MULTI-SENSOR METROLOGY
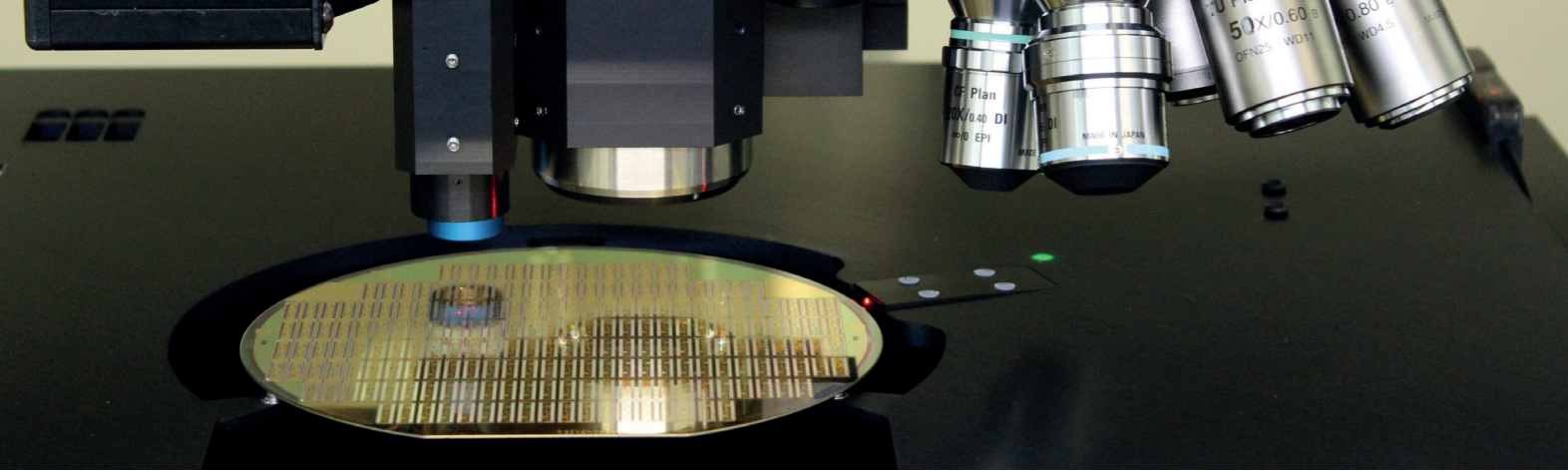# FOR ADVANCED PACKAGING

FRT
MicroProf® AP
Flexible Multi-Sensor Metrology for Every Process Step

FormFactor™

FRT
MicroProf® AP

FormFactor™

FULLY AUTOMATED WAFER METROLOGY FOR ADVANCED PACKAGING

As wafer level packaging (WLP) and heterogeneous integration (HI) approaches gain more relevance, metrology processes begin to creep into back-end process control, where measurement becomes trickier and more diversified. The dawn of fan-out (FO) processes both at the wafer and panel level has added more diversity to metrology needs. The addition of 2.5D and 3D heterogeneous integration, and now chiplet technologies further expands the diversity of applications. FormFactor's FRT Metrology offers integrated solutions for these challenging tasks. We are able to accommodate measurement requirements for the most varied processes and to handle wafers and panels, thinned and bonded wafers, and also film frames.

The **FRT MicroProf® AP** is a fully automated wafer metrology tool for a wide range of applications at different 3D packaging process steps, e.g. for the measurement of photoresist (PR) coatings and structuring, through-silicon vias (TSVs) or trenches after etching, µ-bumps and Cu pillars, as well as for the measurement in thinning, bonding and stacking processes. With its modular SurfaceSens multi-sensor concept the flexible and universally usable MicroProf AP measuring tool is ideally suited to perform a variety of measuring tasks in advanced packaging.

It also provides comprehensive measurement solutions for backside processing (backgrinding, metallization) for power semiconductors such as MOSFET or IGBT, as well as for the control of different substrates, e.g. bulk Si, SOI, cavity SOI, compounds such as GaAs, InP, SiC, GaN, ZnO, and also for transparent materials. Furthermore, it can be used for hybrid bonding and Micro Electro Mechanical Systems (MEMS), included in consumer electronics, automotive, telecom, medical and industrial markets. MEMS are manufactured in processes similar to semiconductor production.
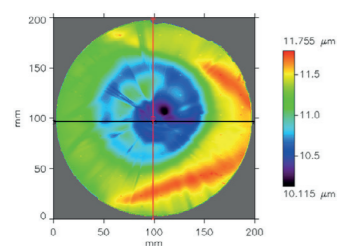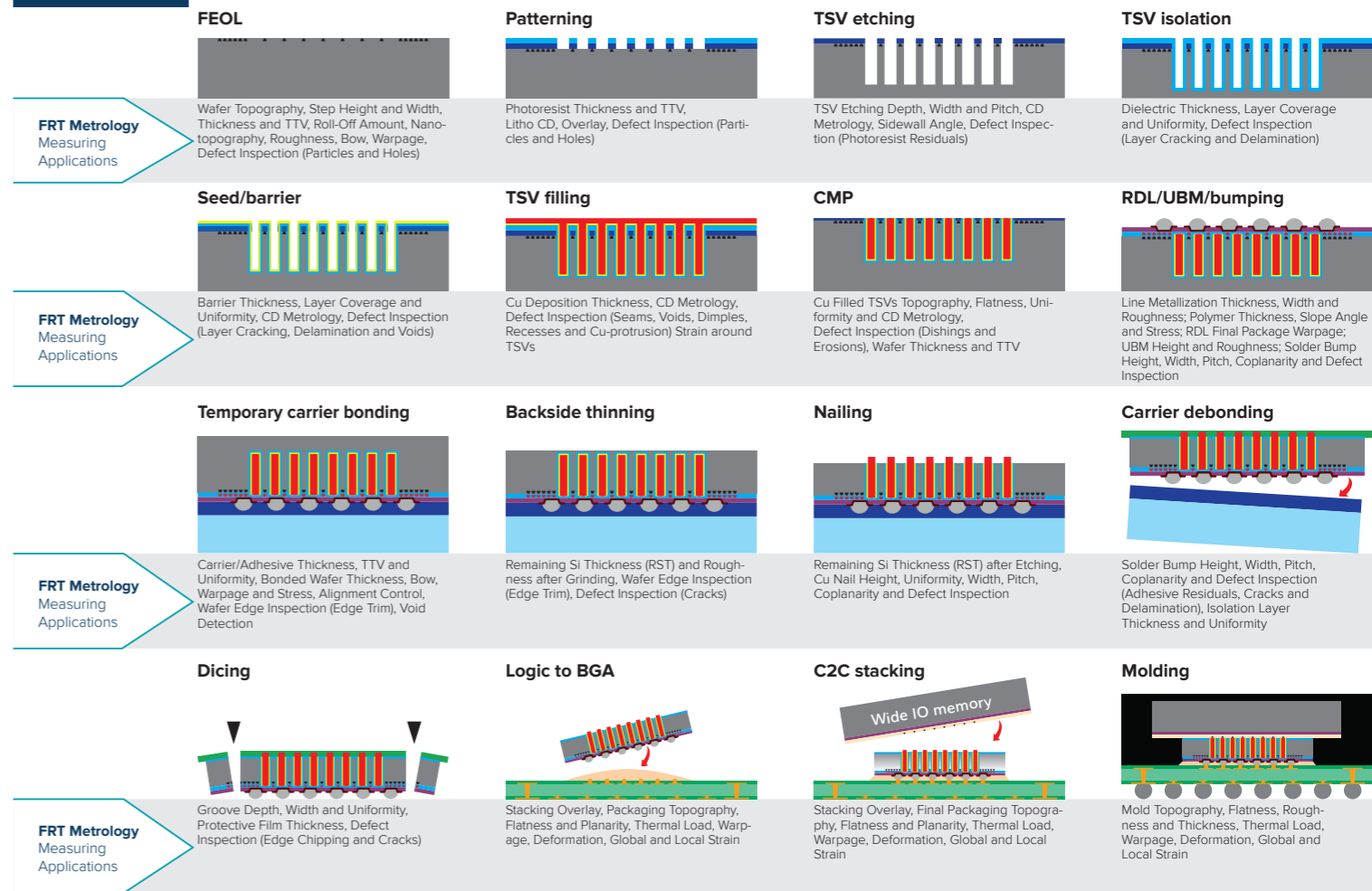
The core component is the worldwide established multi-sensor metrology tool MicroProf 300. It allows both the measurement of wafers at different process steps and – by using SurfaceSens concept for hybrid metrology – to enhances the precision of measurements on samples where a single sensor or measuring principle is just not enough. Depending on the measuring task, these measurements can be carried out with different topography and (layer) thickness sensors, which are fully automated by a single recipe. Controlled by software developed in-house, these sensors act as one to automatically combine different data and thereby generate new information that is not directly accessible.

With a wafer handling system within an Equipment Front End Module (EFEM) and almost maintenance free hardware components, the MicroProf AP provides high throughput and perfectly fits in any high volume manufacturing 3D IC fab.
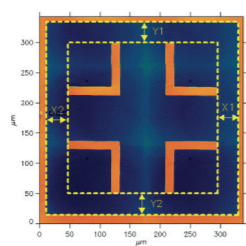
The measurement system of the MicroProf AP is equipped with a granite base setup with a three point sample fixture or a vacuum chuck. Besides the standard configuration, the tool can be equipped with numerous additional features, which can also be retrofitted on site later. The MicroProf AP enables you to keep pace with the fast progress in advanced packaging.
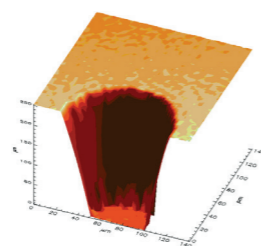
2.5D/3D IC Packaging

Process Flow

FormFactor™

FEOL
FRT Metrology Measuring Applications: Wafer Topography, Step Height and Width, Thickness and TTV, Roll-Off Amount, Nano-topography, Roughness, Bow, Warpage, Defect Inspection (Particles and Holes)

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

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

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

Seed/barrier
FRT Metrology Measuring Applications: Barrier Thickness, Layer Coverage and Uniformity, CD Metrology, Defect Inspection (Layer Cracking, Delamination and Voids)

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

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

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
FRT Metrology Measuring Applications: 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
FRT Metrology Measuring Applications: Groove Depth, Width and Uniformity, 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
Wide IO memory

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
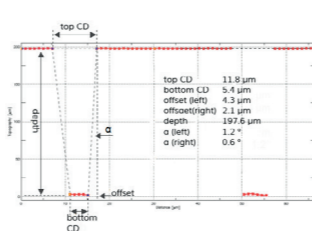

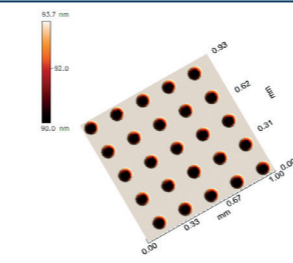Thickness map of a photoresist coating on a Si wafer

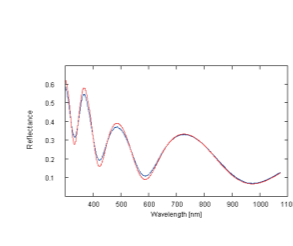Automatic recognition of marks and determination of overlay shift
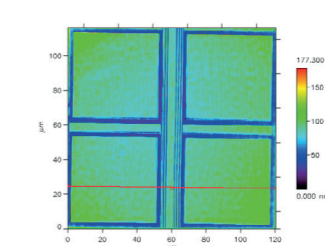
Area measurement of a single TSV

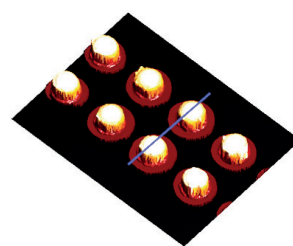Profile measurement of a single TSV (depth, top & bottom CD)

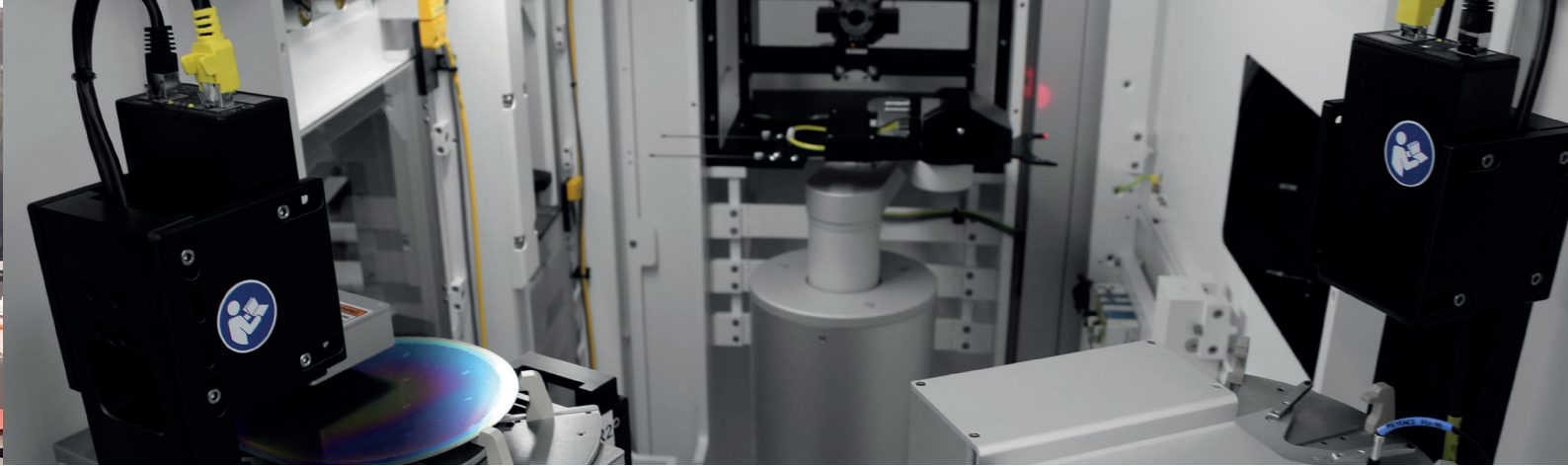Film thickness map of a SiO_2 isolation layer on a TSV array

Film thickness analysis of a 500 nm SiO_2 layer on a Si wafer using a fit algorithm

Topography of a CMP area (flatness, uniformity and defect inspection, TIR=150 nm)

Area measurement of a micro bump array

WAFER METROLOGY WITH AUTOMATED HANDLING

The MicroProf AP is designed for fully automated processing of 300 mm FOUPS/FOSBs and 300 mm/200 mm/150 mm open cassettes. Moreover, the tool also be configured for processing frame cassettes and handling of panels. The handling part features a robot with end-effector, two load ports including mapper and RFID reader, pre-aligner and optional OCR reader stations. The system is able to handle SEMI standard wafers, highly warped wafers (e.g. eLWB), bonded wafers, wafers on tape, TAIKO, bare and thinned wafers and even Fan-Out wafers.

The EFEM is equipped with filter fan units (FFU) providing ISO class 3 clean room conditions within the tool. The system can be configured e.g. as a single 200 or 300 mm tool or as a 200/300 mm bridge tool. Further options are thin wafer handling capability and an ionizer bar. For integration into the shop floor automation, the tool is equipped with a SECS/GEM data interface. Measurement tasks are then triggered by the host and the measurement results are transferred automatically to the fab control system.

POWERFUL RECIPES FOR EVERY PROCESS STEP

The tool is run by the SEMI-compliant FRT Acquire Automation XT software. This software allows recipe based measurement and data analysis of structured and unstructured wafers. Choose the suitable measurement and evaluation routine for your measuring task from a variety of packages. For recurring structures, a layout wizard with a graphical user interface (GUI) can support the user in teaching the measuring positions. In addition, fine sample alignment via pattern recognition is available.
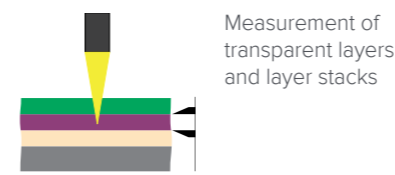
This software provides comprehensive capabilities, from manual measurement on the device to fully automated measurement with one-button operation and integration into production control systems, e.g. via a SECS/GEM interface. You can easily configure various measurement tasks using different sensors to run consecutively within a measurement sequence. This includes the execution of measurements, processing and analysis using intelligent algorithms, output and visualization of results in the form of reports and the export of results in various data formats.
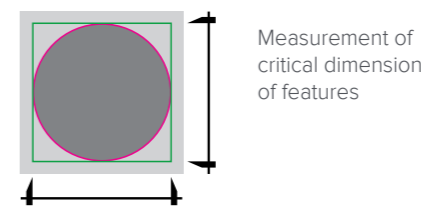
TYPICAL APPLICATIONS

MicroProf® AP

> PI and PR film thickness, PI and PR opening
> CD and overlay
> TSV metrology, fill monitoring, trenches
> seed layer metal inspection
> plated Cu thickness
> flatness and uniformity after CMP
> UBM height and roughness
> RDL thickness, width and roughness
> complement and enhance the performances of automated bump inspection systems
> bump and nail height, diameter and coplanarity
> bow and stress
> carrier, adhesive, bonded wafer thickness, and TTV
> final packaging topography and planarity
> stacking deformation under thermal load
> mold inspection

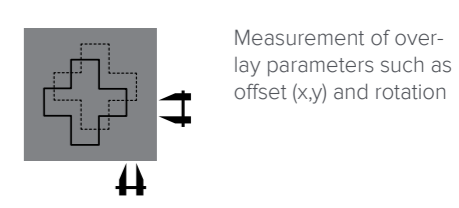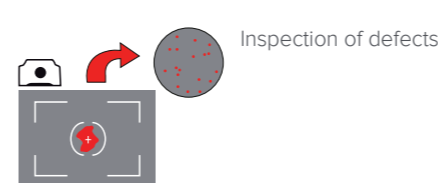Area measurement of a RDL test structure

Profile measurement of RDLs (width, height and spacing)

Area measurement of a mold and contact pad surface

3D topography of a dimple on a Si wafer

METROLOGY CAPABILITIES

FILM THICKNESS / LAYER STACK
Measurement of transparent layers and layer stacks

CRITICAL DIMENSION
Measurement of critical dimension of features

OVERLAY
Measurement of overlay parameters such as offset (x,y) and rotation

DEFECT INSPECTION
Inspection of defects

VIAS / TRENCHES
Measurement of vias and trenches with high aspect ratio

TOPOGRAPHY
Standard topography measurement

TOPOGRAPHY (TOP & BOTTOM)
Topography measurement on both wafer surfaces simultaneously
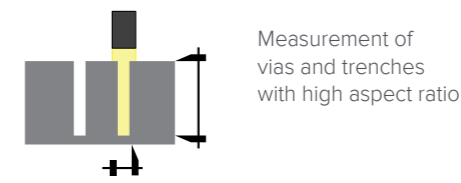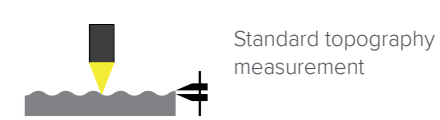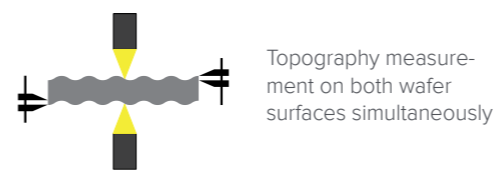
FLATNESS
Measurement of wafer flatness

WAFER THICKNESS / TTV
SEMI-compliant measurement of wafer thickness and TTV

STEP HEIGHT / WIDTH
Measurement of step height and width on structured wafers

ROUGHNESS / WAVINESS
DIN/ISO-compliant measurement of surface roughness and waviness on bare and structured wafers

STRESS
Measurement of wafer stress e.g. induced by layer deposition
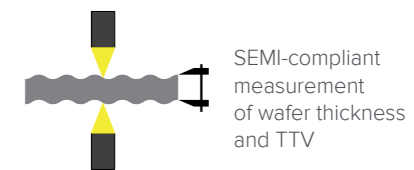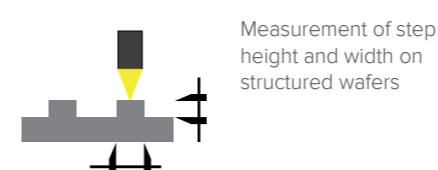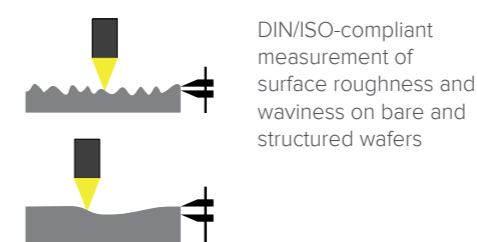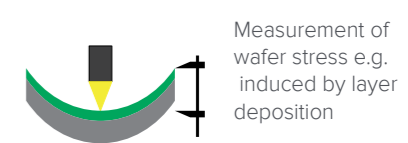
HYBRID TECHNOLOGY
TOPOGRAPHY
FILM THICKNESS
STEP HEIGHT
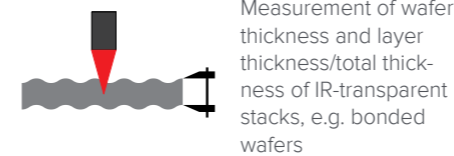Post processing calculation of sample properties using individual results generated by different sensors/measurement principles

BUMPS / COPLANARITY
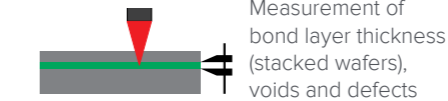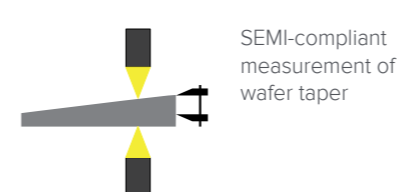Measurement of bump dimensions and coplanarity
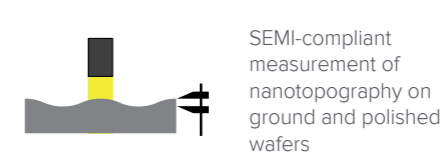
WAFER THICKNESS (IR)
Measurement of wafer thickness and layer thickness/total thickness of IR-transparent stacks, e.g. bonded wafers

BOND LAYER
Measurement of bond layer thickness (stacked wafers), voids and defects

ROLL - OFF AMOUNT
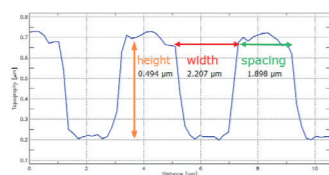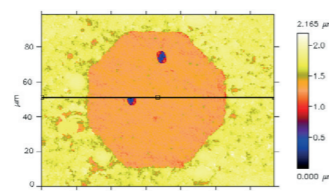SEMI-compliant measurement of roll-off amount

TAPER
SEMI-compliant measurement of wafer taper

NANOTOPOGRAPHY
SEMI-compliant measurement of nanotopography on ground and polished wafers

THERMAL LOAD
Optical metrology under variable sample temperature

CONFIGURE YOUR
FRT MicroProf® AP

METROLOGY UNIT	X/✔
FRT MicroProf® 300	
Chromatic point sensor CWL	
TTV setup	
Film thickness sensor CWL FT / IRT	
Thin film sensor FTR	
Chromatic line sensor SLS	
Confocal microscope CFM / CFM DT	
White light interferometer WLI FL / WLI PL	
Standard camera with illumination	
High resolution camera with illumination	
Brightfield IR illumination + IR camera	
Pattern recognition software	
3-point wafer fixture	
Fully supporting wafer fixture with vacuum	
Thermo unit (controlled hot and cold chuck)	
In-plane deformation sensor	

WAFER HANDLING UNIT	X/✔
Robot unit	
Pre-aligner	
1 load port for 300 mm FOUPs/FOSBs SEMI-standard	
1 load port for open cassette SEMI-standard	
> for 150 mm (6 inch) wafers	
> for 200 mm (8 inch) wafers	
> for 300 mm (12 inch) wafers	
RFID reader	
Vaccum end-effector	
Edge grip handling	
Handling of warped wafers (e.g. eWLB) and panels	
non contact wafer handling	
OCR reader (front/back)	
Ionizer bar	

EFEM ENCLOSURE	X/✔
ISO class 3 clean room conformal housing	
2 filter fan units, one for handling and one for metrology area	

FRT METROLOGY SOFTWARE	X/✔
Acquire Automation XT incl. one evaluation package + additional packages (if needed):	
> TTV, Bow, Warp	
> Bumps, Vias, Trenches	
> Critical Dimension, Overlay	
> Roughness, Waviness, Flatness	
> Step Height	
> Saw Marks	
> Film Thickness	
> Wafer Stress	
> Angle Evaluation	
> Nanotopography	
> Fine Alignment	
SECS/GEM interface (standard or customized)	
Analysis software Mark III	
Manual measurement software Acquire	

Talk to an expert!