

**BRUKER NANO SURFACES AND METROLOGY**

# **Semiconductor Solutions**

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Assess and Improve Semiconductor Manufacturing Processes

Innovation with Integrity

# Process Equipment and Metrology Systems

Bruker's comprehensive suite of specialized technologies addresses the broadest range of metrology and process monitoring needs, from R&D to process improvement. 75% of the world's top 25 semiconductor manufacturers rely on Bruker instrumentation for their front-end and back-end applications. Our commitment to innovation also drives the advances that enable continual development of next-generation semiconductor devices.

## Our dedicated semiconductor solutions include:

- **Ellipsometry and Reflectometry**—Thin film metrology systems for wafer and CD metrology to meet requirements not measurable with conventional equipment
- **Automated X-Ray Metrology**—Systems for high-quality QC monitoring, detailed R&D analysis of epi-layer films, identification of substrate defects, front-end-of-line control of epi films and high-k dielectrics, and analysis of metal films and wafer-level packaging bumps
- **Automated Atomic Force Microscopy**—Systems to reliably measure surface roughness, chemical mechanical planarization (CMP), and etch-depth features
- **Photomask Repair**—Systems to address the critical production issue of controlling pattern defects on high-end photomasks
- **Cryo Dry Cleaning**—Cryogenic CO<sub>2</sub> process equipment to remove contaminants and residues from wafers and electronic devices
- **Surface Metrology**—Measurement and testing solutions for efficient process monitoring and control across the full range of applications



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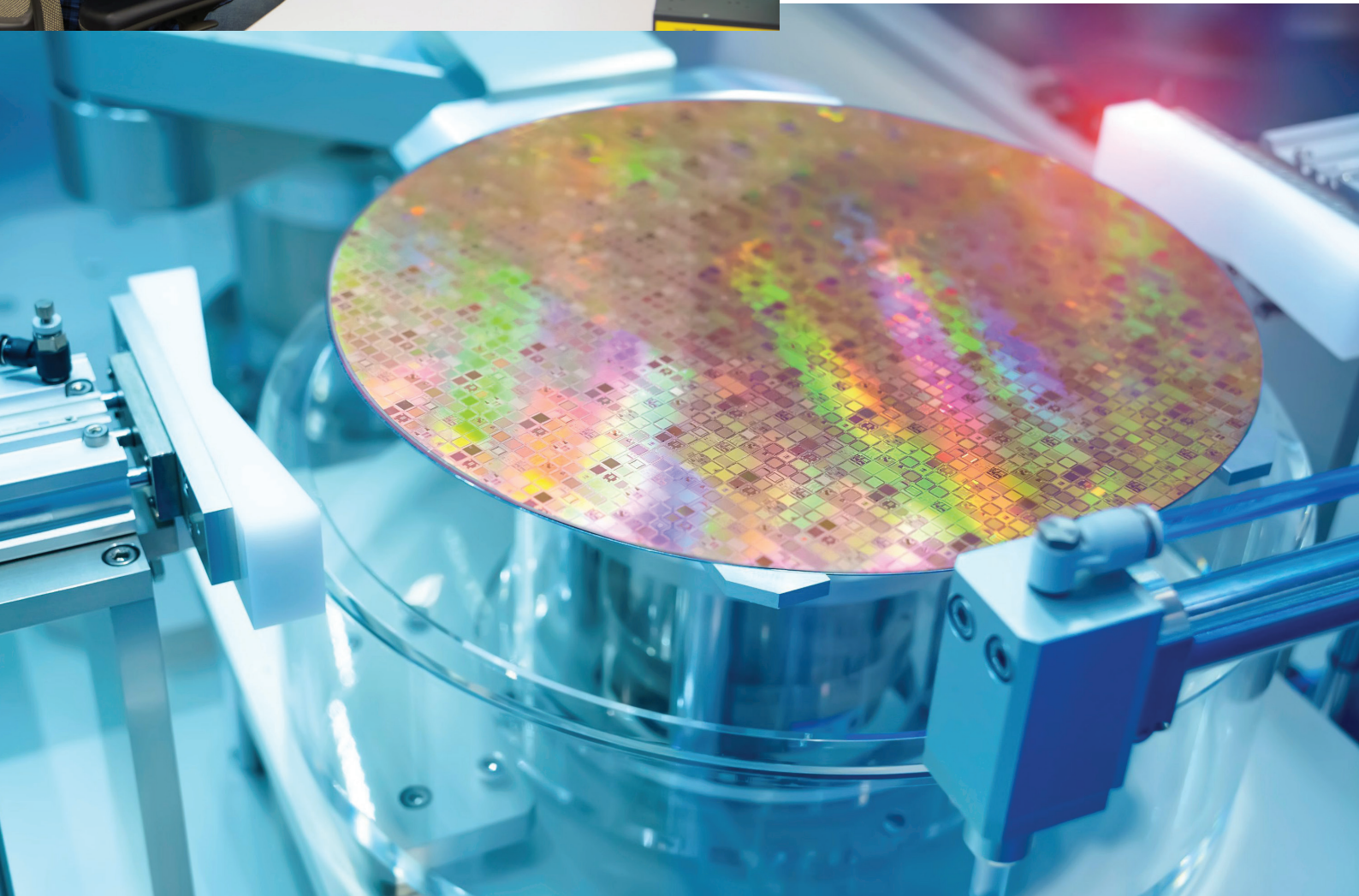
# Service and Application Support to Optimize Tool Utilization



The decision to invest in high-performance metrology is based on more than instrument performance and price. Bruker is committed to keeping your tool running at the peak of up-time and productivity. We have a highly educated worldwide team of service and support personnel that takes great pride in first-time solution of issues. Our variety of service coverage programs can be customized to match your specific requirements, including optimization of tool performance, recipe writing, and in-person technical support visits.

## **Bruker tailors services to your needs:**

- Priority technical support
- Advance replacement parts and assemblies stored in regional warehouses for rapid response times
- Application and training services



# Non-Contact In-Line Metrology for Film Analysis

Featuring exclusive and patented technology for spectroscopic ellipsometry and reflectometry, multiple-angle reflectometry, and reflection-transmission spectrophotometry, Bruker's extensive FilmTek™ product line enables more precise and repeatable measurements on wider film types and thicknesses.

## Broad Capabilities and Efficient Operation

FilmTek ellipsometry and reflectometry systems have best-in-class accuracy and refractive index resolution for many thick, thin, and multilayer films. This performance enables applications that are not feasible with other metrology systems. FilmTek tools are available from fab to lab with a variety of automation options to suit individual customer requirements.

**Metrology:** film thickness, refractive index, total thickness variation (TTV), composition and crystallinity, critical dimensions (CD), and roughness

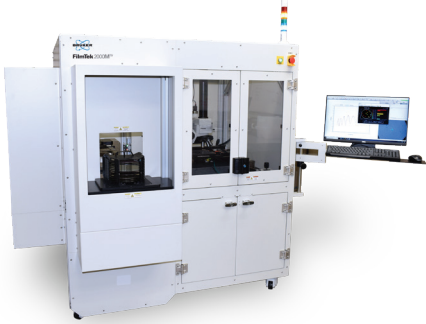
**Layer thickness:** from bare substrate ( $<1 \text{ \AA}$ ) to very thick (2 mm)

**Sample types:** dielectrics, semiconductors, III-V films, thin metals, metal oxides



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# Ellipsometry and Reflectometry Semiconductor Solutions



## Applications

- In-line control for multi-layer film thickness and refractive index on micron-sized device features
- In-line composition control (e.g., %Ge in  $\text{SiGe}_x$ ) for thin films
- In-line process control of thin metal oxide thickness to prevent non-wet open failures
- In-line monitoring of high-aspect-ratio TSV depth and CD
- Accurate, high-throughput trench depth measurement
- High-resolution measurement of film thickness and refractive index for silicon photonics (e.g.,  $\text{SiON}$ ,  $\text{Si}_3\text{N}_4$ )

## Designed for Individualized Needs

**FilmTek 2000M TSV:** Fully automated metrology platform for film thickness, high-aspect-ratio TSV depth, critical dimension, and trench depth

**FilmTek 2000 PAR-SE:** Advanced multi-angle and multi-modal technology for production measurement of thin films and multi-layers

**FilmTek 6000 PAR-SE:** Advanced multi-angle and multi-modal technology for monitoring thickness and refractive index of IC device film layers at the 1x design node and beyond

**FilmTek 4000 NIR:** High-resolution measurement of film thickness and refractive index for silicon photonics and planar waveguide applications

# Non-Destructive X-Ray Technology for Films and Wafers

## **Silicon Semiconductor**

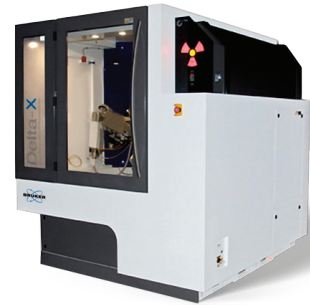
Bruker provides the world's most advanced and non-destructive X-ray technology solutions for thin-film metrology for high-volume manufacturing fabs, covering the full range of processing in both logic and memory. We offer specialized systems for identifying substrate defects and performing front-end-of-line process control of epi films and high-k dielectrics, as well as dedicated products for analyzing metal films and wafer-level packaging bumps.

## **Compound Semiconductor**

X-ray metrology tools for the compound semiconductor industry range from QC monitoring of epi-layer films to detailed R&D analysis of a wide range of semiconductor films and wafers. Bruker offers systems designed specifically for the challenging demands of the production environment, as well as multi-application research tools for development supporting current and future metrology needs.

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# Automated X-Ray Metrology Semiconductor Solutions



## Applications

- Nanosheet thickness and composition metrology
- Thin film crystalline measurements
- Bump metallization process monitoring
- Advanced memory high-aspect ratio 3D metrology
- Power devices FEOL process monitoring
- BEOL metallization process monitoring

## Silicon Semiconductor

**SIRIUS-XCD:** X-ray-based high-aspect ratio 3D profiling for advanced memory

**SIRIUS-XRD:** Next-generation X-ray diffraction metrology for gate-all-around and advanced memory devices

**SIRIUS-RF:** Fully automated  $\mu$ XRF and XRR metrology platform for advanced front-end of line logic and power devices

**SIRIUS-FW:** Fully automated  $\mu$ XRF metrology platform to monitor bump composition and under bump metallization

**7300LSI:** X-Ray metrology for in-fab R&D and in-line production process monitoring

## Compound Semiconductor

**DELTA-X:** Latest generation of X-ray metrology system for semiconductor thin film analysis

**QCVELOX-E:** Latest generation, high-throughput HRXRD for epilayer monitoring

**QC3:** Dedicated HRXRD metrology system for epilayer monitoring

# Advanced In-Line X-Ray Imaging

Bruker defect detection systems use X-ray diffraction imaging (XRDI) to detect crystalline defects on single-crystal substrates, such as slip, cracks, dislocations, and micropipes. Operating without the use of etching acids, our non-contact XRDI inspection systems are broadly employed to detect cracks in Si wafers that cause wafer breakage and to improve yield and quality of other high-value substrates such as CdTe and SiC.

In addition, Bruker offers advanced X-ray imaging (XRI) for 100% inspection and real-time feedback on the die-attach process, revealing even marginal defects that can pass electrical testing. XRI can be used to improve process control systems for a wide range of applications, from system-in-package (SiP) to 2.5D/3D integrated circuit (IC) integration.



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# X-Ray Defect Inspection

## Semiconductor Solutions



### Applications

- Advanced packaging defect inspection
- Thin film crystalline defect monitoring
- Warpage and tilt mapping for advanced processors
- Wetting behavior analysis for automotive controllers
- Automatic non-wet detection for wireless chips

### X-Ray Defect Inspection

**SENSUS-600F:** High-throughput non-visual defect inspection for fully automated 300 mm fabs

**SENSUS-CS:** High-resolution XRDI system specifically designed for production monitoring of SiC

**QC-TT:** Production-dedicated, non-visual defect detection and classification in high-value substrates including Si, GaAs, GaN, and InP

**QC-RT:** Production-dedicated, non-visual defect detection and classification in CdTe, HgCdTe, and other high-density substrates

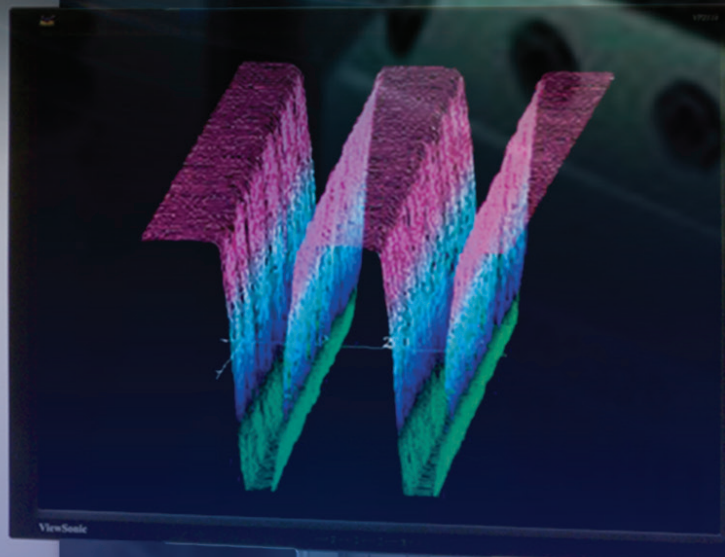
**X200:** Precise, real-time metrology and defect feedback for improving process control systems

# High-Accuracy Probe-Based Metrology

Automated AFM metrology solutions reliably measure surface roughness, chemical mechanical planarization (CMP), and etch-depth features on the most current technology nodes and wafers. Bruker has a long-standing reputation for providing the highest-available speed and performance for industrial metrology applications. Designed specifically for high-volume production environments, our systems offer the utmost ease of use and the lowest cost per measurement for quality control, quality assurance, and failure analysis.

Bruker's InSight® family of fully automated AFM systems are integrated into production lines, allowing data collection to take place without operator intervention for advanced in-line process control. With highly repeatable and accurate roughness, height, and depth measurements—from sub-nanometer steps to high aspect-ratio trenches—you can locate and characterize nanoscale defects on a variety of wafers, substrates, and sliders. Some common applications are in semiconductor, data storage, polymers and thin films, high-brightness LED and solar materials, and display manufacturing.

In the category of probe-based solutions beyond automated AFMs, Bruker's SmartProber P1 enables high-field, high-accuracy current-in-plane tunneling (CIPT) measurements to characterize magnetic tunnel junctions (MTJs), with both in-plane and perpendicular field options available.



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# Automated AFM and CIPT Semiconductor Solutions



## Applications

- CMP process control and development
- Etch process control and development
- Lithography EUV process control and development
- Sidewall metrology and CD reference
- Surface roughness metrology for FEOL/BEOL
- CIS and CFA analysis
- QA/QC for etch depth

## Automated Atomic Force Microscopy

**InSight AFP:** World's only metrology tool designed to measure both CMP and etch-depth, offering unmatched capabilities and precision

**InSight CAP HP:** World's most intuitive, easiest-to-use, cost-effective AFP providing the highest value, performance, and lowest cost-of-ownership

**InSight CAP:** A low-cost automated AFM that is focused on CMP, depth, and roughness applications

## Current-In-Plane Tunneling

**SmartProber-P1:** Advanced CIPT system for semiconductor R&D and failure analysis, mapping 300 mm wafers with a high perpendicular-to-plane magnetic field

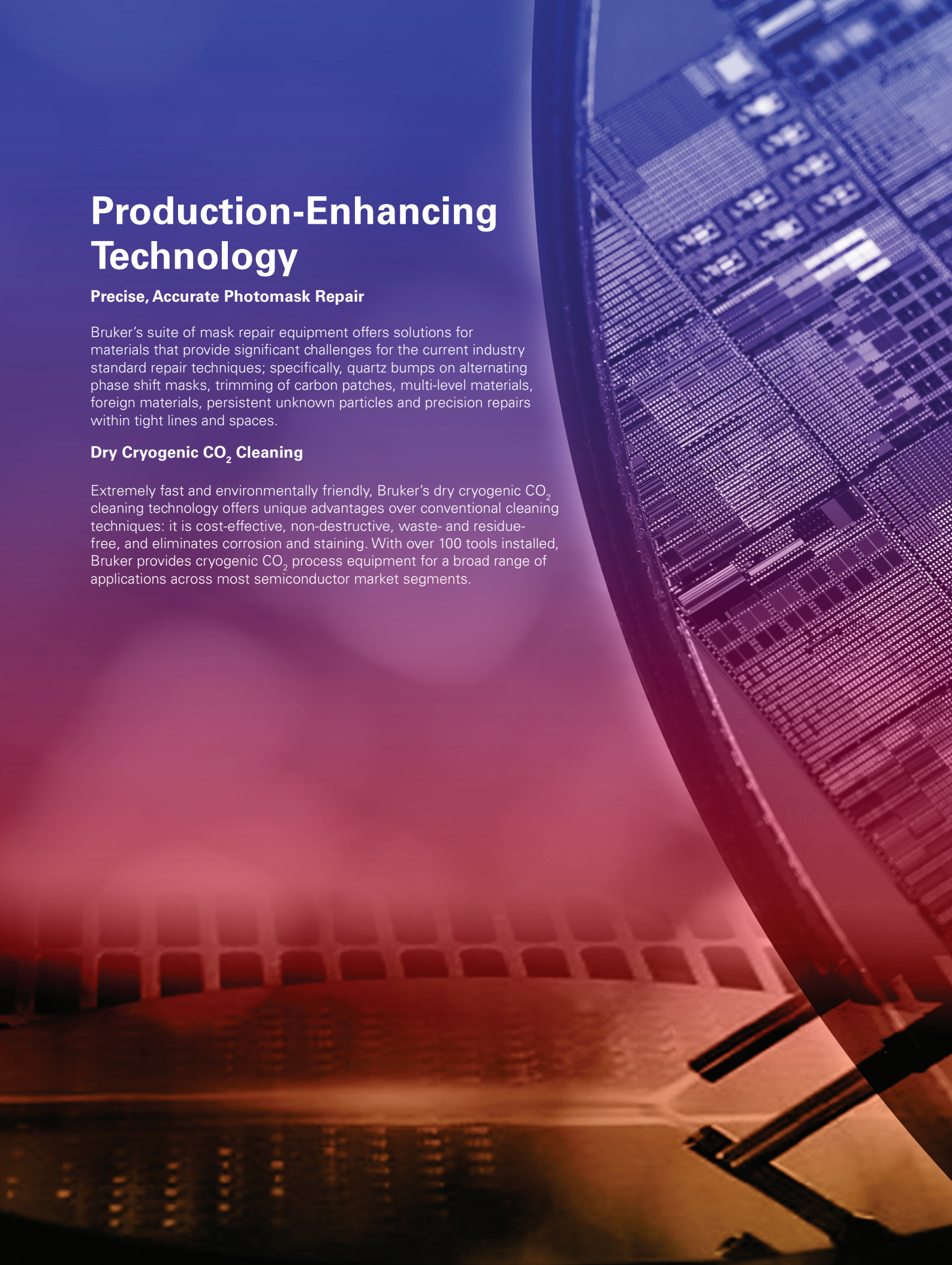
# Production-Enhancing Technology

## Precise, Accurate Photomask Repair

Bruker's suite of mask repair equipment offers solutions for materials that provide significant challenges for the current industry standard repair techniques; specifically, quartz bumps on alternating phase shift masks, trimming of carbon patches, multi-level materials, foreign materials, persistent unknown particles and precision repairs within tight lines and spaces.

## Dry Cryogenic CO<sub>2</sub> Cleaning

Extremely fast and environmentally friendly, Bruker's dry cryogenic CO<sub>2</sub> cleaning technology offers unique advantages over conventional cleaning techniques: it is cost-effective, non-destructive, waste- and residue-free, and eliminates corrosion and staining. With over 100 tools installed, Bruker provides cryogenic CO<sub>2</sub> process equipment for a broad range of applications across most semiconductor market segments.



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# Mask Repair and Wafer Cleaning Semiconductor Solutions



## Applications

- High-end, complex photomask repair
- Precision repairs within tight lines and spaces
- Remove corrosion and staining

## Mask Repair

fp-III: 3rd-generation femto-pulse laser repair system

nm-IV: 6th-generation AFM guided nanomachine

Rhazer III: 3rd-generation haze removal system

## Mask and Wafer Cleaning

EL-C: 2nd-generation photomask dry cleaning system

Wafer Clean 2200: Non-aqueous CO<sub>2</sub> cryogenic dry cleaning

# Lab-to-Fab Characterization

## White Light Interferometry and Stylus Profilometry

Bruker's white light interferometry (WLI) optical profiling metrology systems make obtaining quality 3D areal surface texture and roughness measurements easy and fast. Incorporating 30+ years of innovation and our latest proprietary software and technology, these metrology systems provide the rapid time-to-results and repeatability that Bruker's optical profilers are known for.

Dektak® stylus profilers are the culmination of over five decades of proprietary technology advances. They provide repeatable, reliable, and accurate measurements—from traditional step height measurements and 2D roughness surface characterization to advanced 3D mapping and film stress analyses.

## Nanomechanical Testing and Tribology

Bruker's Hysitron® nanomechanical metrology tools provide automated metrology solutions that deliver high-speed, high-resolution, highest-sensitivity mechanical property and/or interfacial adhesion measurements, streamlining nanomechanical property

sampling and empowering persistent product and process improvement.

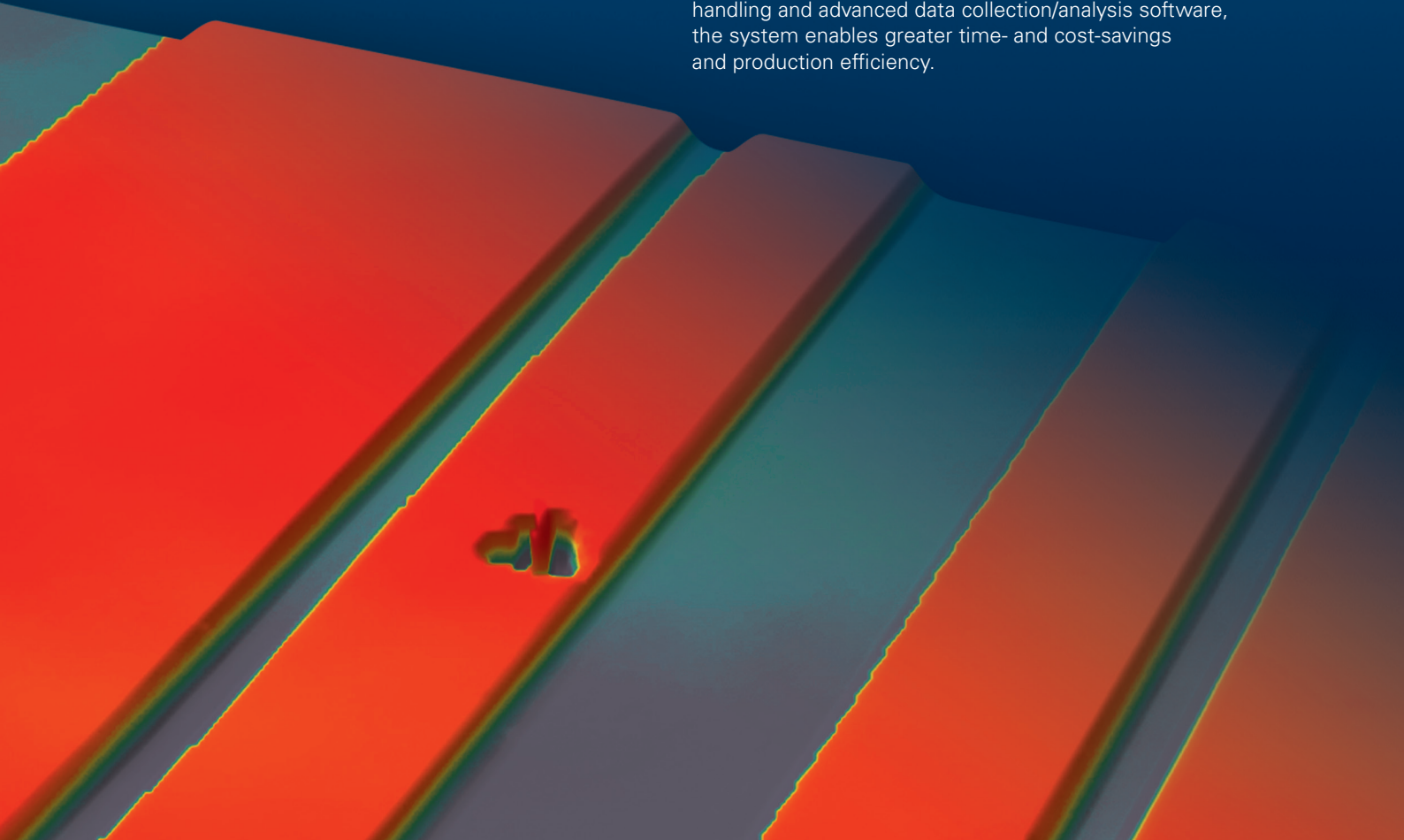
Bruker's PI 89 Auto brings full automation to our market-leading Hysitron PI 89 SEM PicoIndenter®. The new tool facilitates correlative structure-property analysis by automatically moving the advanced Rotation and Tilt Stage (R/T stage) to the indentation position following SEM imaging and EBSD/EDS mapping.

TriboLab CMP brings a complete set of capabilities to the industry-leading TriboLab® platform. The resulting accuracy and measurement repeatability enables the highly effective qualification, inspection, and ongoing functionality testing required throughout the CMP process.

## Nanoscale Property and Chemical Characterization

The Dimension® family of atomic force microscopes (AFMs) have a long-standing reputation for providing the highest available speed and performance for industrial metrology applications. The Dimension FastScan Pro enables automated or semi-automated measurements while ensuring the utmost ease of use and the lowest cost per measurement for quality control, quality assurance, and failure analysis.

Built on the groundbreaking large-sample architecture of the Dimension IconIR platform, IconIR300 provides correlative microscopy and chemical imaging, as well as enhanced resolution and sensitivity. Integrated with automated wafer handling and advanced data collection/analysis software, the system enables greater time- and cost-savings and production efficiency.



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# Surface Metrology

## Semiconductor Solutions



### Applications

- Die flatness and CMP metrology for advanced packaging
- TSV and interconnect measurements
- Hot-spot and defect detection on full reticle die
- Automated thin film mechanical and interfacial adhesion metrology
- In-line and near-line process monitoring
- Complete characterization of CMP processes and consumables
- Surface roughness characterization, step height measurements, and film stress analyses

### White Light Interferometry and Stylus Profilometry

**InSight WLI:** Fully automated optical surface measurement capabilities with wafer-handler integration, designed for R&D, quality assurance, and process quality control.

**ContourSP:** Large-panel metrology system for high-volume, high-precision PCB production control.

**ContourX-1000:** Self-calibrating, fully automated solution for research and production.

**Dektak XTL:** Gage-capable QA/QC profiler for optimal 300 mm performance.

### Nanomechanical Testing and Tribometry

**Hysitron ATI 8800:** Automated thin film mechanical and interfacial adhesion metrology.

**Hysitron TI 980 TriboIndenter:** The world's most powerful nanomechanical and nanotribological test system.

**PI 89 Auto:** Automated co-localized imaging and analysis for high-throughput in-situ nanoindentation

**TriboLab CMP:** R&D-scale process and material characterization system for wafer polishing processes

### Chemical and Magnetic Characterization

**Dimension IconIR300:** Variation of the high-performance IconIR platform with 300 mm of sample access, ideal for semiconductor R&D, failure analysis, and nanocontaminant identification

**Dimension FastScan Pro:** Automated nanometrology for industrial R&D

# Technique Insertion Point Overview

Technique	Instrument(s)	Front End Process	Middle End Process	Back End Process
Automated Atomic Force Microscope (AAFM) Metrology	InSight AFP	•	•	•
	InSight CAP HP			
	InSight CAP			
Cryo Dry Cleaning	Wafer Clean 2200	•		
High-Resolution X-Ray Diffractometry (HRXRD)	Delta-X	•		
	QC3			
	QCVelox-E			
Micro X-Ray Fluorescence ( $\mu$ XRF)	Sirius-FW	•	•	
	Sirius-RF			
	Sirius-XCD			
	Sirius-XRD			
Photomask Repair	EL-C	•		
	fp-III			
	nm-VI			
	Rhazer-III			
Spectroscopic Ellipsometry/Reflectometry	FilmTek products	•	•	•
X-Ray Diffractometry (XRD)	7300LSI	•		
X-Ray Diffraction Imaging (XRDI)	QC-TT	•	•	•
	QC-RT			
	Sensus-600F			
	Sensus-CS			
X-Ray Imaging (XRI)	X200		•	•

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