

Metrios 6S (S)TEM

Automated TEM metrology solution with operator-free TEM grid handling and seamless data connectivity

The Thermo Scientific™ Metrios™ 6S (S)TEM is a (scanning) transmission electron microscope engineered to meet the growing demand for high-volume reference metrology data in advanced memory and logic device applications.

It inherits all the benefits of the Metrios 6 (S)TEM metrology platform while offering enhanced physical and data connectivity. The Metrios 6S (S)TEM features automated grid handling and seamless data connectivity within the Thermo Scientific Vulcan Automated Lab workflow. This design is tailored to the unique challenges associated with scaling TEM lab operations, ultimately enhancing productivity, optimizing resource use, and delivering precise and reliable metrology data.

Fully automated TEM metrology for the Vulcan Automated Lab

The Metrios 6S (S)TEM features newly designed hardware and machine-learning-based capabilities, delivering precise nanoscale measurements through automated image acquisition and analysis, which are essential for semiconductor manufacturing. It retains all the automated TEM imaging and metrology advantages of the Metrios 6 (S)TEM while also increasing productivity through innovations in stage design and energy-dispersive X-ray spectroscopy (EDS) detection. The piezo-driven Smart Stage delivers highly accurate and repeatable TEM sample and feature navigation, while the Ultra-X EDS Detector provides at least 2x faster data acquisition compared to its predecessor (the Dual-X EDS Detector), minimizing sample damage.

In addition, as an integral part of the Vulcan Automated Lab workflow, the Metrios 6S (S)TEM offers TEM grid handling that is compliant with SEMI Standards along with a seamless factory host connection. This integration allows for automated TEM grid transfer from a sample preparation system (such as

Key features

Fully automated TEM imaging and metrology through advanced hardware and machine-learning-based capabilities. Integration with Vulcan Automated Lab allows for SEMI-Standard-compliant TEM grid handling and seamless host connectivity, ensuring continuous data flow with an MES.

Automated TEM grid handling. The Equipment Front End Module offers an automated, operator-free solution for high-throughput loading and unloading of SEMI-Standard-compliant TEM lamella carriers (i.e., grids), compatible TEM holders, and optional in-flow plasma cleaning of the grids and the holders.

Automated data connectivity. Seamless SEMI-Standard communication between the MES and workflow control software streamlines production workflows. For labs without an MES, Metrios Connect Software directly links the sample preparation system to the Metrios 6S (S)TEM, enabling the creation and scheduling of imaging jobs executed in the Metrios 6S (S)TEM application software.

Inherits all the benefits of the Metrios 6 (S)TEM for automated TEM imaging and metrology, with increased productivity through innovations in stage design and EDS detection.

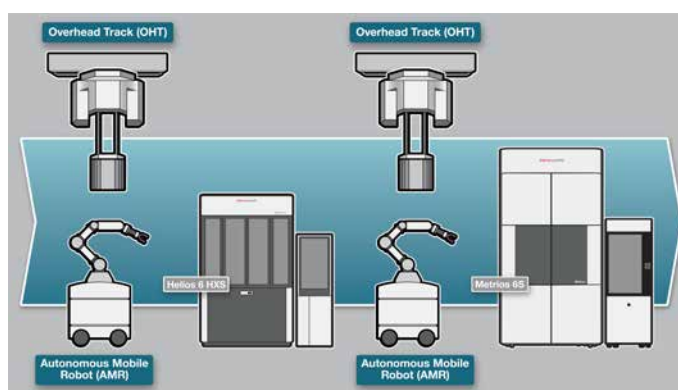


Figure 1. Automated sample and TEM grid handling workflow, enabled by the Vulcan Automated Lab.

the Thermo Scientific™ Helios™ 6 HXS FIB-SEM) and ensures continuous data connectivity with the lab’s MES (manufacturing execution system). Smart Automation Software further enhances productivity by enabling recipe-free automation, making lab operations scalable and optimizing resource utilization.

Incorporating the Metrios 6S (S)TEM into an automated workflow allows for efficient tracking of sample-specific lamella information, such as lot and wafer ID, from sample preparation to metrology data acquisition. By combining and reporting workflow data across multiple tools, the system automates operator actions, minimizes manual errors, and enhances data consistency and traceability.

Automated TEM grid handling

The Metrios Equipment Front End Module (EFEM) is an advanced TEM grid (lamella carrier) handling system designed for the Metrios 6S (S)TEM. It offers an automated, operator-free solution for high-throughput loading and unloading of TEM lamella carriers (LCs) that seamlessly integrates with automated materials handling systems (AMHS) via overhead tracks (OHTs) or autonomous mobile robots (AMRs).

In this workflow, samples are delivered to a compatible Thermo Scientific sample-preparation system via the AMHS for lamella creation and then transferred to the Metrios 6S (S)TEM for high-precision metrology data collection. The Metrios EFEM receives samples on a lamella carrier container (LCC) from the sample preparation system. The LCC enters the Metrios EFEM on a tray via the AMHS. (The LCC contains multiple LCs and each LC can

contain multiple lamellae.) The LC is automatically loaded into the microscope holder, which is then automatically placed in the microscope.

The Metrios EFEM includes an optional integrated plasma cleaner, allowing for automated in-flow plasma cleaning of samples and sample holders.

Automated data connectivity

MES connectivity:

Automated data connectivity facilitates seamless SEMI-Standard communication between the MES and the instrument’s workflow control software; Metrios Connect Software. This includes the ability to interface with the OHT or AMR material handling system.

File-based connectivity:

If the sample preparation system and the Metrios 6S (S)TEM are not connected to the MES, they can be linked together directly for workflow data connectivity. Metrios Connect Software is used to create and schedule imaging jobs for the Metrios 6S (S) TEM, which are then executed in the instrument’s application software. This enables a streamlined workflow with enhanced data connectivity and automated processing.

Metrios Connect Software also enhances the efficiency and control of production workflows in semiconductor environments by: allowing you to configure and execute job automation as defined by workflow files, adjust job priorities with the hot lot queue, and monitor the progress/status of lamellae and LCs in real-time.

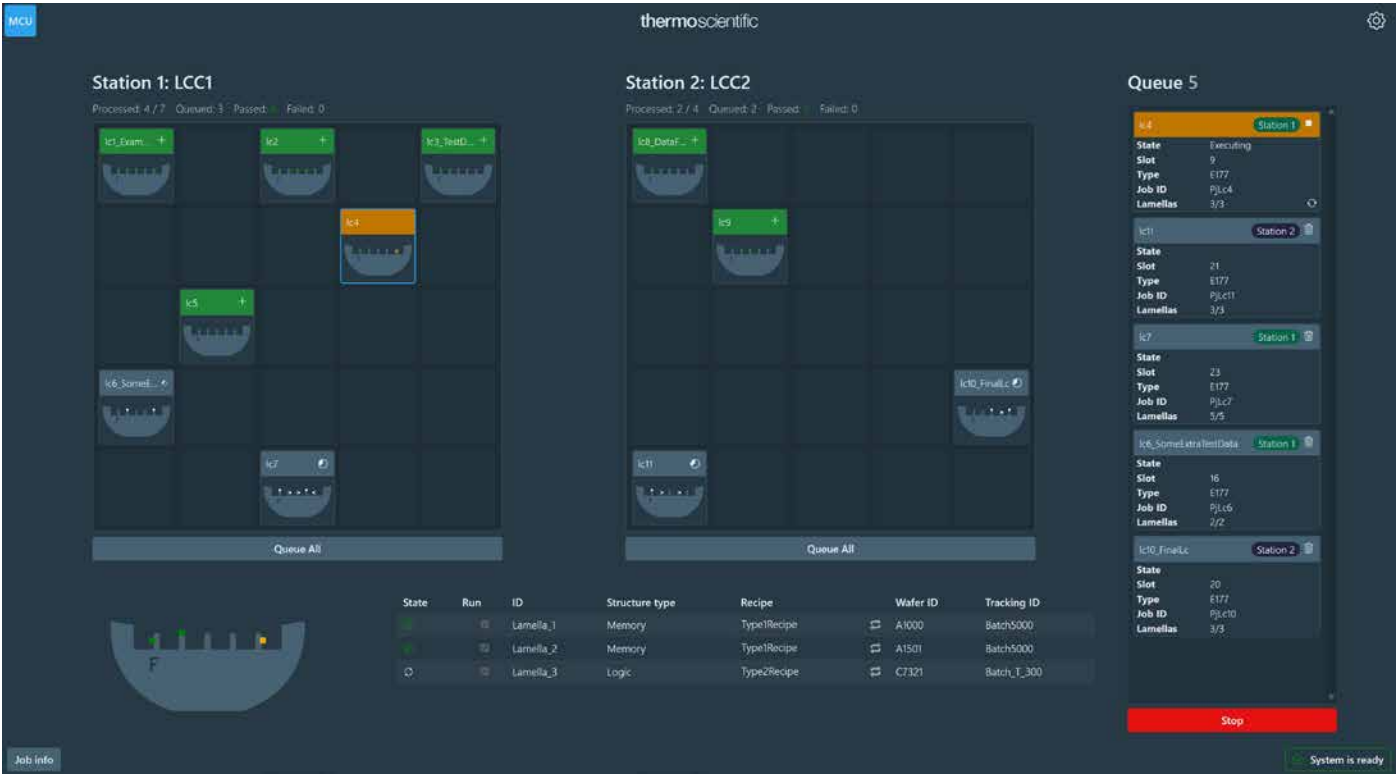


Figure 2. Metrios Connect Software UI.

Technical highlights

Metrios 6S (S)TEM	Energy spread	Information limit (pm)	STEM resolution (pm)
Probe corrector + X-CFEG	0.4 eV	≤110 (≤220 at 60 kV)	≤60 (≤111 at 60 kV)
Probe corrector + X-FEG	1.1 eV	≤110 (≤220 at 60 kV)	≤83 (≤164 at 60 kV)

NOTE: All resolutions reflect a manual use case.

The Metrios 6S (S)TEM inherits all the core benefits of the Metrios 6 (S)TEM, with additional physical and digital connectivity.

Metrios 6 (S)TEM core benefits		Metrios 6S (S)TEM added benefits	
Data Integrity	• Accuracy and precision – <0.75% combined error in distortion and magnification calibration – Automated calibration • Traceability through a high-confidence metrology reference, calibrated against silicon lattices	Automated TEM lamella handling	• Automated, high-throughput loading and unloading of TEM lamella without manual intervention • Seamless integration with an AMHS via OHT or AMR • Vulcan Automated Lab streamlines processes by reducing operator burden and increasing overall productivity
Process Automation	• Enhanced navigation and device identification via AI/ML • Wide variety of metrology applications including logic, DRAM, planar 3D NAND, blanket film, and semi-auto mode • Automated tool alignment for robust TEM automation		
Enhanced productivity	• High sample throughput with a redesigned Smart Stage and Ultra-X EDS Detector, which improve productivity by ~20% and enable >2x faster elemental analysis compared to the previous Metrios AX TEM (estimated based on typical semiconductor workflows; results will vary) • Increased system availability thanks to fast thermal stability (<20 mins) during high-tension switching along with reduced human errors through automated sample insertion • 50x faster model training reduces time to recipe with a web-based segmenter and a new object-detection algorithm	New workflow connectivity	• MES connectivity enables seamless SEMI Standard communication between the MES and the Metrios 6S (S)TEM, as well as interfacing with OHT or AMR systems – Enhances efficiency and data exchange while reducing manual intervention and errors • File-based connectivity (for labs without MES) streamlines workflows by directly linking the sample preparation system and the Metrios 6S (S)TEM – Improves data connectivity, automated processing, and efficient, accurate job execution

Metrios Equipment Front End Module

- Automated TEM lamella handling
 - Receives TEM lamella on an LCC from Thermo Scientific sample preparation systems
 - Automatically loads the LC into the microscope holder and places it in the Metrios 6S (S)TEM
 - Retrieves the holder after inspection/imaging and stores the LC in the LCC
- Compatibility
 - Automated mode: Compatible with the E177 5-finger LC
- Pre-loaded holders
 - Compatible with various TEM grids that can be manually loaded into the high-accuracy beta-tilt holder
- Optional features
 - Integrated plasma cleaner for automated in-flow plasma cleaning of samples and holders

Source

- Choice of ultra-stable, high-brightness Schottky field emission gun (X-FEG) or ultra-high-brightness cold field emission gun (X-CFEG) with an energy resolution of <0.4 eV at optimal extractor voltage conditions and a flexible high-tension range from 60 to 200 kV

Optical column and correctors

- Three-lens condenser system with indicators for convergence angle and the size of the illuminated area
 - Provides quantitative measurement of electron dose and illumination conditions
- S-CORR Probe Corrector provides sub-Ångström imaging resolution at 60 kV as specification and an order-of-magnitude improvement in optical stability. The S-CORR Probe Corrector simultaneously corrects A5 for all accelerating voltages.
- New CEOS Auto S-CORR Alignment Software makes probe corrector tuning fast, easy, and fully automated up to and including 4th order aberrations
- Patented mechanical stacking of column modules minimizes instabilities caused by excessive deflector excitations
- Constant power lenses, designed for improved thermal stability in mode switches, minimize image drift
- Low-hysteresis design minimizes crosstalk between optical components for enhanced reproducibility
- Symmetric Super-TWIN Objective Lenses with a wide-gap pole piece design
- Objective aperture in the back focal plane of the objective lens optimizes TEM dark-field application work
- Automatic apertures enable remote control operation and reproducible recall of aperture positions during aperture change

- Sub-Ångström resolution is possible for all accelerating voltages (60–200 kV) with low specimen drift (manual)
- Integrated Faraday cup: calibrated fluscreen current readout is linear over entire beam current range

EDS detector

- EDS quantification using Thermo Scientific™ Velox™ Software, including dynamic correction of holder shadowing as a function of tilt
- Ultra-X Detector: high-sensitivity, windowless EDS detector system with high solid angle and high cleanliness
 - Output count rate: up to 1.5 Mcps
 - Energy resolution
 - ≤132 eV for Mn-Kα and 10 kcps (output)
 - ≤140 eV for Mn-Kα and 100 kcps (output)
 - 4.45 srad solid angle (without specimen holder)
 - >4.0 srad solid angle (with high-accuracy beta-tilt holder)
 - High P/B ratio (Fiori number) >2,500

Stage

- Five-axis piezo-driven Smart Stage with minimum XYZ step size of ≤20 pm
- Alpha-tilt under-goniometer software control: tilt range ±40 degrees for high-accuracy double-tilt holder
- High-accuracy beta-tilt holder
- Joystick control: improved low jogging speed for more comfortable search and view

Available detector options

- HAADF detector (standard)
- On-axis, solid-state, eight-segmented BF and ADF detectors (16 segments in total) (standard)
- Thermo Scientific™ Ceta™ 16M Camera (optional with speed enhancement)
- Gatan Energy Filter Continuum Series
- Electron microscope pixel array detector (EMPAD) (non-standard request)

Software

- Equipment Control Software (ECS)
 - Provides comprehensive manual control of the Metrios EFEM system for precise and efficient operation
 - Alarm recovery: Facilitates quick and effective recovery from alarms to minimize downtime and maintain productivity
 - Service and maintenance: Offers advanced tools and functionalities for troubleshooting and testing
- MES Connectivity Enabling License allows for seamless SEMI Standard communication between the MES and the Metrios 6S (S)TEM workflow control software
 - Includes the ability to interface with OHT or AMR material handling systems

- For labs without an MES connection, Metrios Connect Software enables efficient control of production workflows
- Recipe Editor Software is a graphical programming language toolkit for building and executing automation recipes
- Smart Automation Software allows operators to quickly set up automation routines for selected workflows
- Tool Readiness Software maintains application-critical microscope alignments and ensures high-quality data, preventing productivity loss due to runtime errors or collection of out-of-spec data

STEM low-dose and high-contrast imaging software

- Integrated differential phase contrast (iDPC) imaging technique in Velox Software
 - Uses low probe current for high signal-to-noise ratio images
 - Improves contrast for light elements, making oxygen atoms visible alongside heavier elements like strontium and titanium
 - Enables differential phase contrast imaging of magnetic and electric fields with the segmented STEM detectors
 - Requires a multi-segment STEM detector and Velox Software (included with the Metrios 6S (S)TEM core system)
- OptiSTEM+ Software offers single-click correction of 1st and 2nd order probe-forming aberrations, delivering enhanced STEM resolution to all users of our probe-corrected tools
- Fully digital system for remote-controlled operation using the SmartCam suite

Available holders

- Smart Stage high-accuracy double-tilt holder

Other features

- Environmental enclosure eases the instrument's acoustic and room temperature variation requirements
- Cold trap provides up to four days of operation, maximizing uptime



Installation requirements

Please contact your sales representative for a complete list of pre-installation requirements.

Learn more at thermofisher.com/EM-semiconductors

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