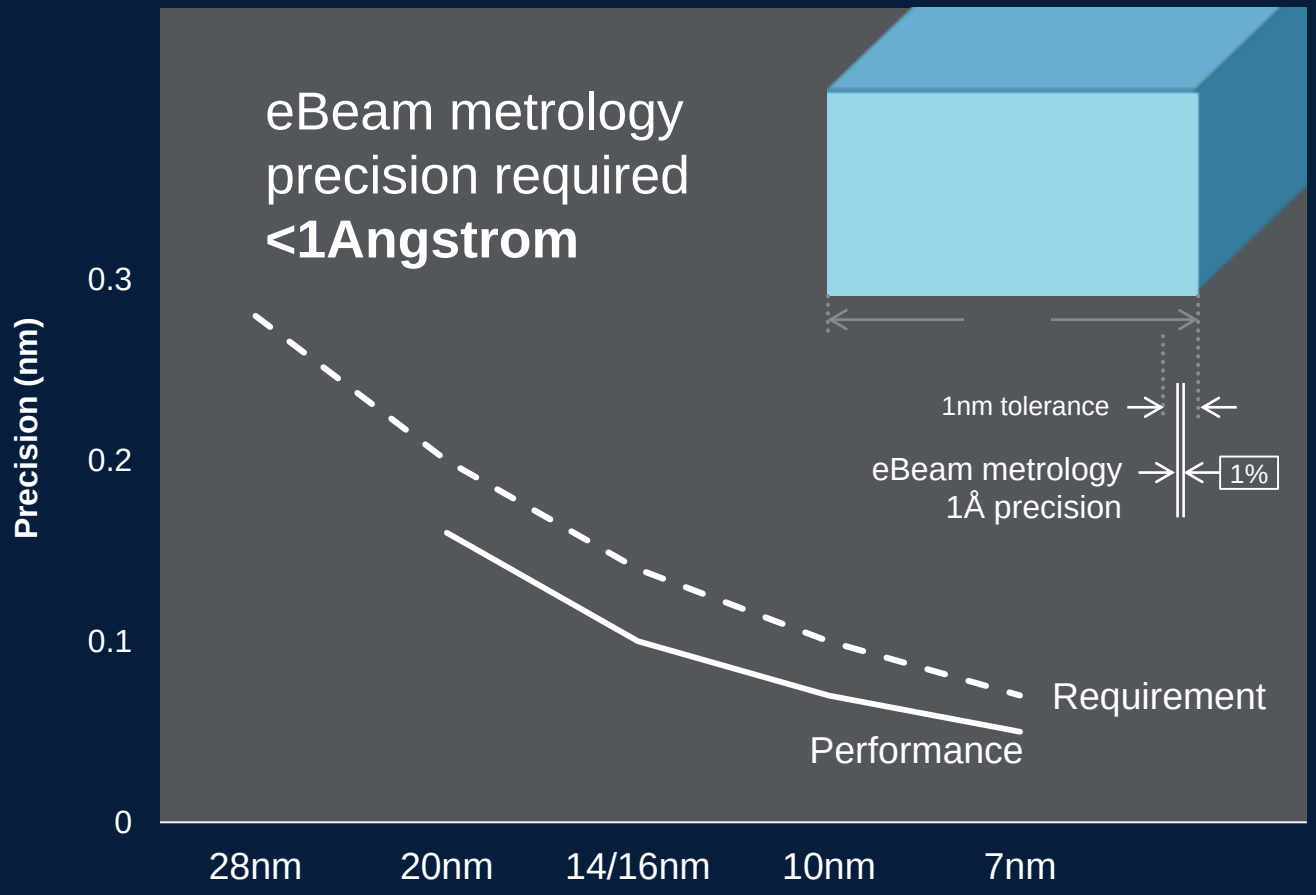
	OPTICAL	eBEAM
OVERLAY	 Measurement on target	 **Direct, on-device, in-die** measurement
CD	 Complex modeling	 **Immediate results, no modeling**

Correlation Challenge

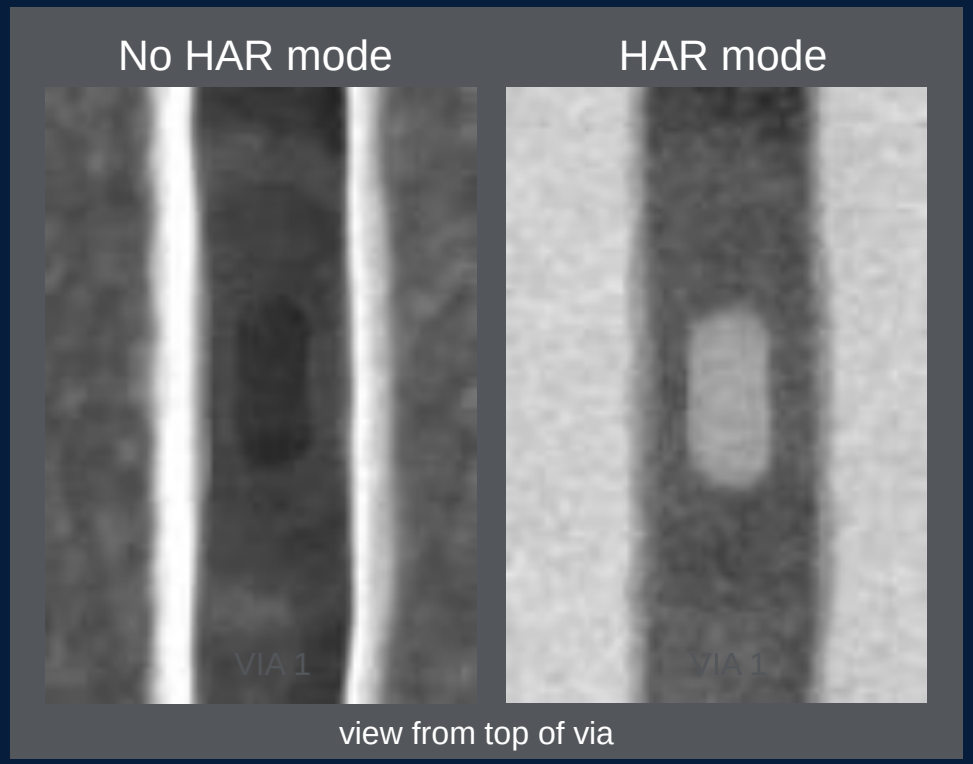
* Source: Gartner and Applied Materials estimate

Metrology: eBeam Required to Directly Measure Yield Limiting Dimensions

Precision



High Aspect Ratio (HAR) Imaging Capability

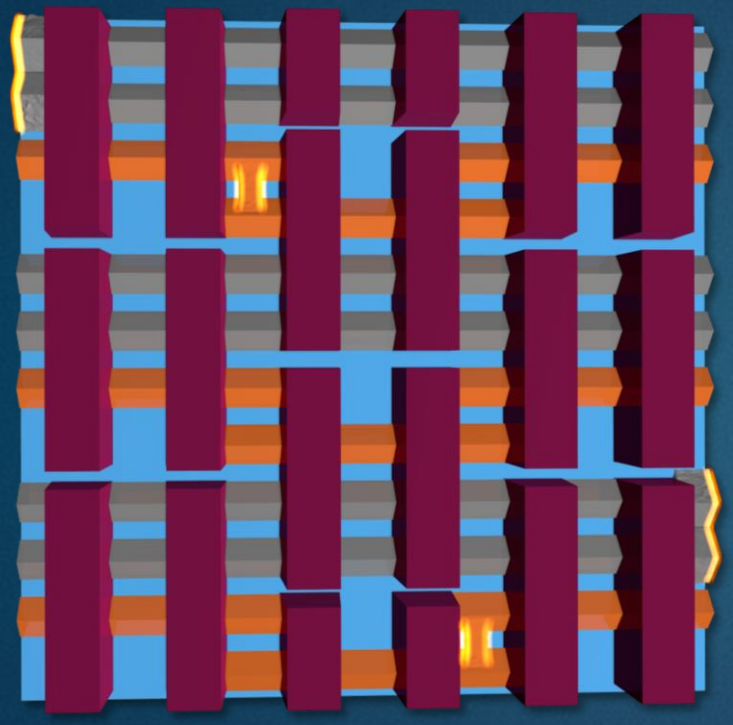


SPIE published by GLOBALFOUNDRIES and Applied Materials

APPLIED MATERIALS

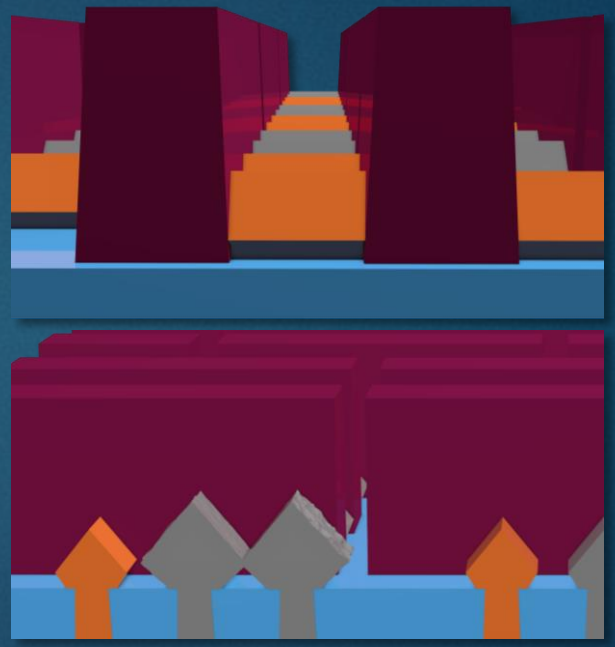
FinFET Multi-Patterning Scaling Challenges

Complex 3D Structure



10nm FinFET Top View

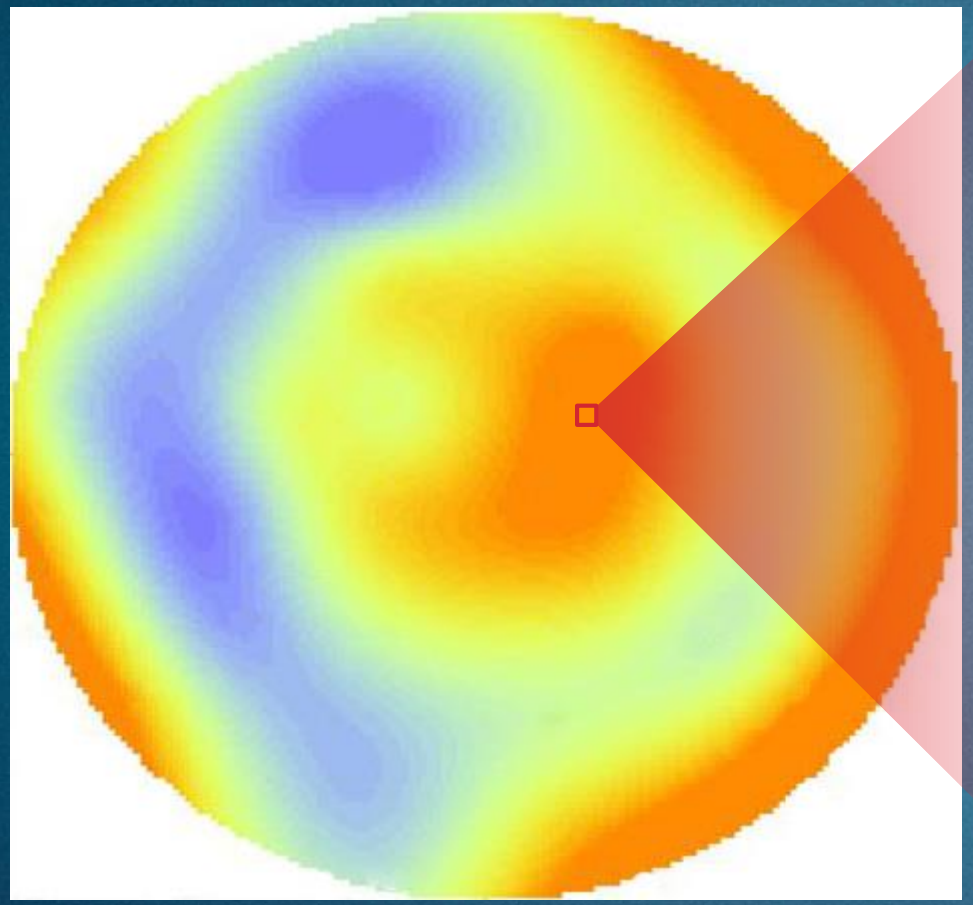
Defects Deep Inside the 3D Structure



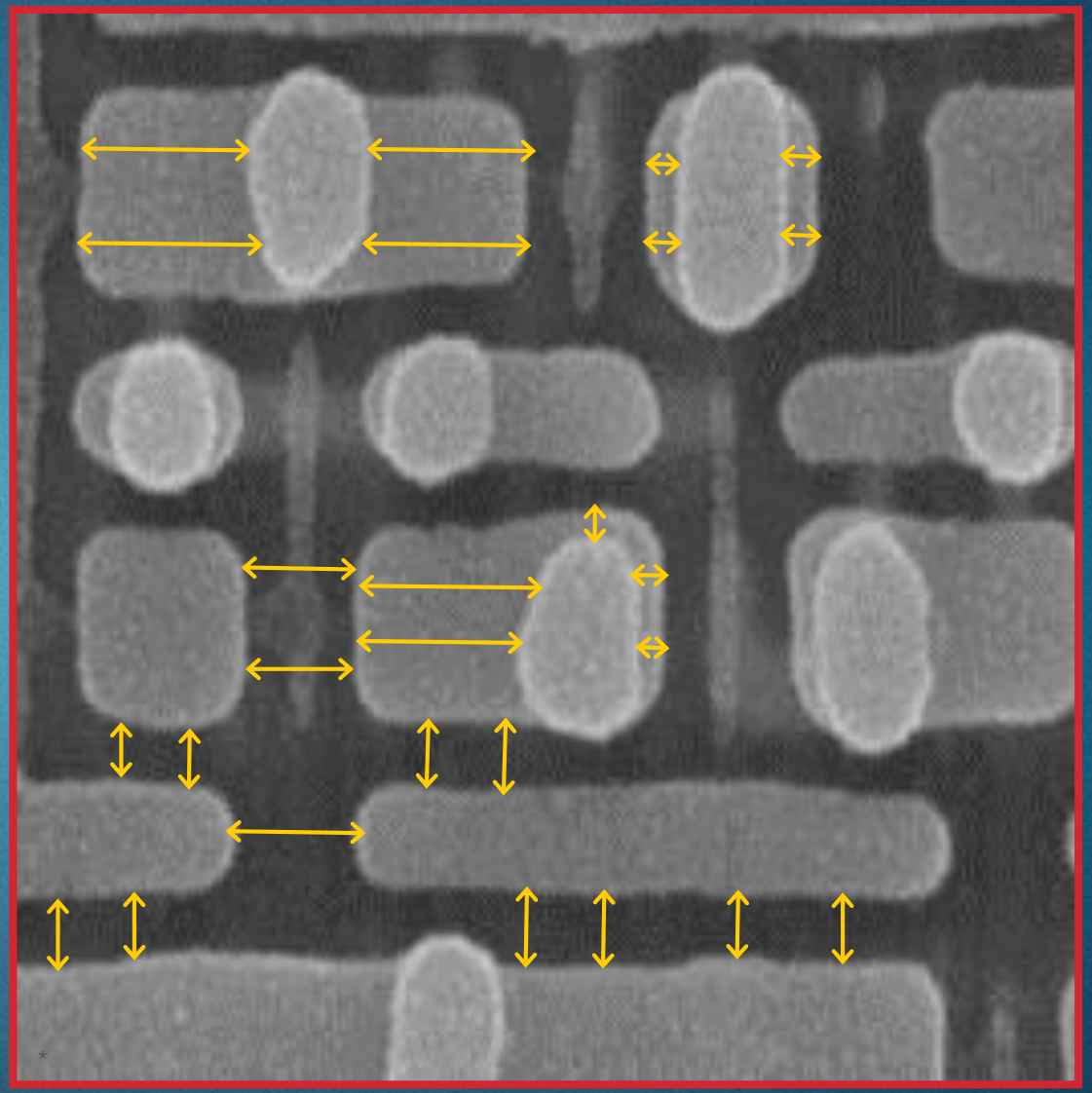
10nm FinFET Side View

Difficult to Detect Small Defects in Deep, Densely Packed Structures

EPE Monitor and Control: Massive Measurement Required



Wafer map: EPE distribution



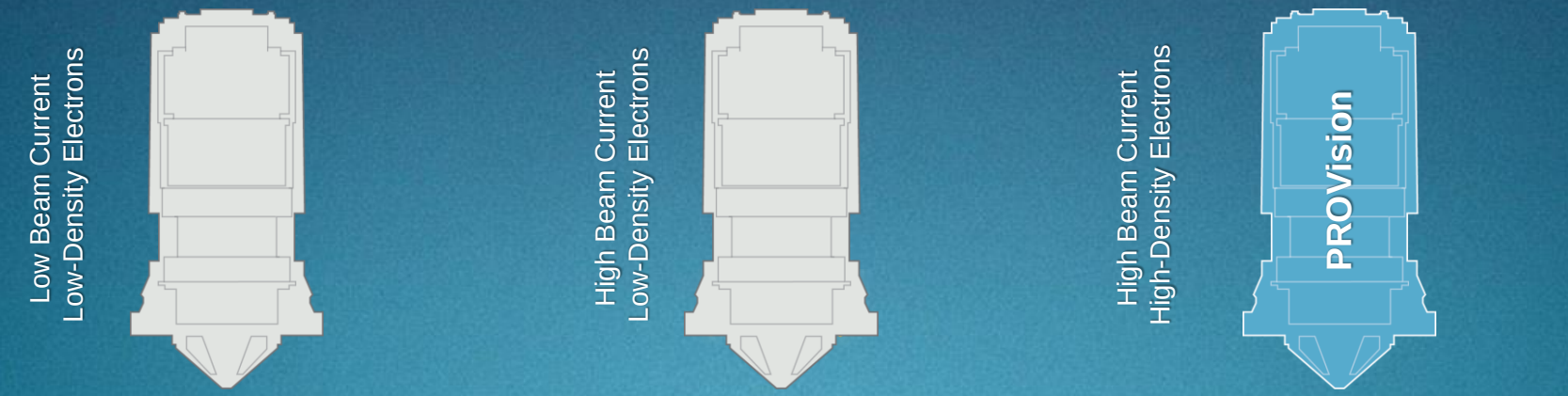
* Source: Chipworks

Applied PROVision™ eBeam Inspection

- Industry's first 1nm resolution EBI captures **smallest killer defects**
- Up to **3x faster throughput** for the most challenging eBeam applications
- Massive sampling uncovers subtle **process variations** for faster time to root cause and higher yield

eBeam Technology with Vision Like no Other

Optimized eBeam Column Technology



Small Spot Size	Large Spot Size	Small Spot Size
High Resolution Low Throughput	Low Resolution High Throughput	High Resolution High Throughput

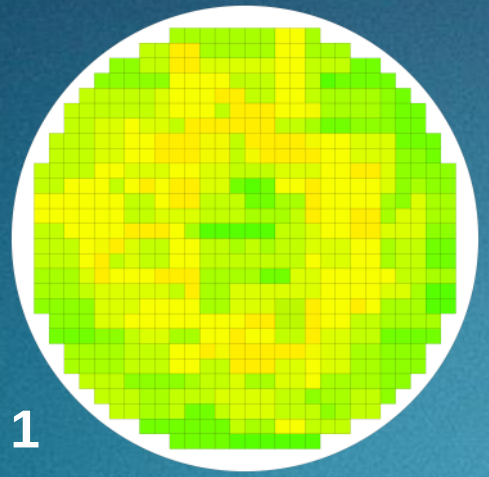
PROVision Delivers Highest Resolution and Fastest Throughput

From Defect Inspection to Process Monitoring

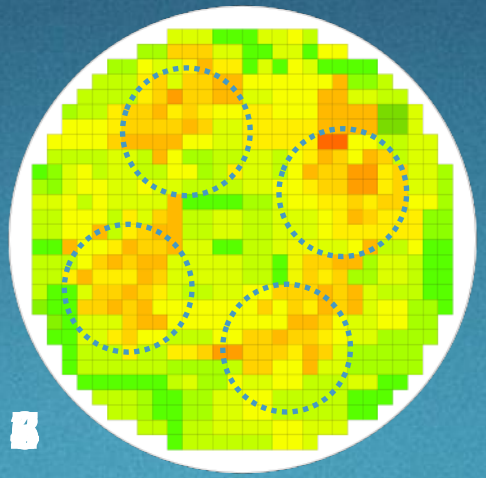
10.0% Sampling

Massive Sampling Uncovers Hidden Process Variations

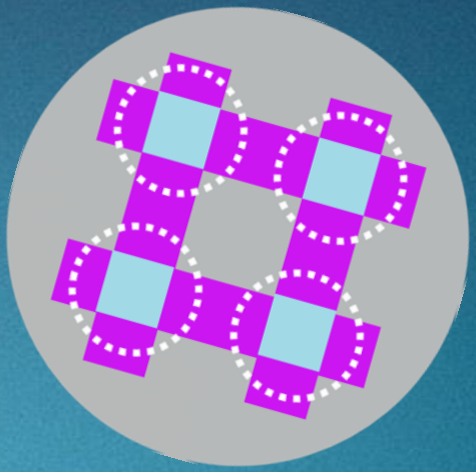
Massive Sampling Reveals Hidden Process Trends



Sparse Sampling
No Signature



Sampling / Die

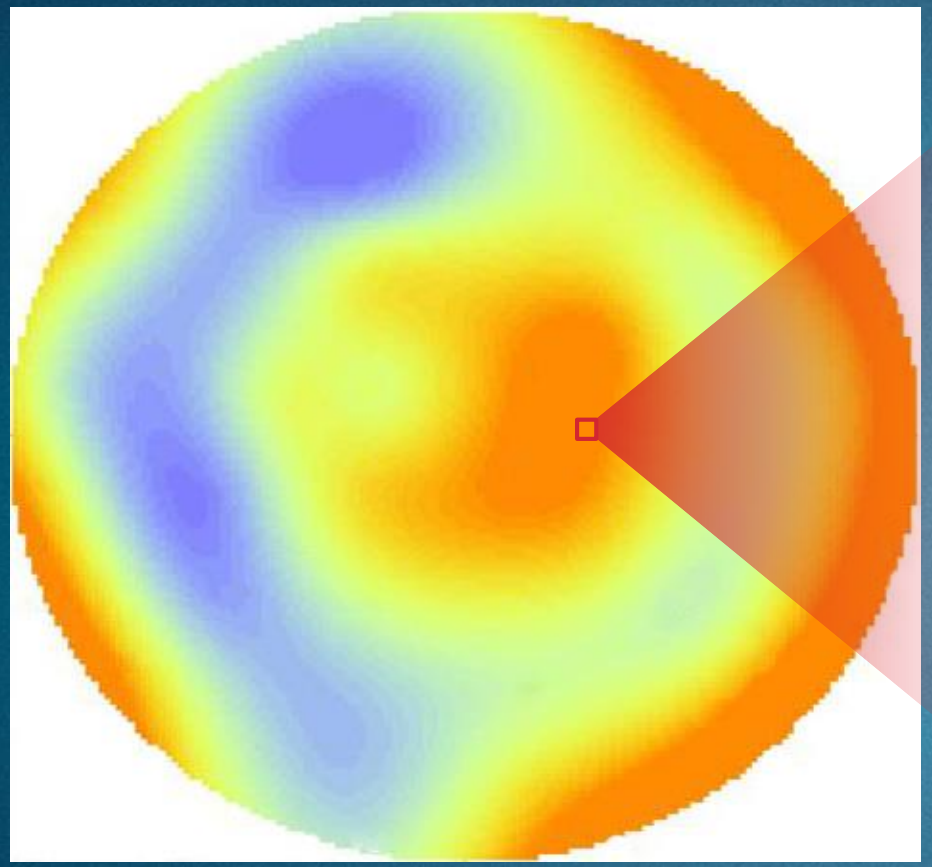


High Correlation to
UV Cure Chamber
Signature

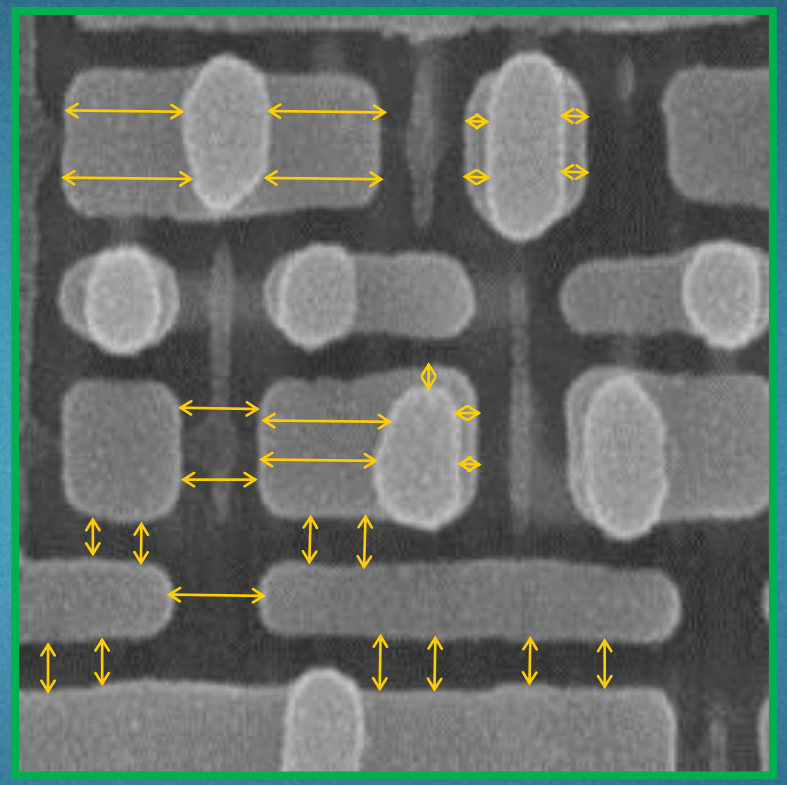
- Process signature helps identify source of abnormality
- Shortens time to root cause from days to minutes

PROVision System Enables Real-Time Process Monitoring

PROVision: Innovation for Massive Measurement at 1nm



Wafer map: EPE distribution

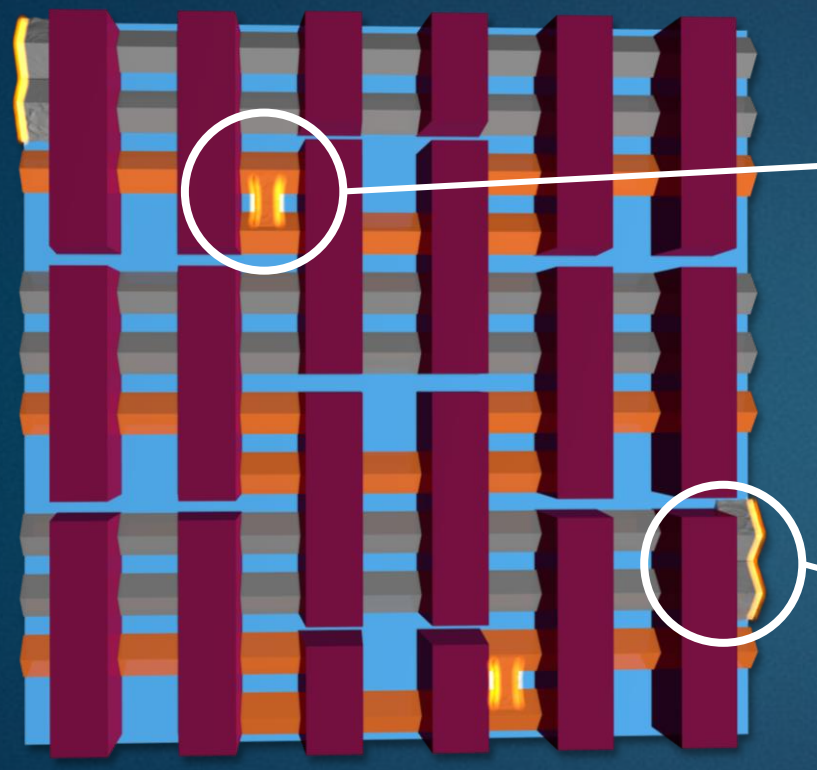


1nm
resolution

Millions
of measurements
in 1 hour

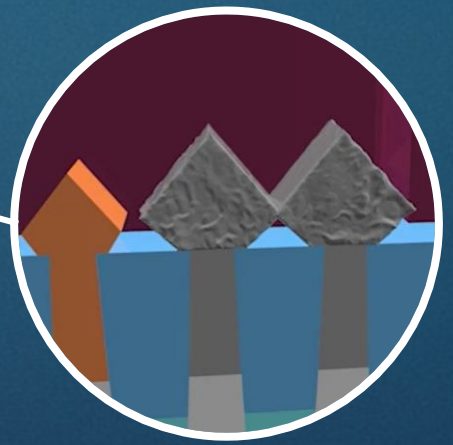
In die, **on device**
across the wafer

FinFET Epi Defects



FinFET Top View

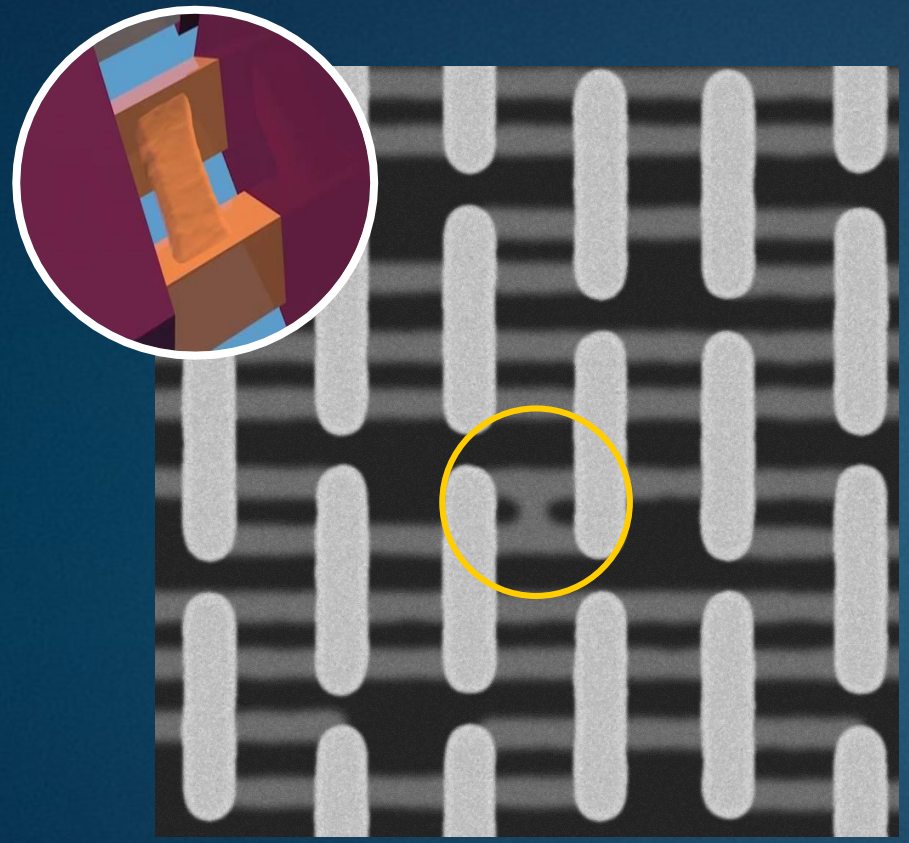
Bridge Defect
Between P-Fins



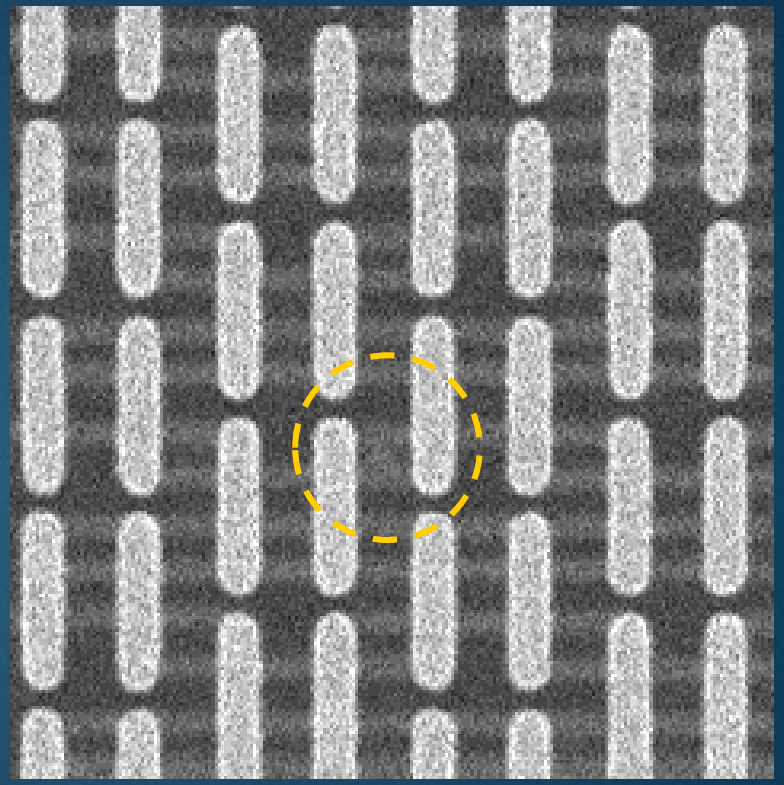
N-Fins Epi
Overgrowth

Detectable by PROVision's 1nm Resolution and Unique Imaging

PROVision Detects Defects Deep Inside the Structure



Superior PROVision Imaging

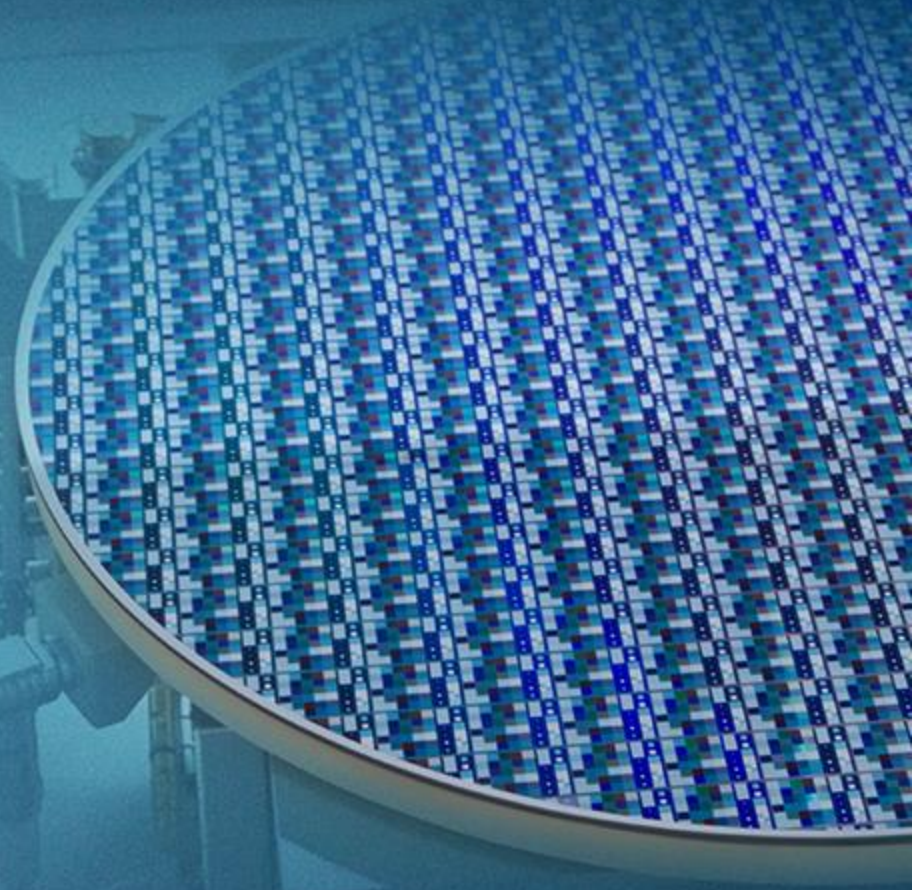


Conventional EBI

*Illustrated images

Applied PROVision™ eBeam Inspection

- The industry's only **1nm resolution** EBI system; critical for R&D, ramp and production
- Up to **3x faster throughput** for the most challenging eBeam applications
- **Rapid** adoption at key customers



eBeam Technology with Vision Like no Other

APPLIED MATERIALS®

make possible