ONYX SERIES

In-line non-destructive wafer inspection and metrology

Rigaku

Semiconductor Metrology Division
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THE WORLD OF SEMICONDUCTOR
Metrology Tools From Lab to Fab

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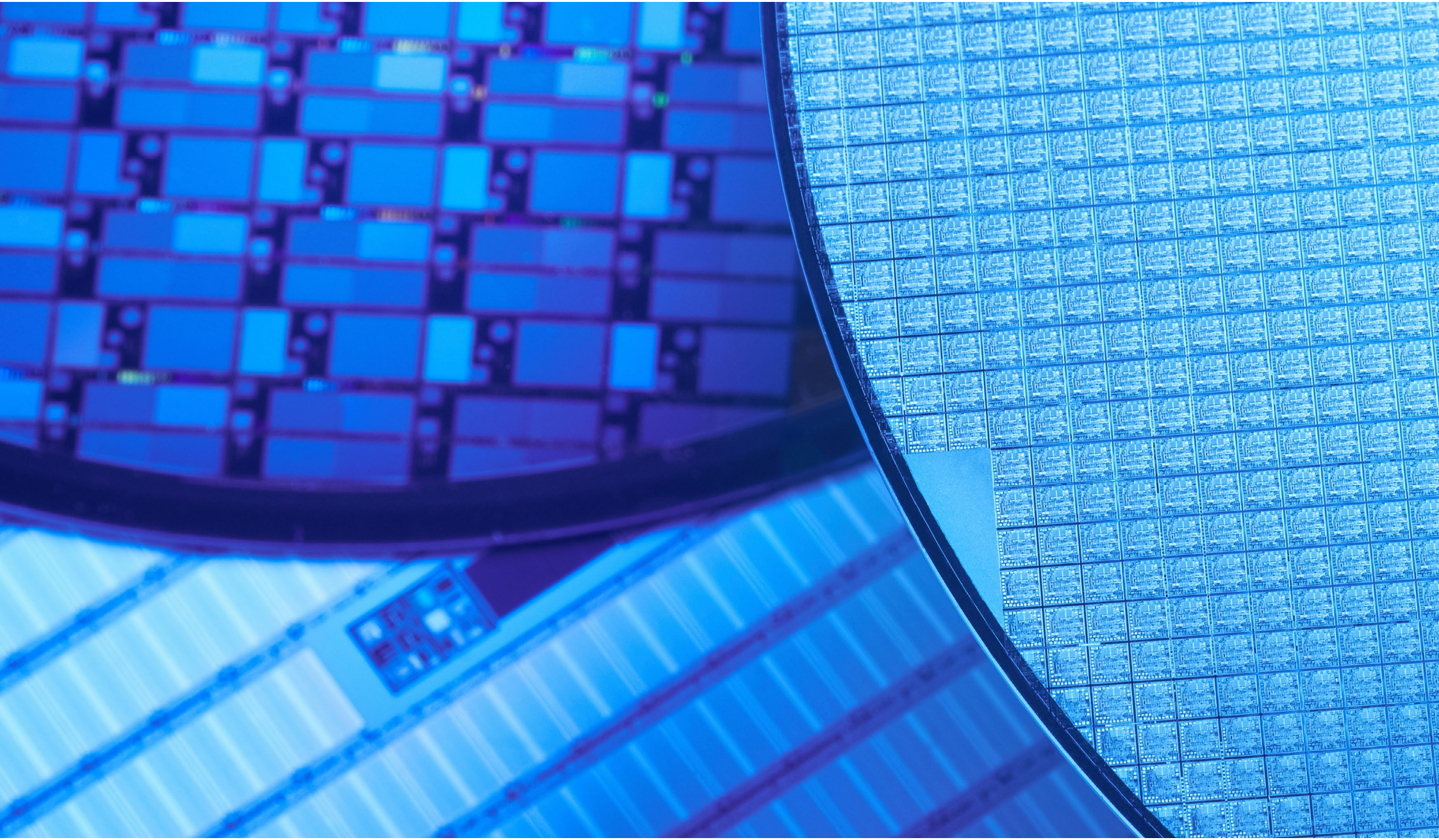

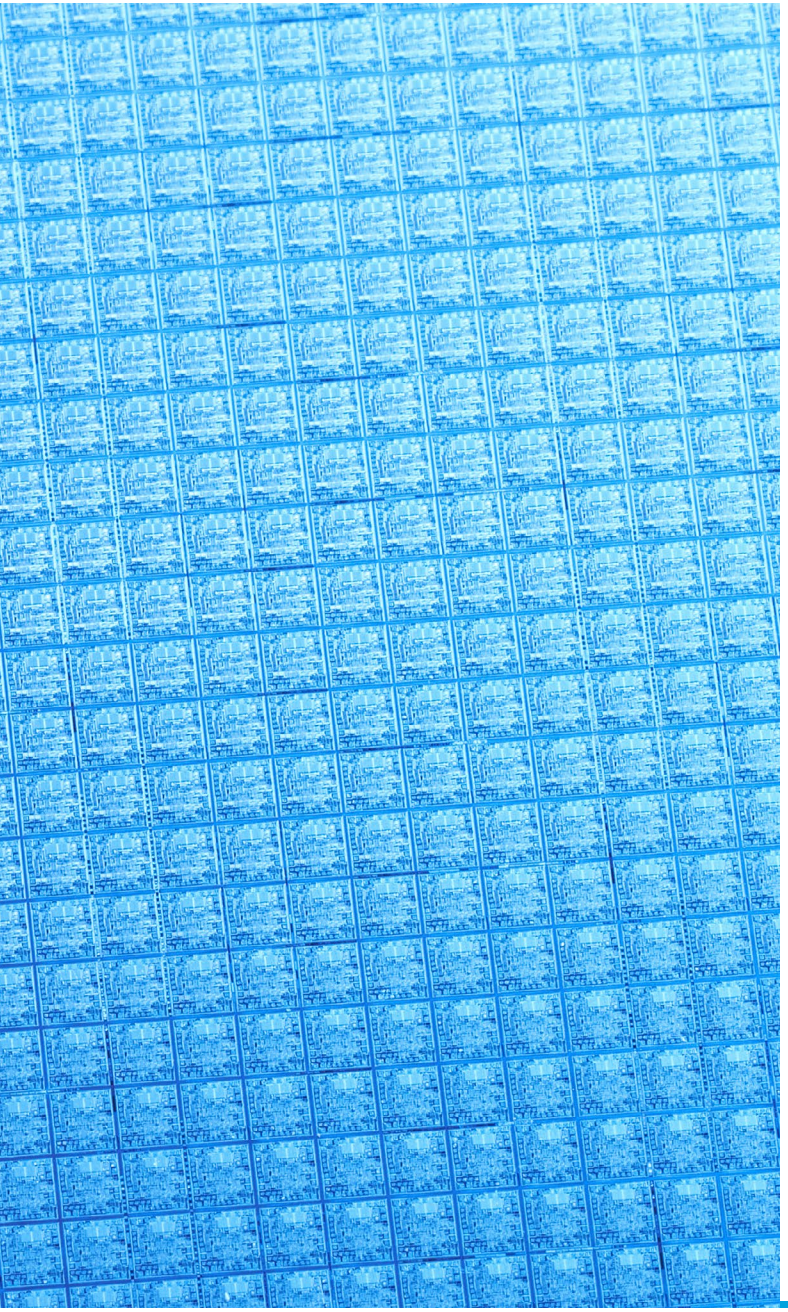

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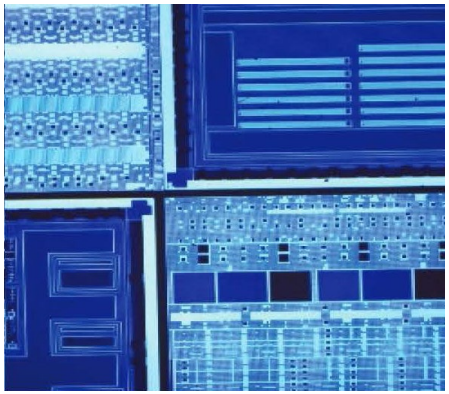
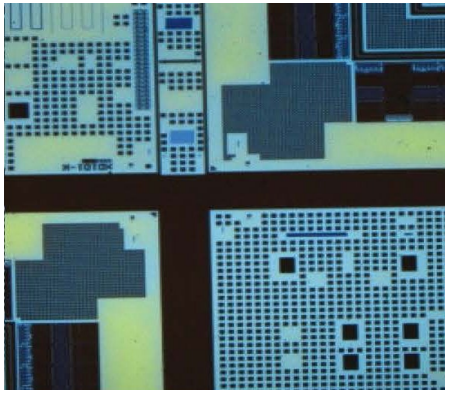
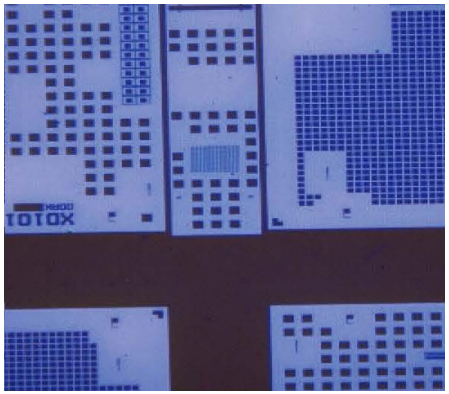




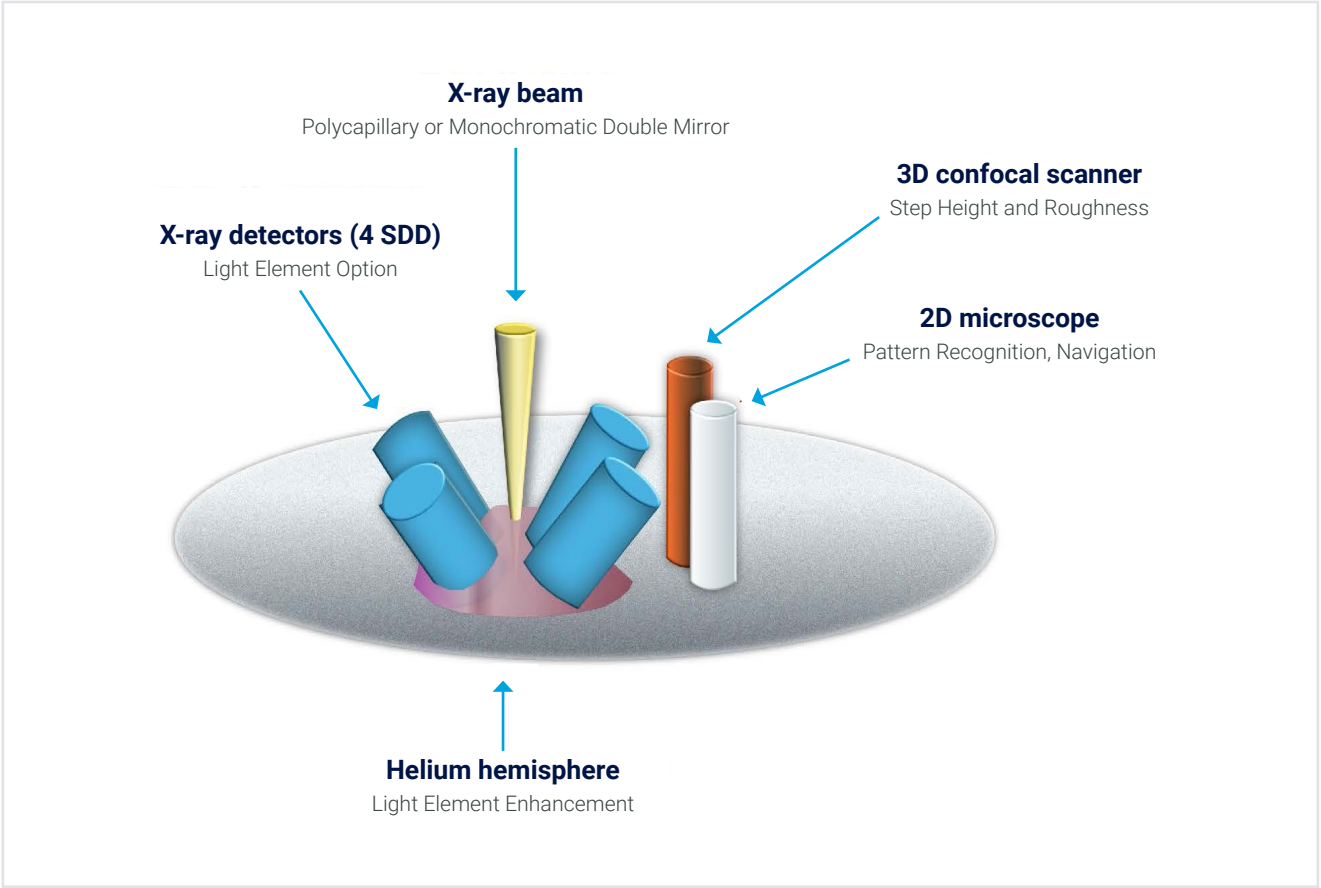


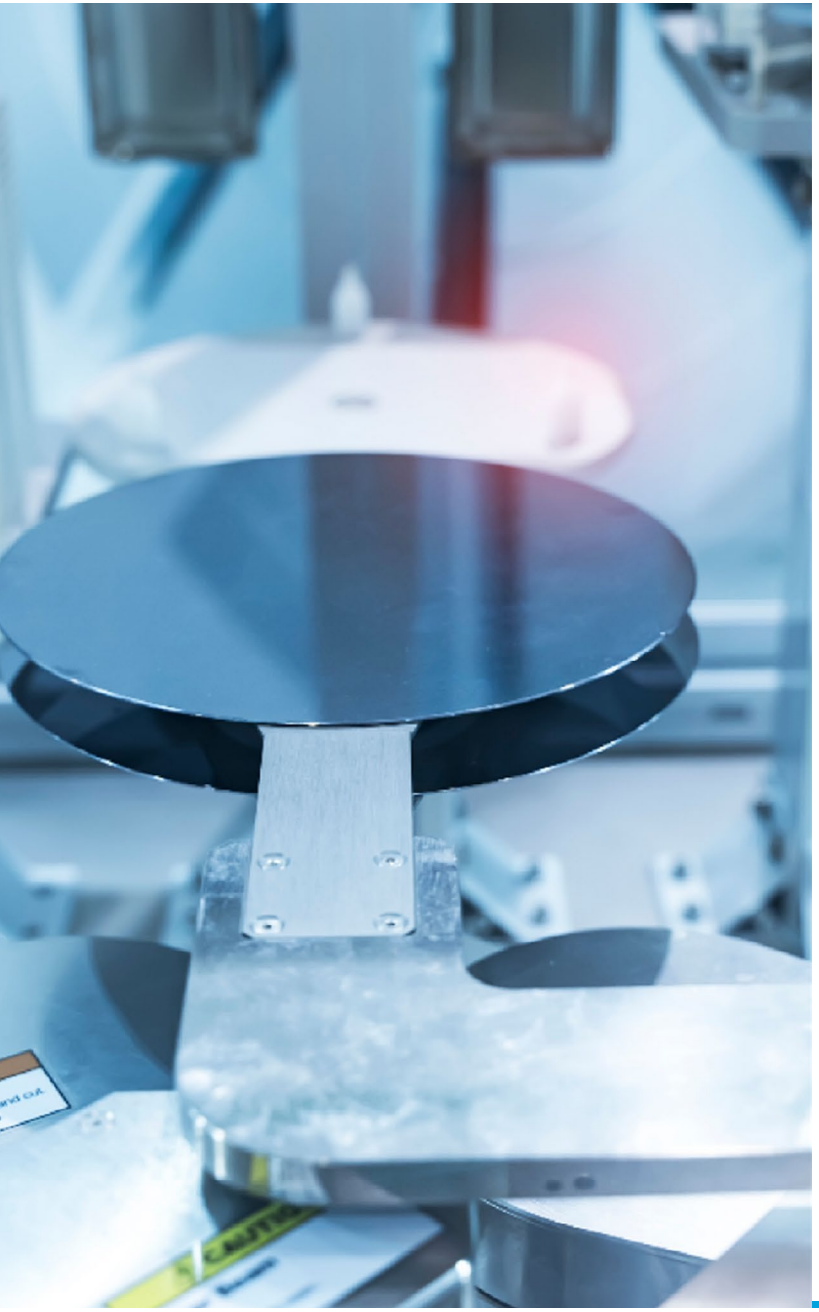
Layer-by-layer wafer inspection with qualitative and quantitative results

XRF measures elemental composition and film thickness

2D Microscope used for pattern recognition and CD calculation.

3D Scanner height measurement, area scan, wafer surface roughness and bump co-planarity, and copper pillars inspection





ONYX Series

In-line non-destructive wafer inspection and metrology Hybrid ED-XRF and optical metrology for in-line, non-destructive wafer inspection and measurement of film thickness, composition, and defect identification/sizing on blanket and patterned wafers.

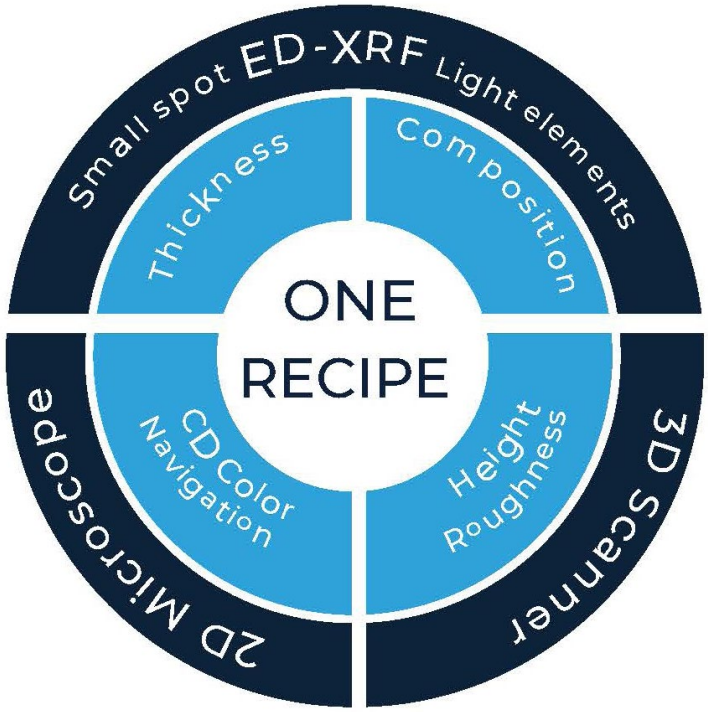
Combining advanced X-ray and optical techniques, the ONYX Series offers a unique wafer metrology approach in many areas, from FEOL through WLP, leading to in-line solutions for these processes. This sophisticated hybrid metrology tool enables high-throughput, in-line measurements on a blanket and product wafers ranging from ultra-thin single-layer films to multi-layer stacks.

The optical feature with 2D microscope and optional 3D scanner enables defect detection, sizing, and characterization of BEOL structures through image analysis (of critical dimensions, height, roughness, etc. of metal stacks, solder bumps, pillars, etc.) complemented by elemental composition and thickness measurements by ED-XRF analysis.

Hybrid configuration | automated x-ray analysis, 2D microscope, and optional 3D scanning for film stack, bumps, and composition measurements on blanket and patterned wafers

Configurable for 300 mm and smaller wafers

150 mm	200 mm	300 mm	**Load Options**



Wafer inspection and metrology for advanced packaging

Hybrid configuration | automated X-ray analysis, 3D scanning, and 2D microscope for film thickness and composition measurements on blanket and patterned wafers.

Single recipe examples

1. Set	**2.** Sample	**3.** Discovery
µEDXRF + 3D Measurement Ag/Sn ratio thresholds Height thresholds Full stuck analysis	**Bumps Pillars µPillars**	**Single bump analysis** Ag/Sn ratio Bump total height Each layer thickness
µEDXRF Measurement Layer thickness thresholds	**Thin films** (pattern or blanket wafers)	**Thin layers thickness** Multi stuck layers thickness
µEDXRF Measurement Composition thresholds	**Metal elements** (Ga, Co, Ni, Fe, Pt, Cr, Zn, etc.) **Alloys** (NiFe, CoNi, NiP, NiPt, CrMn etc.)	**Monitoring of alloy composition**

Applications

Effective dual-inspection process to reduce production costs

Identify bump height variation and defective bumps

Bumped wafer mapping metrology can reduce overall die cost by eliminating assembly and testing for the defective die identified by the system before the dicing operation. The ONYX 3200 Metrology System also offers incoming inspection by monitoring wafer contamination levels and tracking metal passivation defects.

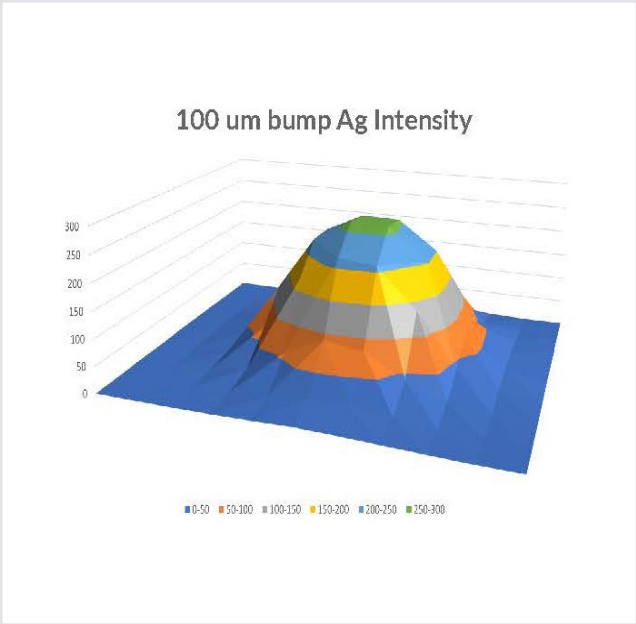
Single-bump metrology

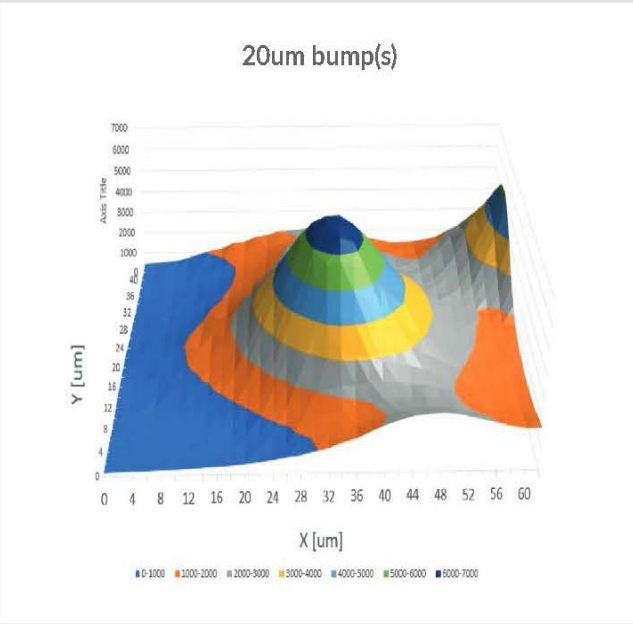
Measure and monitor Ag%, Sn%, AgSn, Ni, and Cu thickness, and total bump height:

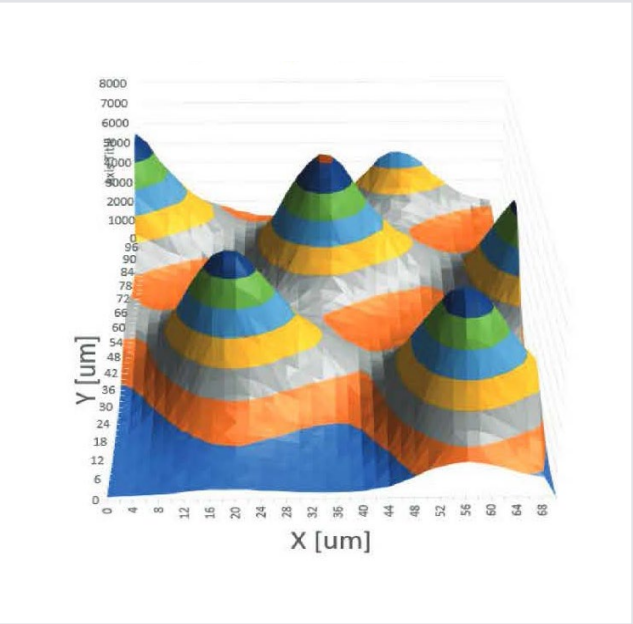
- Measure single solder bumps less than 5 µm diameter
- Inspect a range of parameters: across the wafer, wafer-towafer, and lot-to-lot
- Measure CD and total height of single bumps using a 2D microscope, 3D scanner

AgSn ratio - Silver composition is critical for ensuring longterm device reliability.

Hybrid metrology solution automated 2-D/3-D technology







Applications

UBM / RDL

Conduct metallurgical inspection

Analyze the multi-stack films and structures for layer thickness and composition.Distinguish separate layers simultaneously.

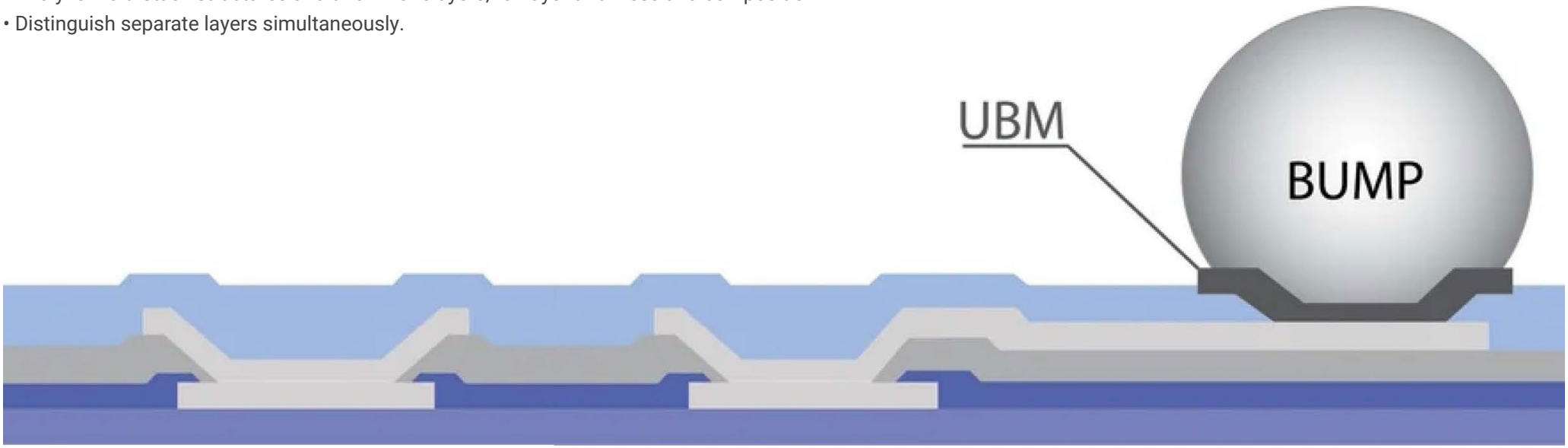
Impact of Process Control on UBM/RDL Contact Resistance with the hybrid metrology systems designed to offer the flexibility of FOWLP, 3D Packaging (Stacked Die/Chip-on-Chip), Wafer-Level Chip Scale Packaging (WLCSP), System-in- Package (SiP), Embedded Die Packaging (EDP), Copper Pillar Flip-Chip, and Fan-In Wafer-Level Packaging (FIWLP) to meet the rising demand for higher-performance advanced semiconductor packages at lower cost, with an increased wafer throughput and tighter defect.

Hybrid metrology solution automated 2d / 3d technology

UBM/RDL

Conduct metallurgical inspections of under bump metallization (UBM) and redistribution layers (RDL):

- Analyze multi-stack structures and thick monolayers, for layer thickness and composition.
- Distinguish separate layers simultaneously.



Applications

Alloy composition

Accurate monitoring of alloy composition

Alloy films for semiconductor applications are critical for targeted performance, yield, and reliability. Obtain high-quality and accurate control of the composition and thickness to achieve the optimal performance established in the heterostructure design.

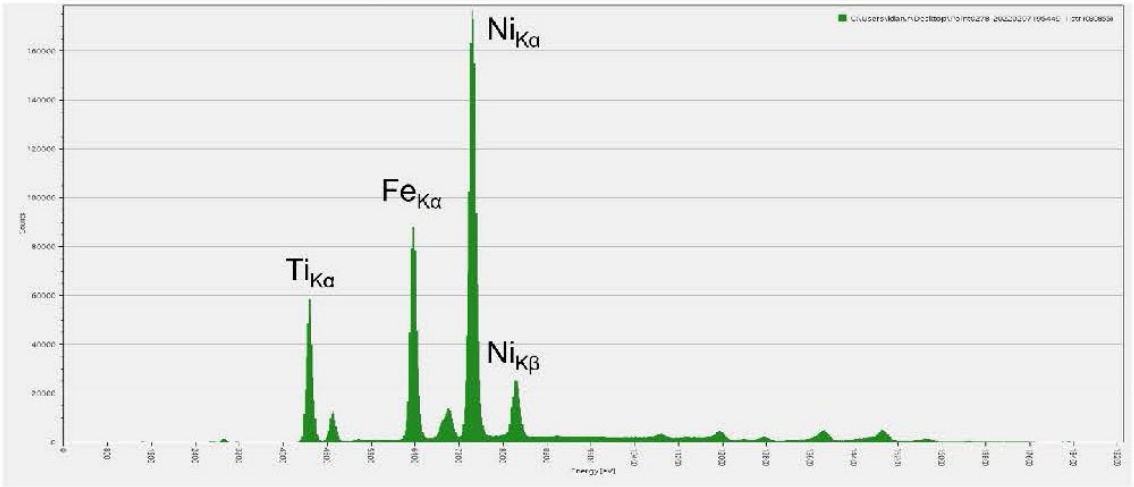
Measure and monitor metals and alloy composition

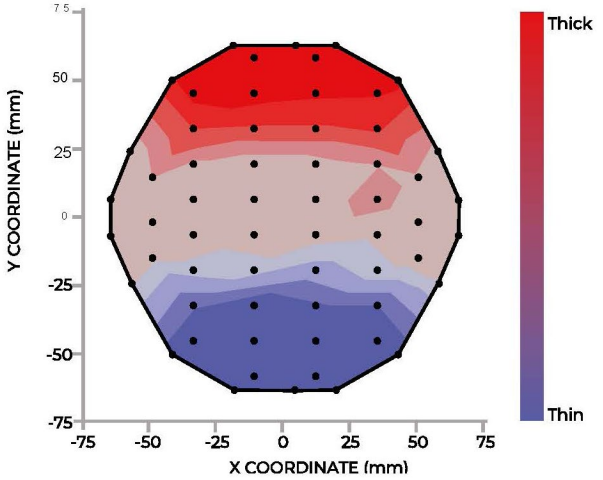
- Analyze metal elements (Ga, Co, Ni, Fe, Pt, Cr, Zn, and Mn)
- Identify alloys (NiFe, CoNi, NiP, NiPt, and CrMn)

ED-XRF spectrum

Measurement of Titanium and nickel-iron alloy samples

EDXRF technology is used for both qualitative and quantitative analysis.





Applications

Precise analysis and monitoring of thin and ultra-thin films

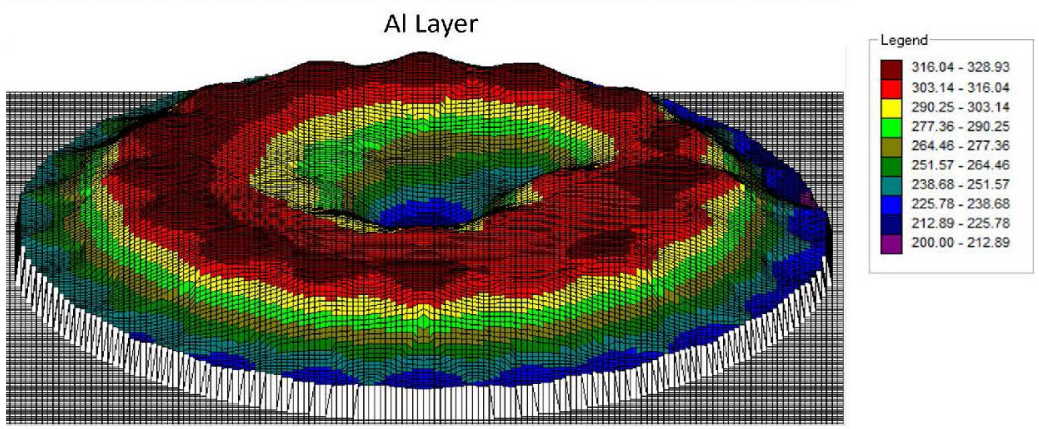
Precise analysis and monitoring of thin and ultra-thin films

Exploring semiconductor thin films grown with applications related to both FEOL and BEOL systems. Including applications such as metals in gate stack and interconnect systems.

Measurements:

- Analyze ultra-thin films, transparent or opaque, regardless of their physical properties.
- Thickness and composition.
- High sensitivity for ultra-thin film.

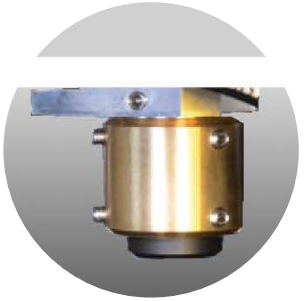
Metrology solution automated 2D / 3D technology



3D confocal scanner

Measurements:

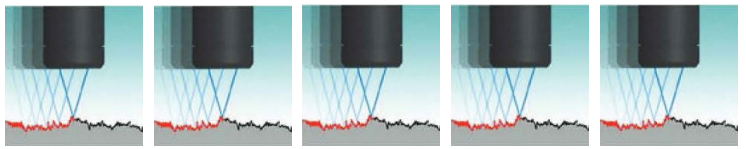
- Feature height
- Surface roughness



High resolution and precision

Vertical resolution	Lateral resolution
100 nm	1 µm

Ability to measure many types of films and surfaces: Transparent/opaque, polished rough semiconductor, metal, glass, ceramic, plastic



Roughness | In-line control | Thickness | Autofocus | Microtopography

ONYX Series unique advantages

Optimized source capability

1. Single µ-bump measurements for process monitoring
2. High yield and improved throughput
3. Accurate analysis for metal thickness and composition
4. Maximum sensitivity for layer thickness and composition

- ✔ Dual-head µXRF configuration offers analytical flexibility for optimal application performance.
- ✔ Monochromatic and polychromatic µXRF optics.
- ✔ Low power X-ray – non-destructive
- ✔ Focused vertical excitation configuration.
- ✔ An array of 4 Silicon drift detectors (SDD) with a large active area and improved resolution.
- ✔ Composition analysis and thickness and measurements.
- ✔ Fully automated calibration processes ensure long-term stability, consistency, and tube aging correction.
- ✔ Advanced motion platform for sub-micron accuracy.
- ✔ Ideal for in-line HVM metrology.

The ONYX 3200 is the most advanced Hybrid Metrology solution in the market; with its dual head, the second-generation tool combines advanced µXRF and optical techniques to provide high accuracy in defect detection and the highest throughput for in-line semiconductor manufacturing. The ONYX series systems are designed to provide a holistic metrology approach in all steps of the manufacturing process from FEOL through WLP, including optimal configuration for Advanced Packaging and single bump applications to monitor Ag/Sn ratio— proven results in measuring and identifying single solder µ-bumps less than 5µm diameter.

With the highest throughput and proven uptime greater than 95%, ONYX 3200 is the optimate solution for In-line manufacturing.

ONYX Series specifications

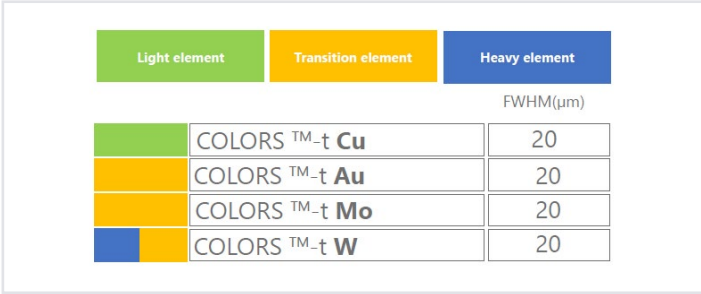
System parameters	ONYX 3000	ONYX 3200
Metrology type	Micro-spot ED-XRF and 2D-3D Optical Inspection	Dual head µ-spot ED-XRF and 2D-3D Optical Inspection
Wafer size	Up to 300 mm Configurable for 150 mm, 200 mm, and 300 mm Si	
Wafer type	Blanket and patterned wafers	
Overall position accuracy	< 1 µm (Stage Resolution 0.1 µm)	X/Y Stage Resolution 0.7 µm Accuracy 0.1 µm
Sample handling	Full-wafer capability with single and dual automatic loader	Dual arm system with single or dual automatic loader
Automation	Si70Ge30	9.482
Navigation	Precise stage complemented with an image recognition algorithm. Sub-micron fast navigation to single featured center.	Precise stage enhanced by an image recognition algorithm. Sub-micron rapid navigation to the center of a single feature.
SW user interface	Auto-calibration. Easy-to-use recipe creation and maintenance. Fundamental parameters optional.	
Beam orientation	Vertical incidence micro-spot µXRF	
X-ray tube energy	Up to 50 kV. 50 W	
X-ray optics	Polycapillary or COLORS TM (Monochromatic X-ray Optics)	Polycapillary and COLORS™ (Monochromatic X-ray Optics)
Micro XRF beam spot size	10 - 50 µm spot sizes adjustable	
Detector Type	Silicon drift detector (SDD) Optional light element detector (C, N, O, F, S)	Silicon Drift Detector (SDD): 3 configurations: **1.** Regular > Al **2.** Heavy elements > Ge (optimized for Ag, Sn) **3.** Light element (C, N, O, F, S)
Detector Resolution	123 ± 5 eV with a large solid angle	
Digital Pulse Processor	High efficiency of more than 1 million photons/sec.	
3D Scanner	Vertical Resolution 100nm	Lateral Resolution 1 µm
2D Microscope	**PIXEL COUNT** 5 Megapixel **SENSOR CCD** Color **LATERAL RESOLUTION** 1 µm	
2D Microscope Magnification	**2x** 5X5 mm FOV 2.7 µm pixel size	**10x** 1X1 mm FOV 0.432 µm pixel size

X-ray optics configuration options

The ONYX 3000 is available with micro-spot, polycapillary x-ray optics or monochromatic COLORSTMt X-ray optics.

COLORS™-t x-ray optics and Polycapillary x-ray optics Rigaku's unique multi-layer mirror technology, the COLORS beam modules are optimized to provide high brightness in small spots for a variety of thin film applications.

- High-brilliance
- Monochromatic



Monochromatic COLORS™-t X-ray optics

Measurements in low background spectrum and effective analysis of low signals.

- High brightness excitation
- Small spots for a wide range of thin film applications.
- Ideal configuration for bumps and copper pillars inspection

COLORS™-t X-ray optics

Normal incidence micro X-ray beam module "COLORS™-t 20 μm"

- Monochromatic: low background
- Micro spot: less than 20 μm FWHM
- Anodes: Cu, Au, Mo, W

Polycapillary X-ray optics

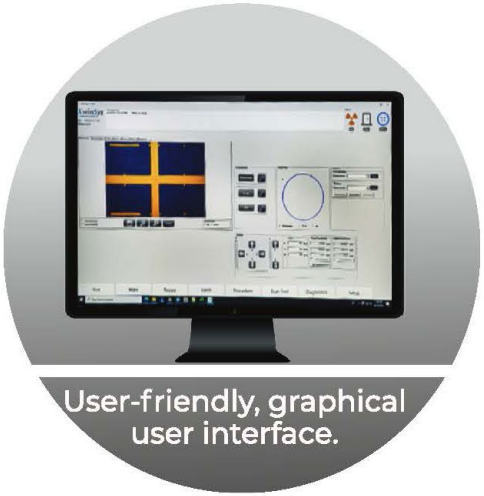
Normal incidence micro X-ray beam module "COLORS™-t 20 μm"

- Monochromatic: low background
- Micro spot: less than 20 μm FWHM
- Anodes: Cu, Au, Mo, W

Accurate navigation and image processing

Software

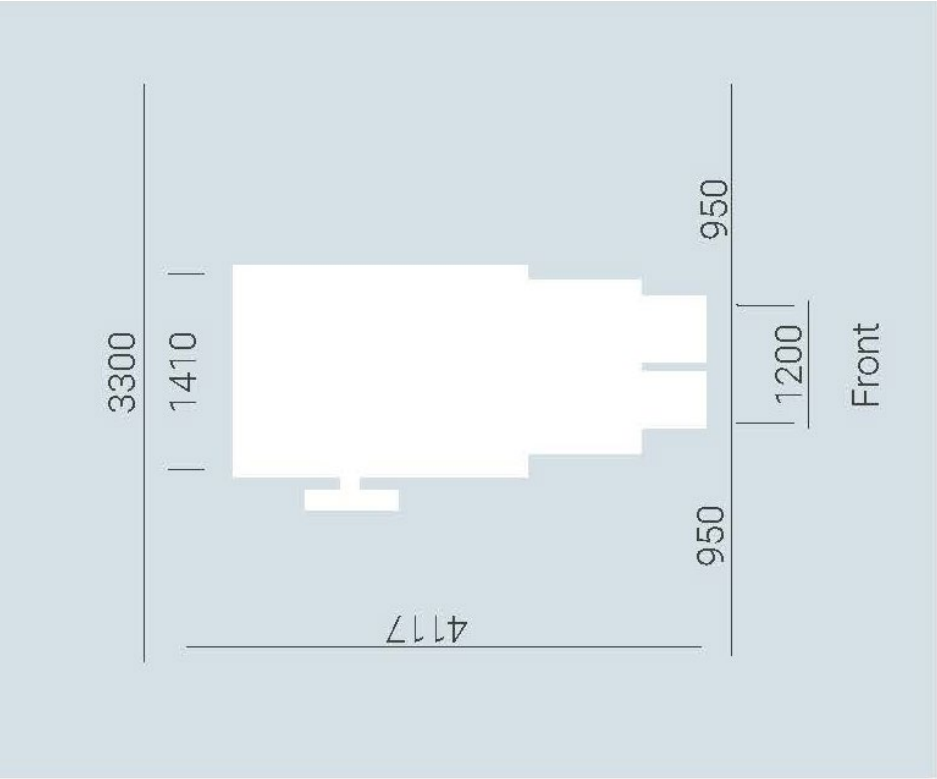
Powered by an advanced motion platform, ONYX Series software achieves submicron accuracy, ensuring unparalleled precision in every inspection, and precise 3D geometrical inspection of features, including micro-bumps, pillars, and pads. Take your semiconductor manufacturing to new heights with composition analysis seamlessly integrated with FinFET structures. The ONYX Series goes beyond expectations with fully automated calibration processes, guaranteeing long-term stability and consistency in your operations. Bid farewell to concerns about tube aging, as our software includes intelligent correction mechanisms to maintain peak performance over time. Stay at the forefront of technological excellence with a software solution that aligns seamlessly with industry standards – the ONYX Series is in line with SECS/GEM communication protocols, ensuring a smooth and efficient workflow.


User-friendly, graphical user interface.

Elevate your wafer inspection and metrology processes with the onyx series, where precision meets innovation

- Optimal configuration for bumps inspection.
- Array of 4 silicon drift detectors (SDD) with a large active area and 123 eV FWHM (@5.9 keV) resolution.
- Measures light (low-energy) elements (carbon, oxygen, magnesium, aluminum, and phosphorous) using an optional helium atmosphere and special SDD detectors.
- Monochromatic or polychromatic x-ray options.
- Inspects micro-features through focused vertical X-ray beam (down to 10 µm diameter for polychromatic optics and 20 µm diameter for monochromatic optics).

Typical floor arrangement



Requirements

Tool body (including load ports)
1430 (W) x 3220 (D) x 2125 (H) mm
Approx. 2600 kg

Chiller unit
870 (W) x 377 (D) x 868 (H) mm
Approx. 50 kg

Power Supply
Main unit 208 VAC Phase 3 50/60 Hz 25A

Chiller unit
200-23 VAC Phase 1 50/60 Hz 10 A

Cooling water for chiller unit
0.3~0.5 MPa 1L/min at 25 degree C

Vacuum#1 -90~-70 kPa 80 L/min

Vacuum#2 -90~-70 kPa 80 L/min
CDA 0.48~0.52 MPa

Safety Standards Compliance: SEMI S2 and SEMI S8

Communication Standards Compliance: GEM300 and SECS/GEM

Quality Standards: ISO 9001 and ISO 14001 approved

About Rigaku

Founded in 1951 in Tokyo, Japan, Rigaku is an analytical and industrial instrumentation leader. With numerous innovations, the Rigaku group of companies is now a global authority in several fields, including X-ray diffraction (XRD), thin-film analysis (XRF, XRD, and XRR), X-ray fluorescence spectrometry (TXRF, EDXRF, and WDXRF), small-angle X-ray scattering (SAXS), protein and small molecule X-ray crystallography, Raman spectroscopy, X-ray optics, semiconductor metrology (TXRF, XRF, XRD, and XRR), X-ray Topography Imaging, X-ray sources, computed tomography, non-destructive testing, and thermal analysis While X-ray and related technologies are the foundation of Rigaku's business, its true strength lies in its commitment to working with customers. By fostering partnerships and driving innovation, Rigaku powers new perspectives and tailor-made solutions to meet the diverse needs of industry, academia, and government.

With a global presence and over 2,000 employees worldwide, Rigaku values collaboration between users and employees to ensure alignment with customer needs and market trends. Its products and services drive innovation in fields as diverse as semiconductor chip design, drug discovery, and nanotechnology research.

We value our customers, value our people, and value our technology. The company's mission is to contribute to the enhancement of humanity through scientific and technological development.

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