



COMPASS
a FormFactor users' group conference

FRT METROLOGY FOR ADVANCED PACKAGING

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FormFactor FRT Metrology

TECHNOLOGY

- Leader in Optical Surface Metrology and Inspection
- SurfaceSens^h Multi-Sensor Technology
- Various optical point, field of view and film thickness sensors and microscopes integrated in one device
- More than 700 FRT Metrology tools are established worldwide

SERVICE

- Global on-site service and maintenance
- Virtual remote support and training
- In-house sensor and software development
- Flexible, expandable and future-proof hardware and software

COMPETENCE

- Comprehensive metrology know-how
- More than 25 years of expertise in optical surface measurement
- Highly qualified team of engineers, physicists and experts
- Contract measurements



- ✓ Optical Metrology and Inspection
- ✓ **Made in Germany**
- ✓ 700 Tools installed worldwide
- ✓ 300mm-Tools (40) at major Capex companies in Taiwan, Korea, US
- ✓ Global presence and local support

FRT: Enabling the ASAP Metrology Roadmap

- FRT is specialized in fully automated multi-sensor metrology system for application-specific advanced packaging (ASAP) measurements

- Cost/Performance optimized for micron-level features
- Supporting the 40µm heterogeneous integration HVM

- Leading-customer guided R&D roadmap

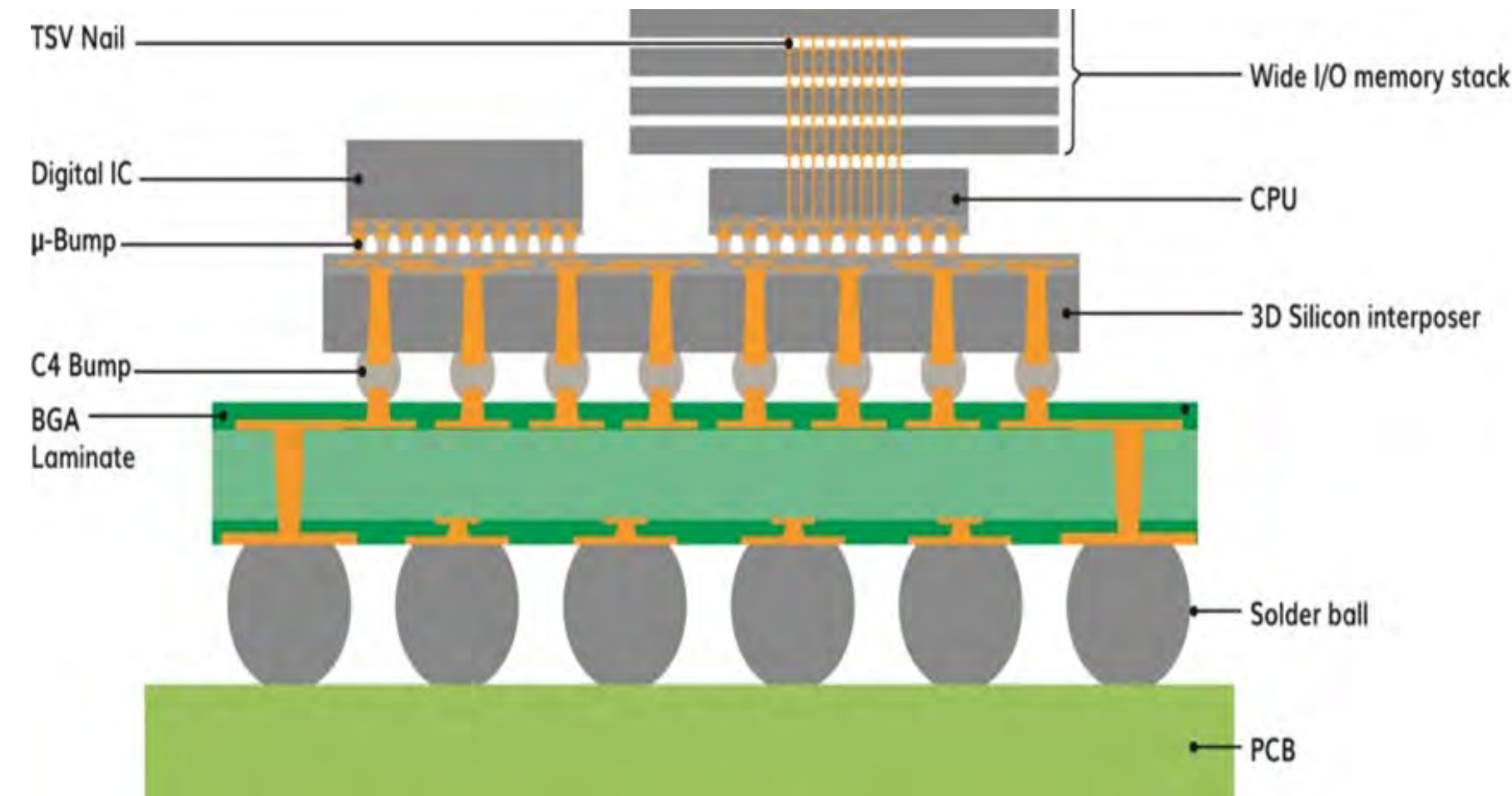
- Developing sub-20µm probing technologies

2019-2025 advanced packaging wafer forecast by packaging platforms (12" eq wafer starts per year)

(Source: Status of the Advanced Packaging Industry 2020, Yole Développement, July 2020)



Trenches
Metal Contacts
TSV
Photo Resist
Interposer
RDL / UBM
Bumps / µ-Bumps
BGA
Reflow soldering



Thin film measurement

Step height / width

Bump analysis

TSV / trench depth / width

CD / Overlay

T-dependent topography

Stress

Bulk thickness

Backgrinding

Applications in Advanced Packaging

FRT: Scalable Platform with SurfaceSens™

Standardized System Platform



MicroProf® 300



MicroProf® MHU



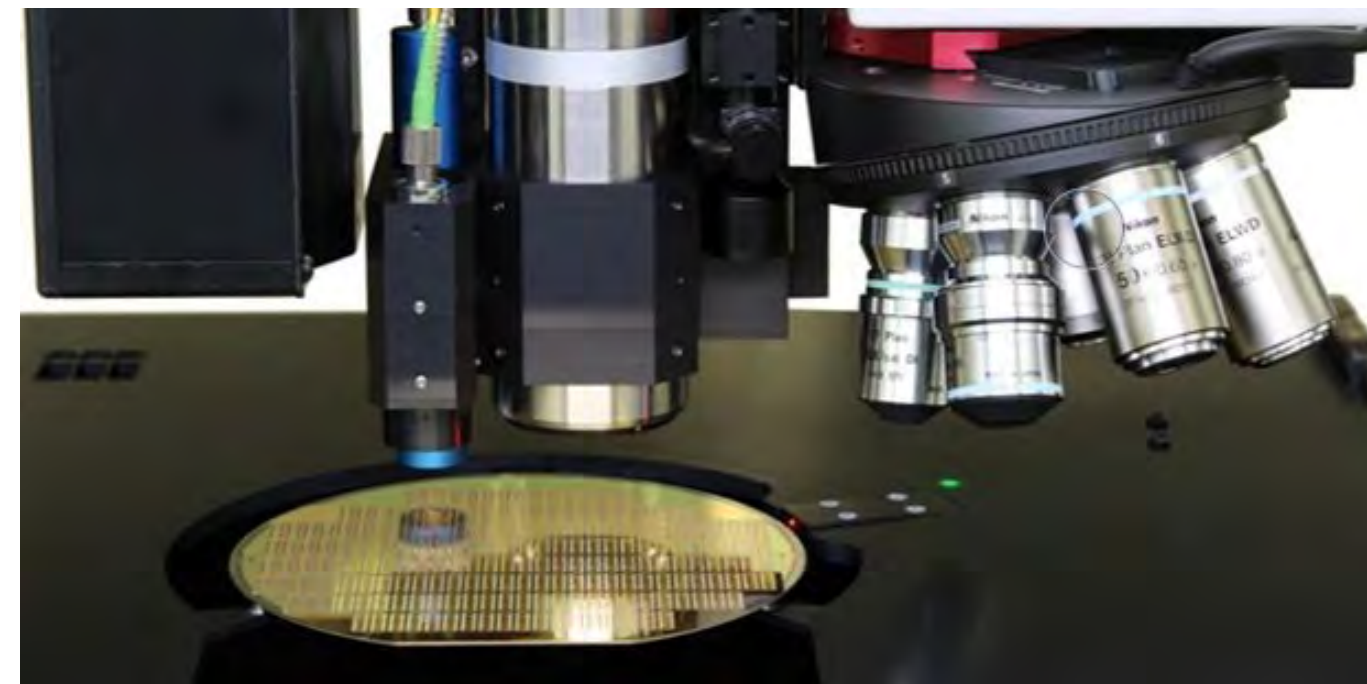
MicroProf® FE



MicroProf® AP

*Fully automated
system for Advanced
Packaging production*

Modular Multi- sensor Configuration



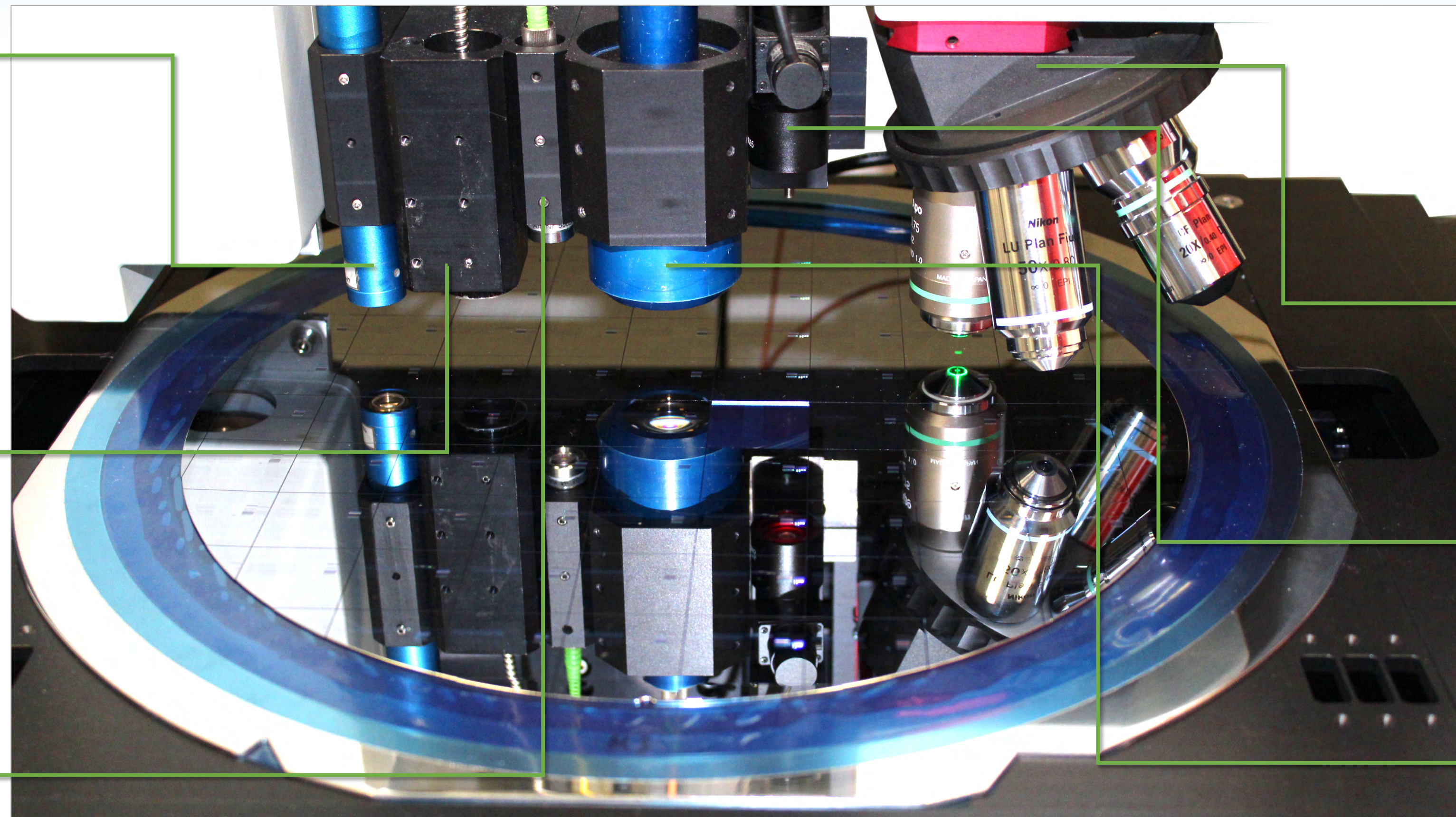
An example of multi-sensor
configuration including topography
point sensors, field of view and film
thickness sensors

SurfaceSens™

CWL sensor for surface
structure evaluation

FTR Thin Film
Reflectometer for film
thickness analysis
down to 20 nm

IRT Infrared Thickness
sensor for wafer
thickness
measurements



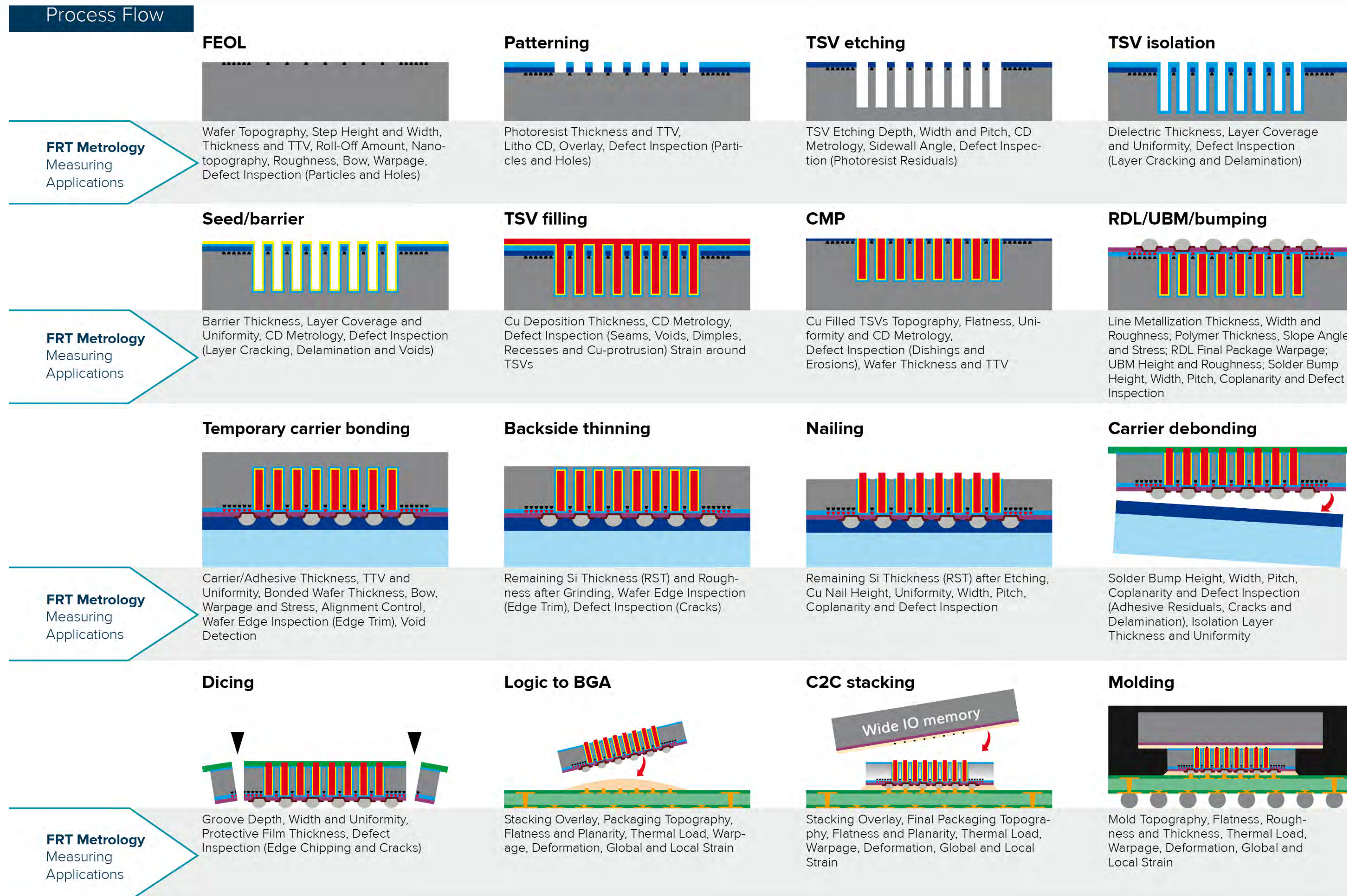
CFM DT confocal
microscope / white
light interferometer for
high resolution

Camera for pattern
recognition of
alignment structures

CWL sensors in TTV setup
(top and bottom sensor)
for TTV, bow, warp
evaluation, e.g. up to 3
mm warp

**Modular optical metrology set-up
for hybrid surface process control**

2.5D/3D IC Packaging Process Flow



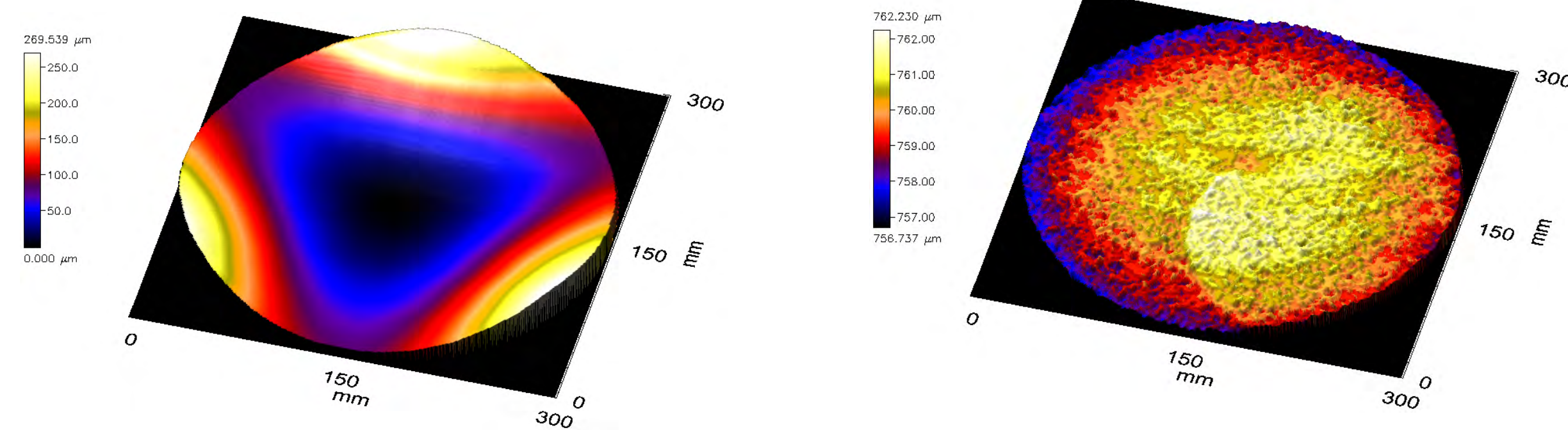
Wafer Geometry – Thickness, TTV, Bow, Warp

- Advanced Packaging Challenge:

- Increasing wafer geometry variation for Advanced Packaging, such as thickness variations and warp post-stack, affect later processes and the device quality

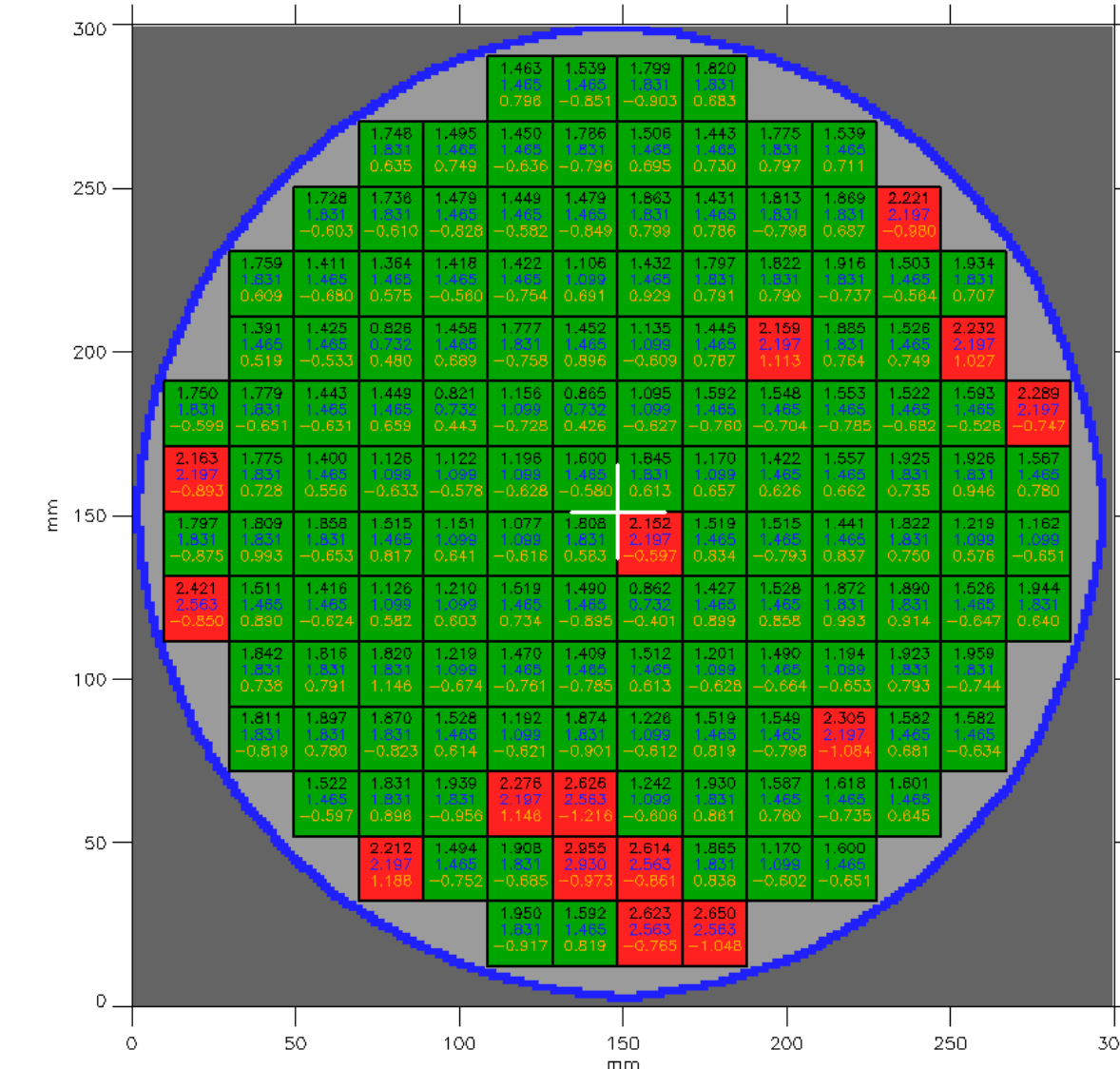
- FRT Solution:

- High-throughput process control of wafer thickness, TTV, bow and warp using MicroProf® TTV with SEMI compliant sensor setup (top and bottom sensor)
- Determination of global wafer parameters with high throughput
- Evaluation of local wafer parameters



Warp / μm	Thickness / μm	TTV / μm
124.47	759.92	4.71

Wafer top topography (left) and thickness (right), showing dimples

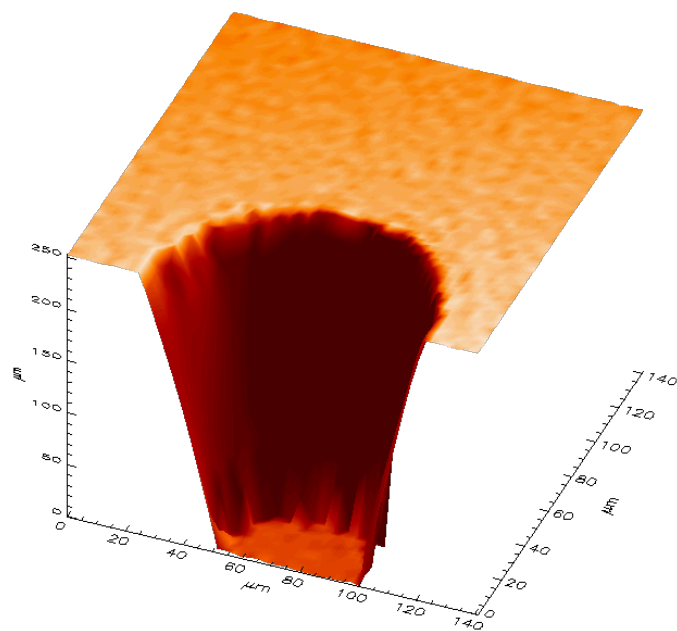


Local wafer parameter map

Etch – Via and Trench Dimensions

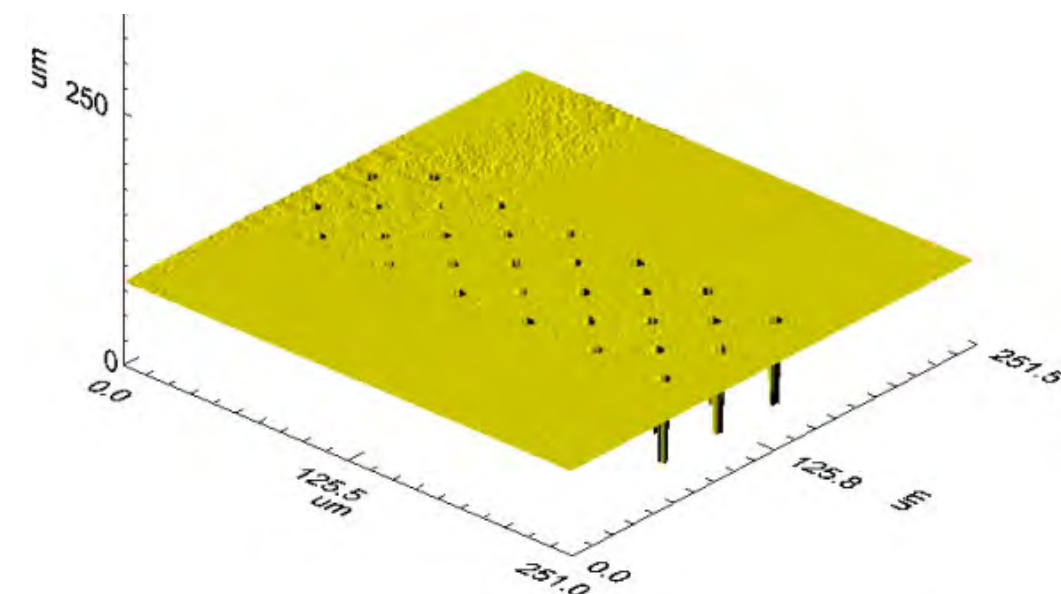
- Advanced Packaging Challenge:
 - Increasing aspect ratio (AR) for vias and trenches process control
- FRT Solution:
 - White light interferometer (WLI) to determine widths and depths

large single via

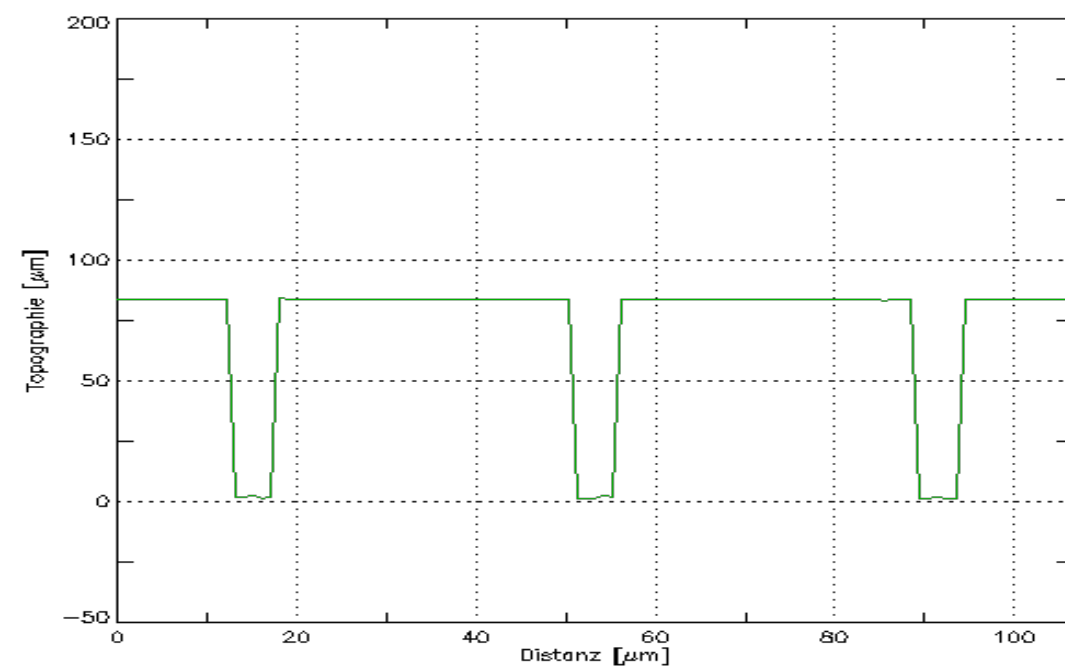


$\varnothing_{\text{top}} \sim 100 \mu\text{m}$
 $\varnothing_{\text{bottom}} \sim 60 \mu\text{m}$
 $t \sim 250 \mu\text{m}$
 $\text{AR} \sim 2.5:1$

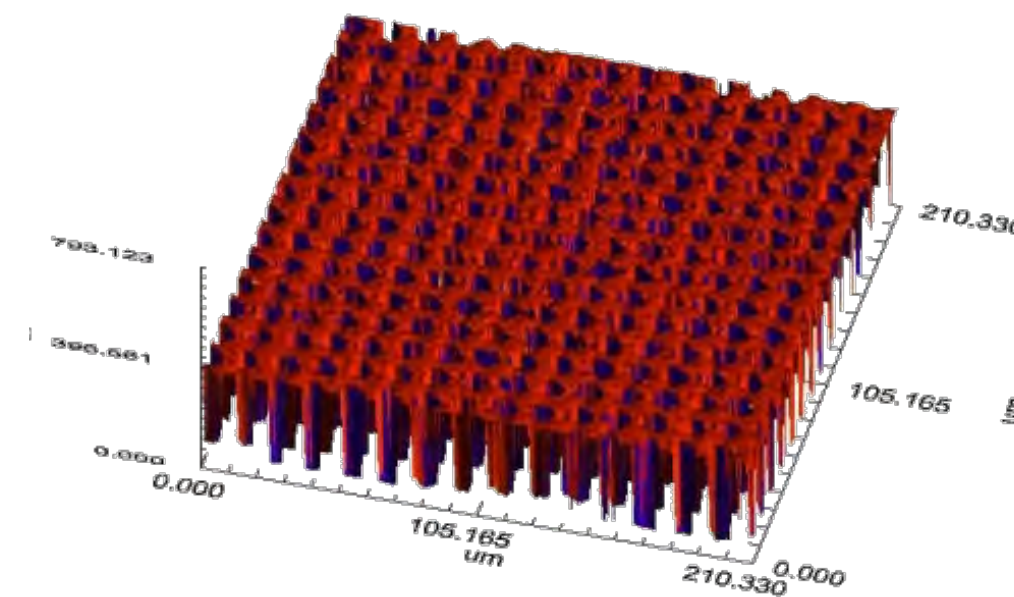
small via array



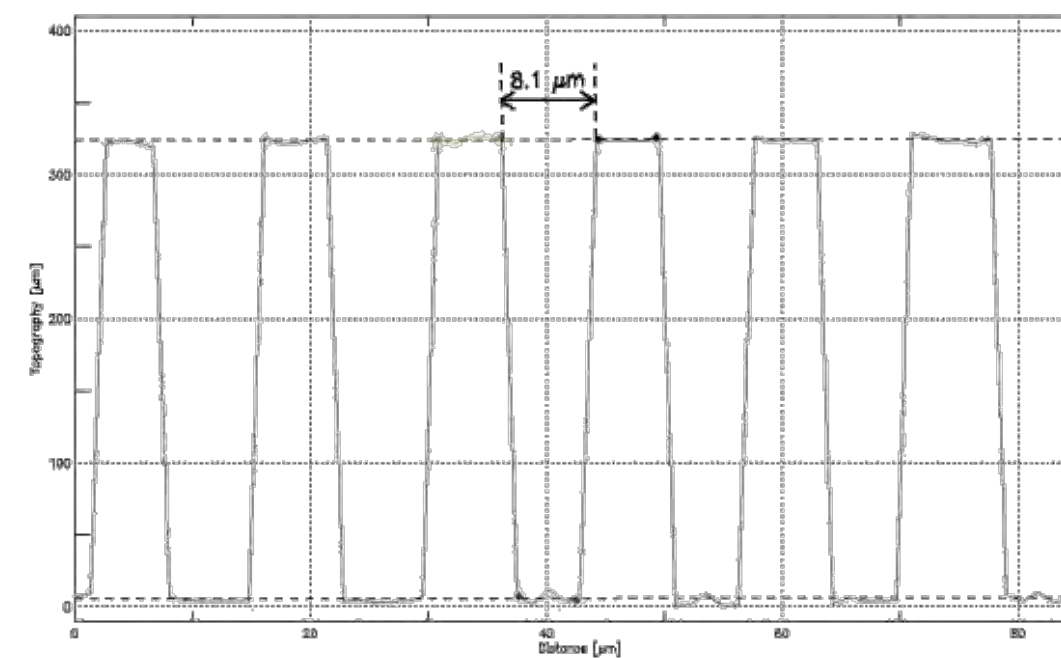
$\varnothing \sim 5 \mu\text{m}$, $t \sim 70 \mu\text{m}$, $\text{AR} \sim 15:1$



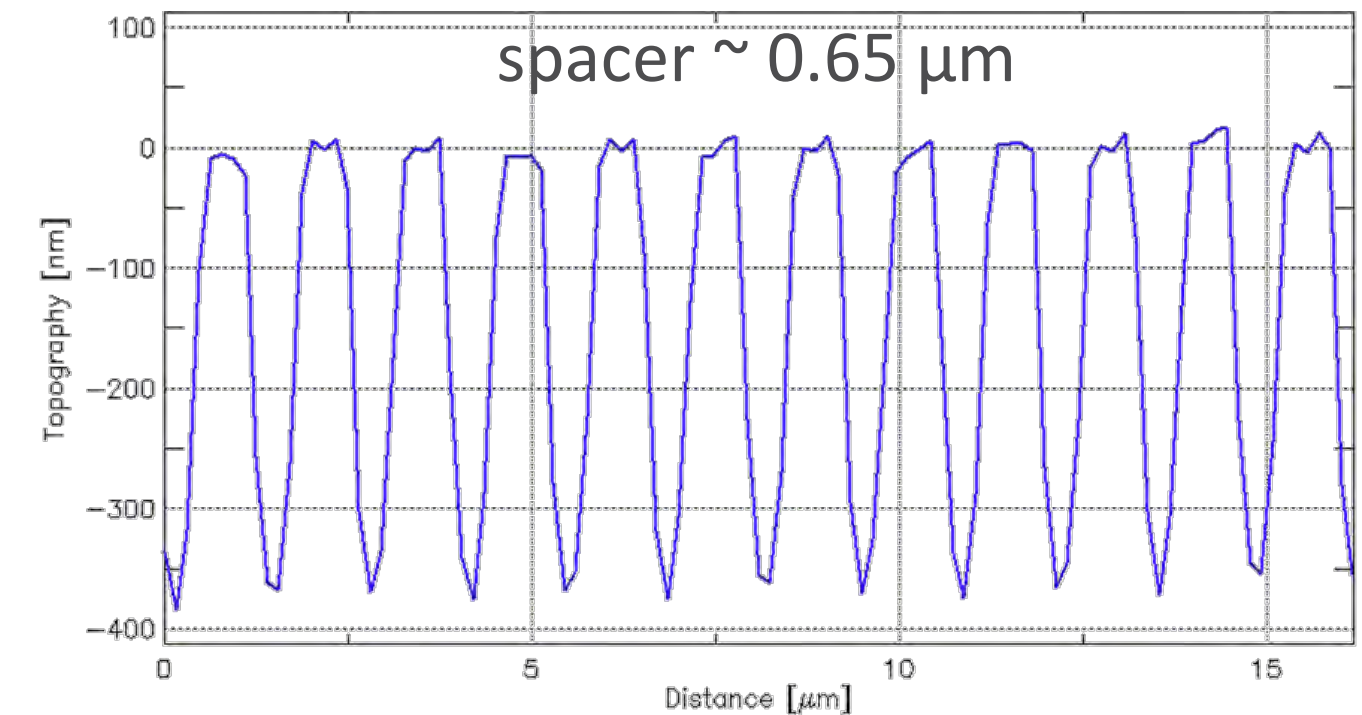
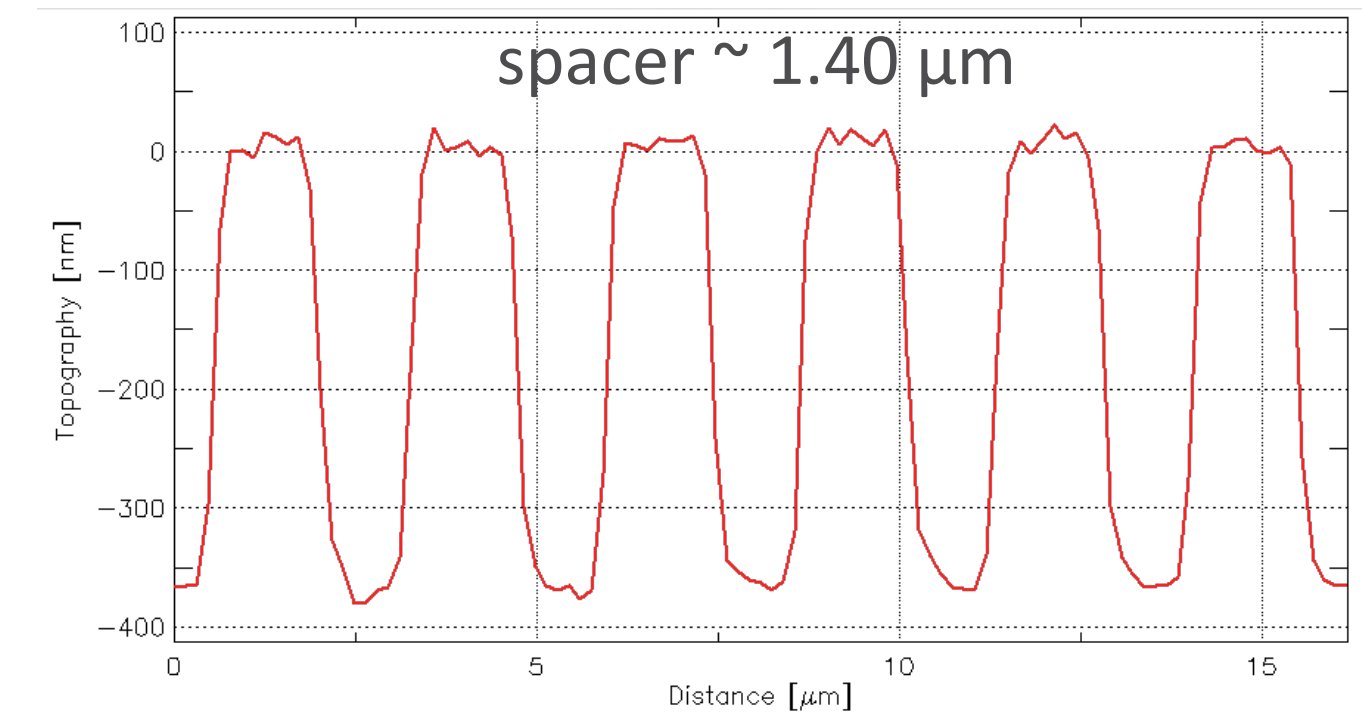
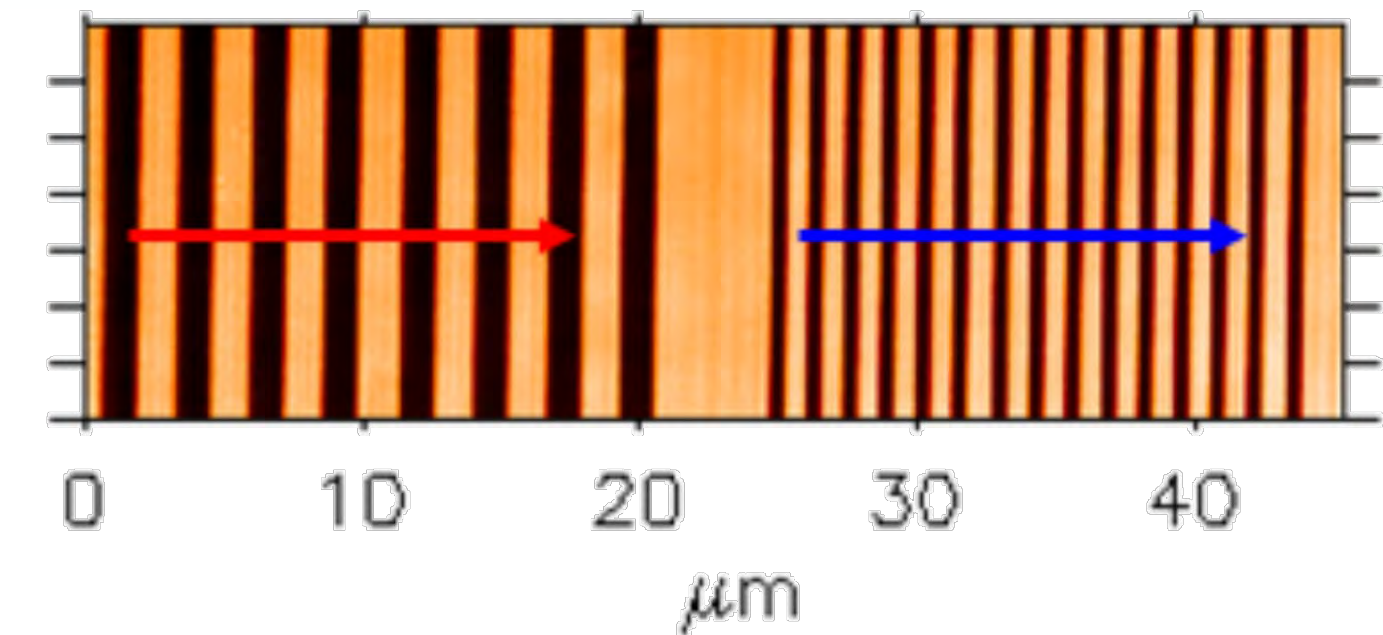
high AR via



$\varnothing \sim 8 \mu\text{m}$, $t \sim 320 \mu\text{m}$, $\text{AR} \sim 40:1$

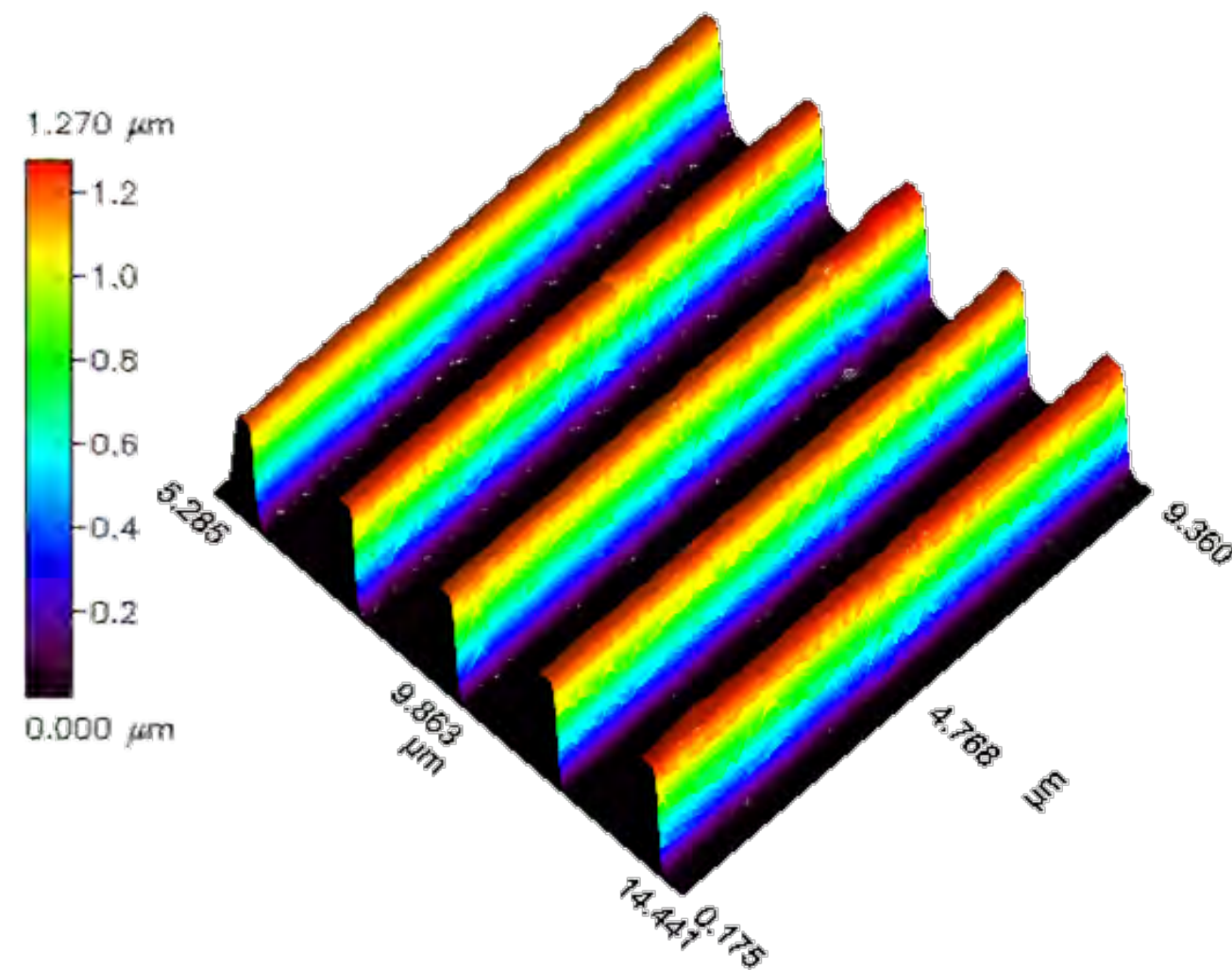
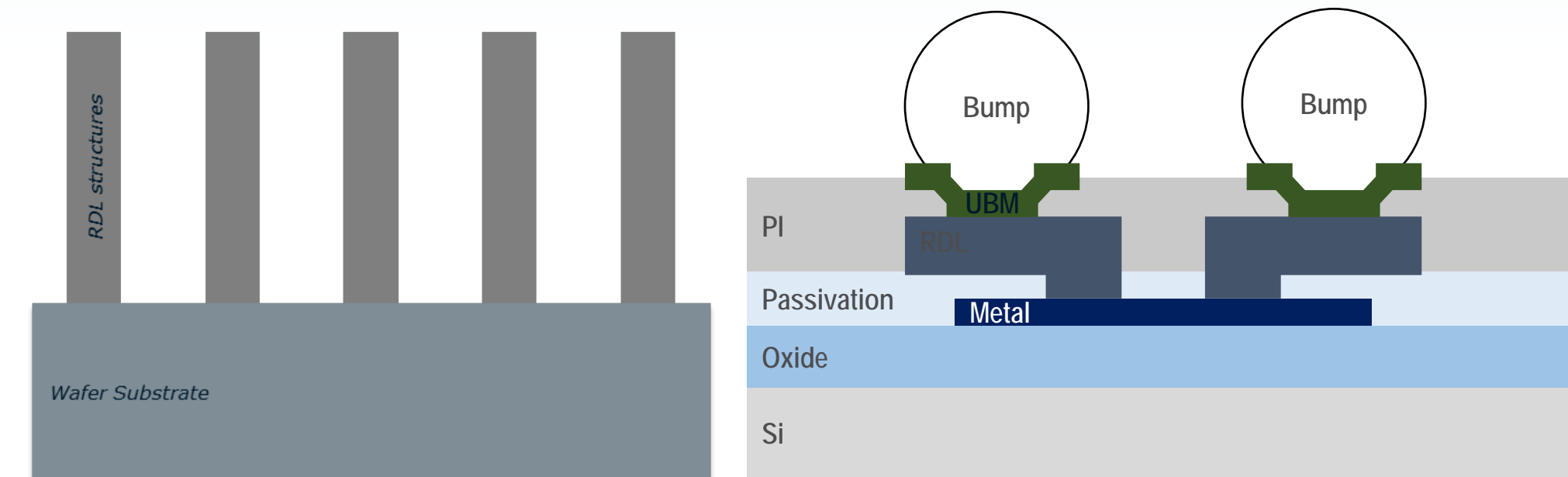


Trench depth 370 ~ 400 nm

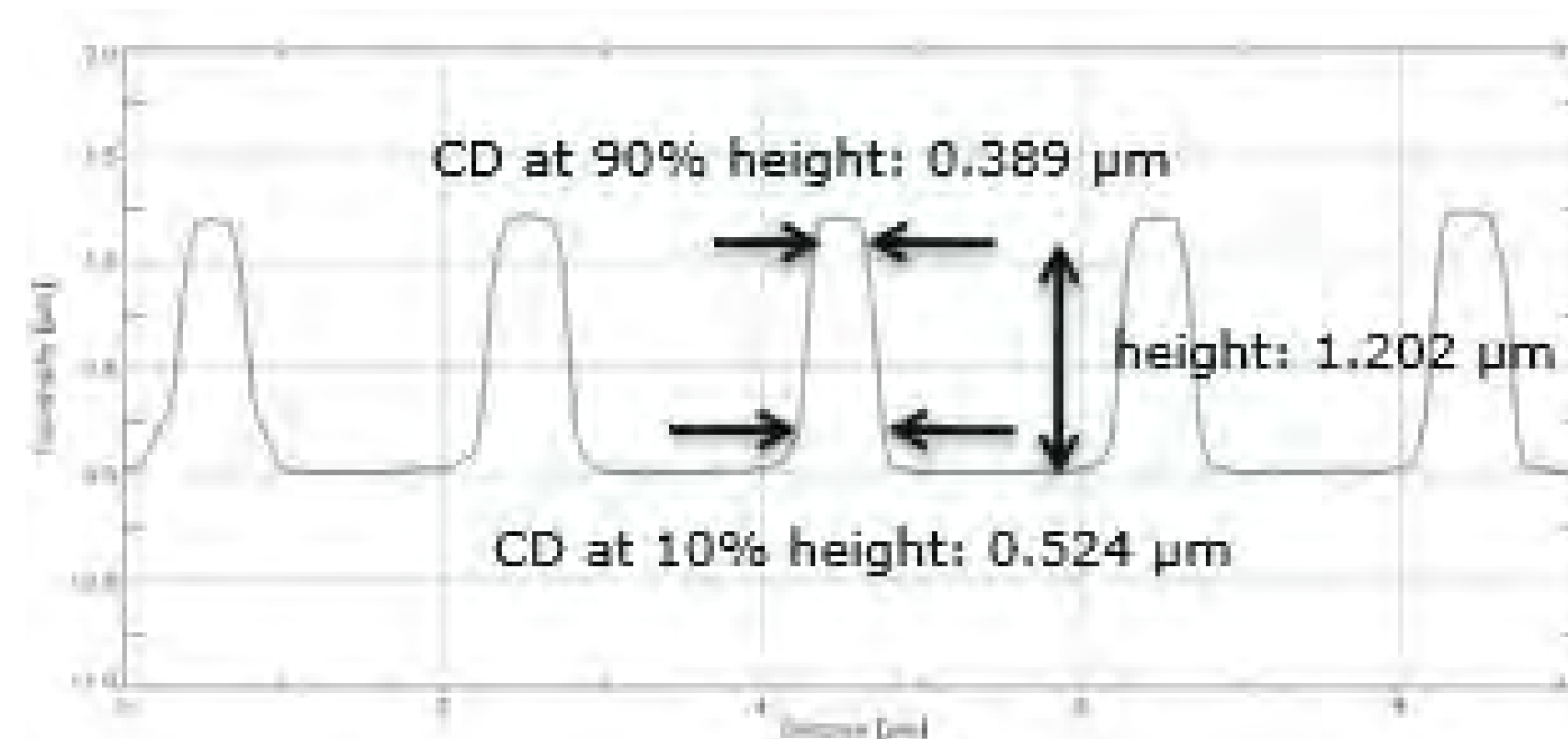


RDL Width and Height

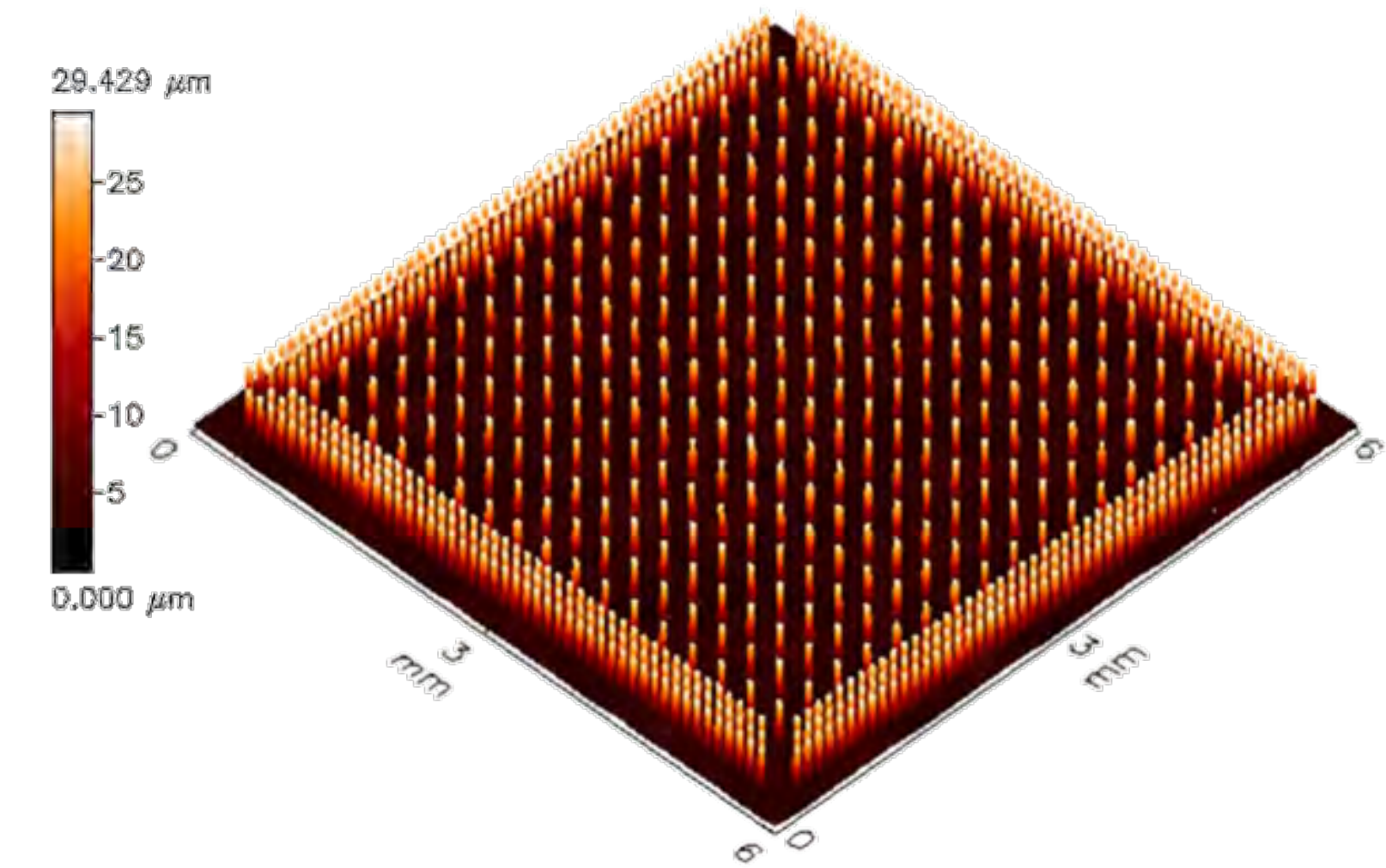
- Advanced Packaging Challenge:
 - High-precision and high-throughput micron-level process control of RDLs
- FRT Solution:
 - Evaluation of RDL height and width using WLI with optimized setup for high resolution
 - Repeatability of RDL width $< 0.01 \mu\text{m}$
 - Monitoring of bump heights, widths, pitch and coplanarity according to JESD22-B108



Topography map of RDL structures



RDL topography profile



Bump measurement of full die

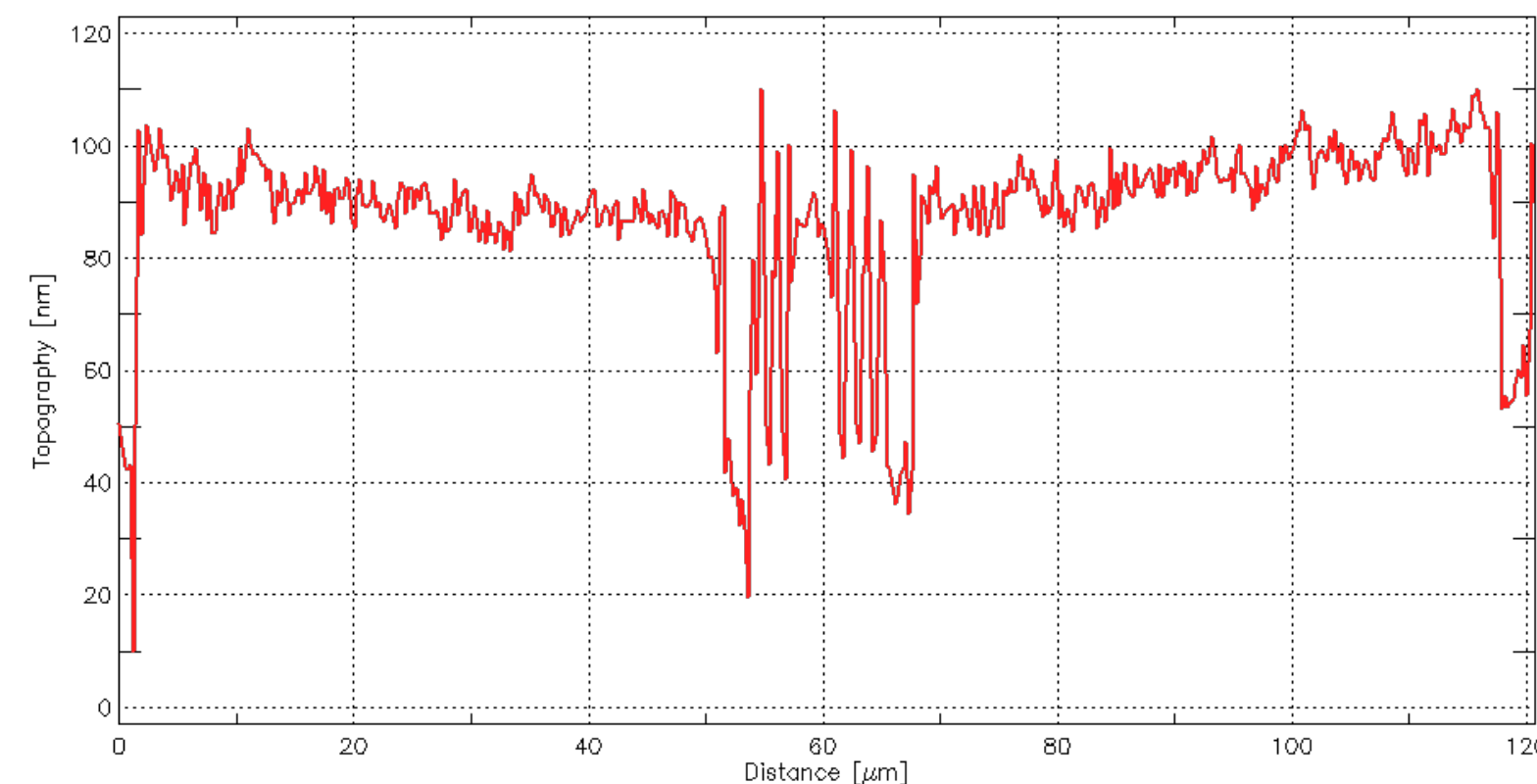
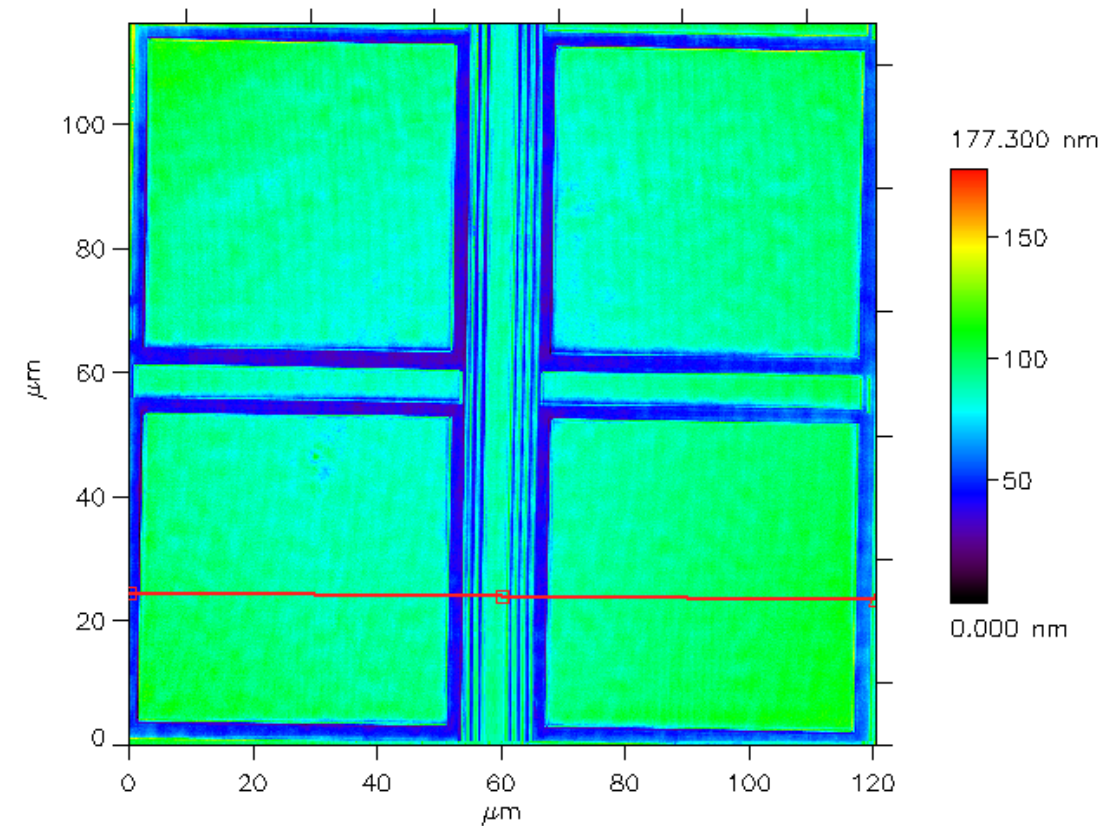
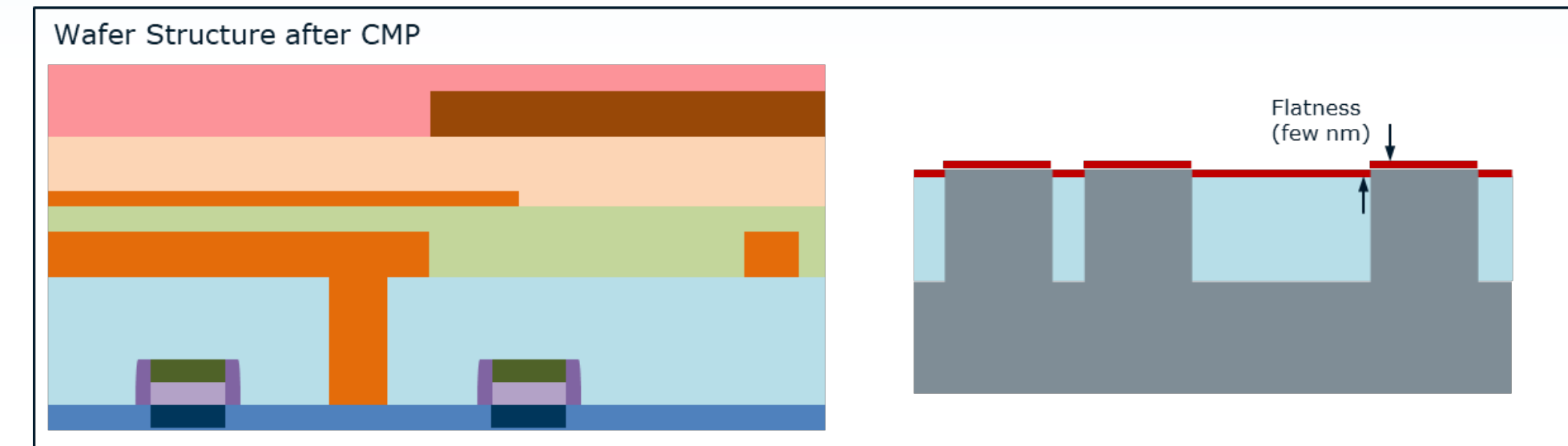
CMP Die and Wafer Flatness

- Advanced Packaging Challenge:

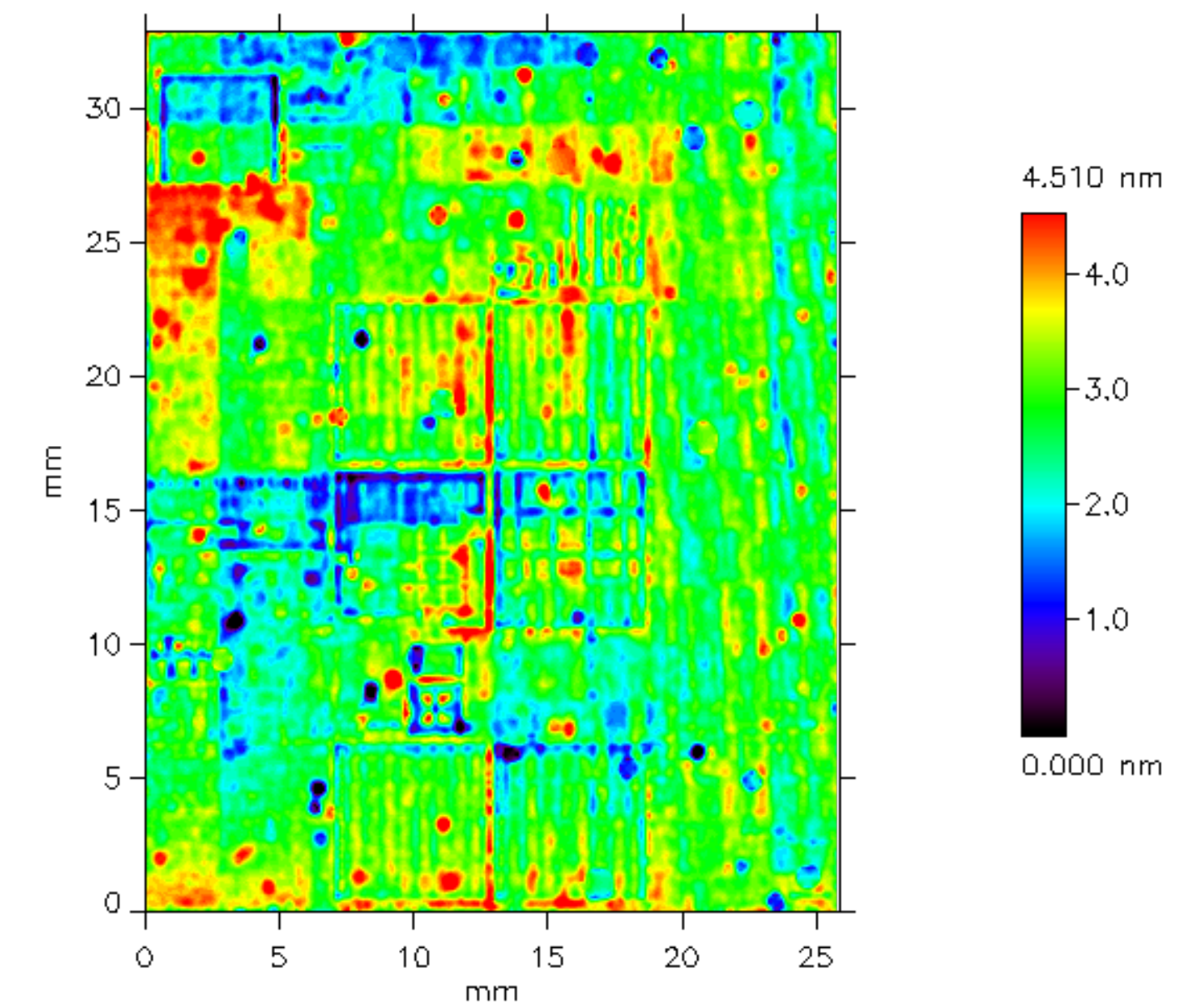
- Detrimental surface irregularities post-CMP with increasing number of layers and process steps, resulting in electrical defects of chips and reduced wafer yield

- FRT Solution:

- New capability to evaluate die areas up to 25 mm x 35 mm per full shot
- Z-resolution of 0.1 nm
- Measurement time ~0.5 h per full shot, with roadmap to higher throughput for HVM
- Image stitching and big data processing



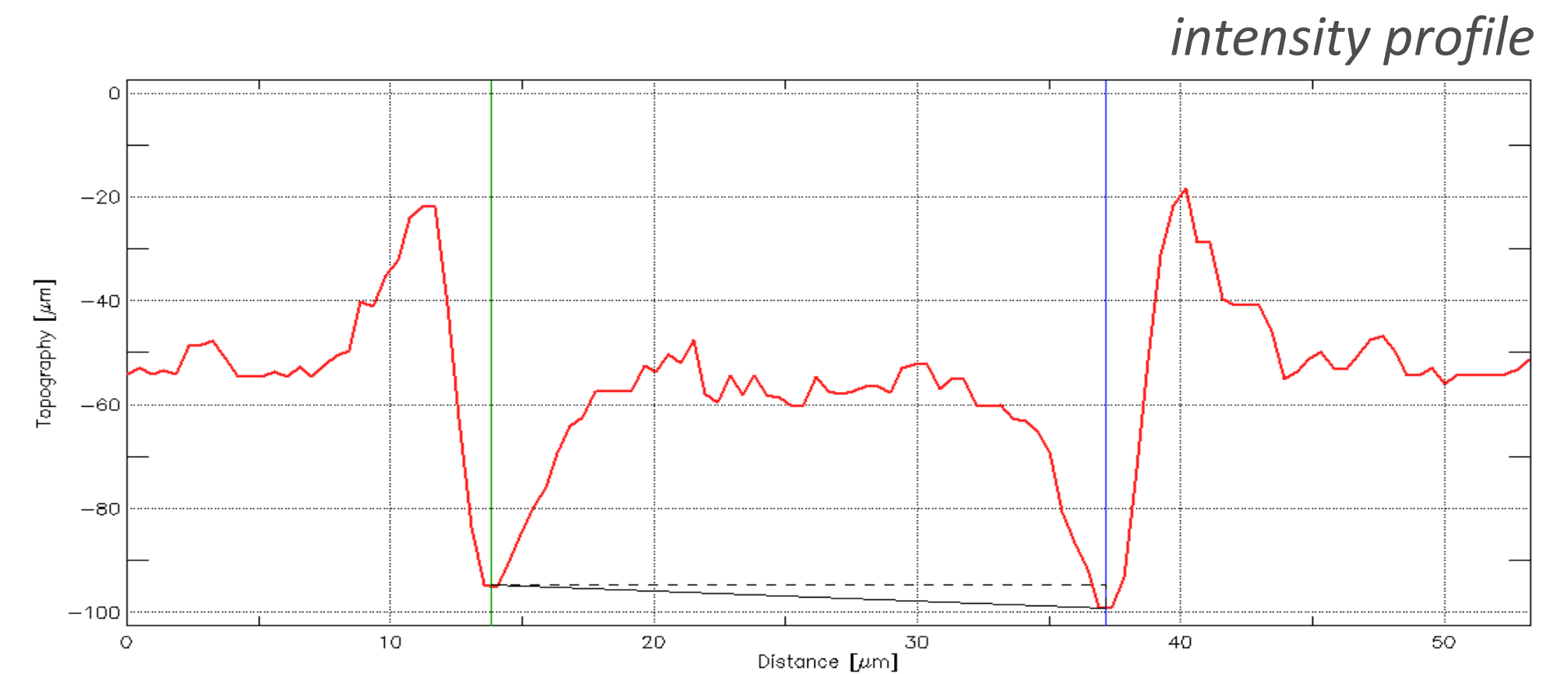
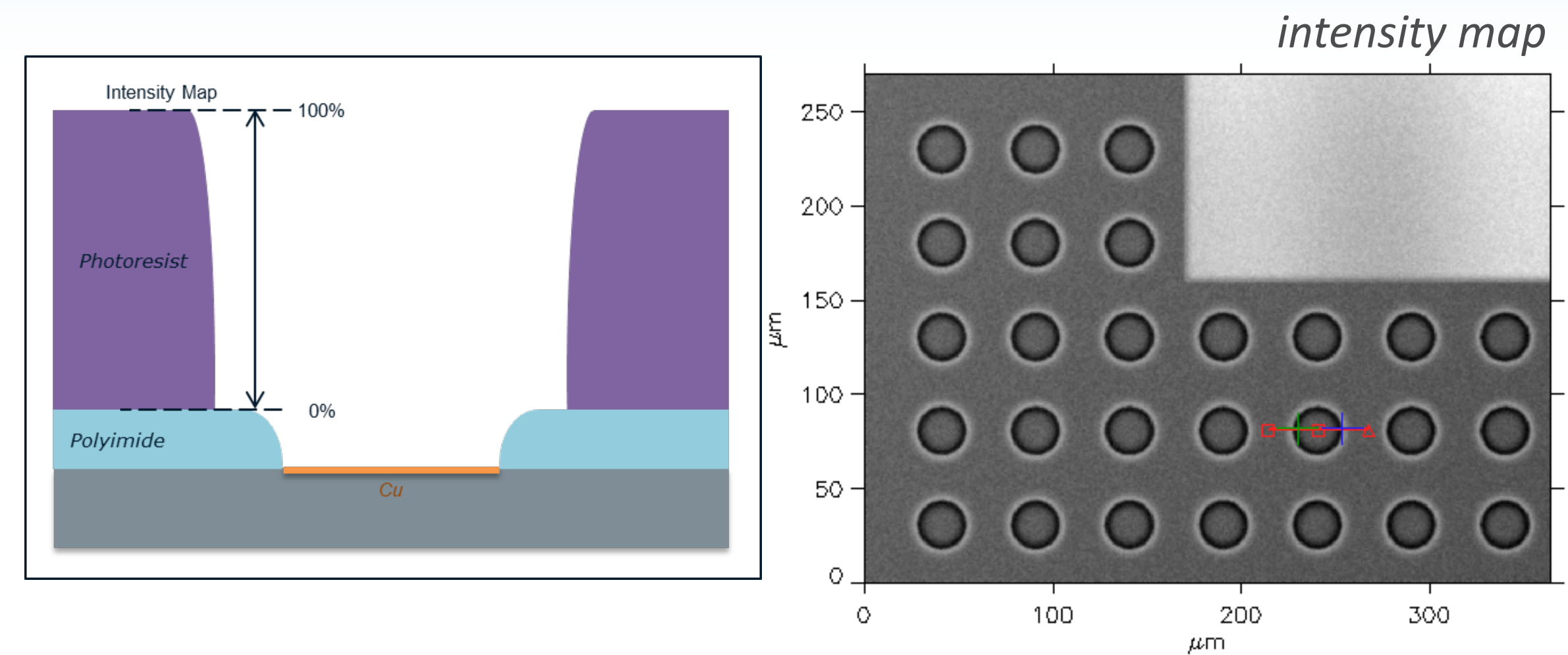
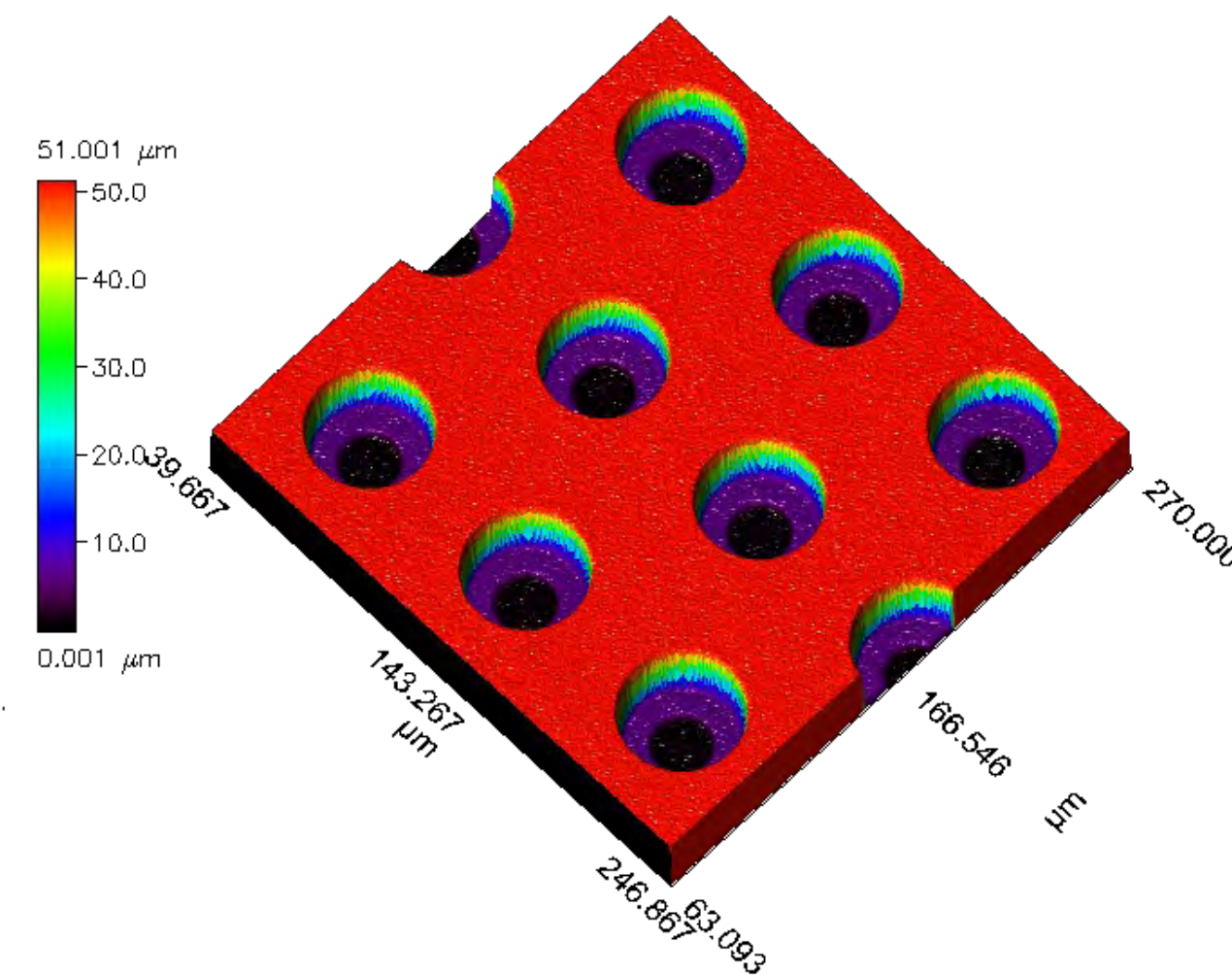
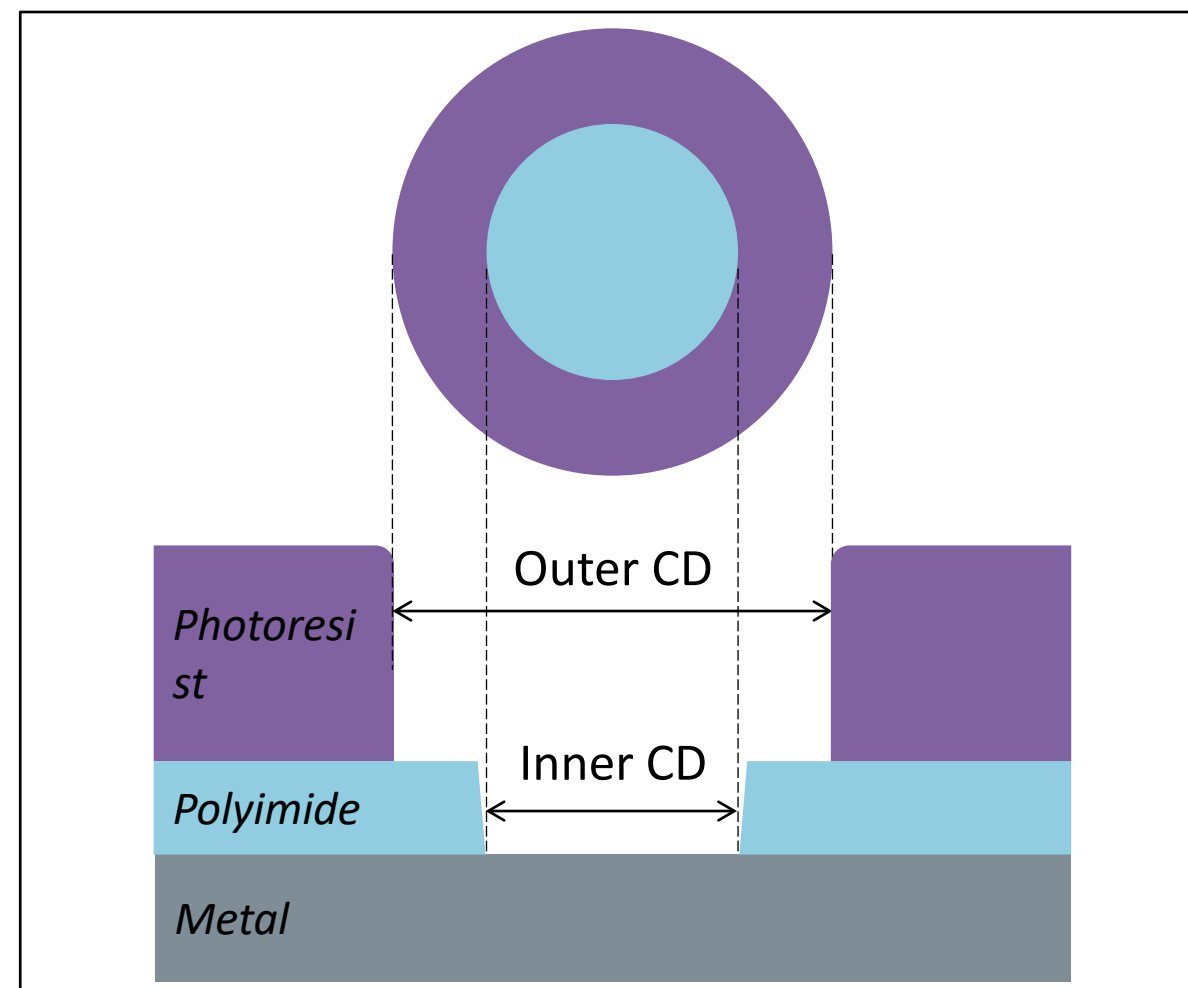
High resolution mapping (left) and profile (right) of single pad flatness



Full shot flatness map

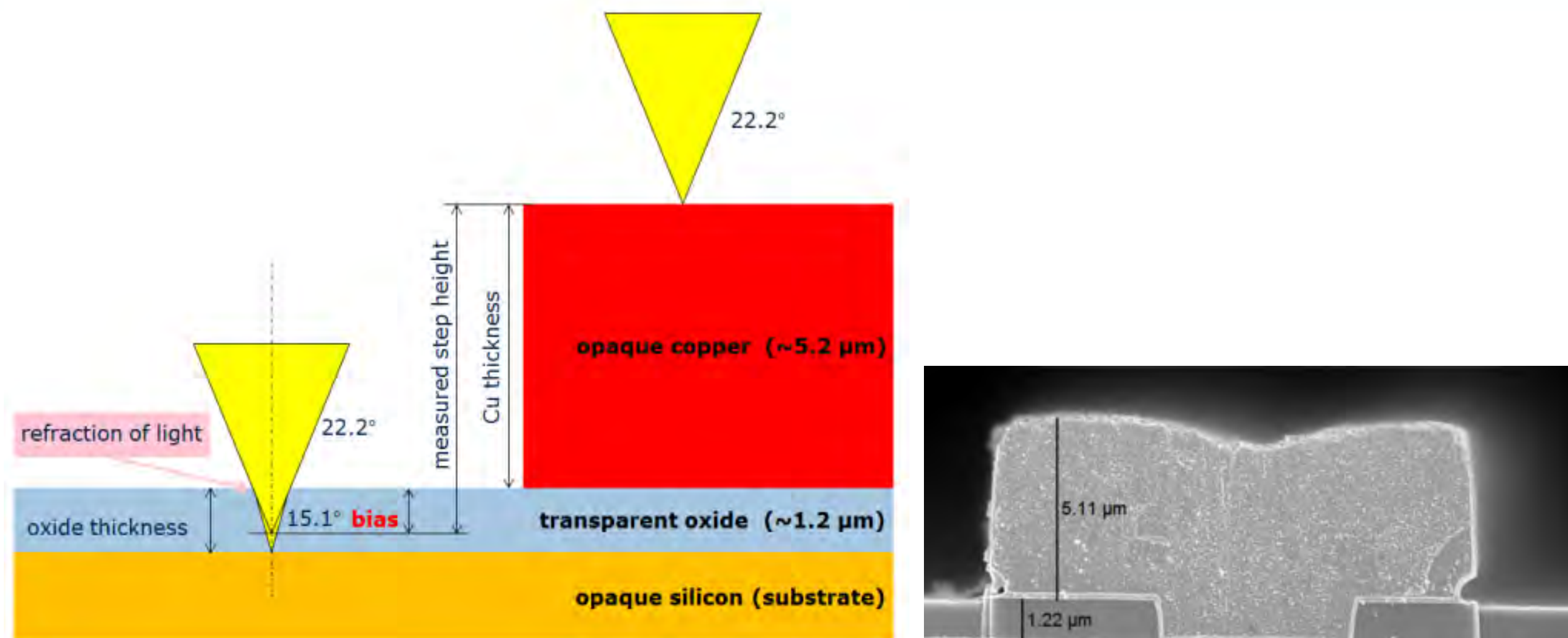
Critical Dimension and Overlay

- Advanced Packaging Challenge:
 - Low CoO monitoring of micro-level CD and overlay
- FRT Solution:
 - Measurement with confocal microscope (CFM DT)
 - CD and OVL analysis

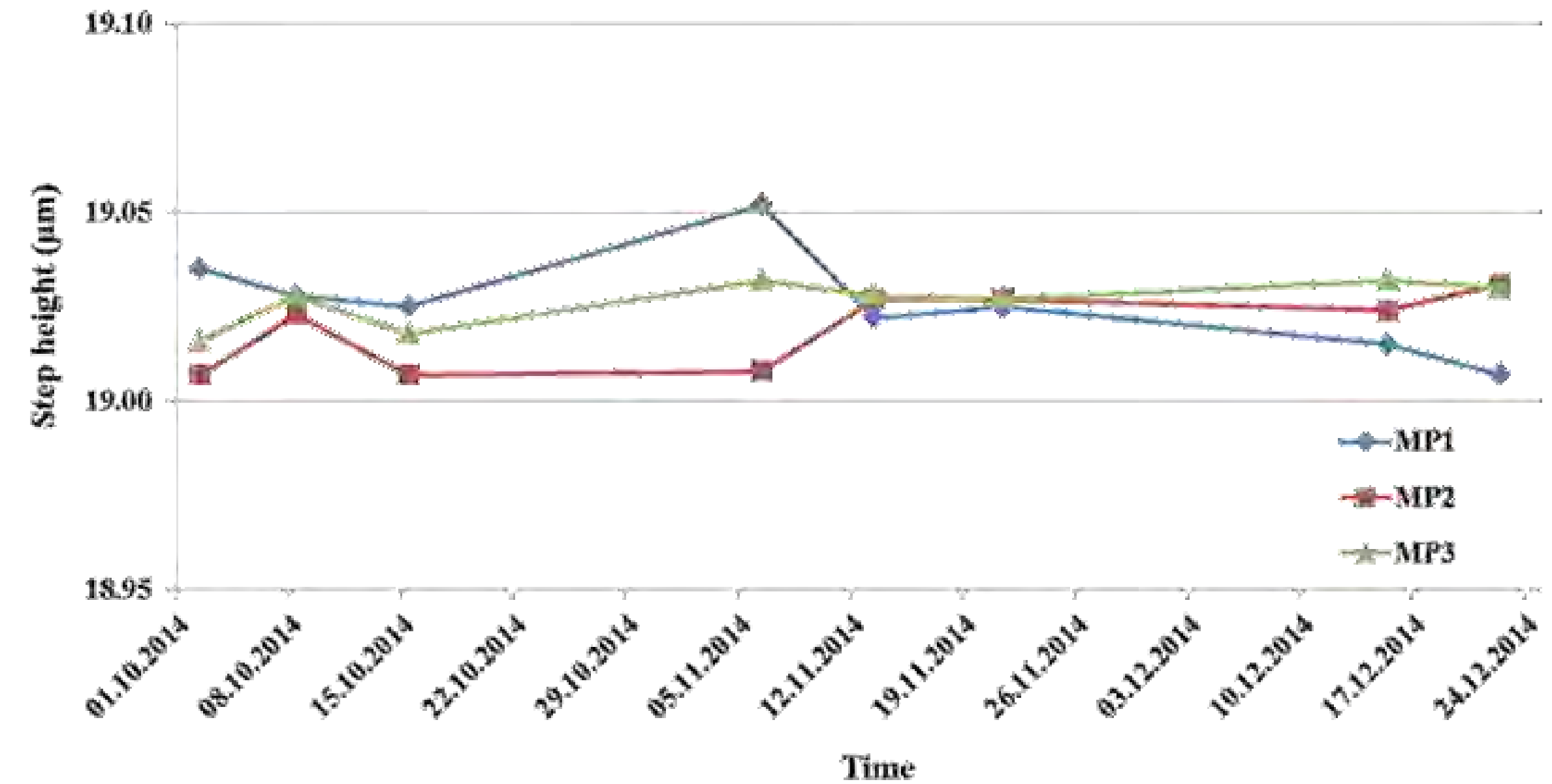
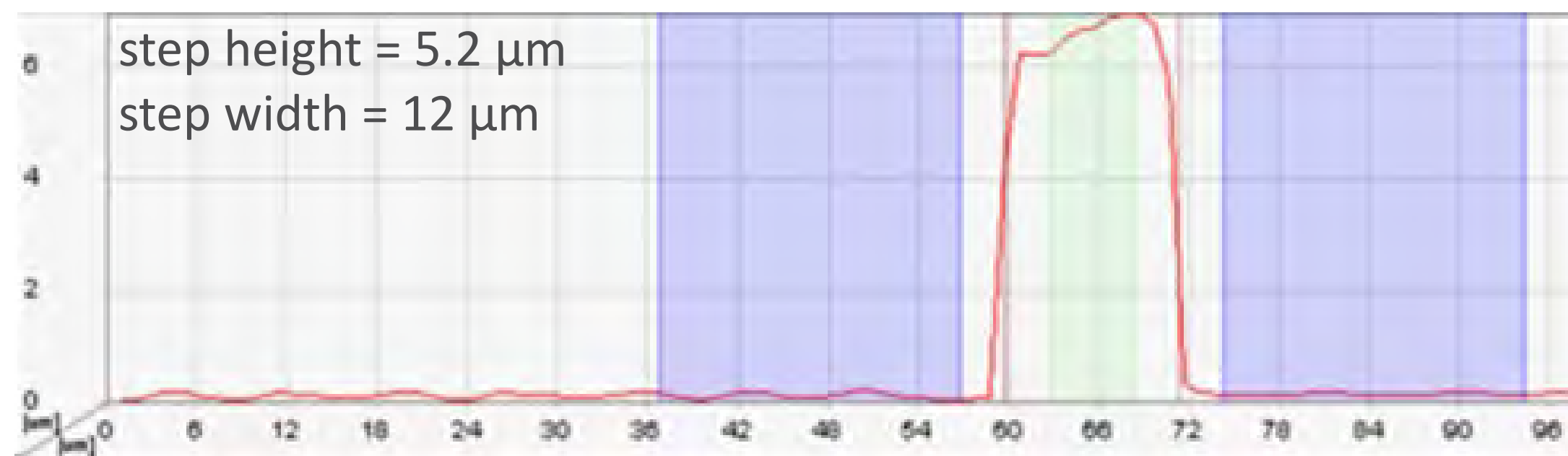


CD and overlay measurement with CFM

Production Case Study: Repeatability of Step Height/Width



Determination with Hybrid Metrology



standard deviation for 12 weeks
dynamic repeatability test: $\sigma = 9 \text{ nm}$ (0.17 %)

Conclusion

- FRT is a leader in surface metrology solutions for Advanced Packaging applications
- We provide the lowest cost of measurements for new heterogenous integration manufacturing processes.
- Our SurfaceSens™ multi sensor technology provides a very flexible system serving R&D as well as high throughput fully automated measurement for production.
- FRT today covers the advanced packaging industry with 40 to 90um pitch in main stream manufacturing.
- Together with leading customers we are developing next generation 20um pitch and below.



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THANK YOU

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