Advanced X-ray Imaging Technologies for 3D ICs

IEEE 7/18/2024

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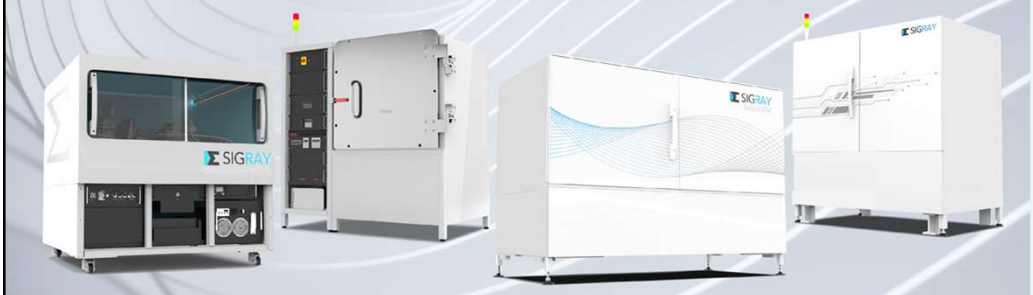
SIGRAY



Intro to Sigray

Founded in 2013

- **Dr. Wenbing Yun**, founded Xradia, now Carl Zeiss Microscopy, OSA Fellow and serial entrepreneur, and **Sylvia Lewis**

Mission: Dev. next generation x-ray technologies to Lab. and Fab.

Our Technology:

- Strong IP: 66 patents, 30+ pending, many trade secrets
- Disruptive x-ray components (source & optics)
- 5 world leading product families

Rapidly Growing: >60% Y/Y over 3 years

- 34k sq. ft. of manufacturing space in Concord, CA (San Francisco Bay Area) and 86 employees
- Global installation base of leading universities and companies (semiconductor & pharma)

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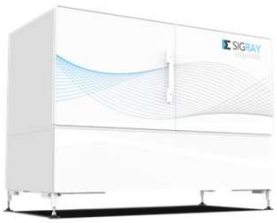
Suite of World Leading X-ray Systems

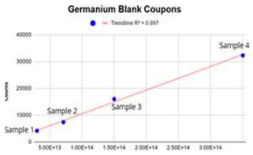


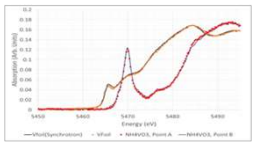
AttoMap microXRF
Highest sensitivity to low Z
Highest resolution microXRF

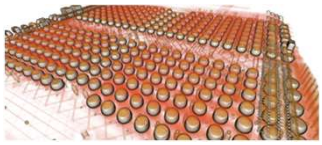
QuantumLeap XAS
Only commercial f-XAS
Highest quality EXAFS

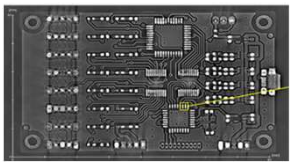
EclipseXRM
Highest resolution (0.3µm spatial) 3D x-ray microscope on the market

Apex XCT
Highest throughput 3D x-ray tool (>1000X) for semi









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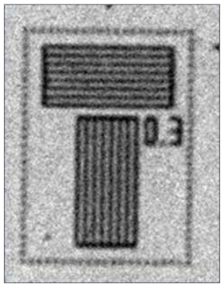
Leading Lab Instruments for Semiconductor

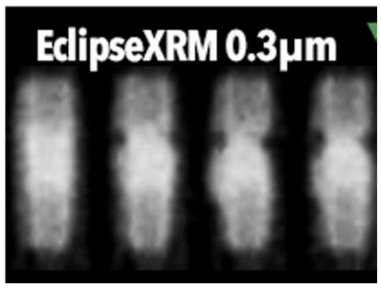
Eclipse XRM and Apex XCT

Received and expecting multiple POs

Eclipse: Highest (0.3um) resol. meeting the most challenging requirements

Apex: Best 3D imaging system for large (300 mm wafer) 3D package applications

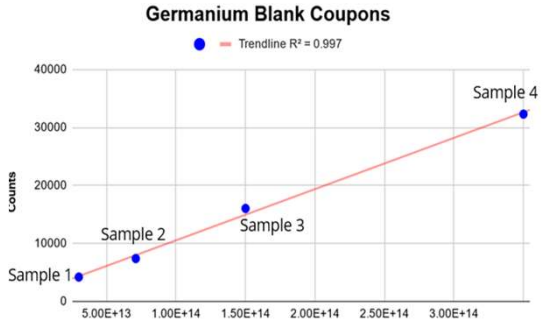




Attomap XRF

Multiple installations in two major companies

Highest sensitivities materials/thin-film metrology, e.g., 0.1 atomic layer measurement,



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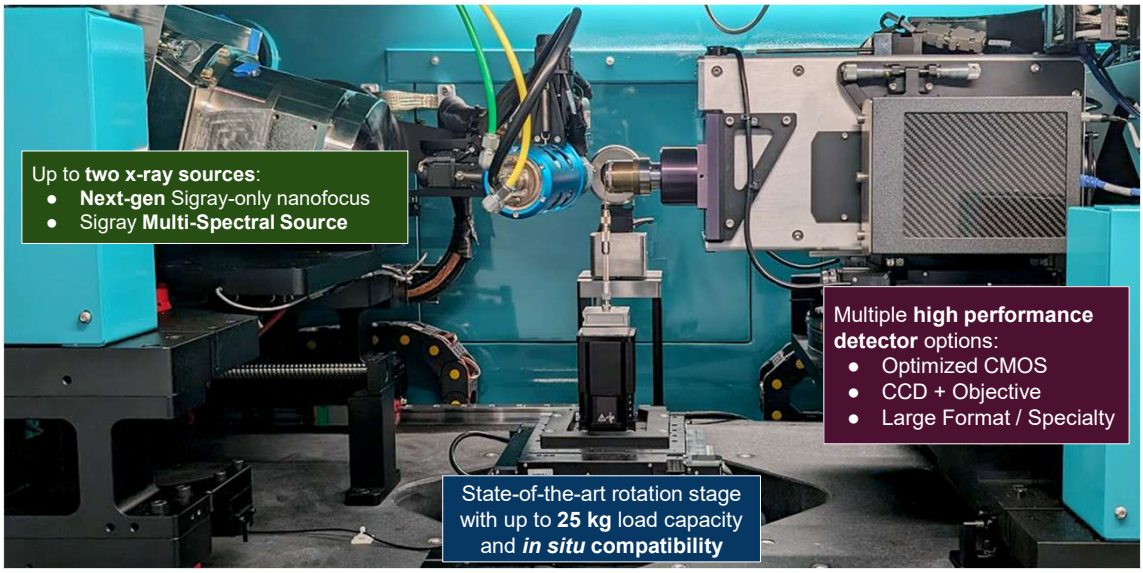
EclipseXRM Interior



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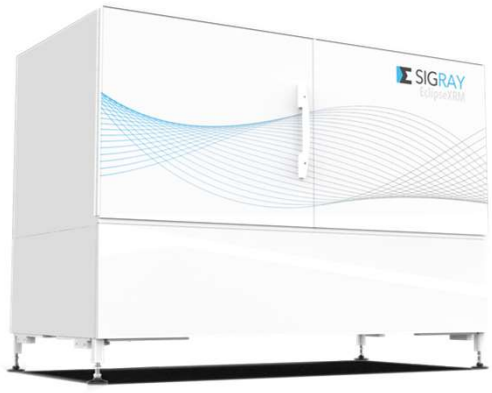
EclipseXRM Options

Configurations for Next-Generation Capabilities



- **Switchable Multi-Spectral Source (MSS)**
- **Detector Options**
- **Robotic Sample Handling**
- **Tomography Modes (Helical, Offset)**
- **User-Friendly Software**

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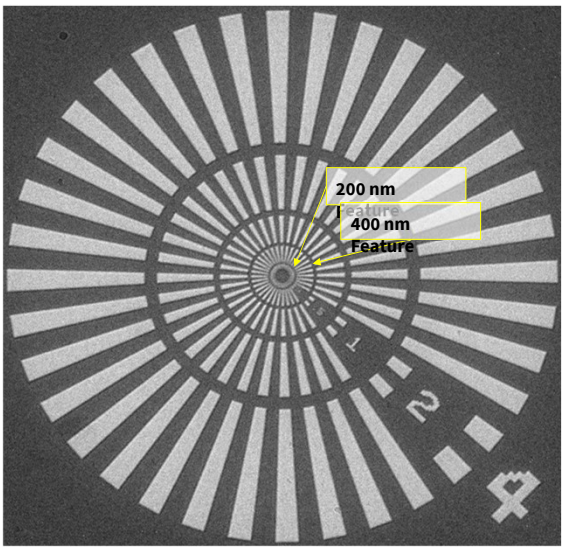
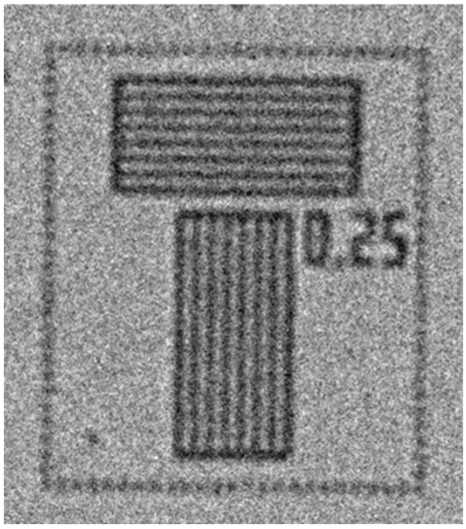
Achieving 300nm 3D with Prisma and Apex





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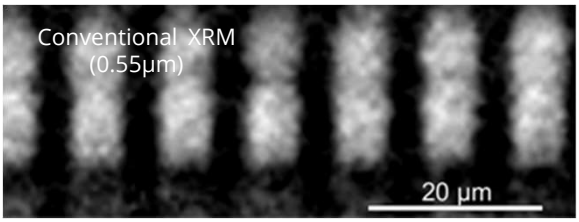
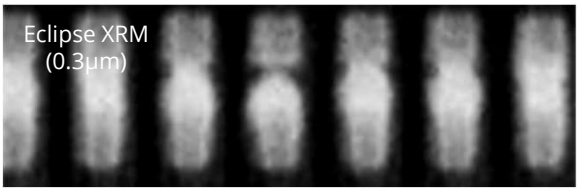
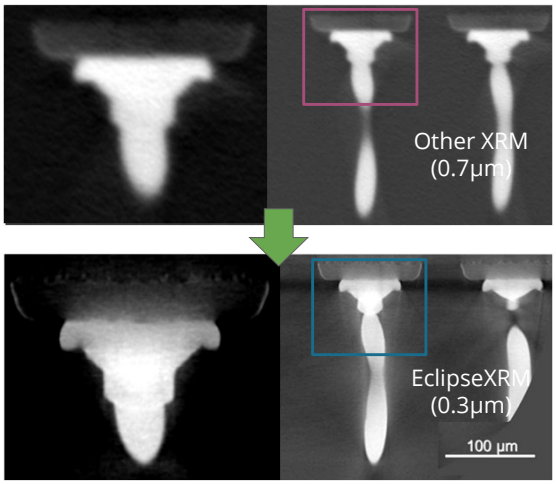
Resolution & Contrast Improvements

Semiconductor Examples: Other CT systems (top) and EclipseXRM (bottom)





Ultra-challenging microbumps (~6µm)



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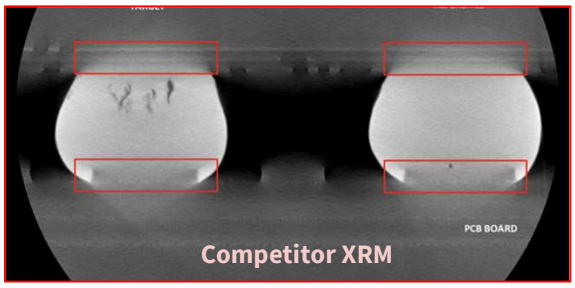
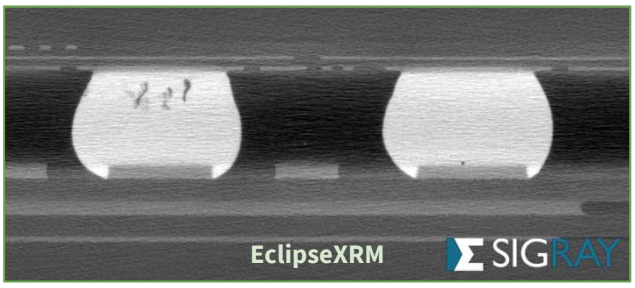
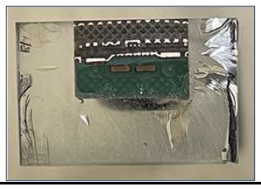
BGA Inspection: Cracks & Delamination

Clear Images, Superior to Competition | **EclipseXRM** with **Nanofocus Source**







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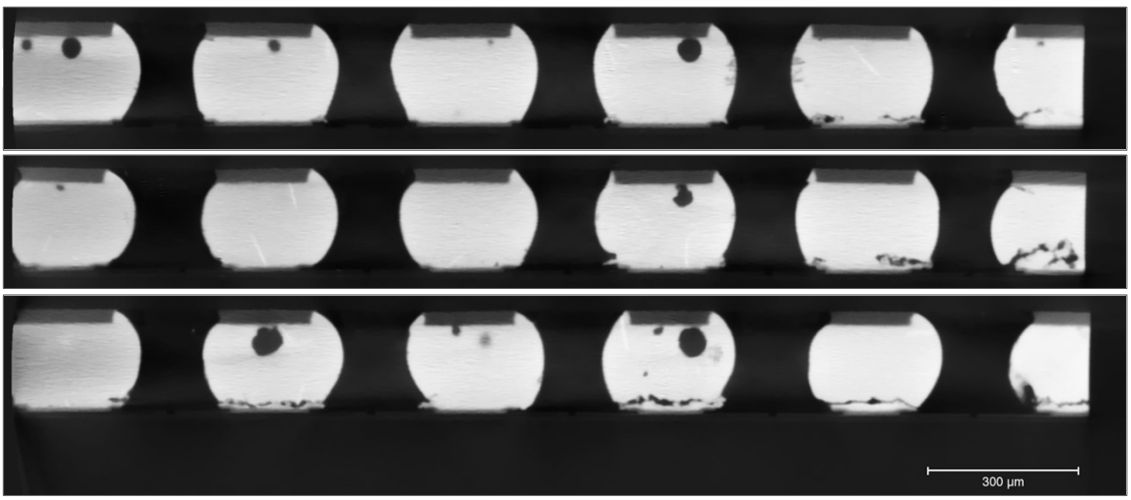
BGA Inspection in 3D

Cross-Sectional Views (Sagittal Plane) | **EclipseXRM** with **Nanofocus Source**



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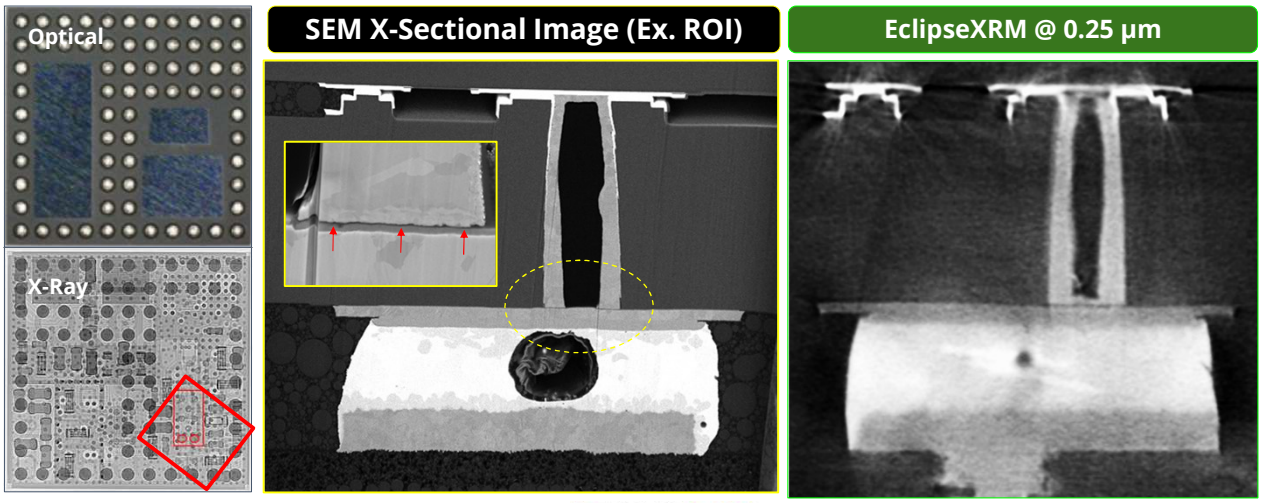
Package Inspection at Via Connection

Via Interface Separation: 12 hrs @ 0.25 µm



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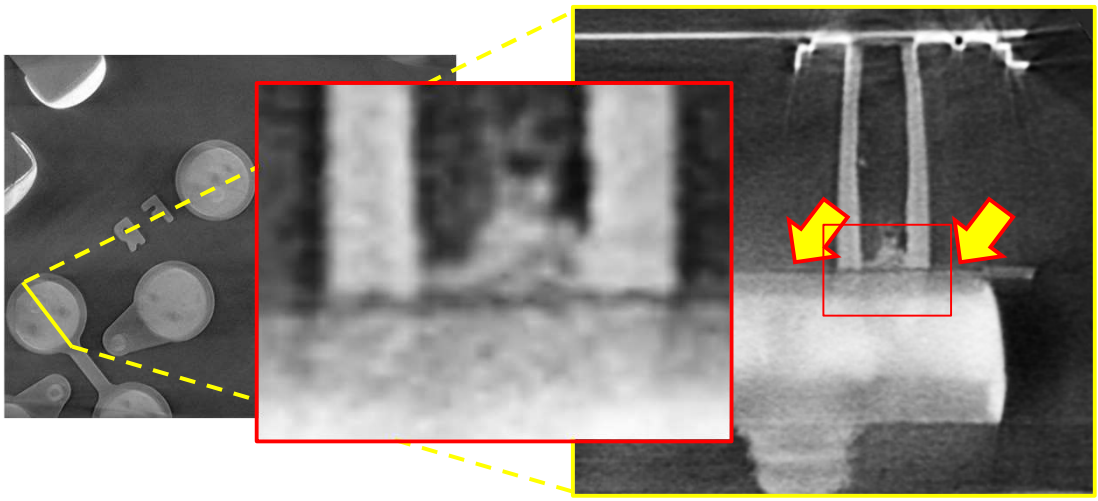
Crack/Delamination at Via Interconnect

Virtual Slice Inspection: 12 hrs @ 0.25 µm



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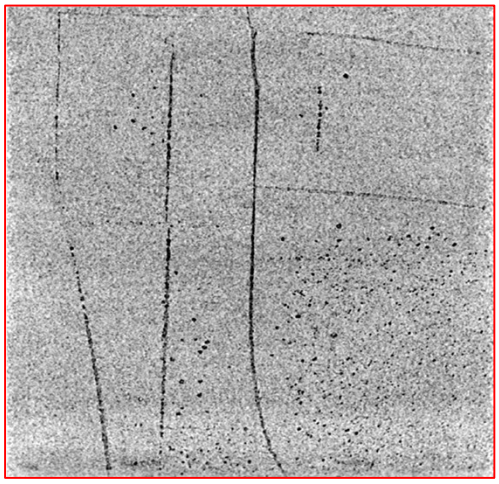
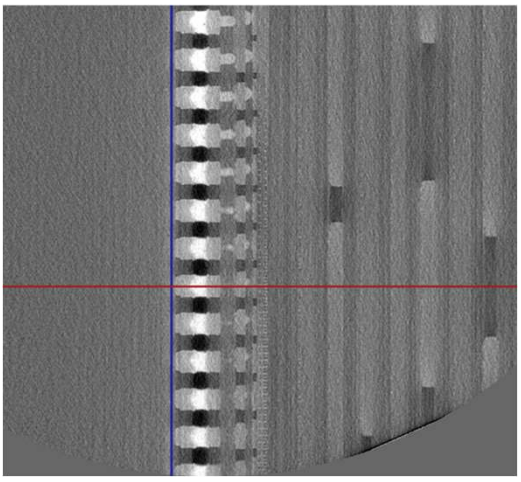
Achieving 300nm 3D with Eclipse and Apex

Imaging Si die cracks



Imaging micro-bumps



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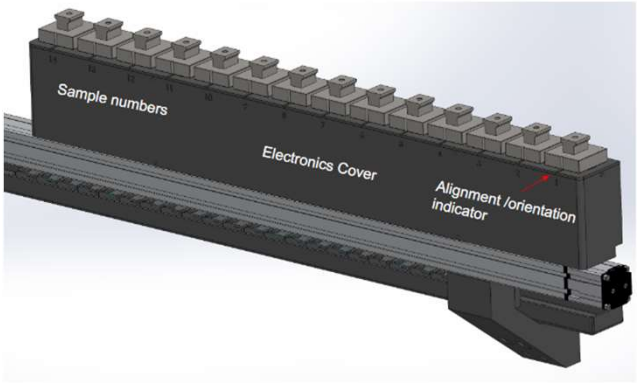
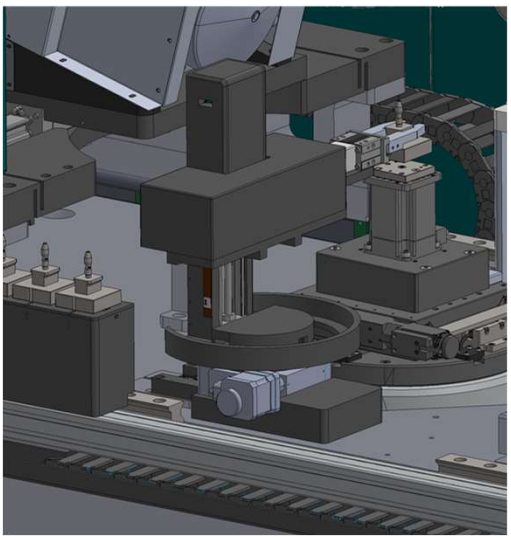
Robotic Sample Handling

Robot

Up to 14 Sample Positions (50mm Each)

Design based on Apex robotic sample handler used at semiconductor companies





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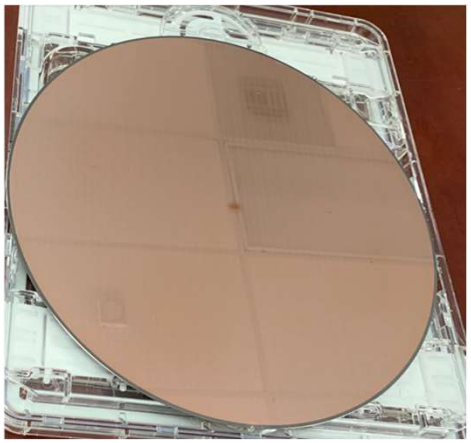
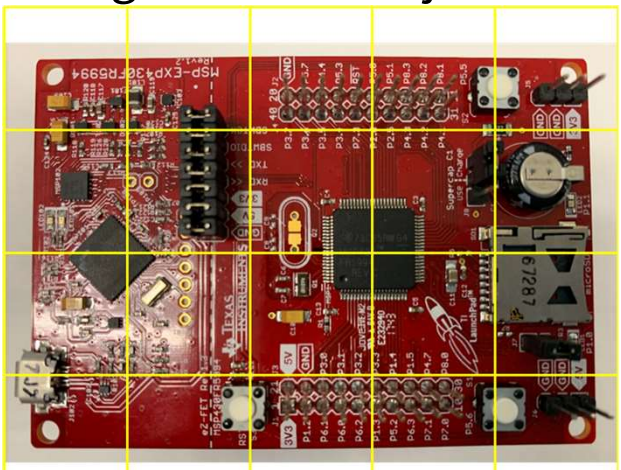
APEX-XCT: Optimized 3D for Large Planar Objects

- *0.5um Resolution and <0.3um Voxel*
- *3D imaging in minutes of large planar objects*
- *Negligible radiation hardening artifacts*
- *High speed reconstruction*
- *Advanced algorithms for defect detection*
- *Automated montage multiple 3D imaging*
- *Numerous successful competitive demos*

Need of Fast 3D Imaging of Large Plannar Objects



Microbumps and TSVs on 300mm Wafer



Bumps and circuitry of large PCB boards

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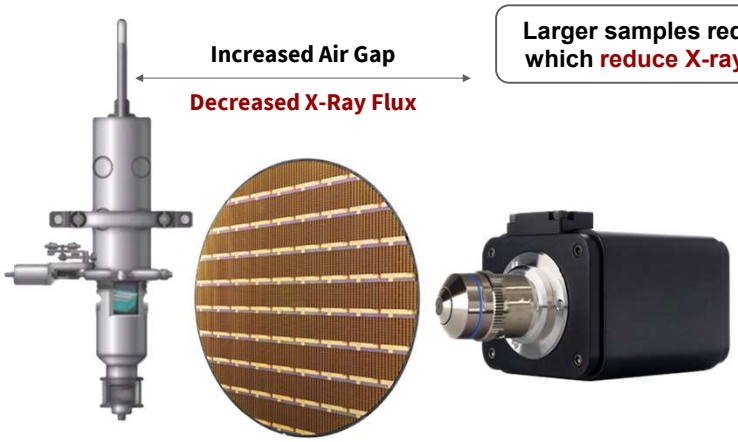
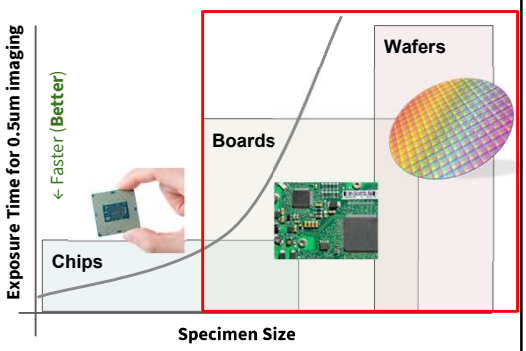
Challenges of Conventional XCT

Unacceptably Long Exposure Times and Radiation Hardening Artifacts for Large Samples



Larger samples require increased source-detector distances, which reduce X-ray flux by $1/r^2$ and increase exposure times.



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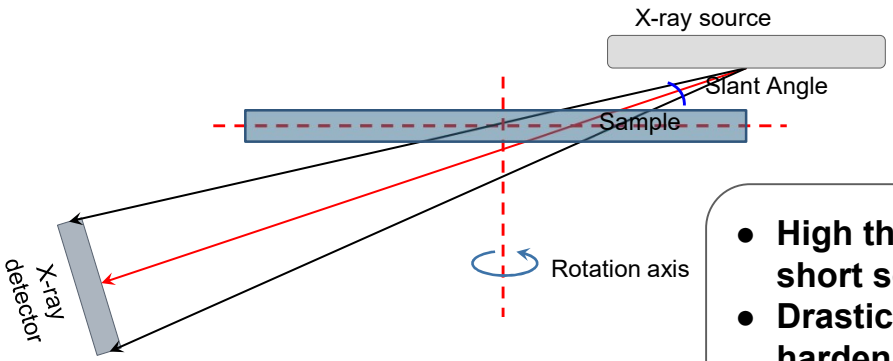
Computed Laminography (CL): Optimal for Large Planar Objects



- **High throughput due to short source-ROI distance,**
- **Drastically less radiation hardening artifacts**
- **Large PCBs and wafers**

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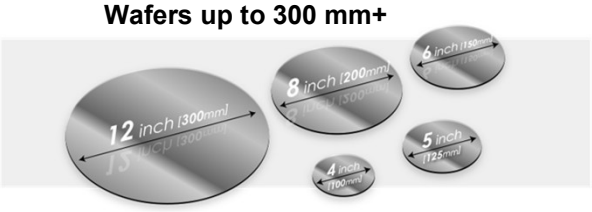
Scalable Technology with Apex XCT

Non-Destructive Inspection Capabilities: From PCBs to Full Wafers

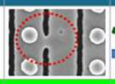
Sample Types

Components & PCBs

Wafers up to 300 mm+



Inspection Workflows

Defect	Good Solder Joint	Non Wet	Non Contact	Head in Pillow	Voids	Solder/RDL Crack	Die/Molding Compound Crack	Bridging	Warpage
									
Apex XCT	Y	Y	Y	Y	Y	Y	Y	Y	Y

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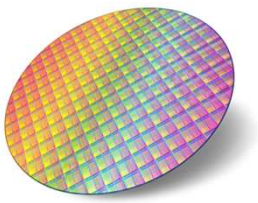
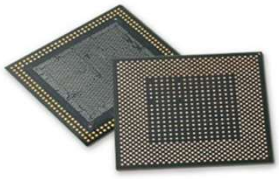
Key Applications & Sample Types

Focus on Electronics Segment: Large, Flat Samples



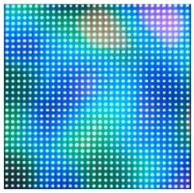
Wafers (Up to 300 mm)

Integrated Devices (PCBs, Modules)



Large Packages

NDT / Large Integrations



Advanced Modules (e.g. LEDs)

Dev Lab

Pouch Batteries

Solar Cells

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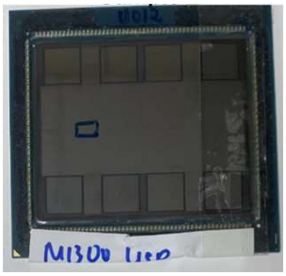
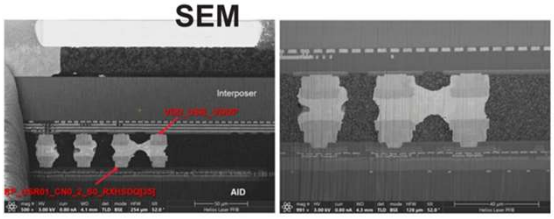
Bridging Demo: Intact Die

Identifying Bridge Defect

	High res	Throughput
Total integration time	**30 mins**	**12 mins**
Voxel Size	**0.5 µm**	**2.5 µm**
Field of View	1.47 x 1.15 mm	7.35 x 5.75 mm



SEM



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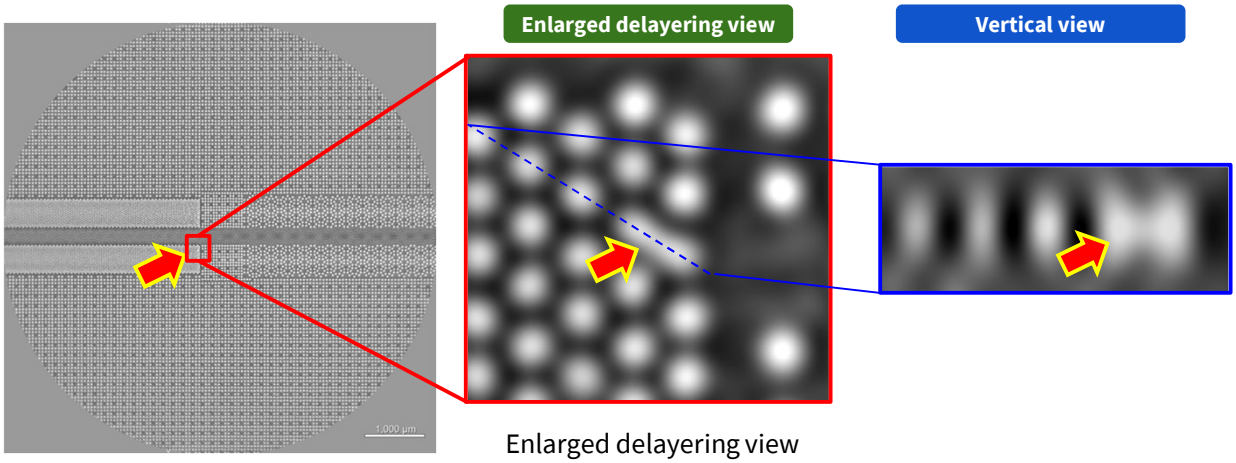
Accelerating Throughput @ 12 mins

A close examination of the solder melt in both delayering and vertical perspectives



Enlarged delayering view

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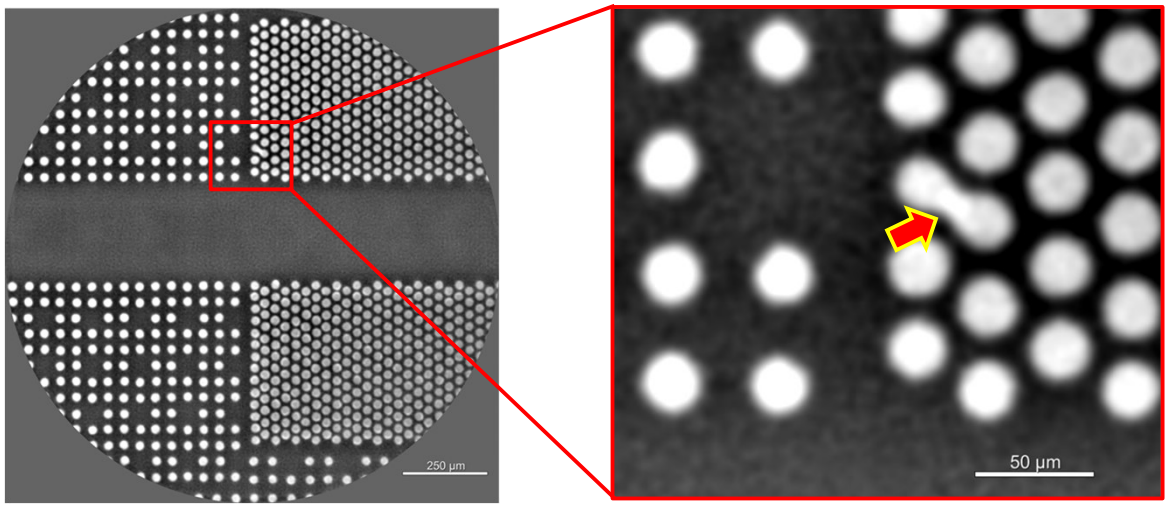
Bridging: High Res Scan @ 0.5 µm

Slicing through 3D volume data in a delayering perspective.



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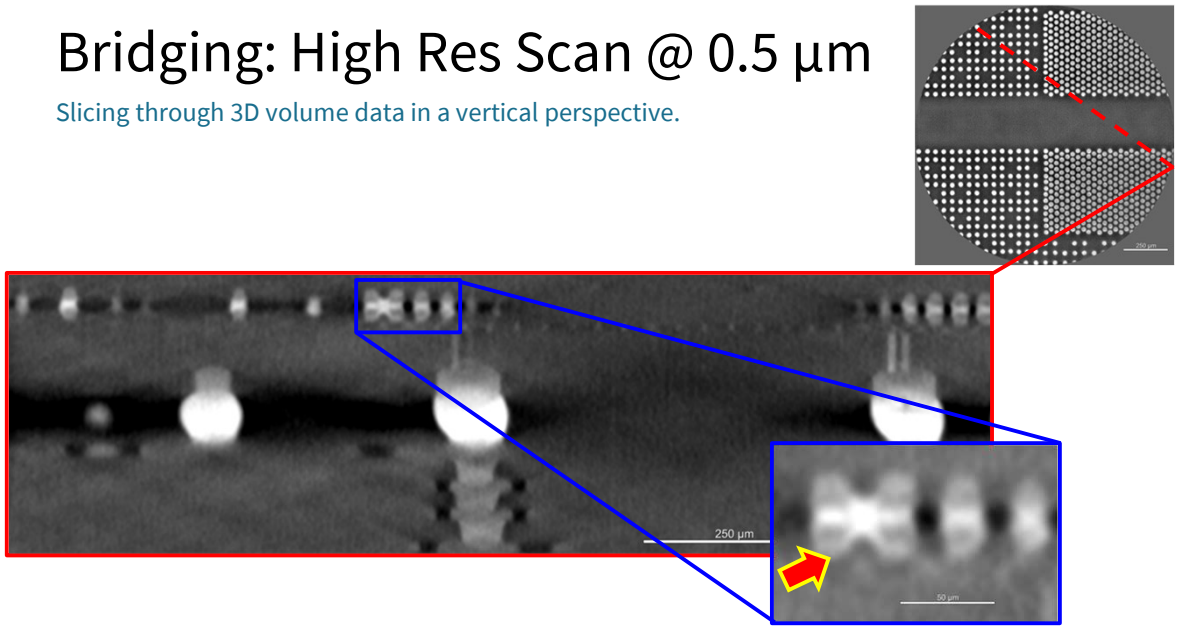
Bridging: High Res Scan @ 0.5 µm

Slicing through 3D volume data in a vertical perspective.



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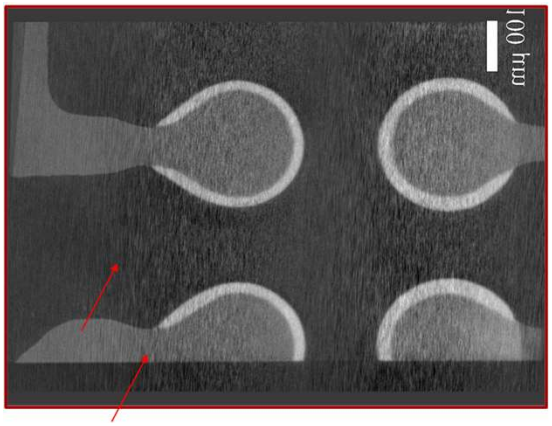
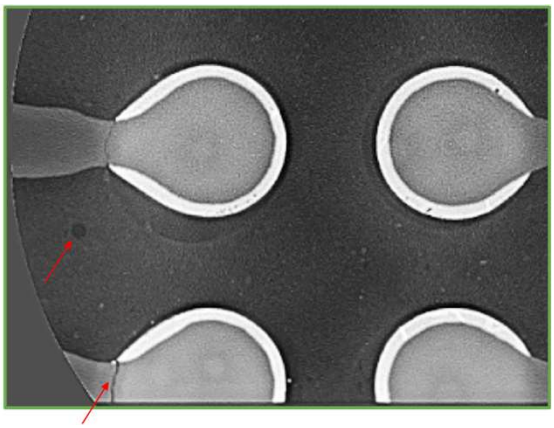
Cracks, voids, defects in Organic Layer

Conventional XRM (4 hours) **vs** **Apex XCT (30 min)**



Poor signal to noise
~4 hour measurement time
Difficult to see cracks



Excellent signal to noise
30 min measurement time
Easily resolves cracks

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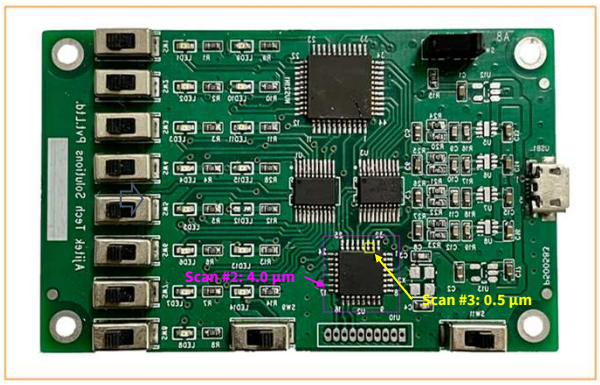
Multi-Scale Imaging

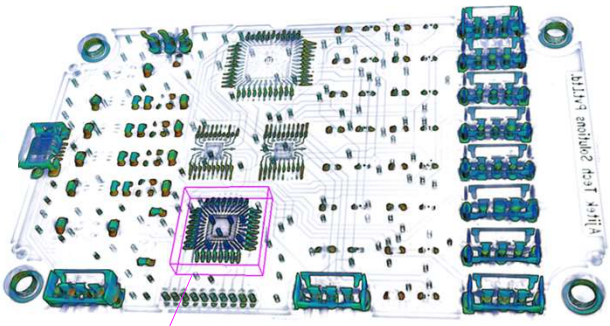
8.0 → 4.0 → 0.5 µm Resolution

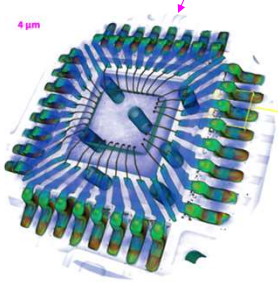
Scan #1 : 8.0 µm Montage



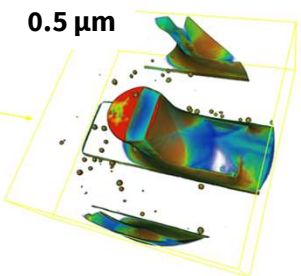
Intact PCB (50 mm x 100 mm)

4 µm





0.5 µm



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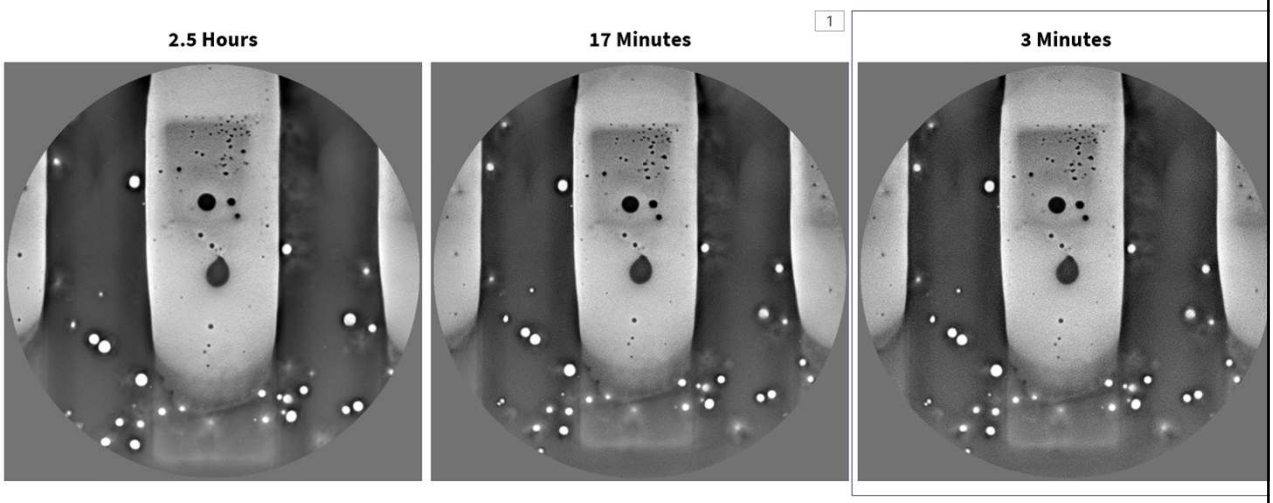
0.5 µm - Exposure Time Comparison

Example Virtual Slice - Intact PCB (50 mm x 100 mm)



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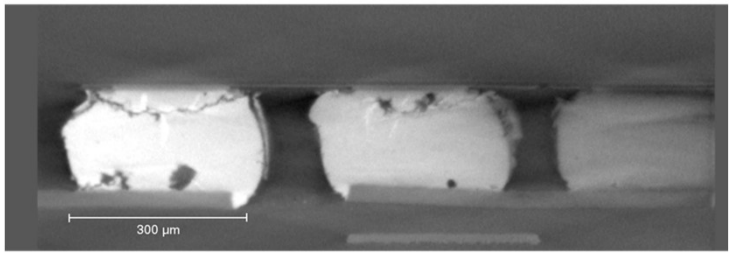
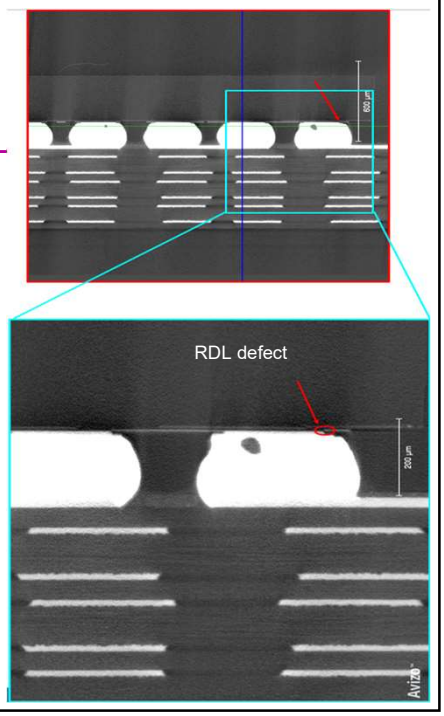
Rapid Stress Crack Detection to RDL defects in minutes



Rapid Stress Evaluation 5 min Scan after Burn in



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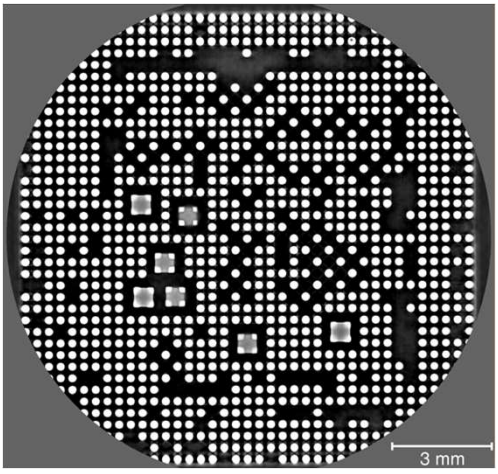
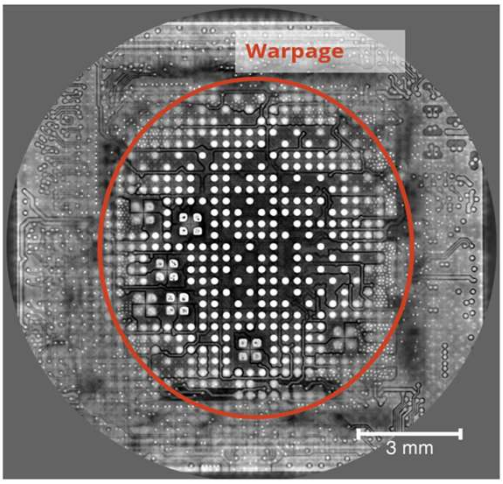


15 x 15 mm Package



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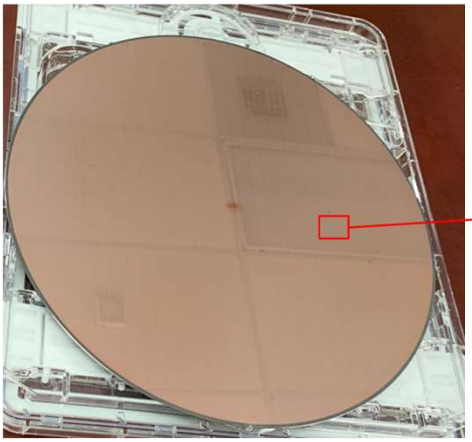
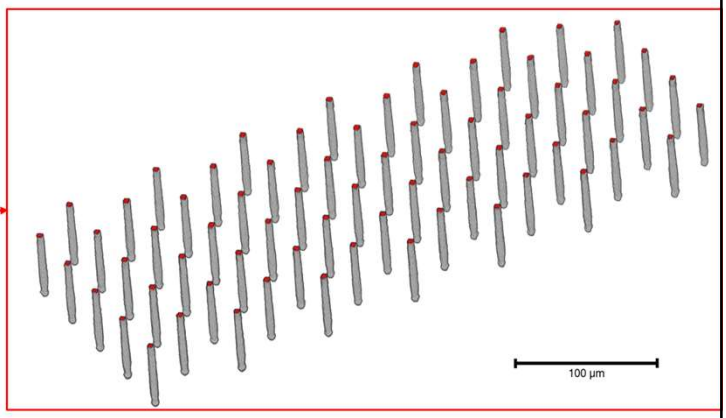
Case Study #1: 300 mm Wafer

12 Minute Scan, 0.2 µm Pixel Size





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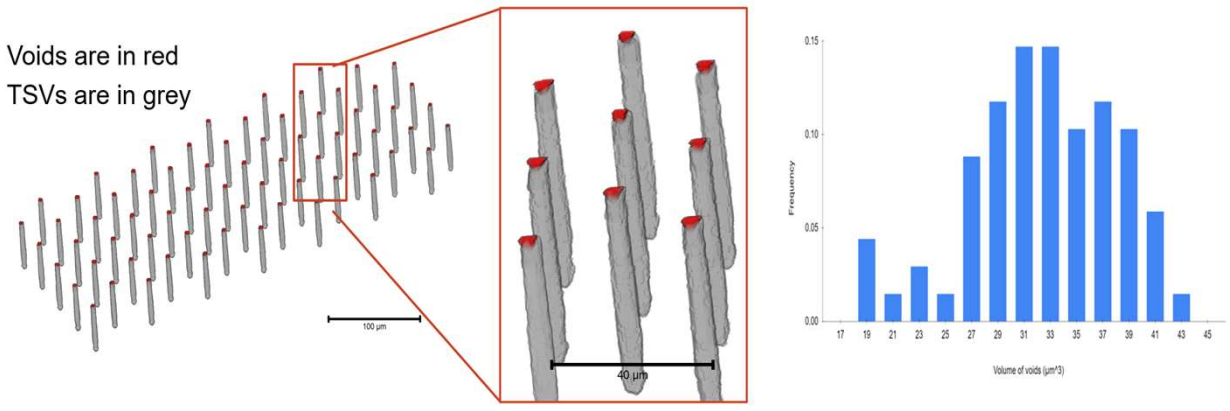
Void Identification in TSVs

3D Volume Rendering of TSVs and Voids



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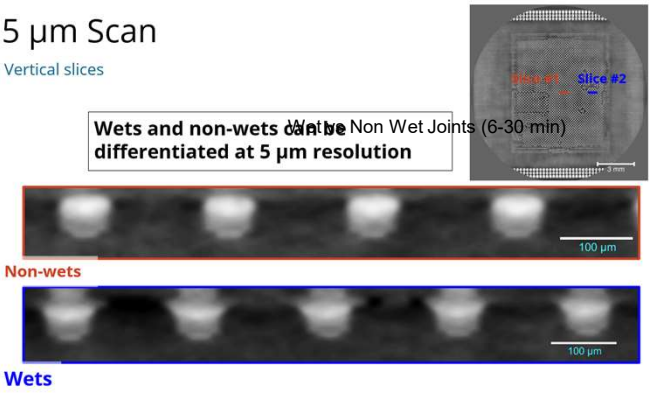
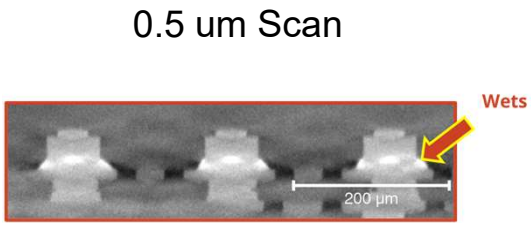


Wet vs Non Wet Joints (6-30 min)



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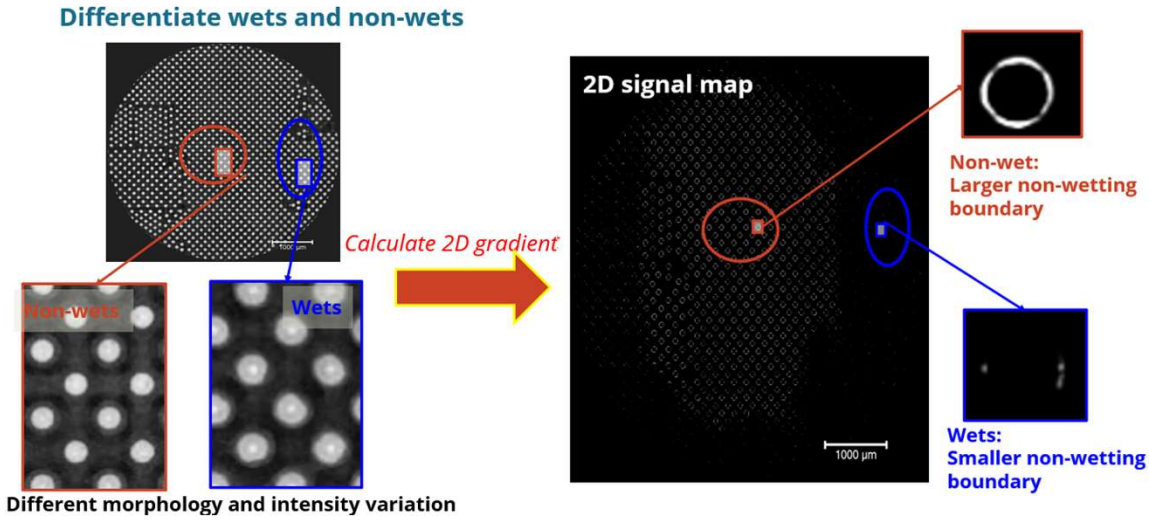
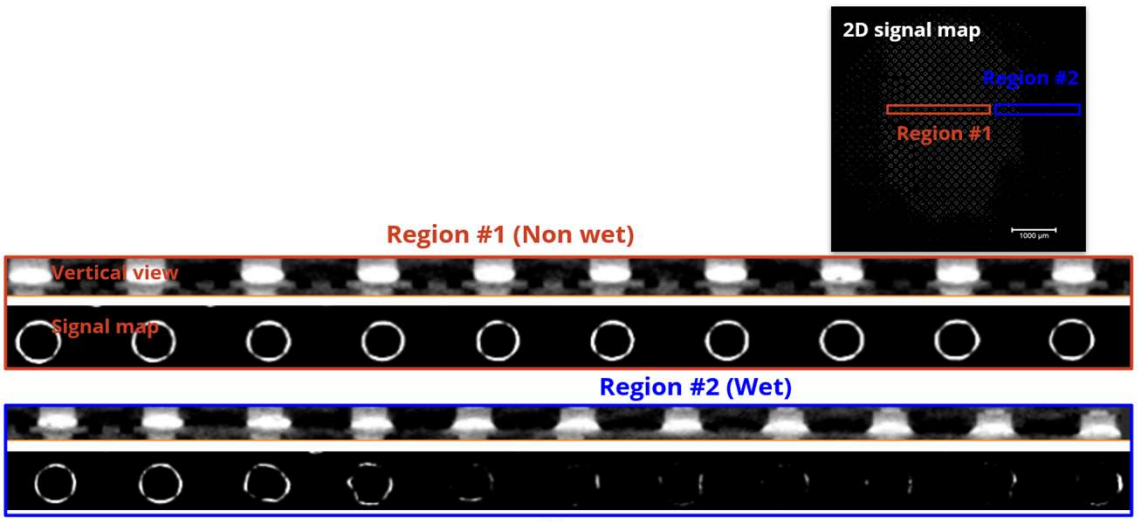
Wet vs Non Wet Joints



Wet vs Non Wet Joints (Machine Learning)



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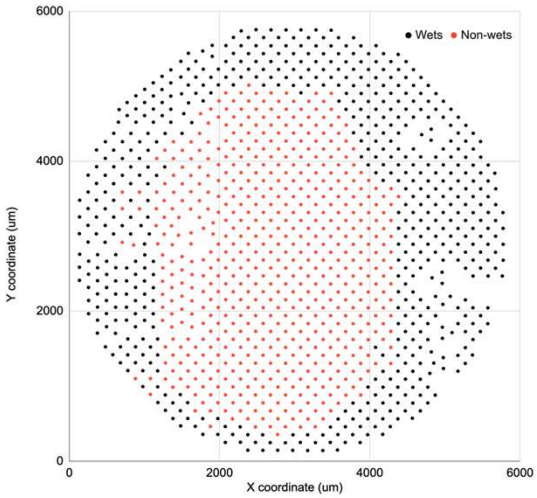
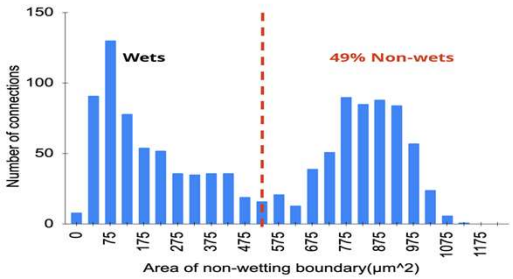
Statistics: Wet vs Non Wet Joints





- The wetting status and locations of **1187** joints were analyzed **< 6 min**.
- 575 non-wets were detected
- The **distribution pattern** of non-wets is consistent with the **warpage** of the layer

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Apex XCT-in-Line

In-line System for Advanced Packaging

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