Datasheet

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Metrios 6 (S)TEM

The new-generation, fully automated, (S)TEM reference metrology platform developed for high-volume, scalable metrology workflows

The Thermo Scientific™ Metrios™ 6 (S)TEM (scanning transmission electron microscope) is designed to meet the unprecedented demand for high-volume reference metrology data on advanced memory and logic devices. It increases productivity, optimizes resource utilization, and delivers high-confidence metrology data. Leveraging artificial intelligence, automation, and metrology precision, the Metrios 6 (S)TEM delivers repeatable, consistent data quickly, independent of the tool, the site, and the operator.

Fully automated workflow

The Metrios 6 (S)TEM provides automated sample insertion, precise region of interest (ROI) navigation, imaging optimization, and acquisition. Automated sample insertion accepts a wide variety of TEM samples prepared by our industry-standard DualBeam™ FIB-SEMs and prevents potential sample damage and vacuum drop due to human error. These capabilities maximize tool availability and throughput. Adding the Metrios 6 (S)TEM to an automated workflow solution facilitates tracking sample-specific lamella information, such as lot ID and wafer ID, from sample preparation to metrology data acquisition. By combining and reporting workflow data across multiple tools, decision-making time is minimized while data consistency and traceability are increased.

Recipe-free automation

The Metrios 6 (S)TEM is designed for unprecedented ease of use and scalability. The recipe-free full automation (Smart Automation) uses machine-learning algorithms to substantially reduce recipe development time for each new process or sample type. The application-specific smart automation (see Figure 1) supports a variety of semiconductor processes, e.g., gate-all-around (GAA), DRAM, and 3D NAND. The new web-based segmenter and object detection algorithm provide 50x faster model training on device structures. The Metrios 6 (S)TEM is also extensible to meet the future needs of the latest semiconductor R&D and manufacturing.

Key features
Fully automated workflow: Developed for high-volume, fully automated metrology and process characterization workflows. Automated sample insertion, precise ROI navigation, imaging optimization, and acquisition increase workflow productivity.
Recipe-free automation: Machine-learning-based automation eliminates the necessity of tedious recipe development for high-volume (S)TEM imaging and analysis applications.
Data integrity: Trusted, repeatable, and traceable TEM results, independent of the tool, the site, and the operator.
Enhanced productivity: Sample throughput and approximately 20% average productivity improvements enabled by innovations in stage, EDS detection, lens, and source technology.
Fast elemental analysis: The new Ultra-X EDS detector (4.45 Sr un-shadowed) delivers at least 2x faster data acquisition compared to other commercially available EDS systems, resulting in minimal sample damage on even the most beam-sensitive materials.

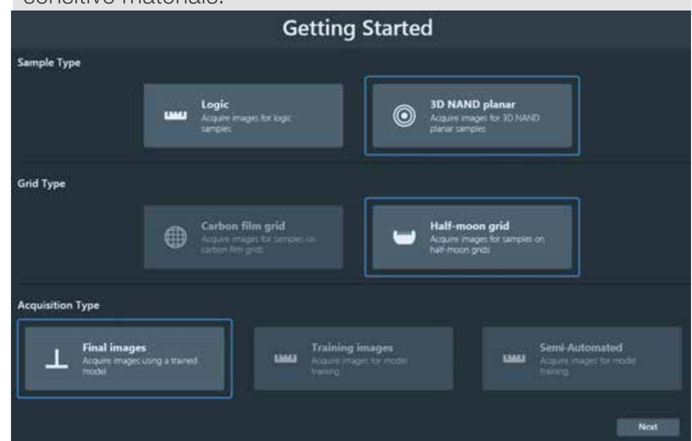

Figure 1. Application-specific Smart Automation UI showing a variety of semiconductor processes. You can select between different sample types and grid types to fit the application needs.

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Data integrity

The Metrios 6 (S)TEM comes with a series of hardware innovations and software enhancements, making it more capable of obtaining reliable and repeatable data.

- Smart auto zone axis alignment aligns a high-order silicon zone axis (e.g., Si<130>) in a defined region of interest.
- Smart tilt alignment automatically aligns 3D NAND planar samples to the beam, ensuring precise metrology analysis.
- Tool readiness maintains critical tool alignment for high-quality data and robust TEM automation.
- (S)TEM image quality matrix assured by Smart Automation.
- <0.75% combined error in distortion and magnification calibration for both TEM and STEM.

The use of these automation functions ensures extremely high image quality and data accuracy to support the latest semiconductor process (Figure 2).

Enhanced productivity

The Metrios 6 (S)TEM is a 60–200 kV instrument, designed to deliver high-quality and consistent TEM- and STEM-based imaging, analytics, and gauge-capable metrology results with 20% average productivity improvements. Fast sample throughput is delivered by the Smart Stage, the Ultra-X EDS detector, the new objective lens, the high-brightness X-CFEG source (optional), and the latest Smart Automation software. The newly designed, piezo-driven Smart Stage delivers highly accurate and repeatable TEM sample and feature navigation with an extensive movement range. The Smart Stage enhances the efficiency of imaging processes and enables you to perform high-resolution imaging at a faster pace.

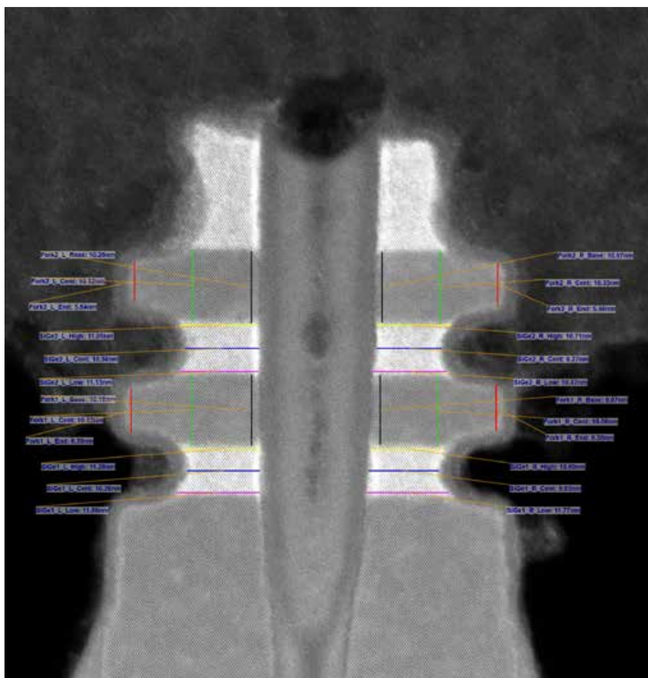

Figure 2. Automated metrology measurements applied to STEM image of a GAA forksheet transistor structure to highlight the support of <3 nm technology node processes. Measurements target the Si channel and remaining sacrificial SiGe for local process variations.

The Metrios 6 (S)TEM also features the new S-TWIN objective lens, which operates at constant power for all accelerating voltages between 60 and 200 kV. Fast accelerating voltage switching increases productivity and allows fast time to optimized results at different high tensions for more materials.

Fast elemental analysis

The Metrios 6 (S)TEM brings the next era in EDX detection to the market with the Ultra-X EDX detector, providing a solid angle at least two times greater than any other EDX detector solution in the market. It is comparable to the cleanest EDX available (<1% spurious peaks). The Ultra-X detector opens up new capabilities in EDX analysis of beam-sensitive semiconductor devices. Figure 3 shows the difference in normalized count rates of Ge Kα using the new Ultra-X detector compared to the Super-X and Dual-X detectors.

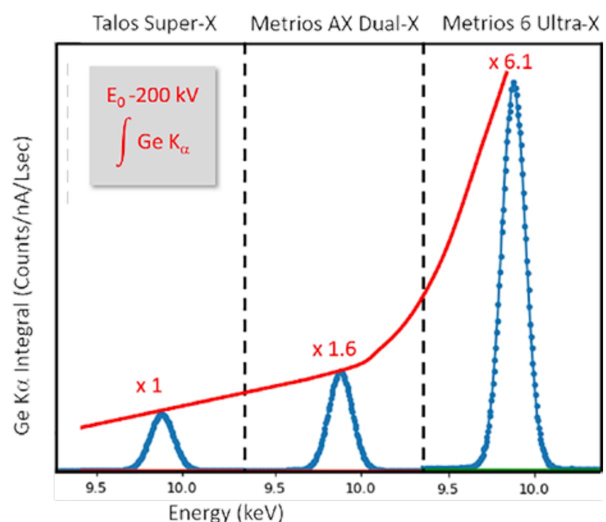

Figure 3. Normalized count rates of Ge Kα using the Super-X, Dual-X, and new Ultra-X detectors. Data recorded at 200 kV with optimized specimen holders for each detector configuration. *Source: Zaluzec, et al., Microscopy & Microanalysis, 2021*

Technical highlights

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

Note: All resolutions reflect a manual use case.

Metrios (S)TEM core benefits		Metrios 6 (S)TEM added benefits	
Data integrity	• **Accuracy:** <0.75% combined error in distortion and magnification calibration for both TEM and STEM • **Precision:** automated distortion and magnification calibration • **Traceability:** high-confidence metrology reference calibrated against silicon lattices	Enhanced productivity	• **High sample throughput** enabled by redesigned Smart Stage and new Ultra-X EDS detector: – Average productivity improvement: **~ 20% faster** (estimated based on typical semiconductor workflows; results will vary) – Efficient elemental analysis: > **2x faster** • **High system availability:** – **Faster time to thermal stability (<20 mins)** during high-tension switching using constant power lenses – **Minimized human errors** during sample load/unload by automated sample insertion on Smart Stage • **Time to recipe: 50x faster** model training with web-based segmenter and new object detection algorithm
Automation	• **Enhanced via AI/ML** for navigation and device identification • **Wide variety of metrology applications:** logic, DRAM, planar 3D NAND, blanket film, semi-auto mode • **Flexibility:** Smart Automation and recipe-based automation • **Tool Readiness:** automated tool alignment for robust TEM automation		
Connectivity	• **Connected workflow** with Thermo Scientific DualBeam TEM sample prep solutions • **High-volume** and **statistically relevant** (S)TEM data	Enhanced data integrity	• **Precise automated zone axis alignment** by piezo-driven Smart Stage tilt with minimum step size at 0.03 degree • **Low-dose analysis on beam-sensitive materials** by higher EDS collection efficiency and faster high-tension switching

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 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 size of the illuminated area provide 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 corrector simultaneously corrects A5 for all accelerating voltages
- New CEOS Auto S-CORR Alignment Software makes probe corrector tuning easy, fast, 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 have “space to do more,” accommodating unique holders such as heating, cooling, and STM/AFM holders
- Objective aperture in the back focal plane of the objective lens allows optimum TEM dark-field application work
- Automatic apertures enable remote control operation and reproducible recall of aperture positions during aperture change
- Rotation-free imaging makes operation easy and creates a clear orientation relationship between imaging and diffraction
- 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 (featuring 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)
  - 3.70 srad solid angle (with high-accuracy beta-tilt holder)
  - High P/B ratio (Fiori number) >2,500

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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
- Linear drift compensation provided by the Smart Stage can be used to mitigate throughput limitations caused by thermal drift

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 (optionally with speed enhancement)
- Gatan OneView/OneView IS Cameras
- Gatan Energy Filter Continuum Series
- Electron microscope pixel array detector (EMPAD) (non-standard request)

Software

- Recipe Editor Software is a graphical programming language toolkit for building automation recipes
- Smart Automation Software allows operators to set up automation routines in <4 hours for selected workflows
- Smart Alignments 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
- The microscope data viewer is a database that collects, organizes, and displays all imaging, EDS, and metrology data through a web browser (Smart Alignments are also displayed through this portal)
- Differential phase contrast (DPC) STEM technique enables live measurements of intrinsic magnetic and electric fields
- Integrated DPC (iDPC) software increases imaging contrast in STEM on materials across the whole periodic table
- Low-dose technique expands materials science use cases and replaces annular bright-field for light elements, invaluable when applied to samples that are typically damaged under short exposures to the electron beam

- OptiSTEM+ Software for single-click correction of 1st and 2nd order probe-forming aberrations; delivers enhanced STEM resolution to all users on our probe-corrected tools
- Fully digital system for remote-controlled operation using the SmartCam suite

Available holders

- Smart Stage high-accuracy double-tilt holder

Compatible with optional holder sleeve (available 2024):

- CompuStage single-tilt holder
- CompuStage double-tilt holder

Please ask for a list of functional holders.

Other features

- Environmental enclosure to relax the acoustic and room temperature variation requirements
- Cold trap to provide 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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