

FRT METROLOGY FOR ADVANCED PACKAGING

Kenan Görgülü Head of Sales & Business development - FRT Metrology

FormFactor FRT Metrology

TECHNOLOGY

- Leader in Optical Surface Metrology and Inspection
- SurfaceSensh 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



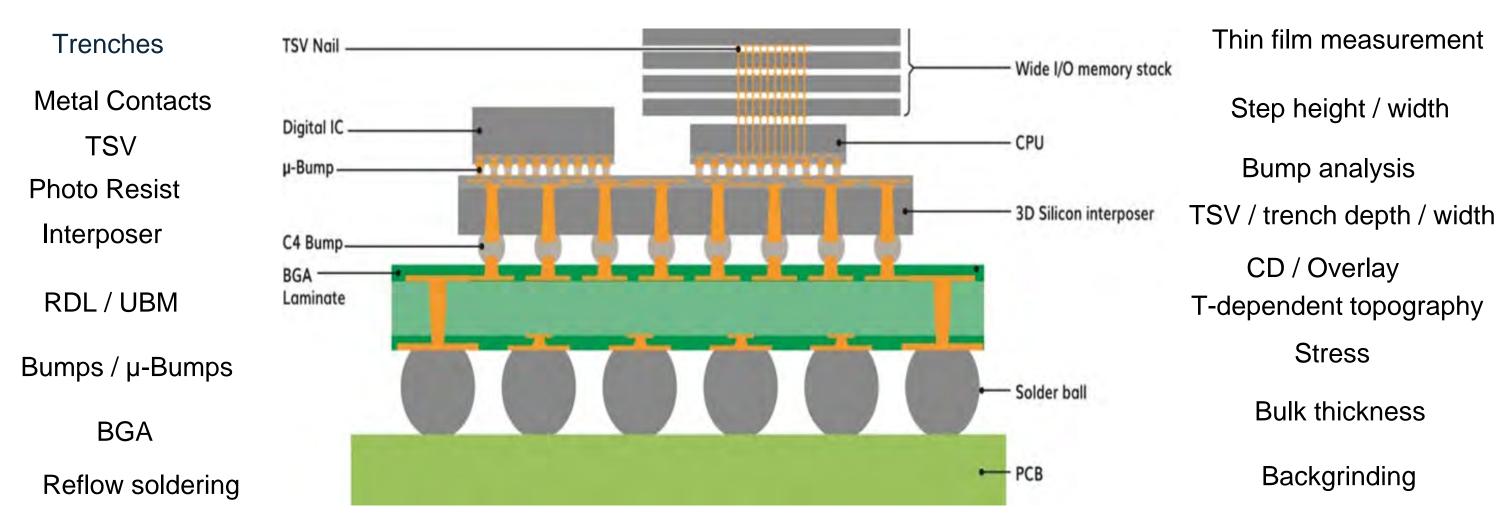
FRT: Enabling the ASAP Metrology Roadmap

- 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 heterogenous 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)





Applications in Advanced Packaging



FRT: Scalable Platform with SurfaceSensTM

Standardized
System Platform



MicroProf® 300



MicroProf® MHU



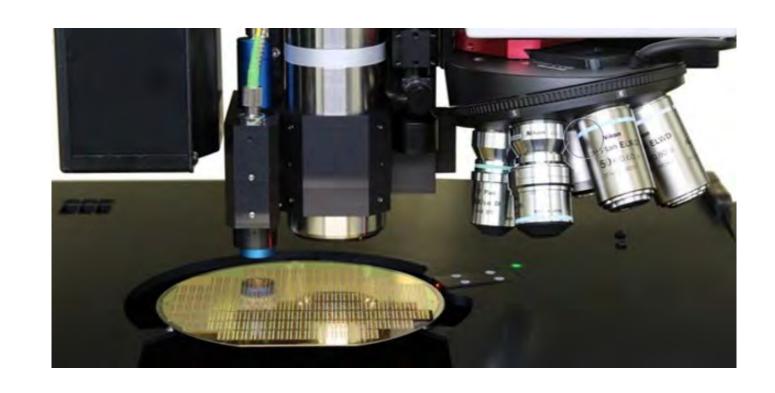
MicroProf® FE



Fully automated

system for Advanced Packaging production

Modular Multisensor Configuration



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

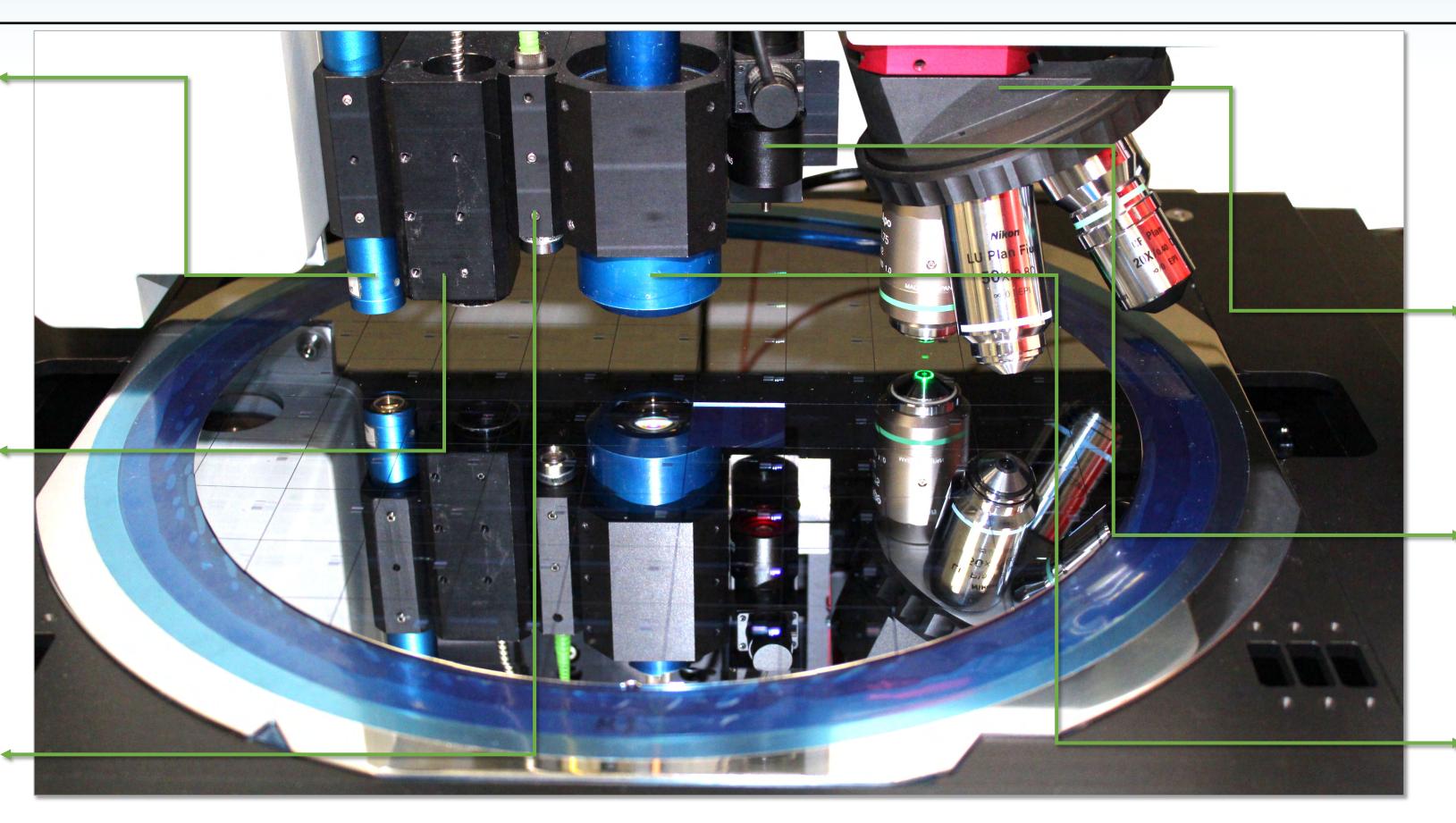


SurfaceSensTM

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



Modular optical metrology set-up for hybrid surface process control

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



2.5D/3D IC Packaging Process Flow

Process Flow

FEOL

.....

FRT Metrology
Measuring
Applications

FRT Metrology

FRT Metrology

Measuring

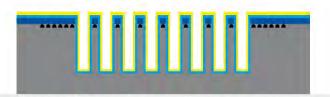
Applications

Measuring

Applications

Wafer Topography, Step Height and Width, Thickness and TTV, Roll-Off Amount, Nanotopography, Roughness, Bow, Warpage, Defect Inspection (Particles and Holes)

Seed/barrier



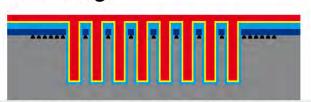
Barrier Thickness, Layer Coverage and Uniformity, CD Metrology, Defect Inspection (Layer Cracking, Delamination and Voids)

Patterning



Photoresist Thickness and TTV, Litho CD, Overlay, Defect Inspection (Particles and Holes)

TSV filling



Cu Deposition Thickness, CD Metrology, Defect Inspection (Seams, Voids, Dimples, Recesses and Cu-protrusion) Strain around TSVs

TSV etching



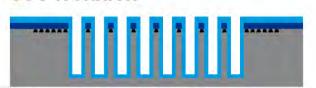
TSV Etching Depth, Width and Pitch, CD Metrology, Sidewall Angle, Defect Inspection (Photoresist Residuals)

CMP



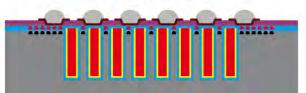
Cu Filled TSVs Topography, Flatness, Uniformity and CD Metrology,
Defect Inspection (Dishings and
Erosions), Wafer Thickness and TTV

TSV isolation



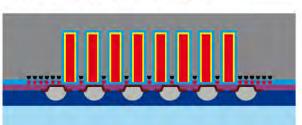
Dielectric Thickness, Layer Coverage and Uniformity, Defect Inspection (Layer Cracking and Delamination)

RDL/UBM/bumping



Line Metallization Thickness, Width and Roughness; Polymer Thickness, Slope Angle and Stress; RDL Final Package Warpage; UBM Height and Roughness; Solder Bump Height, Width, Pitch, Coplanarity and Defect Inspection

Temporary carrier bonding



Carrier/Adhesive Thickness, TTV and Uniformity, Bonded Wafer Thickness, Bow, Warpage and Stress, Alignment Control, Wafer Edge Inspection (Edge Trim), Void Detection

Backside thinning



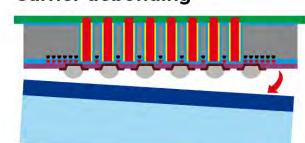
Remaining Si Thickness (RST) and Roughness after Grinding, Wafer Edge Inspection (Edge Trim), Defect Inspection (Cracks)

Nailing



Remaining Si Thickness (RST) after Etching, Cu Nail Height, Uniformity, Width, Pitch, Coplanarity and Defect Inspection

Carrier debonding



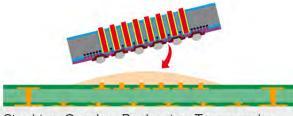
Solder Bump Height, Width, Pitch,
Coplanarity and Defect Inspection
(Adhesive Residuals, Cracks and
Delamination), Isolation Layer
Thickness and Uniformity

Dicing



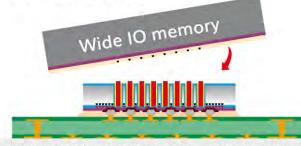
Protective Film Thickness, Defect
Inspection (Edge Chipping and Cracks)

Logic to BGA



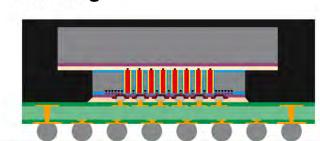
Stacking Overlay, Packaging Topography, Flatness and Planarity, Thermal Load, Warpage, Deformation, Global and Local Strain

C2C stacking



Stacking Overlay, Final Packaging Topography, Flatness and Planarity, Thermal Load, Warpage, Deformation, Global and Local Strain

Molding



Mold Topography, Flatness, Roughness and Thickness, Thermal Load, Warpage, Deformation, Global and Local Strain

FRT Metrology
Measuring
Applications



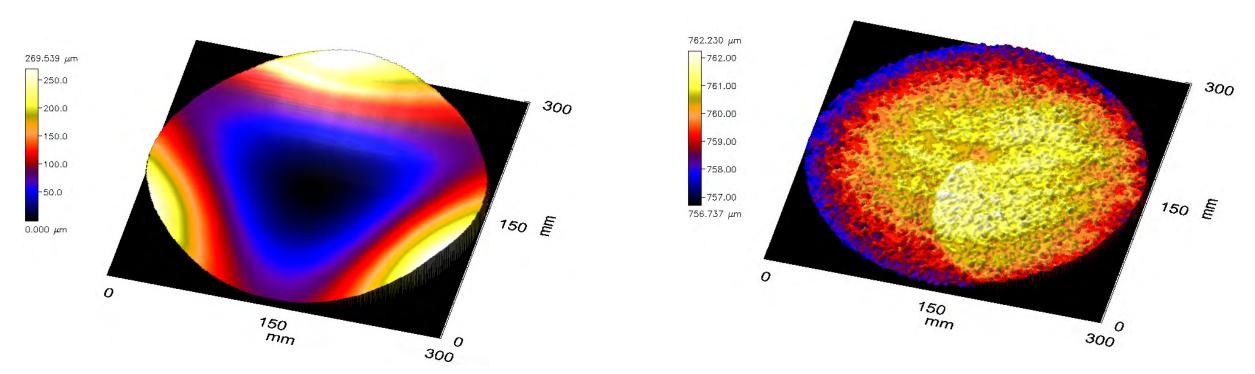
Wafer Geometry – Thickness, TTV, Bow, Warp

Advanced Packaging Challenge:

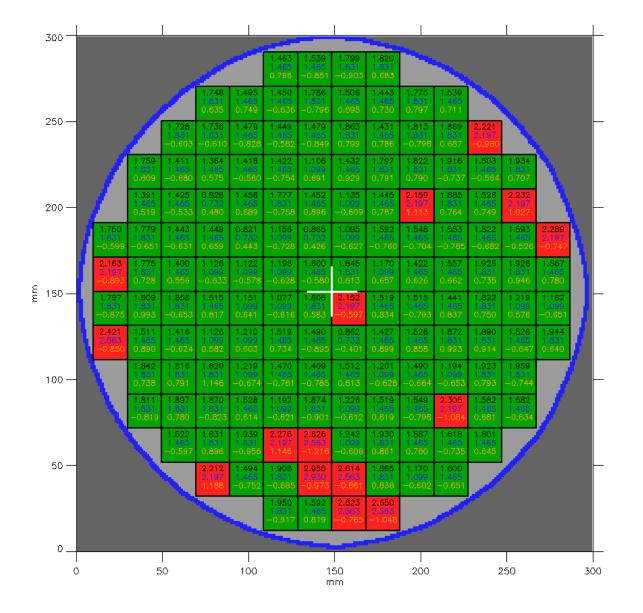
• Increasing wafer geometry variation for Advanced Packaging, such as thickness variations and warp post-stack, affect later processes and the device quality

• 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



Local wafer parameter map

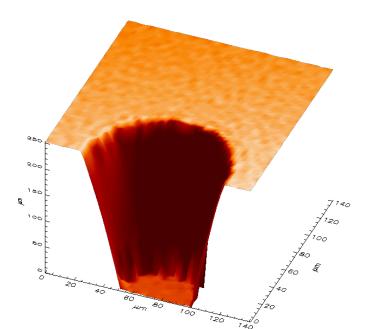
Wafer top topography (left) and thickness (right), showing dimples



Etch – Via and Trench Dimensions

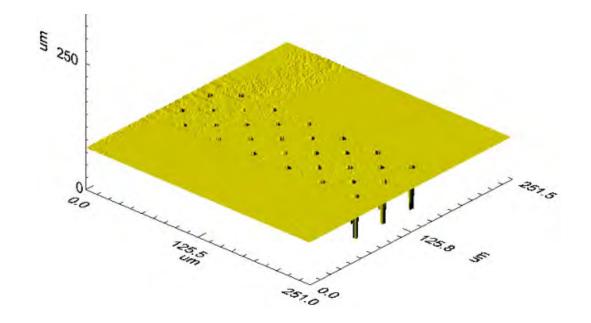
- Advanced Packaging Challenge:
 - Increasing aspect ratio (AR) for vias and trenches process control
- FRT Solution:
 - White light interferometer (WLI) to determine widths and depths

large single via

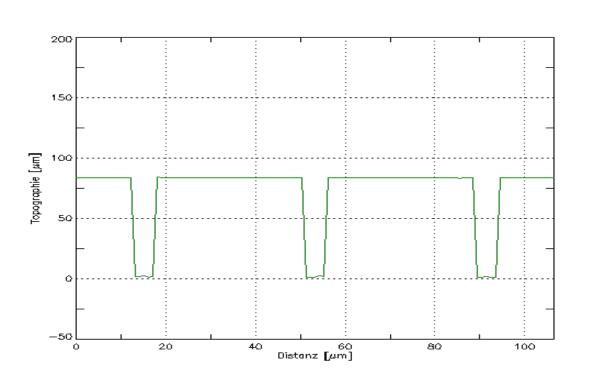


 \emptyset_{top} ~ 100 μm \emptyset_{bottom} ~ 60 μm t ~ 250 μm AR ~ 2.5:1

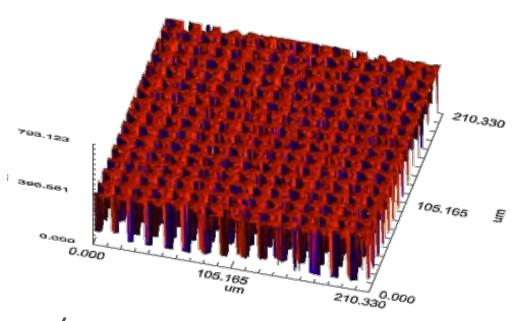
small via array



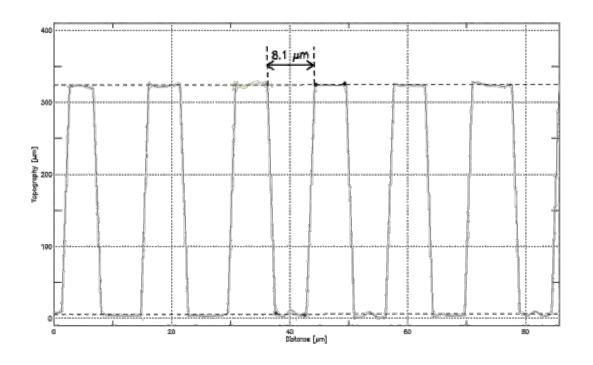
 $\emptyset \sim 5 \mu m$, t $\sim 70 \mu m$, AR $\sim 15:1$

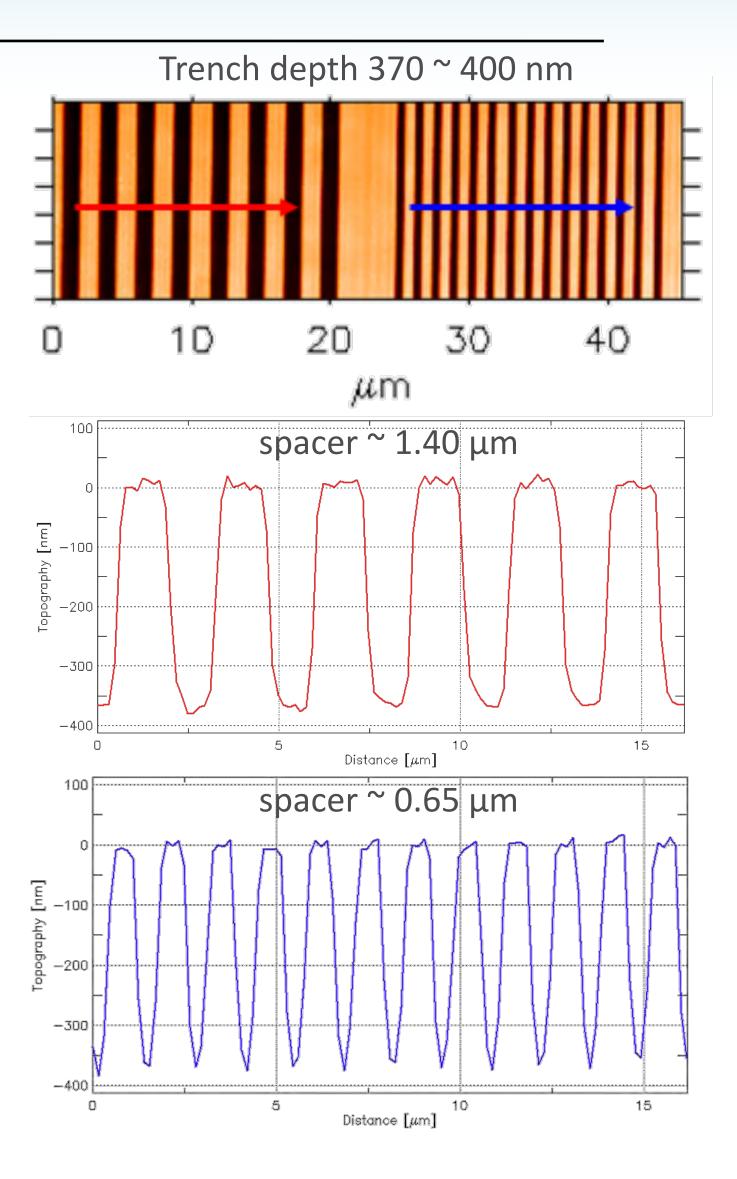


high AR via



 \emptyset ~ 8 μ m, t ~ 320 μ m, AR~ 40:1

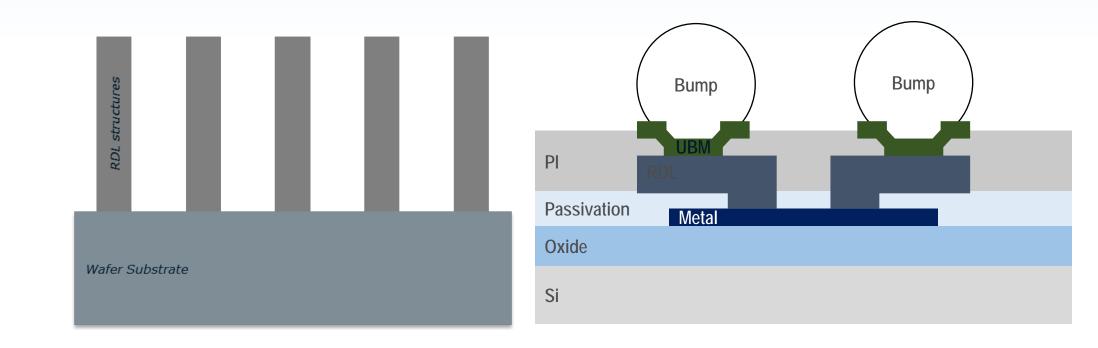


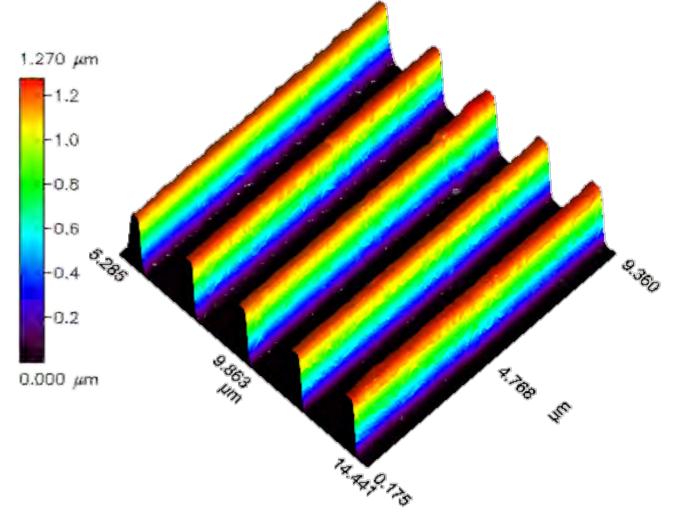




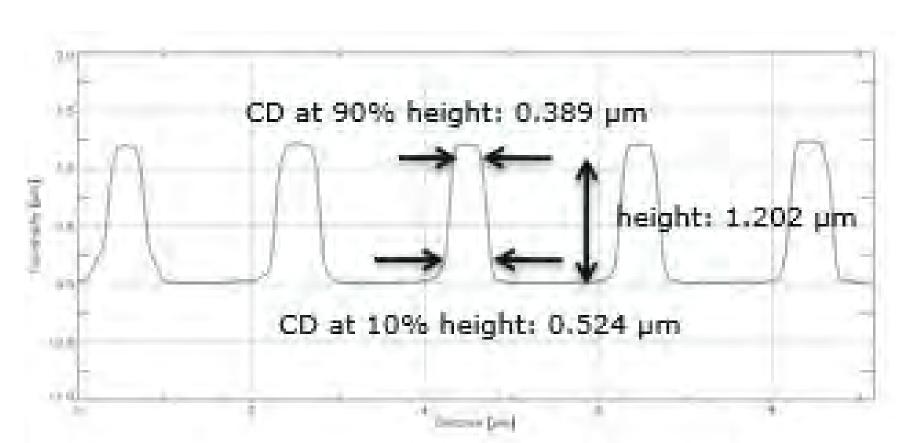
RDL Width and Height

- 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 $< 0.01 \, \mu m$
 - Monitoring of bump heights, widths, pitch and coplanarity according to JESD22-B108

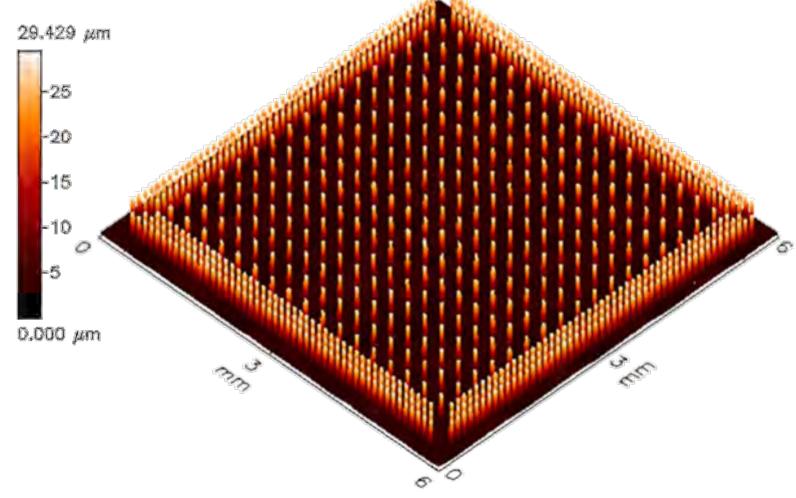




Topography map of RDL structures



RDL topography profile



Bump measurement of full die



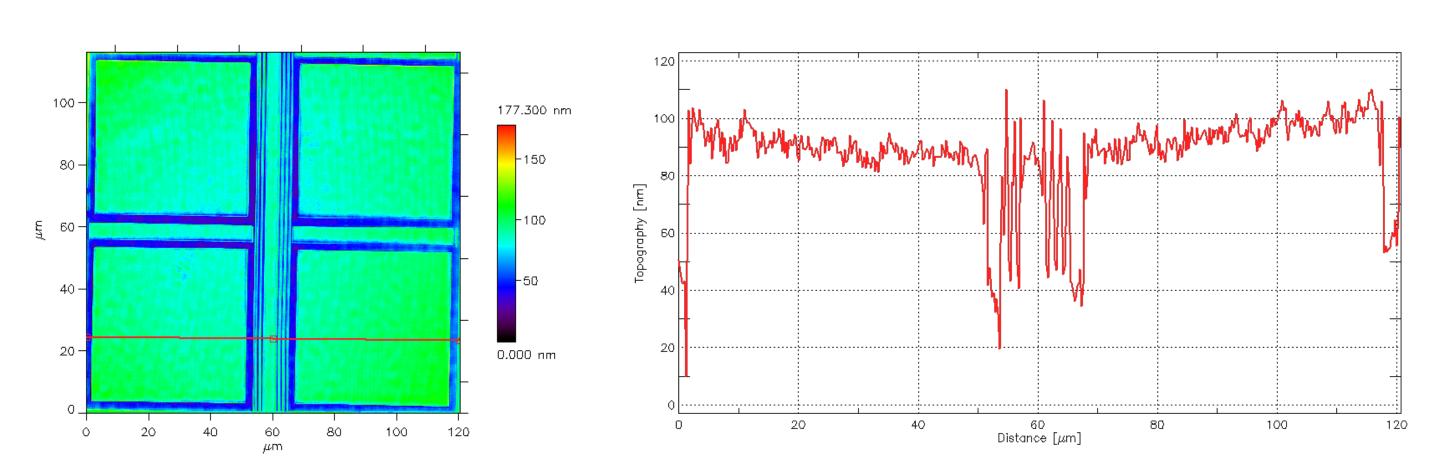
CMP Die and Wafer Flatness

Advanced Packaging Challenge:

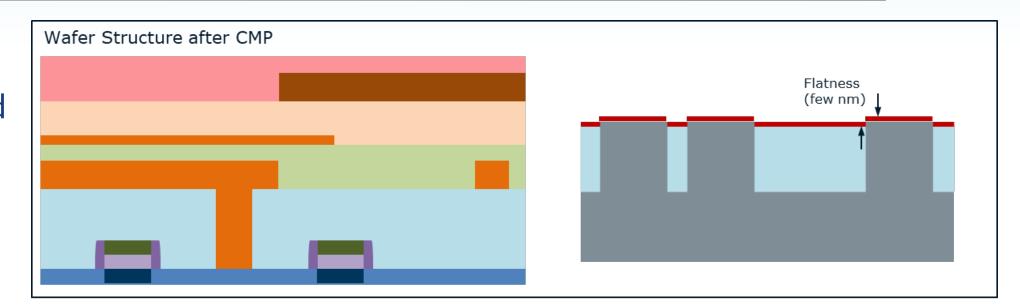
• Detrimental surface irregularities post-CMP with increasing number of layers and process steps, resulting in electrical defects of chips and reduced wafer yield

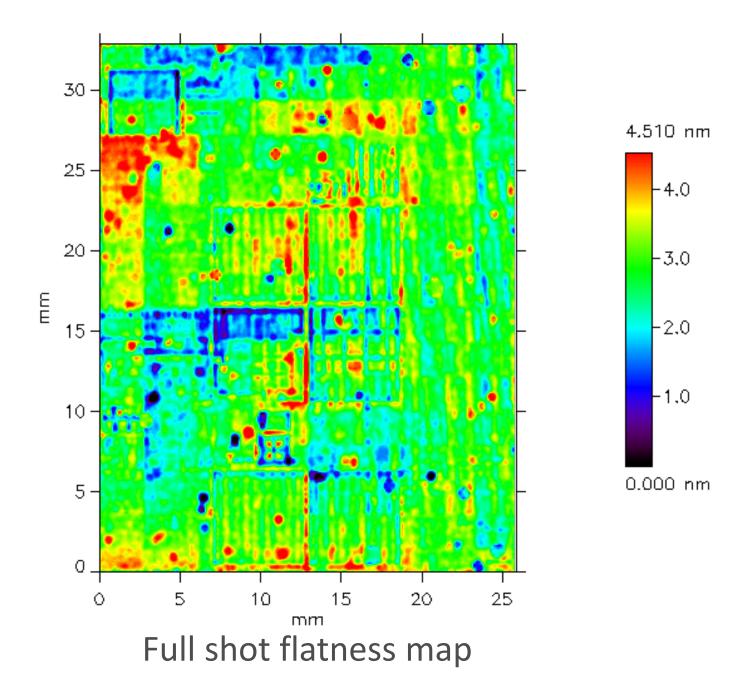
• FRT Solution:

- 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





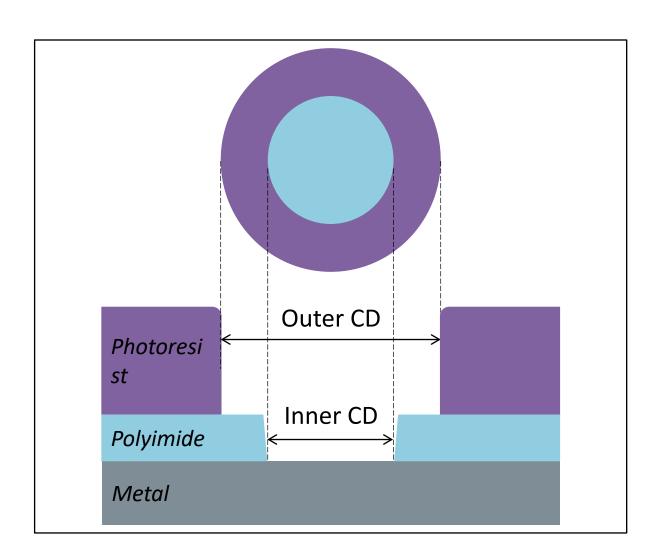


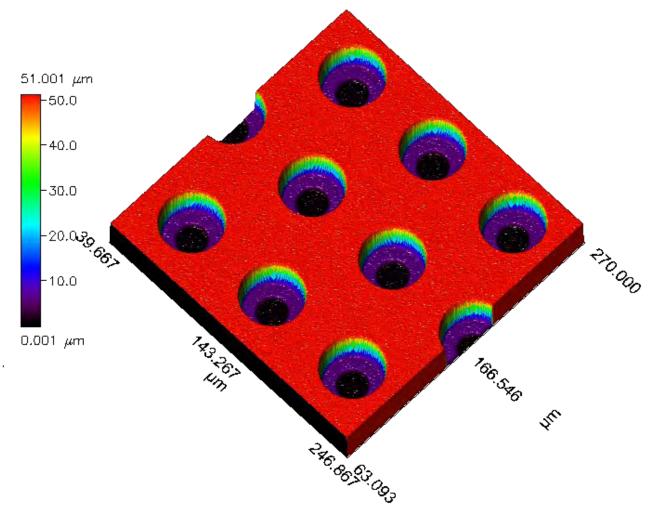
intensity map

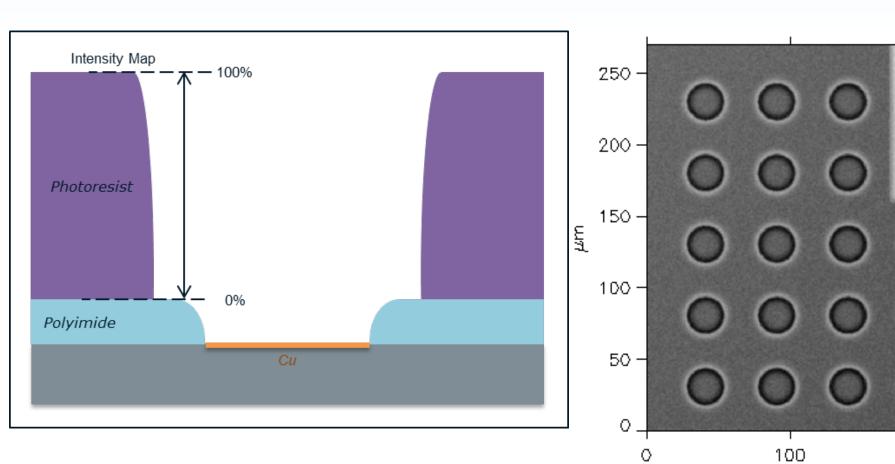
300

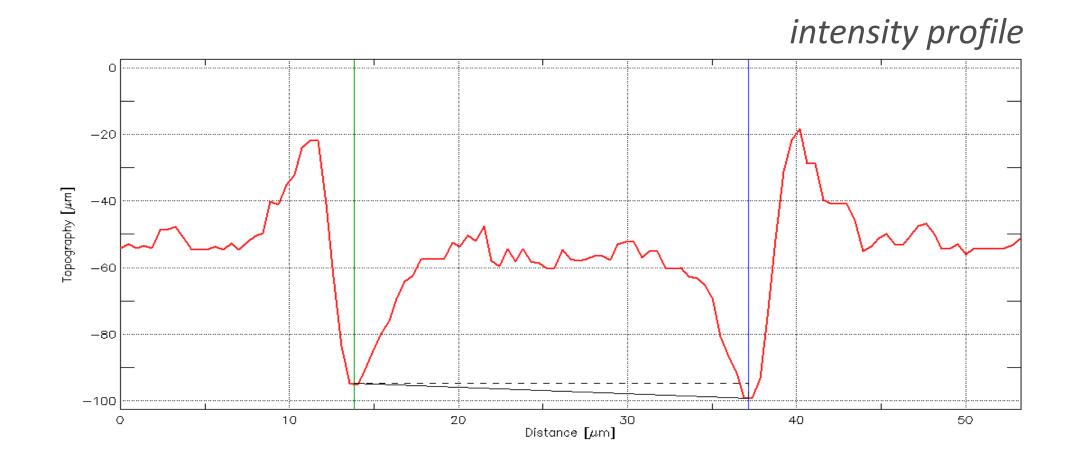
Critical Dimension and Overlay

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





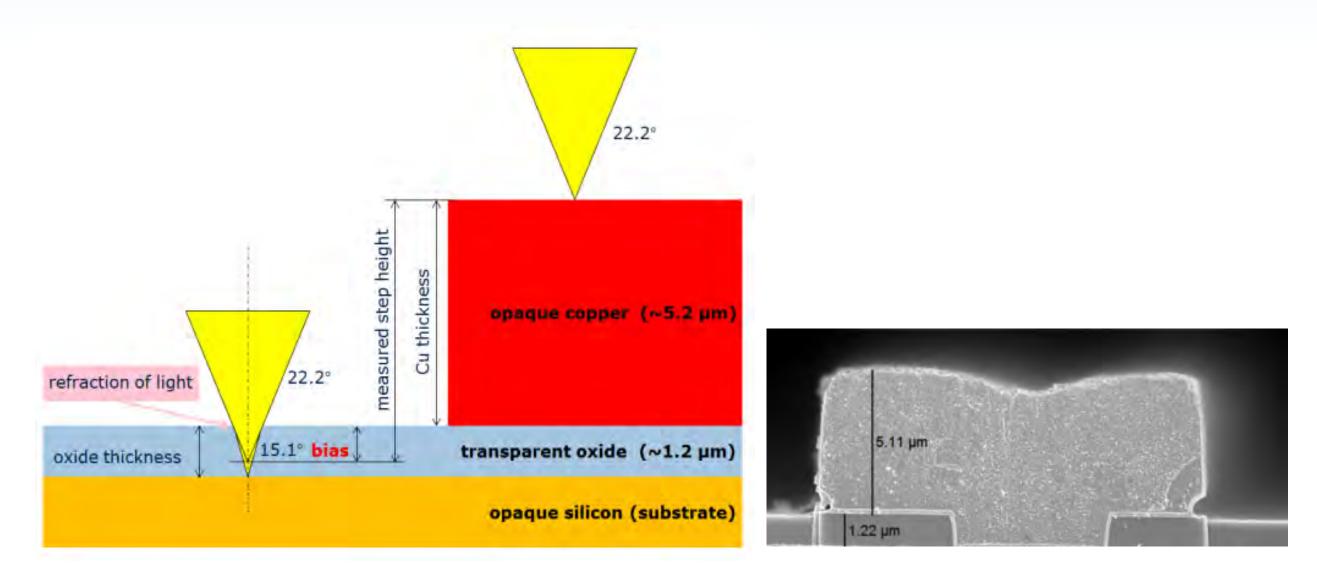




CD and overlay measurement with CFM



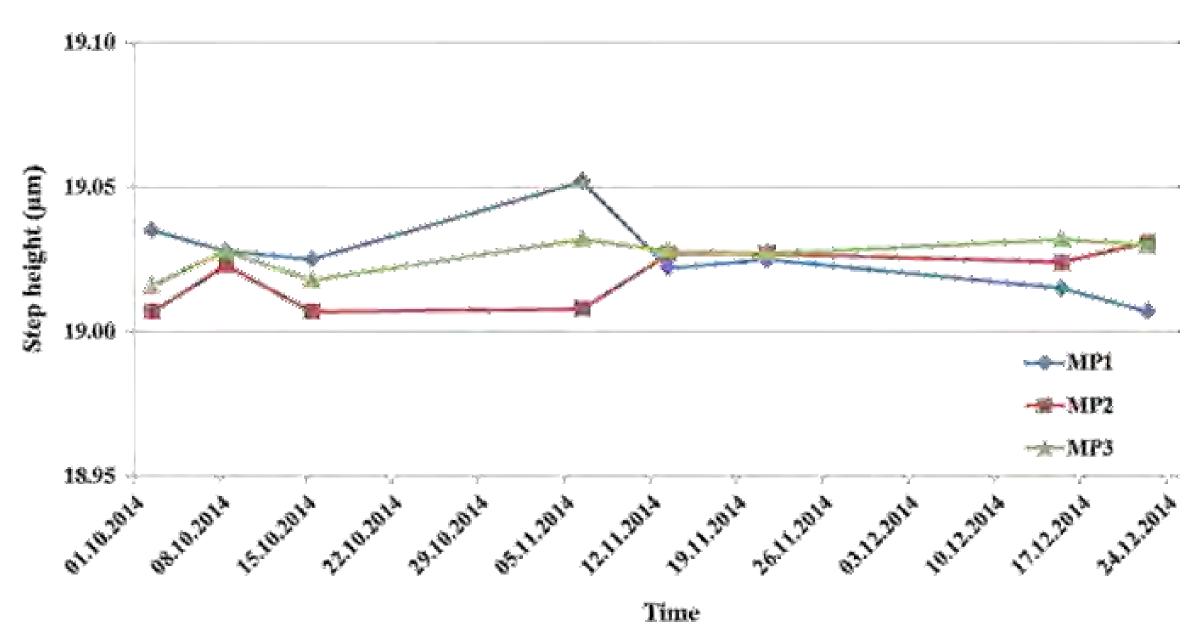
Production Case Study: Repeatability of Step Height/Width



Determination with Hybrid Metrology







standard deviation for 12 weeks dynamic repeatability test: σ = 9 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 SurfaceSensTM 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.



THANK YOU

FRT GmbH
Friedrich-Ebert-Strasse 75
51429 Bergisch Gladbach
Germany