Improved optical profiler metrology for advanced packaging

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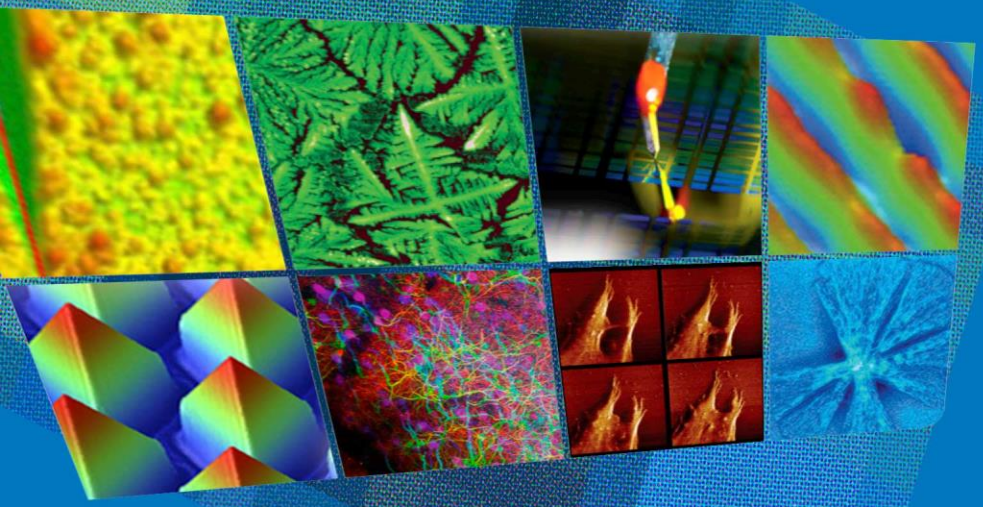


Atomic Force Microscopy
3D Optical Microscopy
Fluorescence Microscopy
Tribology
Stylus Profilometry
Nanoindentation

Innovation with Integrity

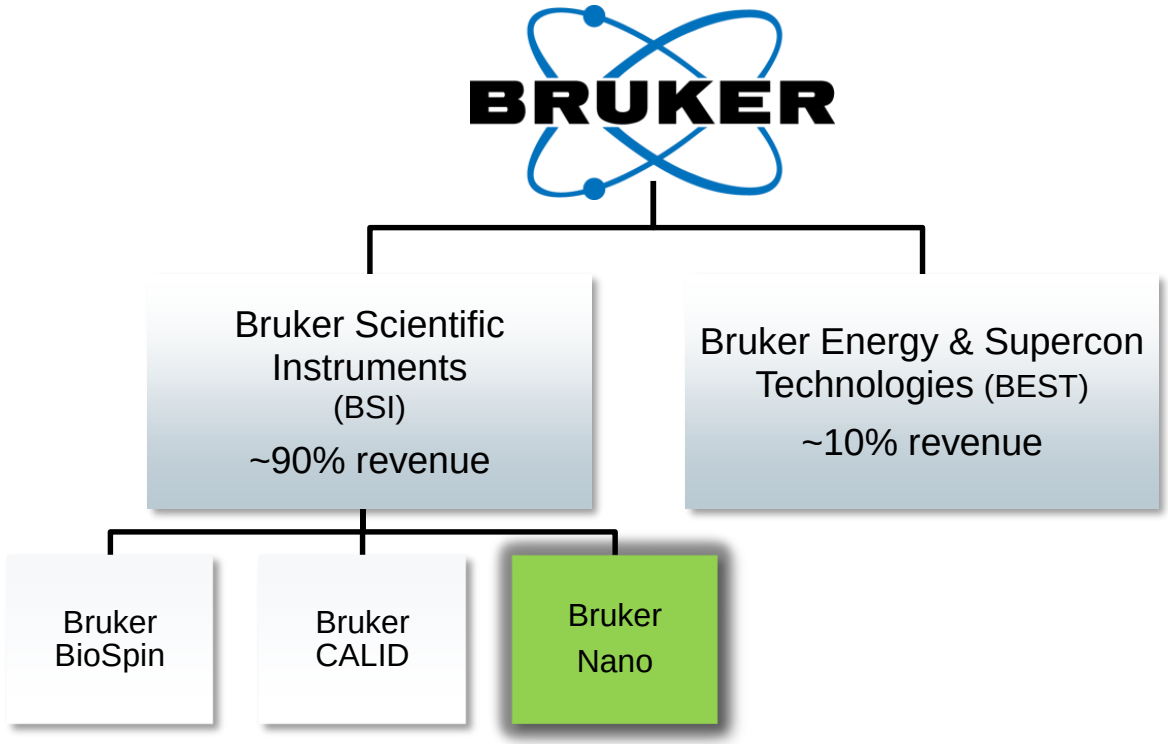
Bruker Nano Surfaces Division

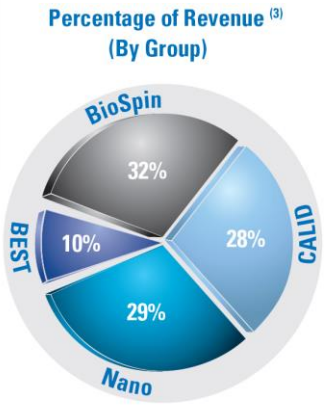
Bruker Company Profile

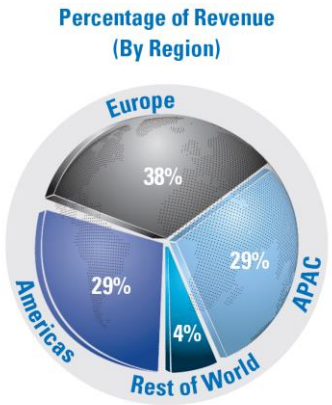
Bruker: Leading provider of high-performance analytical instrument solutions for life science, diagnostic and applied markets

KEY FIGURES

- **Founded in 1960**
- **$1.77B revenue**
- **~6,200 employees**
- **~71% revenue outside of US**
- **~Direct sales in 33 countries**





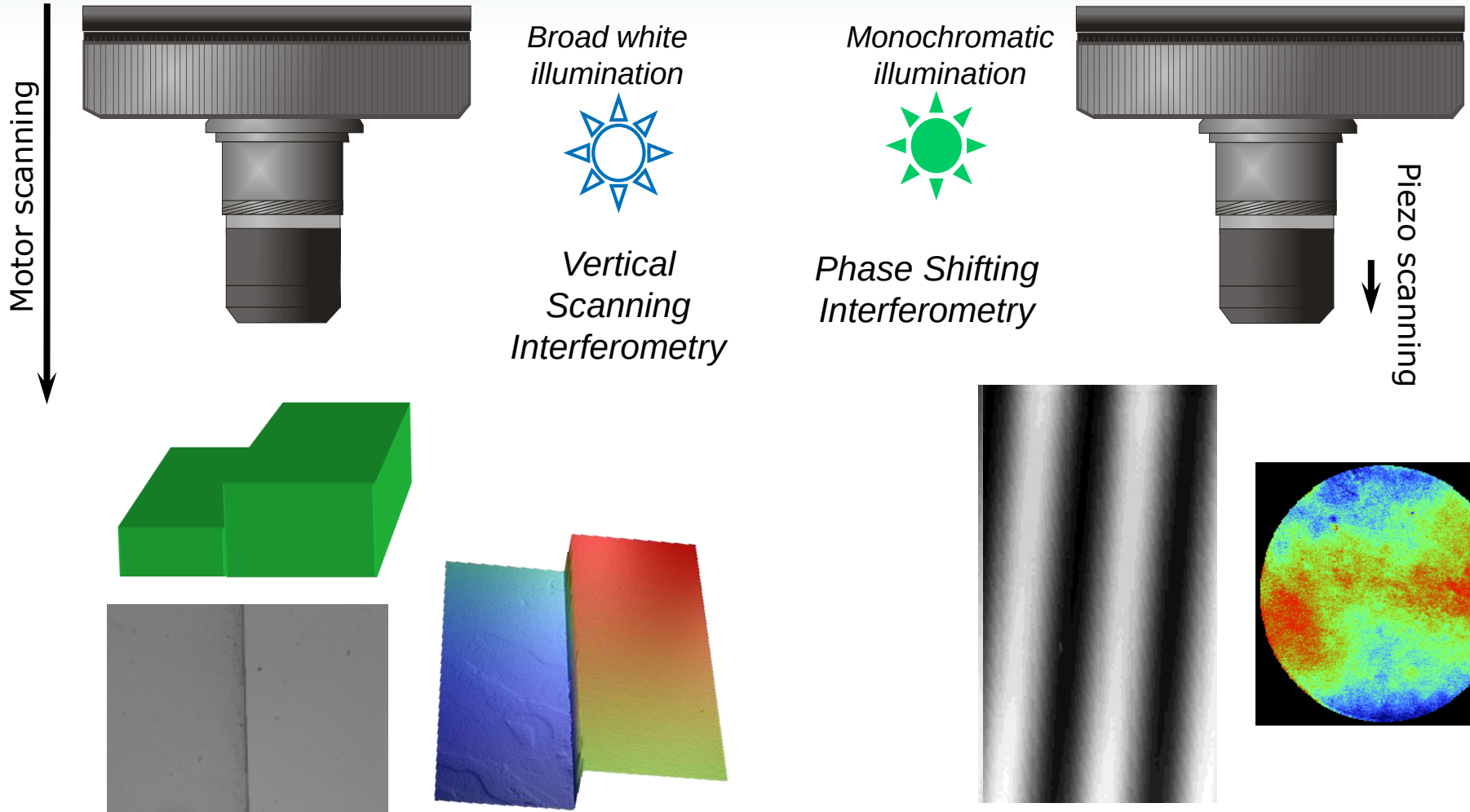


001186

Bruker's 3D Surface Metrology Solution with Automated Part and Wafer Handling

001187

Optical Interferometric Profiler
Principles



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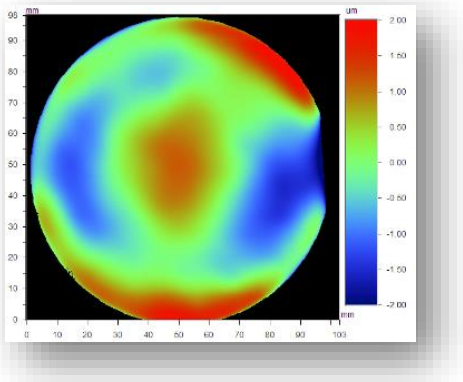
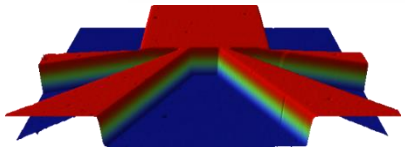
Optical Interferometric Profiler
Single head – multi mode concept

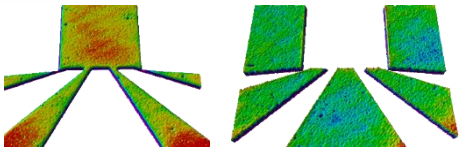
- Multi-scale: lateral



4'' sapphire wafer
Full Stitching



µm step

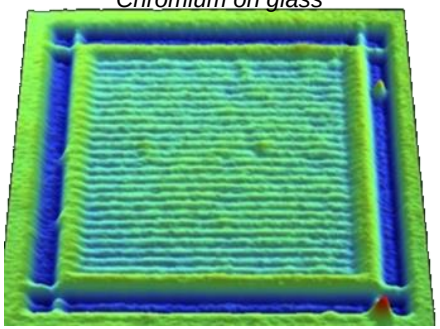


Sub-nm roughness

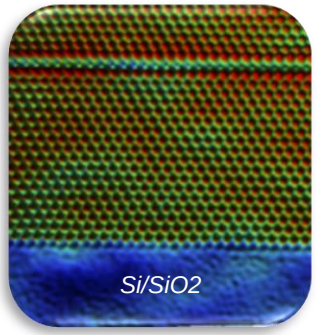
- Multi-scale: vertical

- Ultimate lateral resolution

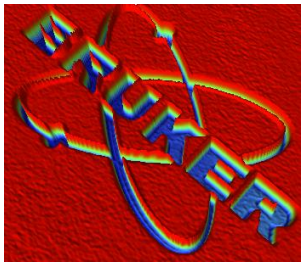
Chromium on glass



200nm spaced lines



190nm diameter spaced by 900nm

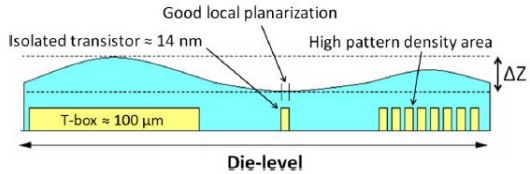


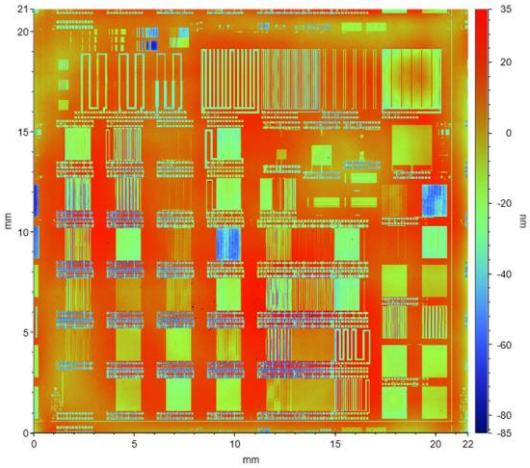
- Simultaneous Optical Inspection

Front-End Metrology

Die Flatness

- Why Important?
  - Localized measurements (T-box) are not representative of the die topography
  - Die-level topography characterization provides new and relevant data for the assessment of CMP process
  - Help with CMP design rules and improve CMP process
  - Help improving wafer to wafer & Hybrid bonding
- What Information?
  - High resolution full die map
  - Localized zoom-in view and 2D profiling
  - Full die Z-range & height distribution
  - In-die analysis of structure impact on its neighborhood
  - Evaluate the pattern density dependency of the CMP processes
  - Full wafer measurement for areas of interest



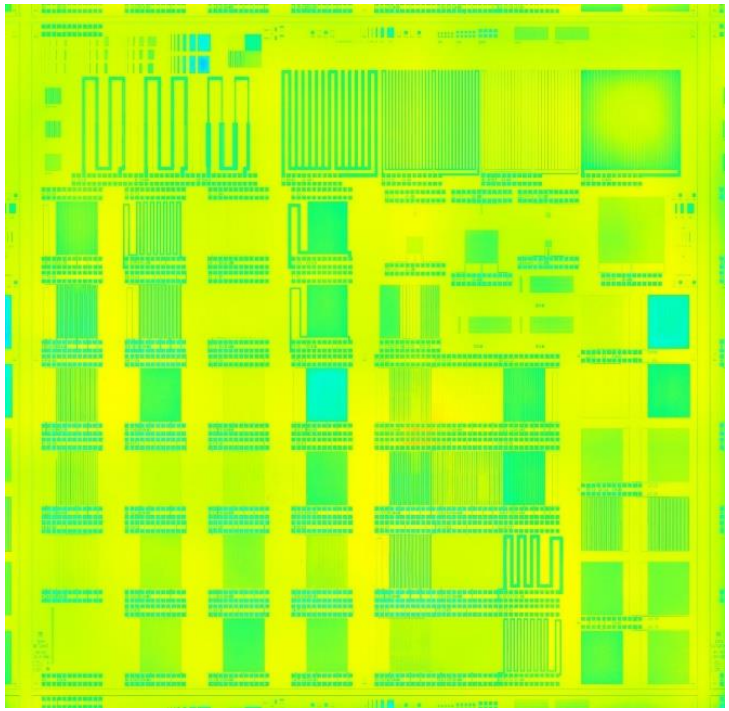


Reference: https://www.sciencedirect.com/science/article/abs/pii/S016793171300573X

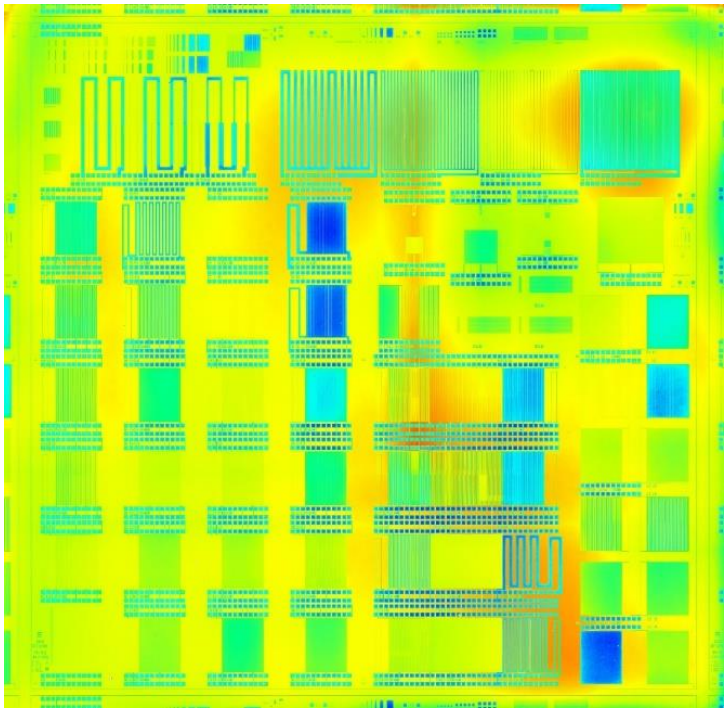
Full Die Stitching
Dishing & Erosion versus wafer position

- Capability to detect post-CMP defects on pattern wafers in a large area (e.g. 20mm^2) with proper throughput (~20 min)

Center (0,0)



Edge (4,0)



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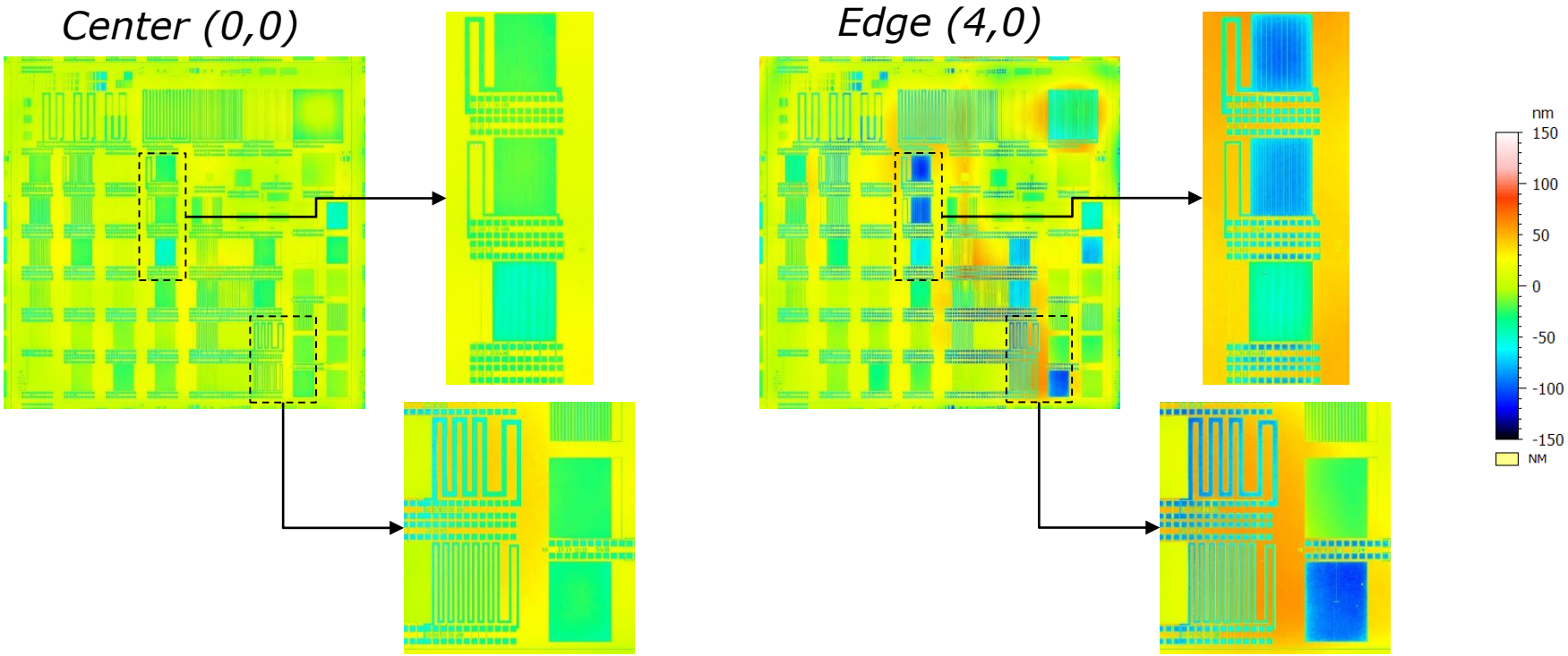
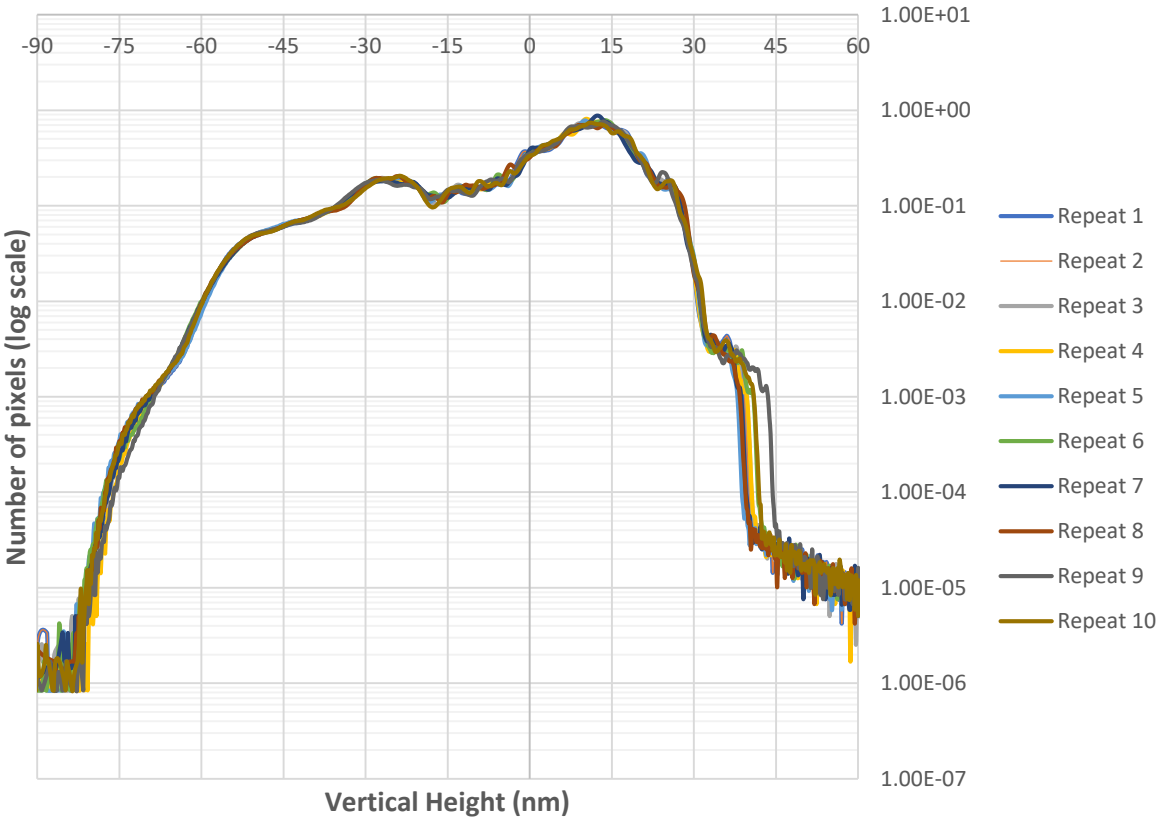
Full Die Stitching
Pattern & die position effects

- Ability to retain high lateral resolution (3.4µm) over large area (e.g. 20mm^2) with proper throughput (~20 min)



Full Die Stitching
Gauge capability



Reproducibility at sub-nanometer level across the full height distribution

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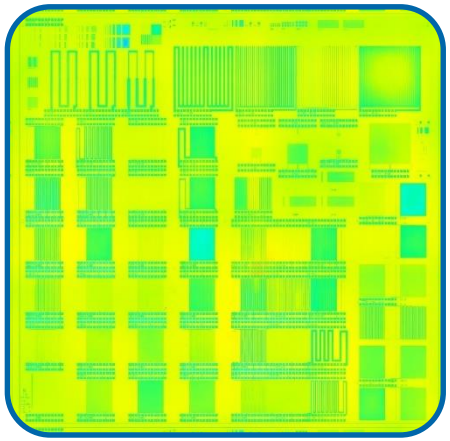
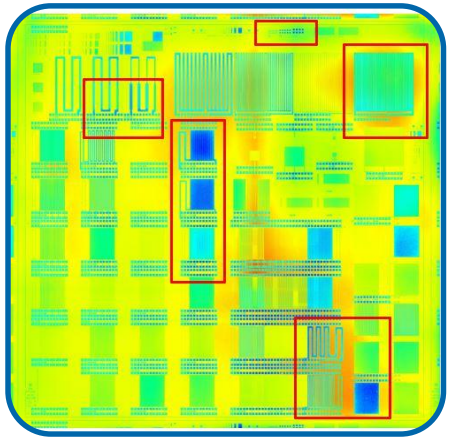
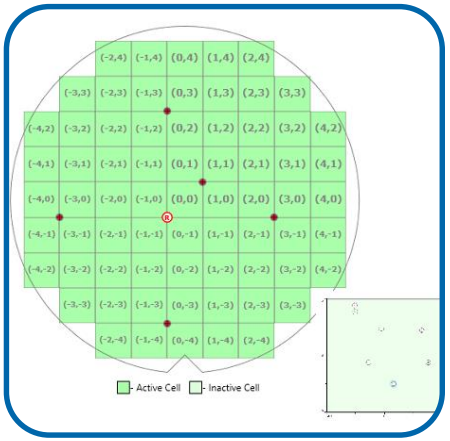
Process Flow
Post-CMP automatic characterization



Full Die Stitching
- Large area e.g. 20mm x 20mm
- 3.6um lateral resolution
- <1nm vertical resolution
- Repeatability of Sq (1σ) < 0.1nm
- High throughput ~20min



Identify Area of Interest
- Die-to-die comparison
- Record XY coordinates
- Decide objective/FOV combination
- Setup automation routine

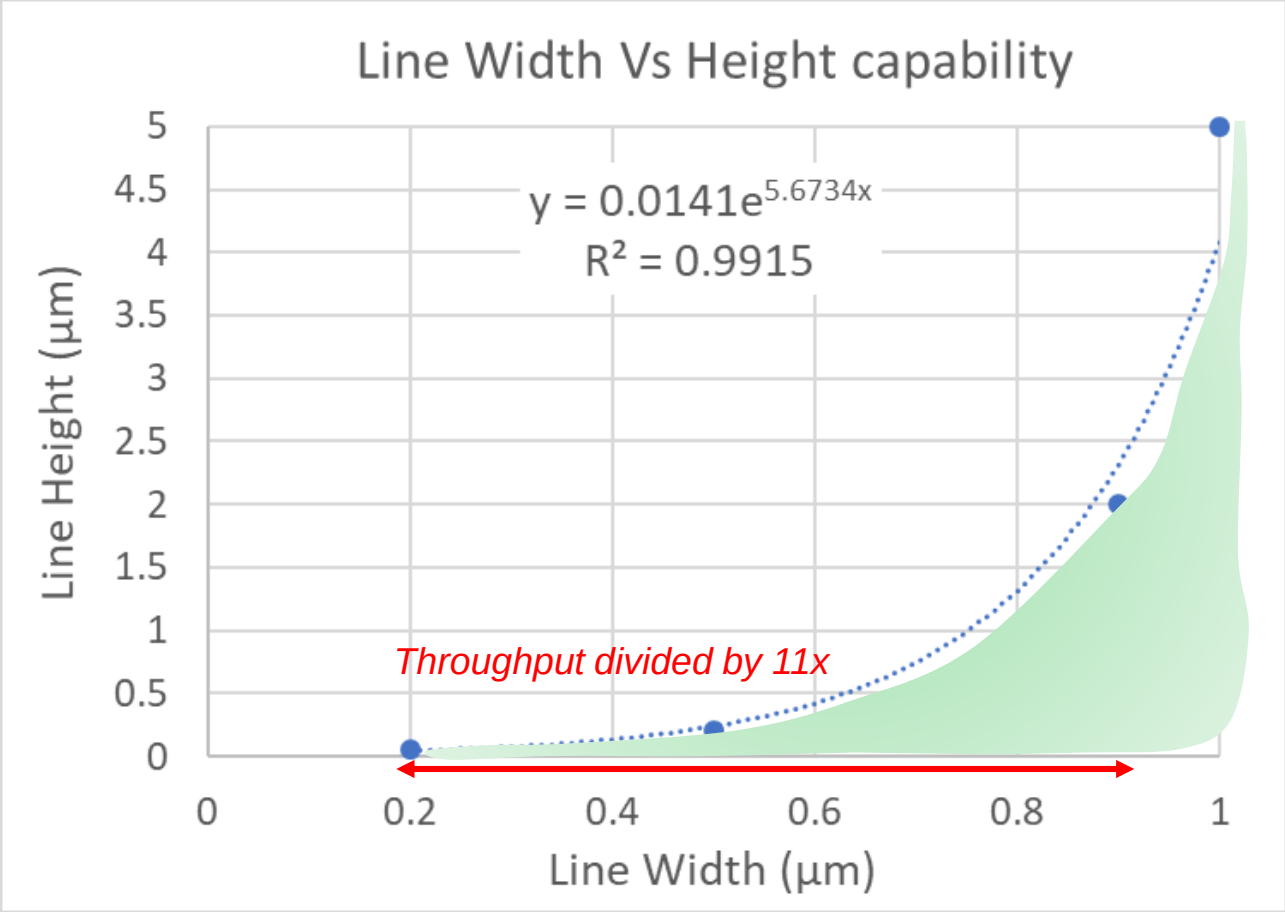


Program for Full Wafer Measurement
- Single FOV imaging / localized area stitching with high magnification objective
- Automated measurement & analysis
- High flexibility
- High throughput

BRUKER

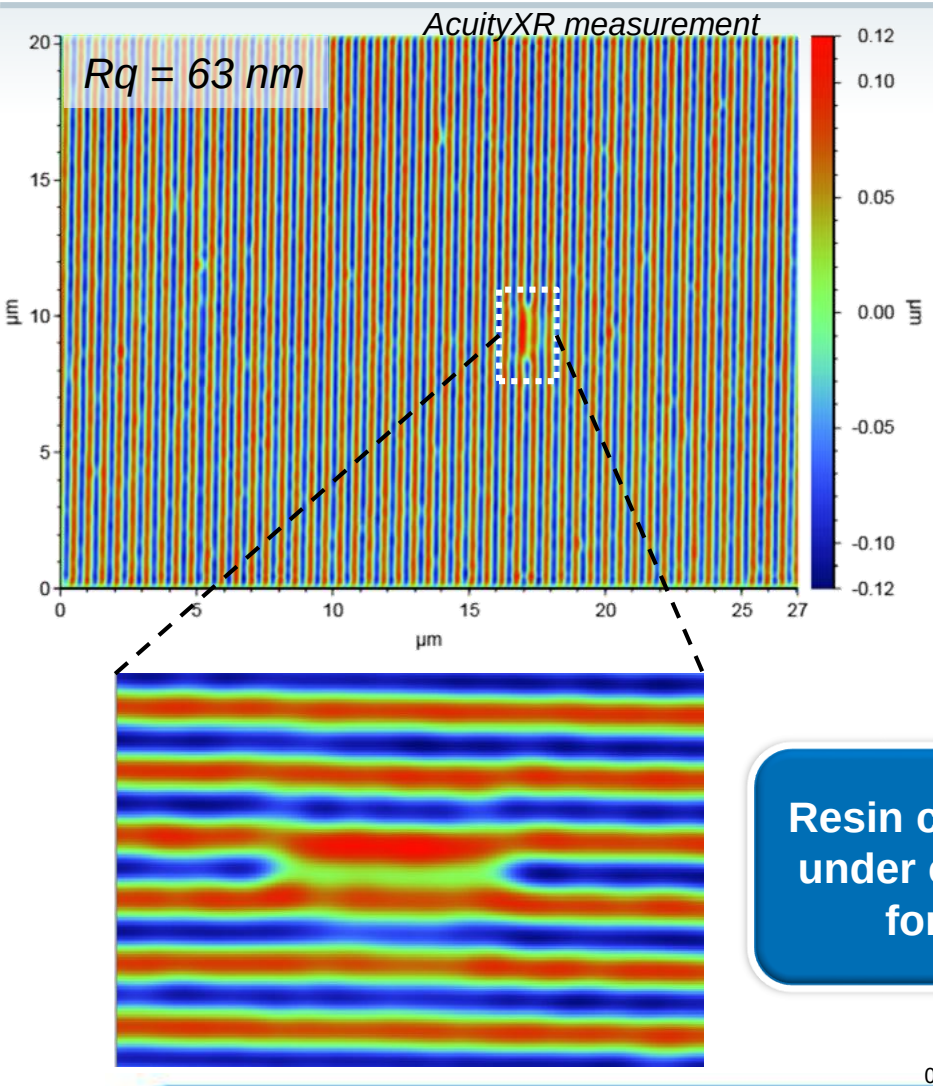
Back-End & Advanced Packaging

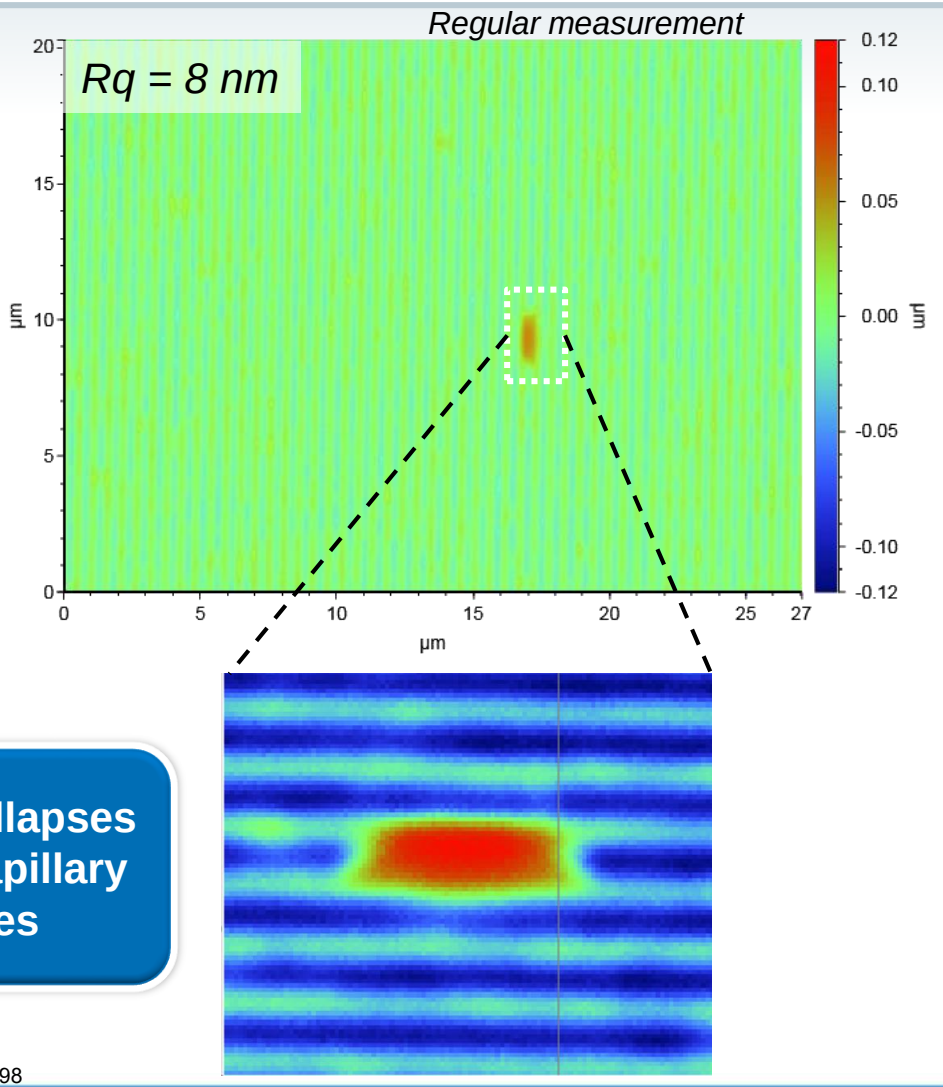
Line width measurement
Optical boundaries



Line width measurement

True understanding of defect



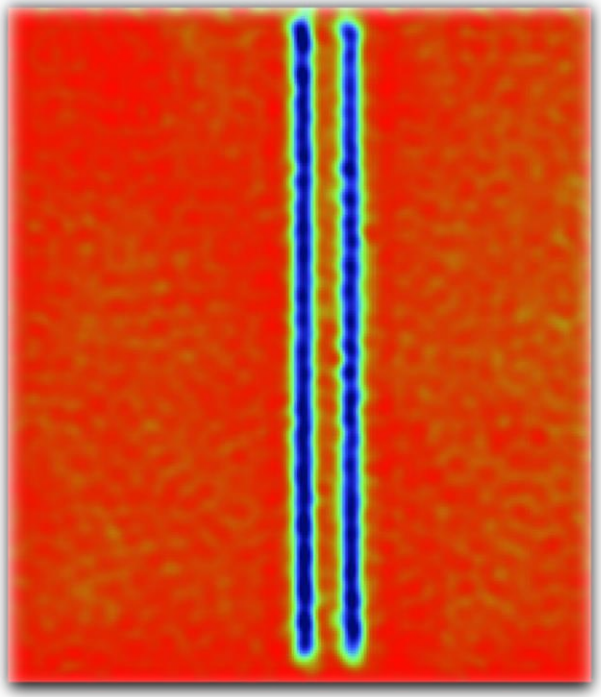


Resin collapses under capillary forces

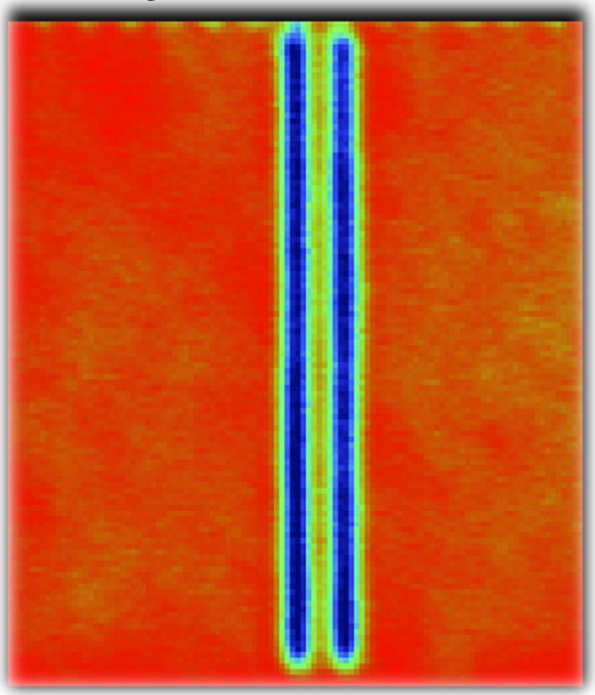
001198

Line width measurement
Better performances in metrology

AcuityXR measurement



Regular measurement



11µm x 10µm
Z scale: 12nm

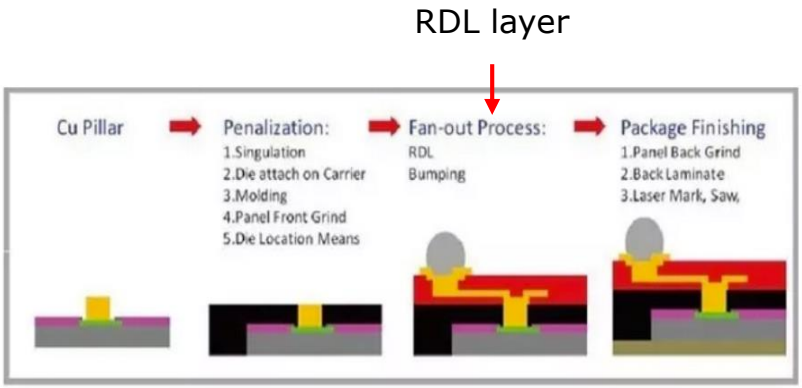
300nm line space

Parameters	Standard	AcuityXR	Improvment
Line Width Std Dev (nm)	35.16	5.27	6.7x

001199

InFO Packaging
Overlay Application

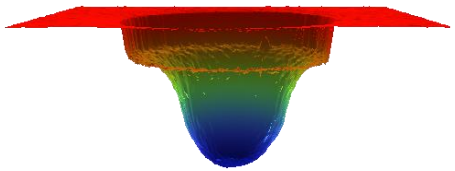
- 2.5D & 3D Stacking Technologies
  - Heterogeneous integration
- RDL layer with PR film on top
- Displacement (ΔX, ΔY) of two pattern centers locate on
- 1 sigma ~ 100nm



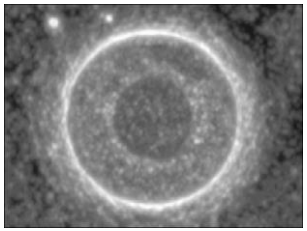
InFO Packaging- Overlay Application
Production Process Control

Single acquisition

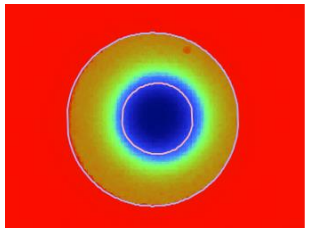
Topography



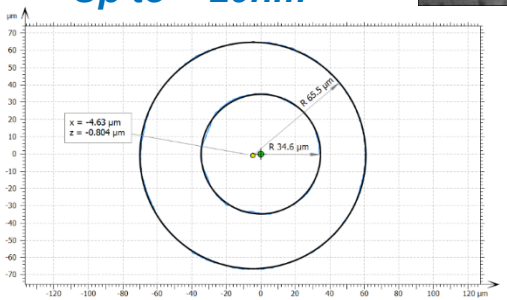
Optical Inspection



1 sigma Overlay
Up to < 10nm



Bottom Ra	4.817	µm
Top Ra	0.458	µm
Via Max Depth	72.294	µm
Via Mean Depth	63.332	µm
Via Min Depth	43.611	µm



Point coordinate Overlay Offset	
x	-1.17 µm
z	0.512 µm
Dimension Inner Diameter	
Diameter (Rabs)	61.959 µm
Dimension External Diameter	
Diameter (Rabs)	147.118 µm

Same database

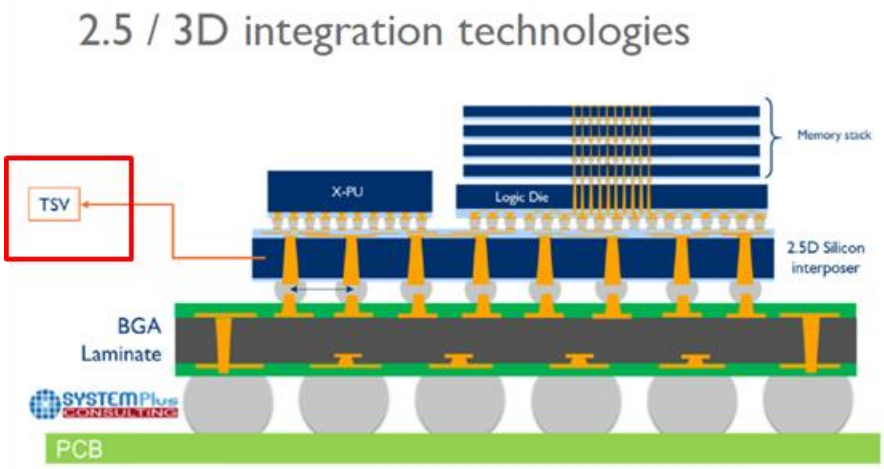
Database

Measurement Number	Bottom Ra µm R: N/A M: N/A Always Always	Top Ra µm R: N/A M: N/A Always Always	Via Mean Depth µm R: N/A M: N/A Always Always	Overlay Offset X µm R: N/A M: N/A Always Always	Overlay Offset Y µm R: N/A M: N/A Always Always	Outer Ring Diameter µm R: N/A M: N/A Always Always	Inner Ring Diameter µm R: N/A M: N/A Always Always
1	4.817	0.458	63.332	-1.168	0.512	147.118	61.959

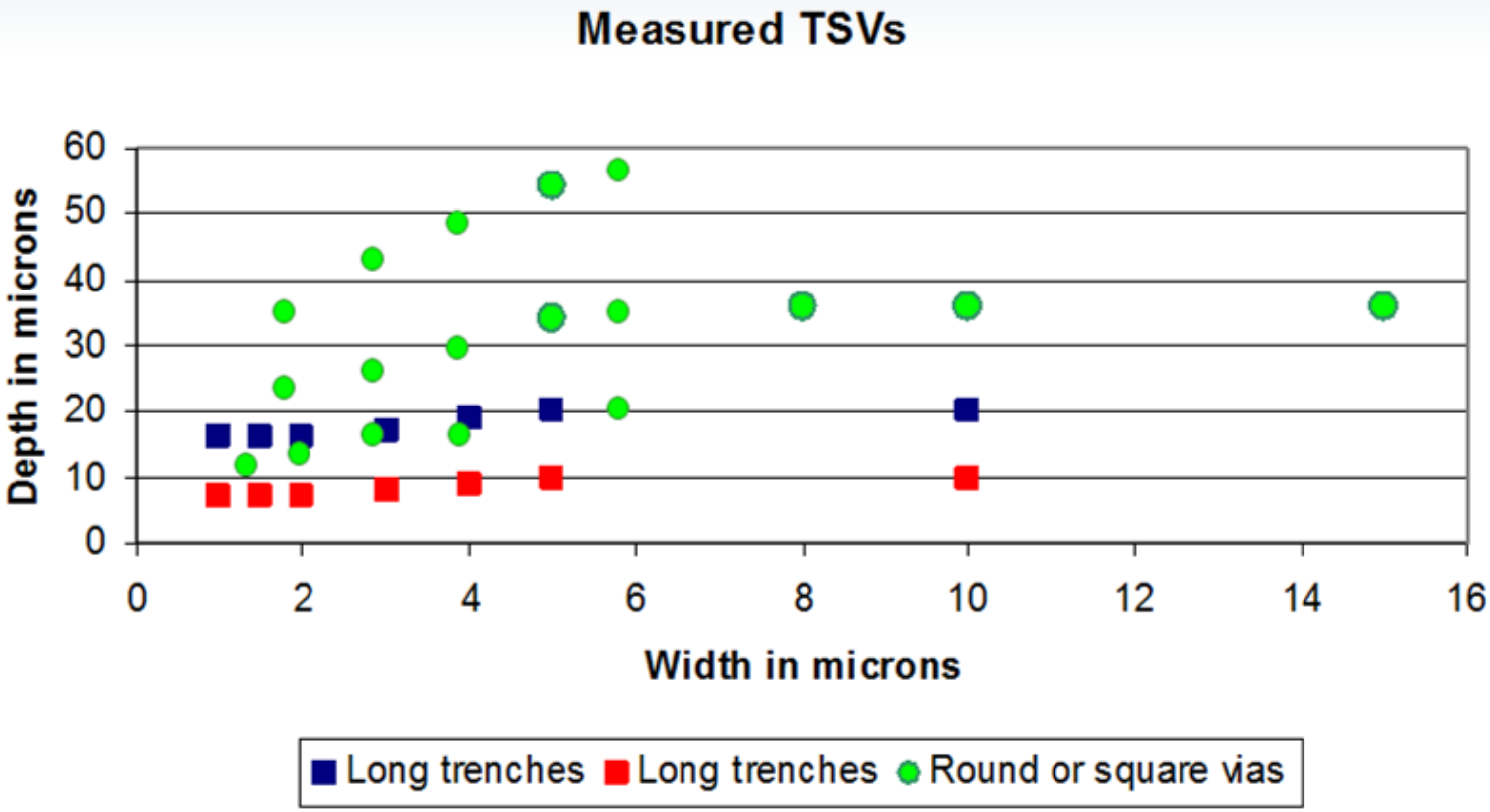
001201

Through Silicon Via (TSV)

- Memory
- 2.5D & 3D Stacking Technologies
  - Heterogeneous integration
  - Hybrid bonding
  - Wafer to Wafer bonding
  - Advanced packaging
- Top opening >=5 um
- AR up to 1:10 / 1:20
  - Top opening dependent



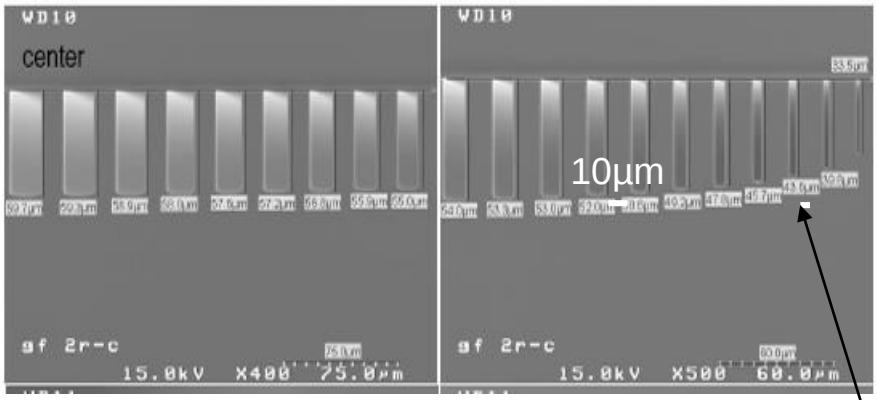
Through Silicon Via (TSV)
Measurement space

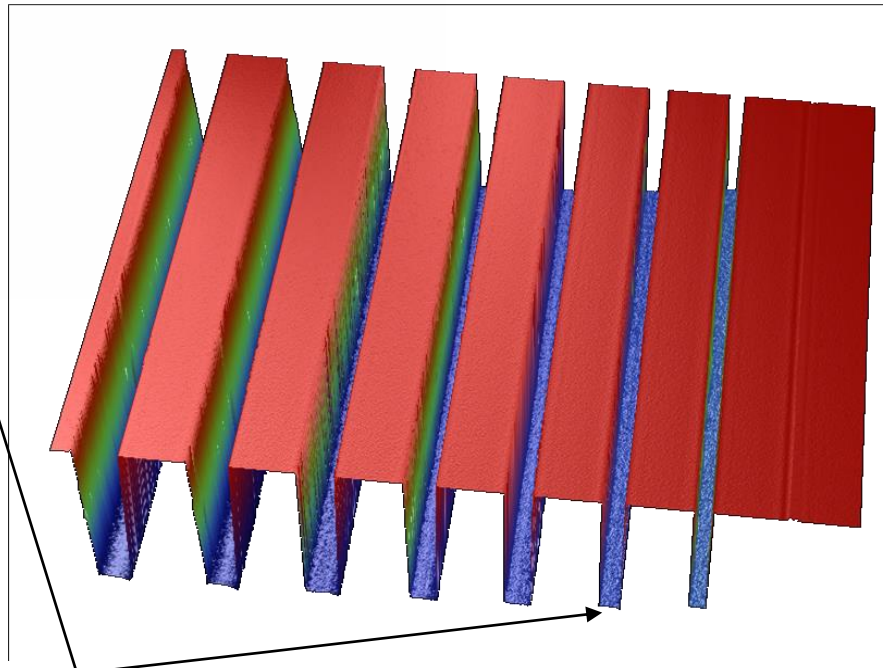


Proven wide capabilities

Through Silicon Via (TSV)
Correlation with SEM cross-section

Location	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13	Tr14	Tr15	Tr16	Tr17	Tr18	Tr19	Tr20
CD (um)	1.0	2.0																		20
Center Si etch depth (um)	33.1	39.6	43.2	45.8	47.8	49.2	50.6	52.0	53.0	53.3	54.0	55.0	55.9	56.8	57.2	57.6	58.0	58.9	59.3	59.7
Edge Si etch depth (um)	34.4	41.3	45.1	47.8	49.8	51.2	52.6	54.0	54.3	55.7	56.4	56.7	57.6	58.0	59.7	59.7	59.7	60.6	61.0	61.0

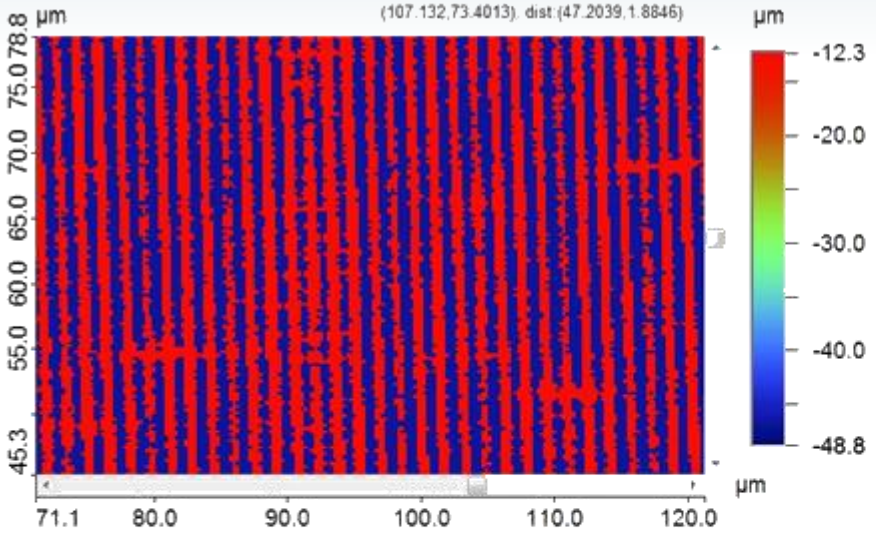


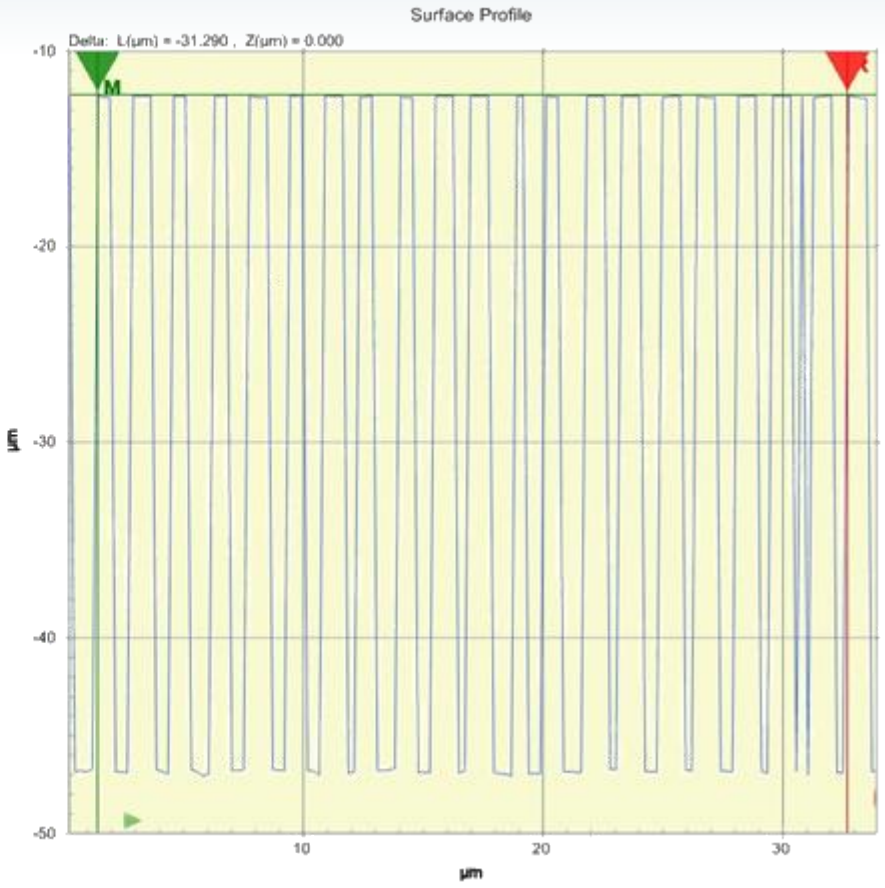


001204

Through Silicon Via (TSV)

Extreme case

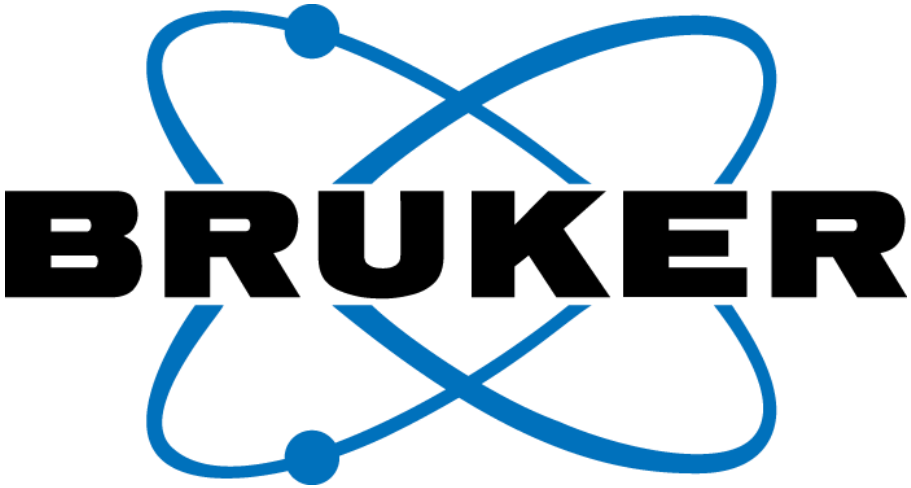




Pitch: 1.5 µm
Width: 1.5 µm
Depth: 34 µm

Summary

- Bruker WLI enables both Front & Back End applications
- Automated measurement routine with high throughput
- Industry-leading vertical and lateral resolution
- Proven repeatability and stability by world's leading semiconductor institutions
- Successful use cases at major semiconductor companies around the world



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