TESCAN

TESCAN SOLARIS

Solution for semi-automated high-quality TEM lamella preparation

- TEM lamella preparation
- Cross-sectioning
- FIB-SEM tomography
- Orage™ Ga FIB column
- Triglav™ electron column
- UHR SEM
- Resolution (1.0 nm at 1 keV)
- In-column detectors
- Beam Deceleration Technology (BDT down to 50 eV)

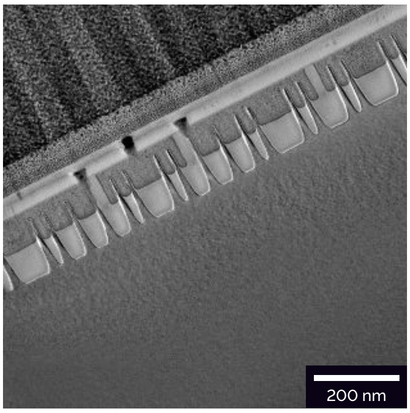
Solution for semi-automated high-quality TEM lamella preparation

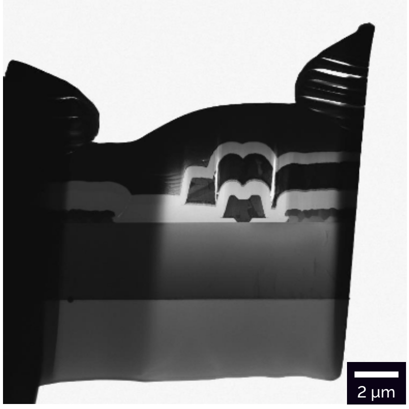
TESCAN SOLARIS is a turnkey FIB-SEM solution for ultra-thin TEM lamella preparation in semiconductor failure analysis labs. TESCAN SOLARIS combines the most precise Ga focused ion beam with UHR-SEM immersion optics, to ensure the best possible synergy between ion beam milling and ultra-high-resolution SEM imaging. Powerful TESCAN Essence™ software allows users to customize the GUI for specific application workflows and to accommodate user expertise or preferences. TESCAN SOLARIS is easy to implement in failure analysis labs and semiconductor R&D labs that assess the production quality of semiconductor devices.

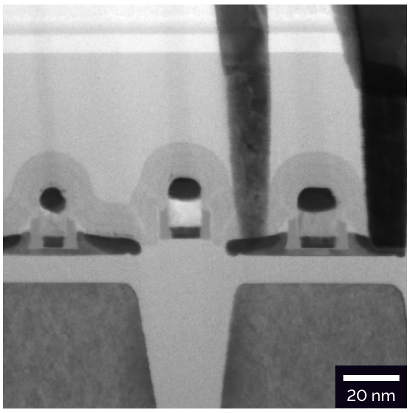
Key benefits:

Create ultra-thin TEM samples from sub-10 nm semiconductor technology nodes using dedicated, advanced workflows

TESCAN SOLARIS supports high-throughput, site-specific and high-quality TEM sample preparation from sub-10 nm node semiconductor devices for in-situ STEM or TEM investigations. This requires advanced preparation techniques that demand the highest performance from both SEM and FIB columns. The excellent in-lens SE detection capabilities of Triglav™ UHR SEM are crucial for monitoring the process so as to maintain control of such complex nanofabrication. Our AutoSlicer™ module further boosts TEM sample preparation productivity by performing the initial steps for lamella creation automatically – in less than 10 minutes for each site – to speed the workflow when preparing multiple samples. All together, these features make TESCAN SOLARIS an ideal tool for advanced TEM sample preparation.



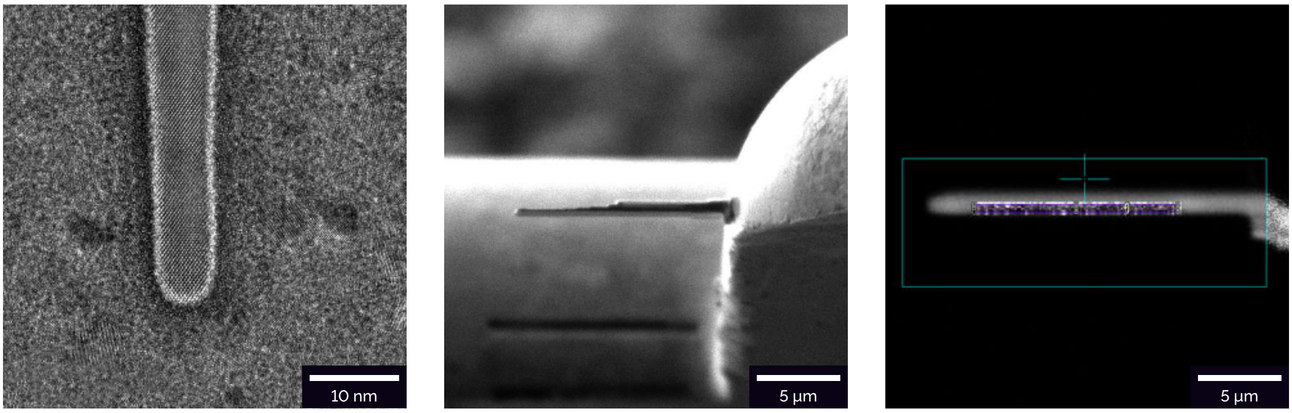




▲ (left) 7 nm FinFET device, 200 kV TEM image (center) GaN device, 30 kV STEM image (right) 28 nm Si device, 30 kV STEM image.

Achieve high quality TEM samples with negligible beam damage by using gentle FIB thinning

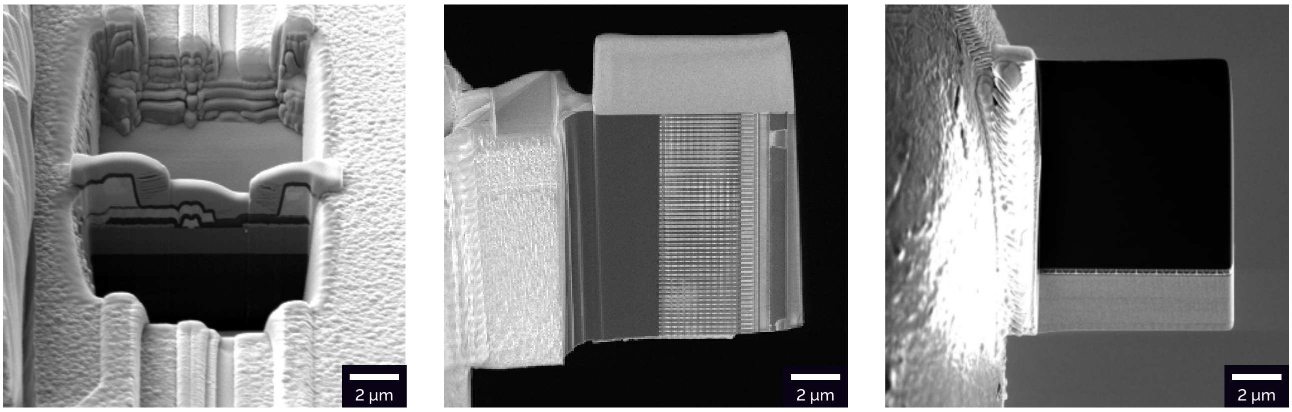
TESCAN SOLARIS routinely produces samples of thicknesses less than 10 nm for high resolution imaging in TEM. This ability to target small, site-specific regions of interest greatly expands the capabilities for failure analysis as well as for process control. When preparing a thin specimen, care must be taken to not only target the specific region with individual transistors or memory cells, but also avoid ion beam-induced damage. Our Orage™ FIB column delivers excellent image resolution at low kV and greatly reduced beam damage after the final low energy sample thinning step, while also maintaining precise beam placement.



▲ (left) 7 nm FinFET device, 200 kV TEM image; (center) TEM lamella attached to the grid, imaged with FIB at 5 kV; (right) Filled polishing rectangle placed exactly on the location to be thinned, imaged with FIB at 1 kV.

Investigate structures using inverted, planar and cross-lamella advanced preparation geometries

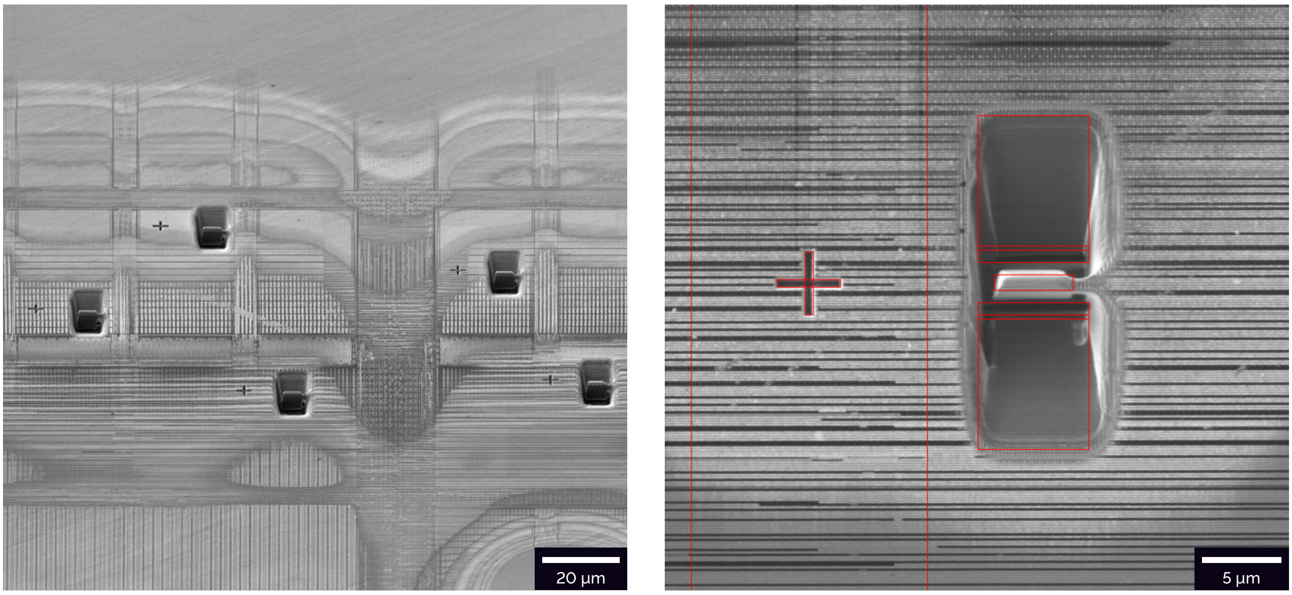
TESCAN SOLARIS is not only perfectly optimized for the preparation of site-specific TEM samples in traditional top-down geometry, it is also capable of handling other preparation geometries that might be beneficial for achieving the highest quality TEM samples. Planar view preparation aims at fabricating a lamella originally parallel to the bulk sample surface. The inverted workflow targets a cross section lamella mounted upside down on the grid, so that thinning can happen from the bottom. This can be useful to avoid curtaining, to bring the region of interest closer to the lamella top or to avoid thinning through soft layers. TESCAN SOLARIS allows users to access all these geometries in an efficient and simple way.



▲ (left) GaN device, top-down geometry; (center) 3D NAND device, planar geometry; (right) 14 nm FinFET device, inverted geometry.

Shorten time to results with the AutoSlicer™ semi-automated TEM sample preparation module

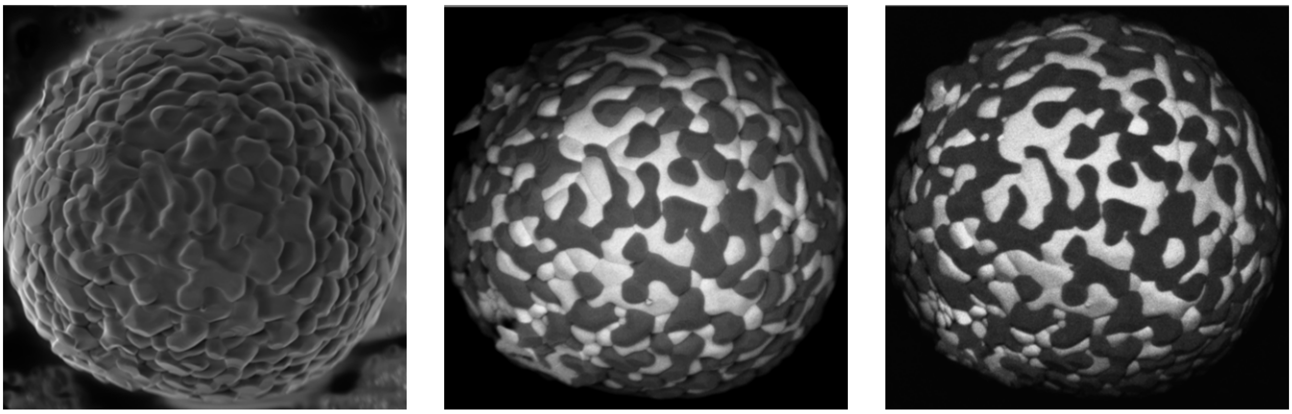
The AutoSlicer™ software module automates the most common sample preparation routines, like FIB cross-sectioning or TEM sample preparation, up to the undercut step. Automating these processes helps to increase overall productivity and free the operator for other tasks. Moreover, Autoslicer™ module allows definition of multiple TEM lamella liftout-sites at multiple sites as well as set-up for unattended operation. All the parameters and workflows are defined within the loaded job template, which can be modified and stored for repeat or later use.



▲ (left) 4x site-specific TEM sample lift-out sites prepared with AutoSlicer™. (right) Overlay of initial TEM sample preparation process steps with Autoslicer™ shown in the live FIB image.

Image even the most beam-sensitive structures at ultra high resolution, with excellent surface sensitivity and high material contrast

TESCAN SOLARIS features a multi-detector system designed to extract maximum information from every sample. TriSE™ and TriBE™ detectors enable collection of SE and BSE signals respectively throughout the entire take-off angle range. Optimized placement of the in-column detectors allows simultaneous acquisition of topographic and compositional contrast from the sample at various imaging conditions.



▲ Examples of (left) Topographic contrast (In Beam SE detector); (center) Material contrast and topography (Mid Angle BSE detector); and (right) pure material contrast (In Beam f-BSE detector)

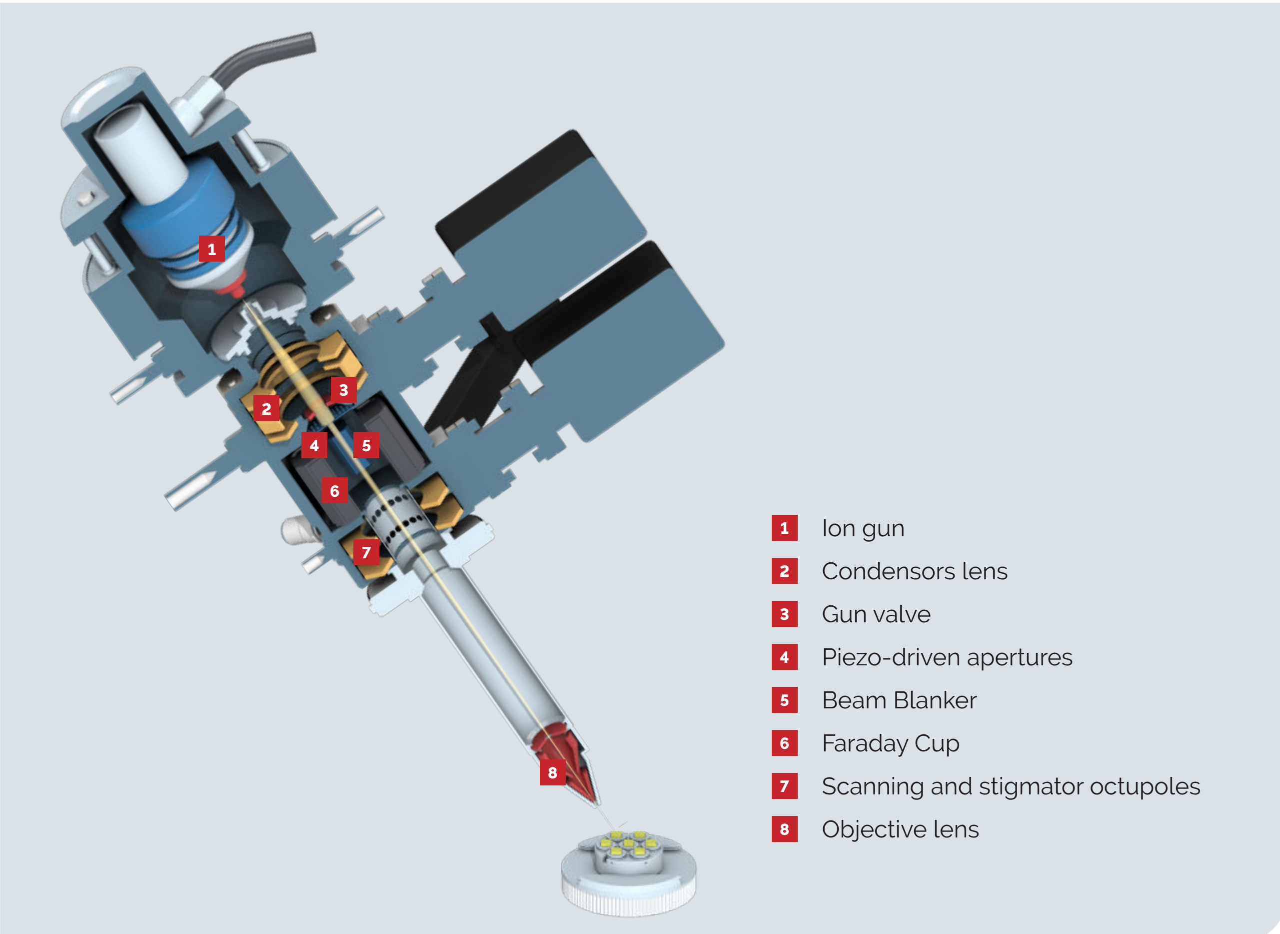
Enabling technologies:

Orage™ FIB column

TESCAN is a leading supplier of both gallium liquid metal and xenon plasma FIB solutions, which we combine with high resolution SEM imaging and a broad range of analytical techniques to provide you with an ultimate tool for your the most challenging failure analysis tasks.

The Orage™ FIB column was designed to meet increasingly stringent focused ion beam sample preparation requirements. With its ultimate FIB resolution and a broad range of beam current choices, the Orage™ FIB column on TESCAN SOLARIS routinely delivers the highest quality sample preparation. The exceptional low energy (down to 500 eV) performance of the Orage™ FIB column guarantees the highest final quality for TEM specimens. Conversly, the Orage™ column's high ion beam currents, up to 100 nA, enable rapid, large-volume material removal to speed cross-sectioning. Additionally, these high ion beam currents facilitate more efficient bulk sample preparation for FIB-SEM tomography of microelectronics devices with significantly reduced timeframes and minimal milling artifacts.

The Orage™ FIB column is fitted with an ultra-stable high voltage supply and precise piezo-driven aperture changer (30 positions), which allows fast switching between FIB presets and excellent repeatability. In addition, a FIB spot-optimization wizard allows users to easily fine tune the ion column parameters to reach the best milling conditions for a particular application independent of an operator`s expertise.



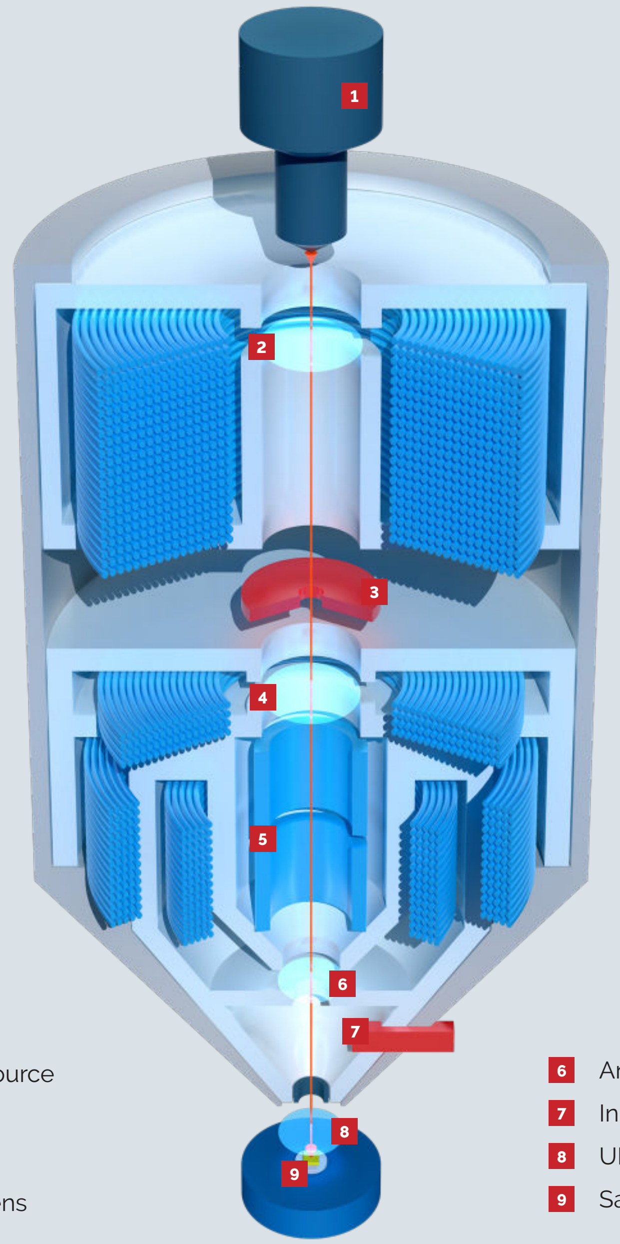
▲ Orage™ FIB column description.

UHR SEM with TriLens™ immersion optics

The Triglav™ SEM column features TriLens™, a three-lens compound objective system that enables both an ultra-high-resolution (UHR) immersion imaging mode and a high-throughput analytical mode. The UHR mode can be combined in a unique way with a crossover-free configuration, resulting in reduced aberrations and a significant improvement in beam performance at low beam energies.

Moreover, immersion optics technology remains the best choice for STEM and microanalysis, delivering an 0.5 nm resolution at 30 keV electron beam energy. Microanalysis (i.e. EDS, EBSD) is performed in the field-free analytical mode. Field-free analytical mode is ideal for morphological characterization of magnetic samples. This analytical mode also provides a large field of view for fast, smooth and easy navigation across the sample surface.

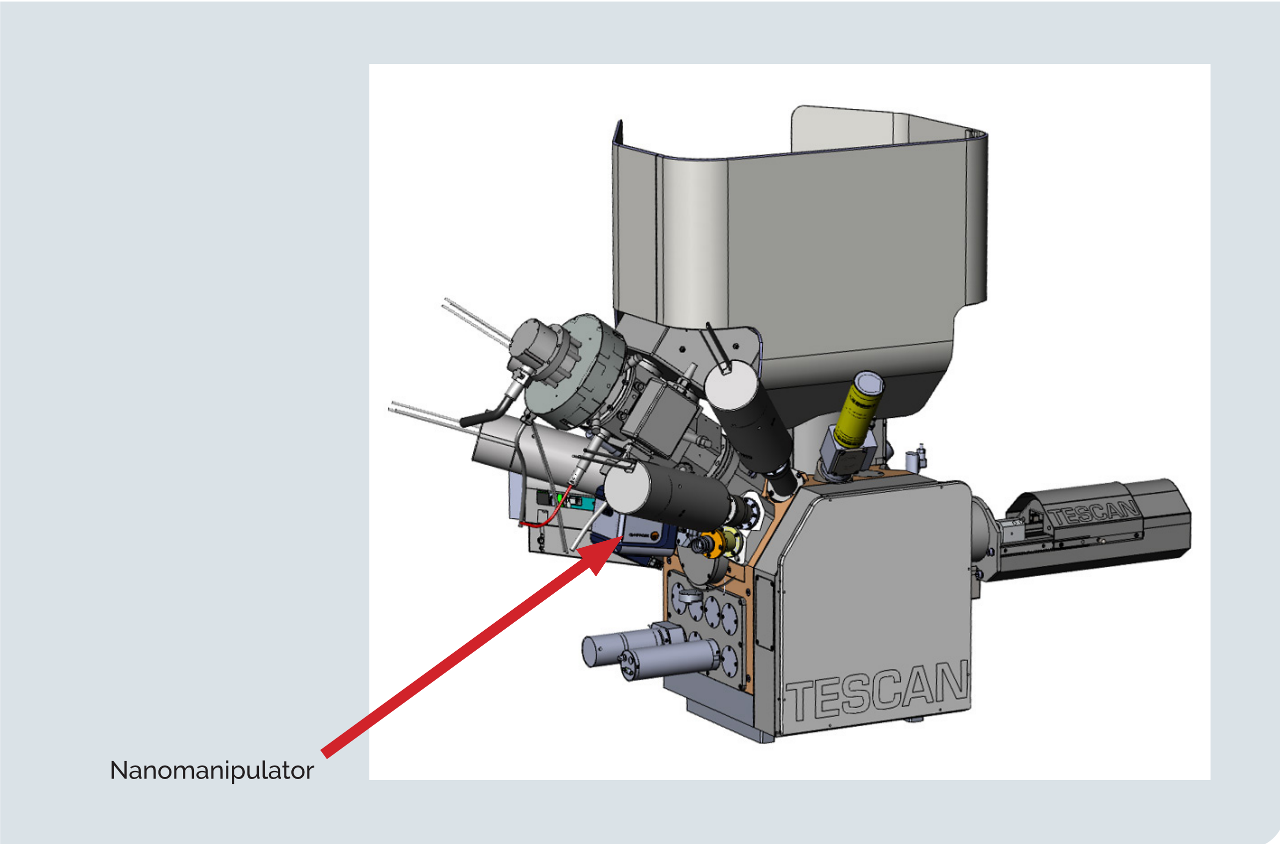
The new generation of Triglav™ SEM column also comes with adaptive spot shape optimization, which results in improved resolution at high electron beam currents. Such a feature is beneficial to speed analytical techniques such as EDX, WDX and EBSD. In addition, the Schottky FE gun is capable of generating beam currents up to 400 nA, with rapid beam energy changes guaranteeing excellent signal for all microanalytical applications.

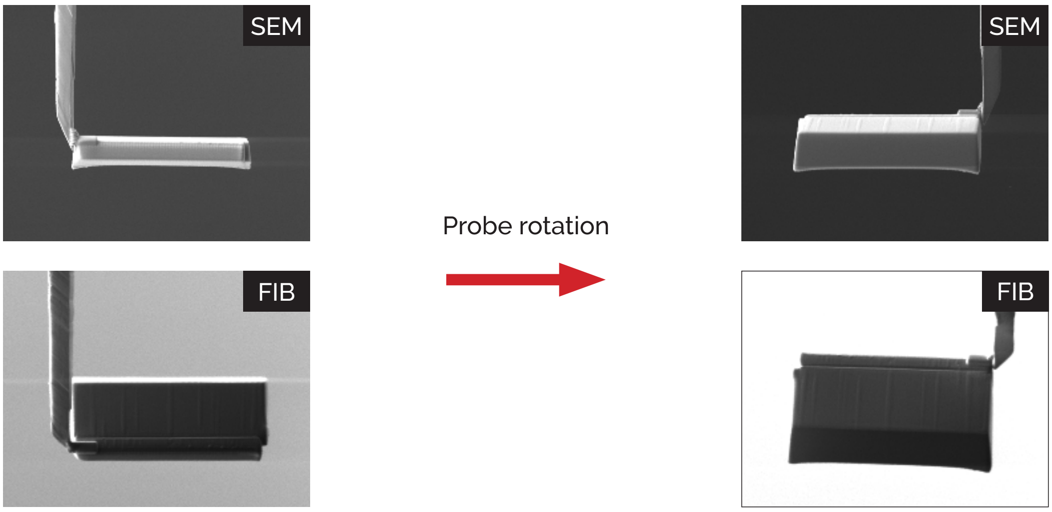


1 Field Emission Source
2 Condenser lens
3 In-Beam BSE
4 Third objective lens
5 Stigmators
6 Analytical objective lens
7 In-Beam SE
8 UH-resolution objective lens
9 Sample

Unique patented nanomanipulator`s location – below FIB implementation – supports easy access to inverted and planar geometries for TEM sample lift-out

Achieving top-down, inverted and planar TEM sample geometries in one step, without breaking vacuum or using additional sub-stages is now possible thanks to our unique, patented *below-FIB implementation* of a nanomanipulator. TESCAN SOLARIS uses this to provide quick and intuitive manipulation of the lamella on the tip. Thanks to this geometry, the lamellae attached to the probe can be rotated by 180° in the plane of FIB column making the entire inverted TEM sample preparation process simple and straightforward.

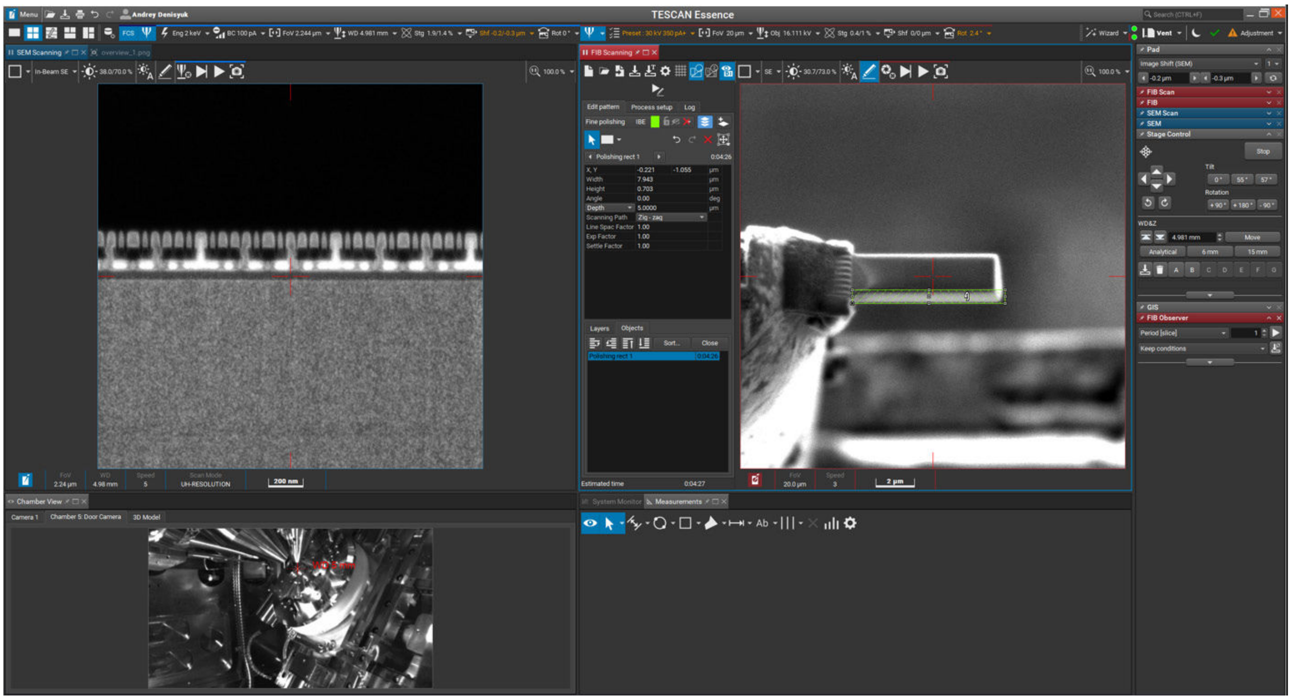




▲ (top) TESCAN SOLARIS with the patented *below-FIB implementation* position of the nanomanipulator.
(down) 180° TEM sample rotation showed from FIB/SEM perspective during inverted TEM sample preparation.

Essence™ graphical user interface boosts productivity with advanced workflows

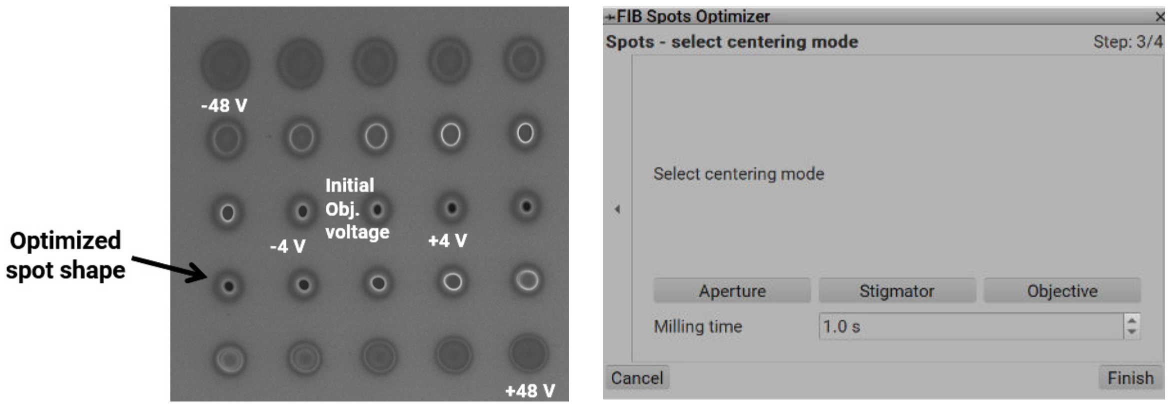
TESCAN Essence™ graphical user interface features a layout manager that provides fast and easy access to all of TESCAN SOLARIS's main functions. This modern, user-friendly interface can be customized to streamline specific application workflows as well as the layout preferences of novice, routine and expert users. A collection of software modules, wizards and recipes all contribute to enhanced productivity throughput in the lab.



▲ TESCAN Essence™ SW interface allows users to customize the GUI layout.

FIB spot optimization wizard

TESCAN Essence™ features a semi-automated spot-shape tuning wizard to help the FIB operator obtain the optimum FIB spot shape — a key requirement for achieving high quality cross sections, ultra-thin TEM samples and artifact-free 3D tomographic images. This wizard combines parameters such as beam aperture centering, stigmation, octupole settings and objective lens focus, with corresponding values that are then automatically saved as a user preset that can be recalled anytime.



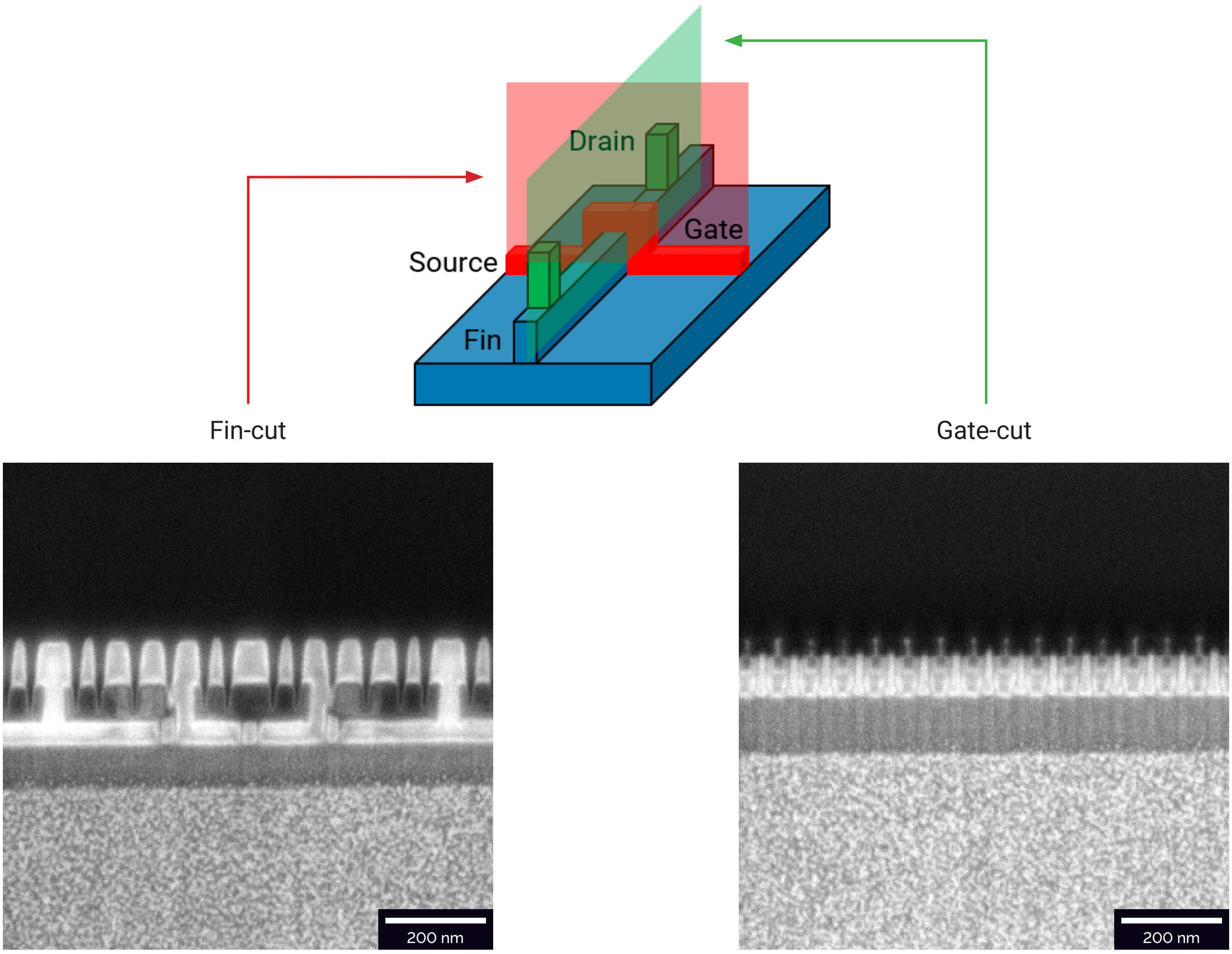
▲ (left) Matrix of FIB beam spots milled into silicon sample. (right) User interface showing available FIB parameters for which the value can be optimized by the wizard. Select only one value or all values.

Ideal Applications for TESCAN SOLARIS:

Ultra-thin TEM sample preparation from the most advanced semiconductor technologies

Modern integrated circuits are multilayer structures whose key elements are multi-gate transistors, where a source–drain channel ("fin") is surrounded by a 3D gate. Failure analysis of such integrated circuits typically involves delayering and electrical nanoprobing. After the defective area is located, a lamella containing the failure of interest can be prepared for TEM inspection.

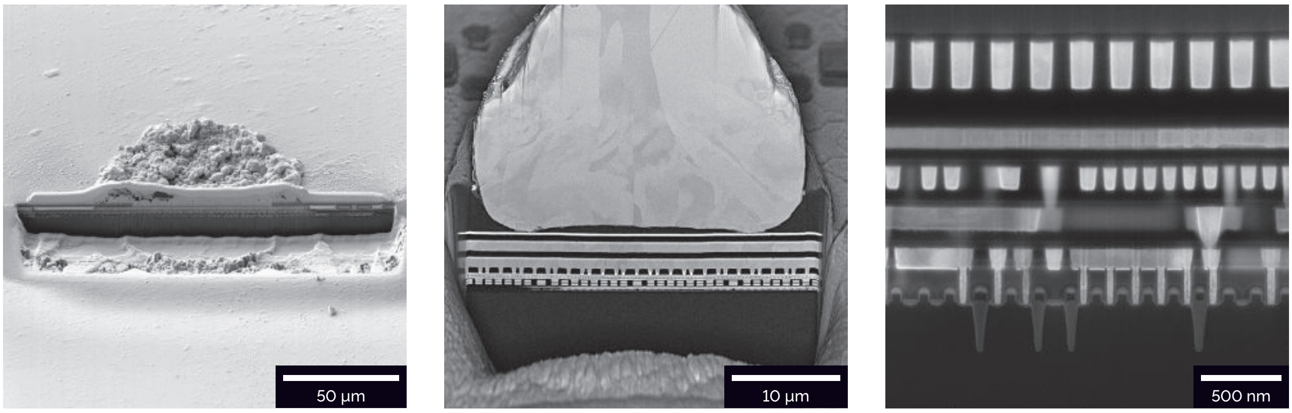
At TESCAN, we have developed sophisticated solutions for failure analysis labs. When preparing ultrathin lamella, short time to results and the process of final cleaning with low energy ions become crucial. TESCAN SOLARIS provides the required milling precision and throughput over the full energy range, from 30 keV to 0.5 keV, to address these needs. Another challenge with lamella preparation can be curtaining artifacts which appear because of the different milling rates for the materials used in integrated circuits. One way to eliminate these artifacts is to apply the technique of inverted lamella thinning, which is performed easily on TESCAN SOLARIS, thanks to the unique nanomanipulator position and optimized TEM sample lift-out geometries.



▲ (left) The schematic showing internal arrangement of the modern FinFET transistor (center)(right) Corresponding Fin and Gate FIB cuts in inverted geometry. A 14 nm device, In-Beam SE images at 2 kV.

Cross-sectioning, analysis and sample preparation for microchip electronics

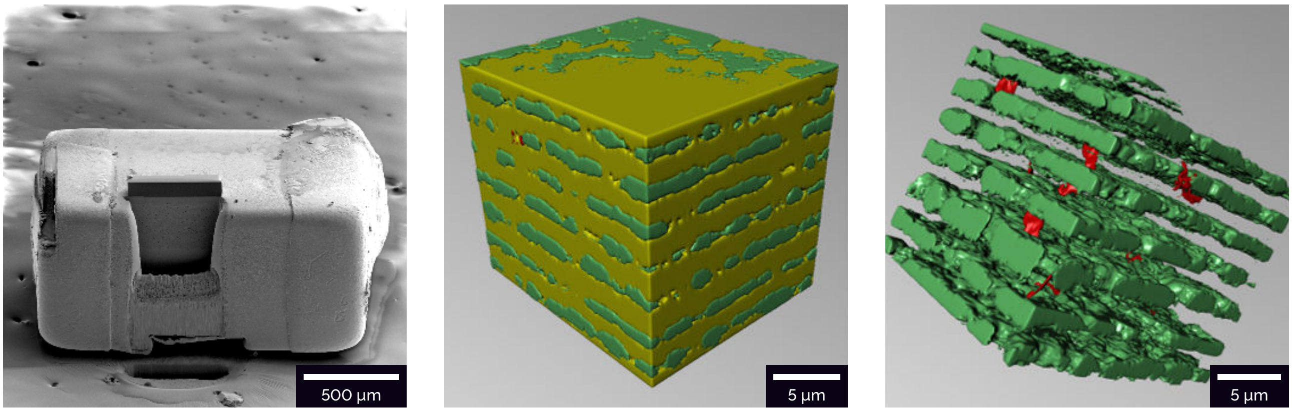
Cross-sectioning is a valuable semiconductor failure analysis technique for unveiling defects or structures not visible at the surface. The surface of the cross sections or that of lamellae must be smooth. Additionally, the task of finding or identifying possible failures can be difficult as they may easily be hidden among surface defects. For comprehensive and straightforward targeting of such hidden features, the TESCAN SOLARIS is delivered with FIB Observer™ module enabling progressive *"slice then view"* cross-section method and with variety of SEM-based end-pointing techniques to precisely target the desired transistor line or defect location.



▲ (left) 100 x 30 x 20 μm^3 milled in 20 minutes using 100 nA ion beam current. (center) 40 µm wide cross-section of Au ball bond in 5 minutes. (right) Detailed image of the CMOS device at 2 kV using In-Beam SE detector.

Multi-modal, nanoscale FIB-SEM tomography

The TESCAN SOLARIS, with our patented geometry for static 3D EBSD acquisition, enables 3D sample reconstructions with extreme speed and precision. The TESCAN SOLARIS can be equipped with EDX and EBSD detectors, as well as our novel FIB-SEM tomography software module, which when used together deliver automated, simultaneous 3D EDX, 3D EBSD and also standard 3D SE/BSE characterization of integrated circuits, 3D NANDs, MLCC capacitors, etc. Data is available as 3D chemical maps and complete crystallographic information.



▲ (left) SEM overview image of the MLCC capacitor. (center) 3D reconstruction of MLCC volume (25x25x25 μm^3) from EDS data. Yellow – barium titanate ceramics, green – nickel plates, red – silicon inclusions (right) 3D reconstruction of MLCC volume from EDS data. Green – nickel plates, red – silicon inclusions.

Technical Specifications

Electron Optics:

Electron Gun:	High brightness Schottky emitter		
Electron Optics:	Triglav™ column		
Resolution:	**Standard mode:** 0.6 nm at 15 keV 1.2 nm at 1 keV	**Beam Deceleration mode:** 0.9 nm at 1 keV	**STEM:** 0.5 nm at 30 keV
Maximum Field of View:	>10 mm at max. WD		
Electron Beam Energy:	50 eV to 30 keV		
Probe Current:	up to 400 nA		

Ion Optics:

Ion Column:	Orage™
Ion Gun:	Gallium liquid metal ion source
Resolution:	< 2.5 nm at 30 keV
Ion Beam Energy:	500 eV to 30 keV
Probe Current:	< 1 pA to 100 nA
SEM-FIB Coincidence at:	WD_{SEM} = 5 mm

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