TESCAN SOLARIS X

A Plasma FIB-SEM platform for deep sectioning and the highest resolution end-pointing for package level failure analysis

- Cross-sectioning
- FIB-SEM
- In-column detectors
- TEM lamella preparation
- i-FIB+™ Xe plasma FIB column
- Triglav™ electron column
- IC planar delayering
- UHR SEM
- Resolution

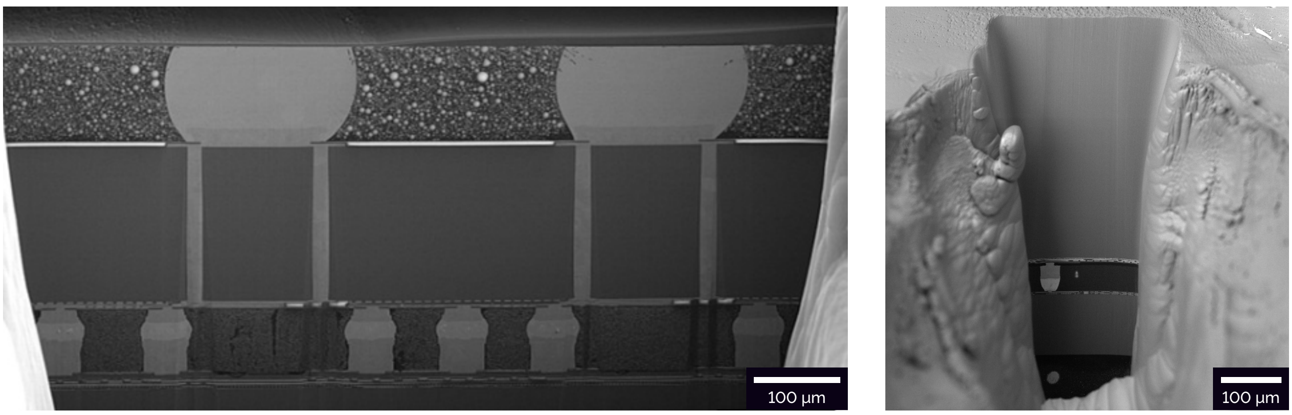
A Plasma FIB-SEM platform for deep sectioning and the highest resolution end-pointing for package level failure analysis

TESCAN SOLARIS X pairs the high-throughput i-FIB+™ Xe plasma FIB column with the Triglav™ UHR electron column to extend the capabilities of FIB physical failure analysis to include large--area and deep cross-sectioning on advanced packaging, microelectromechanical devices and optoelectronics. Powerful TESCAN Essence™ software allows users to customize the GUI for specific application workflows and to accommodate user expertise or preferences. TESCAN SOLARIS X is easy to implement in quality assurance labs and R&D labs that assess semiconductor packaging quality.

Key features:

Artifact free, large-area cross-sectioning for physical failure analysis of advanced packaging technologies

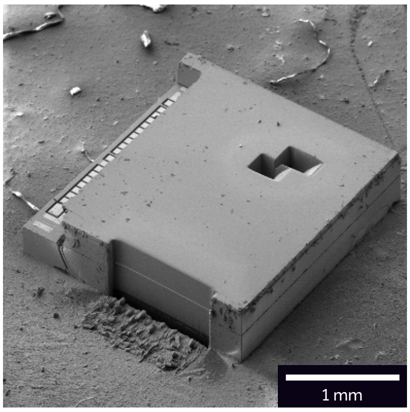
TSVs, MEMS, solder bumps, Cu pillars, whole BGA areas and other large or buried structures can be cross-sectioned effortlessly, without any curtaining or rippling artifacts, in a matter of hours or even minutes. TESCAN SOLARIS X offers a range of techniques to help instrument users achieve the highest quality cross sections — without compromising the higher milling speeds provided by the plasma focused ion beam.

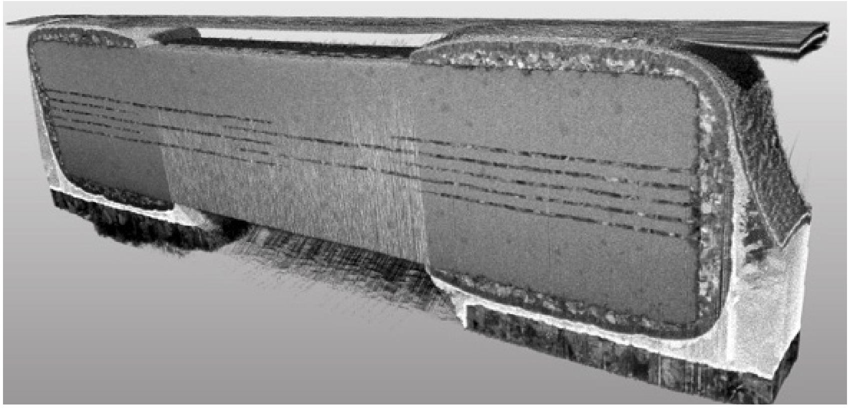


▲ (left) 650 µm wide FIB cut through C4 bumps, TSVs and µ-bumps; (right) 600 µm deep GPU flip-chip cross section.

Prepare large area FIB cross sections

TESCAN SOLARIS X is built around making it easy to create cross sections — up to 1 mm-wide — in electronic packaging technologies and other large or deeply buried structures. The iFIB+ Xe plasma FIB column, with its maximum ion beam current of 3 μA, enables large-volume bulk material removal, without the limitations encountered with traditionally used methods for large-scale volume material removal.

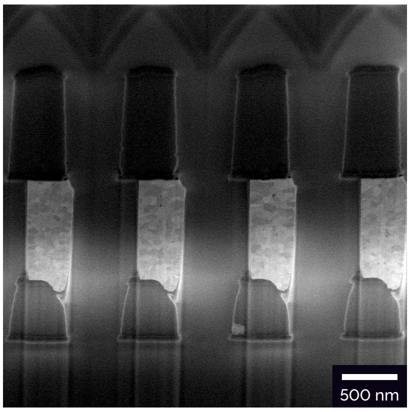


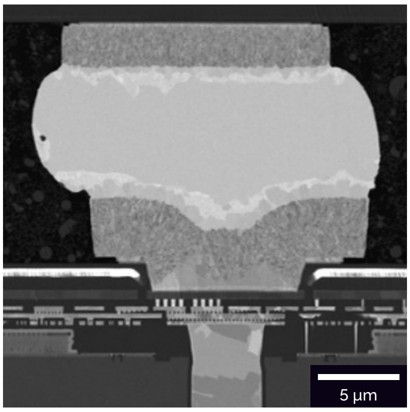


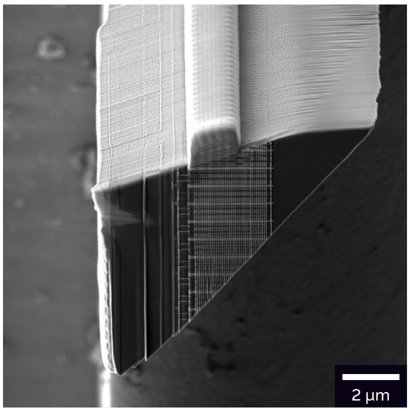
▲ (left) 1 mm cross section in MEMS accelerometer device; (right) 1000 μm x 250 μm x 500 μm 3D volume reconstruction of SMT capacitor.

Fast acquisition of low noise, low kV SEM images, even while the sample is tilted

SEM imaging of modern semiconductor devices typically requires the use of low beam energies and short acquisition times in order to prevent beam damage or contamination of target structures. But using low beam energies often means compromising your resolution requirement. The immersion field between the pole piece and sample benefits both imaging resolution and contrast at low electron beam energies, providing that extra performance boost for high-resolution end-pointing and imaging tasks, even while the sample is tilted.



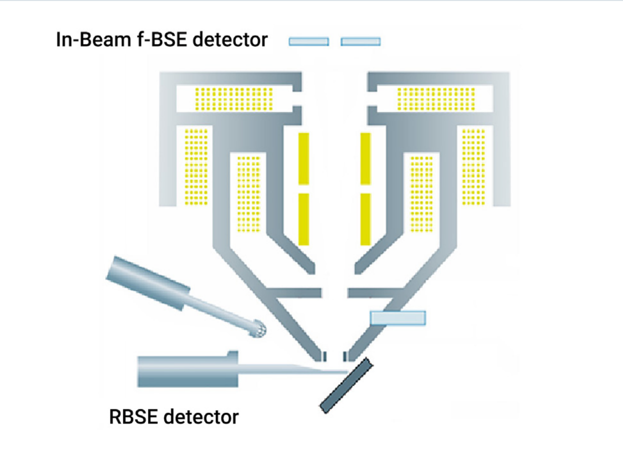


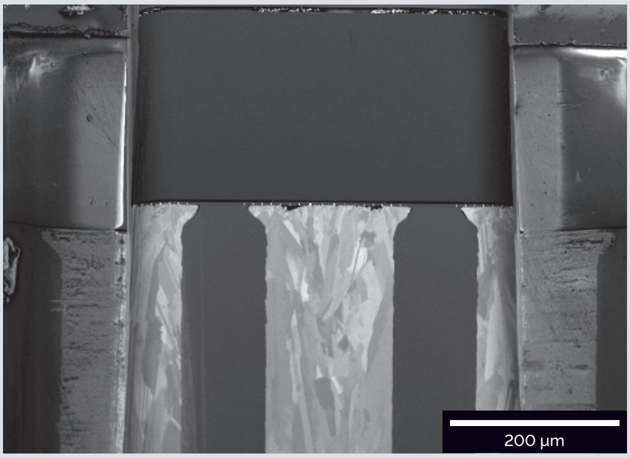


▲ (left) Tungsten vias, imaged using the In-Beam SE detector at 2 kV; (center) Flip-chip to TSV connection, imaged using the Mid-Angle BSE detector at 5 kV; (right) 3D NAND edge, imaged using the In-Beam SE detector at 2 kV.

Precise end-pointing at the beam coincidence point

When searching for failures, researchers typically employ the progressive “slice then view” cross-section method to pinpoint the exact location for the feature of interest. With this approach, the FIB is used to mill away one or more thin sections of material, then is paused, and the SEM subsequently acquires a single image. With TESCAN SOLARIS X, this exact functionality is performed from the FIB Observer™ module. In addition, the In-Beam f-BSE detector can be utilized for simultaneous live backscattered SEM imaging during Xe plasma FIB milling to make precise end-pointing much easier.

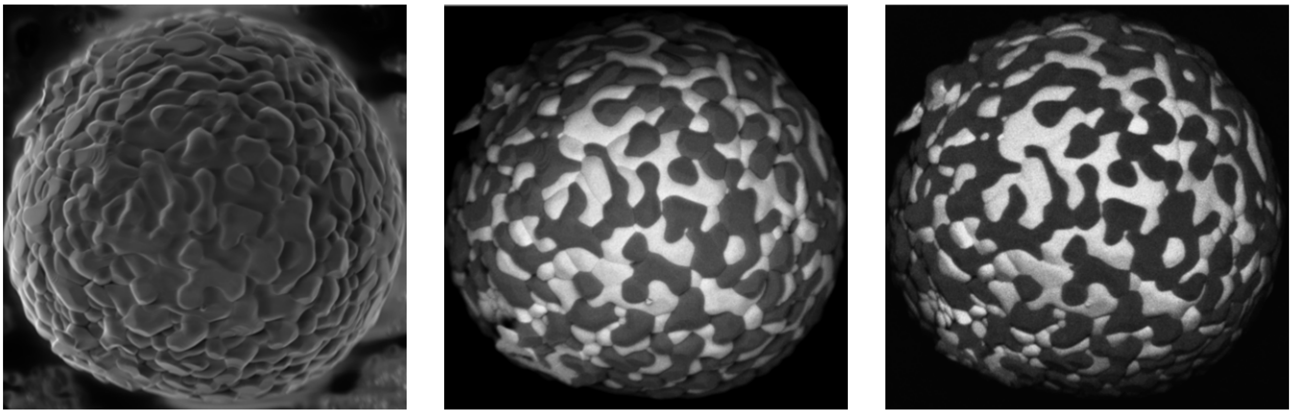




▲ (left) Live SEM observation during FIB milling can be performed with either the In-beam f-BSE detector or the RBSE detector. (right) End-pointing TSVs center during final polishing step.

Obtain maximum information from every sample

TESCAN SOLARIS X features a multi-detector system designed to extract maximum information from the 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 enables simultaneous acquisition of topographic and compositional contrast from the sample at various imaging conditions.

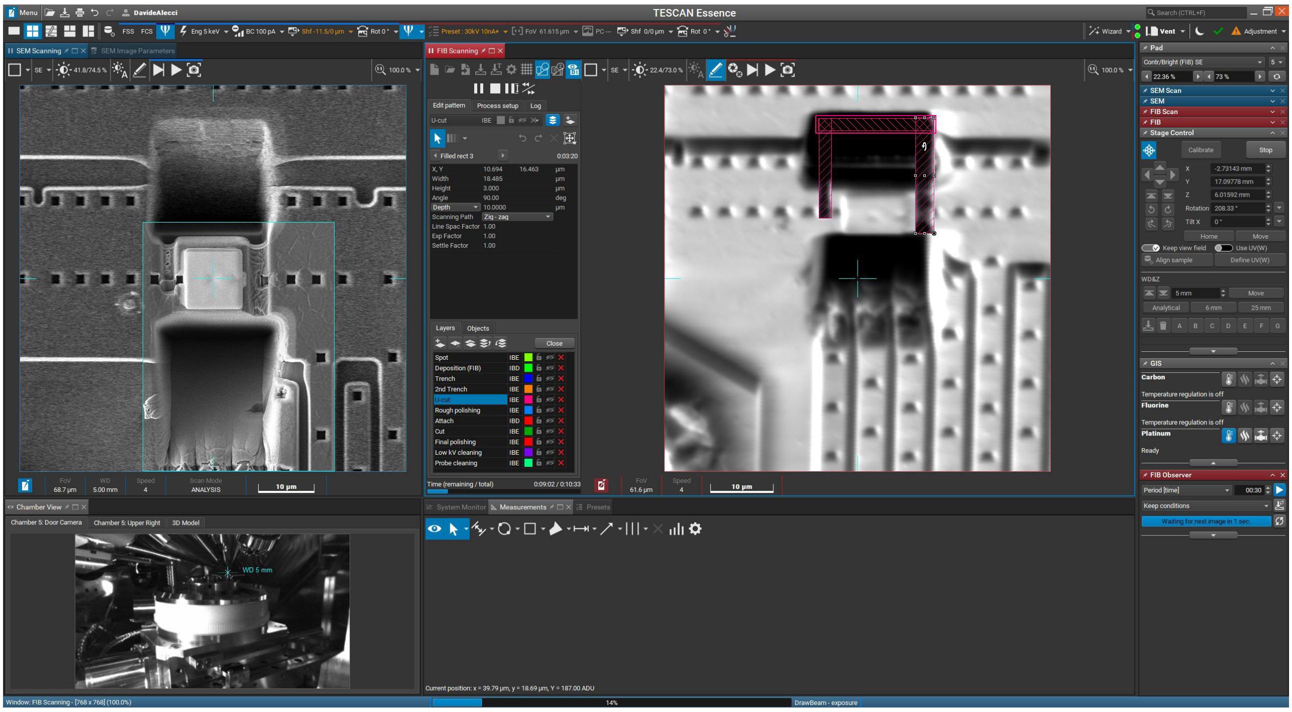


▲ Examples of (left) Topographic contrast (In Beam SE detector), (center) Material contrast and topography (Mid Angle BSE detector); and (right) pure material contrast (In Beam f-BSE detector)

Enabling technologies:

Easy-to-use modular user interface

The TESCAN Essence™ graphical user interface features a layout manager that provides fast and easy access to all of TESCAN SOLARIS X'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.



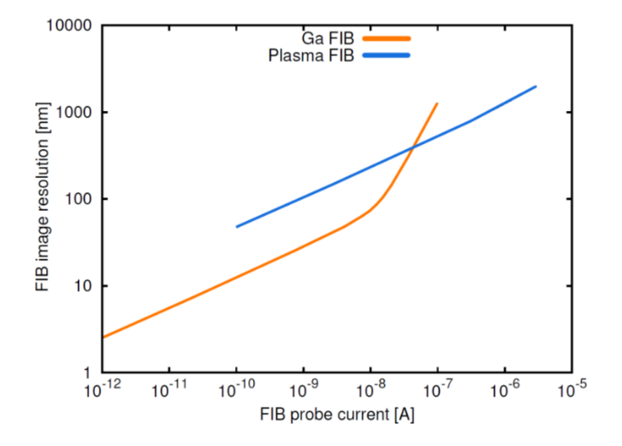
▲ (center) TESCAN Essence™ SW interface allows users to customize the GUI layout.

High-throughput plasma focused ion beam

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, including EDS, WDS, EBSD and even TOF-SIMS.

Localized physical failure analysis tasks in the semiconductor industry traditionally have been performed using Ga FIB, but it is too slow for milling volumes approaching ~100 µm^3. TESCAN SOLARIS X features a Xe plasma FIB column capable of FIB currents up to 3 µA while also maintaining beam spot quality required for bulk milling at maximum current. Thus, large volumes of material can be removed at ultra-fast sputtering rates that are only possible with Xe ions and overall times for completing milling tasks are dramatically decreased.

The ion implantation range and interaction volume of Xe ions is significantly less than those of Ga ions. This results in reduced amorphous damage, which is particularly important when preparing thin TEM specimens. In addition, the inert nature of Xe ions prevents the formation of intermetallic compounds with atoms of the milled sample. This can result in changes to the physical properties of the specimen and interfere with electrical measurements, and other characterization routines.



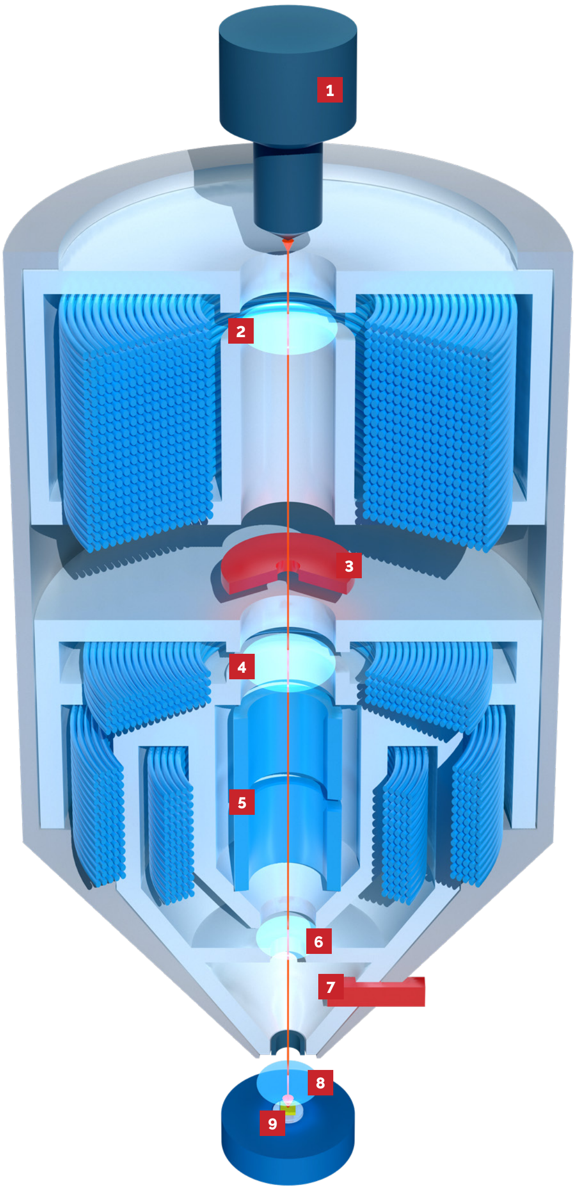
Ion Type	Xe^+	Ga^+
Sputtering rate at 30 kV on silicon [atoms/ion]	3.2	2.4
Sputtering rate at 30 kV on silicon [μm^3/nC]	0.4	0.28
Maximum probe current [nA]	3000	100

▲ (left) Comparison of FIB technologies. Image resolution is dependent on the probe current. Ga FIB loses its source size advantage at currents >60 nA. (right) Comparison table of sputtering rates between Xe^+ and Ga^+ ions.

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 a 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.

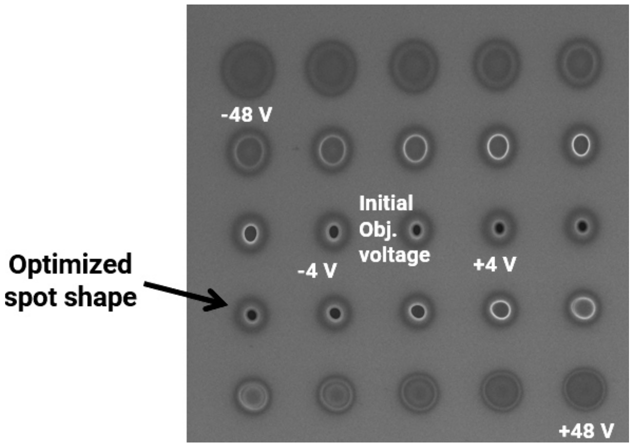


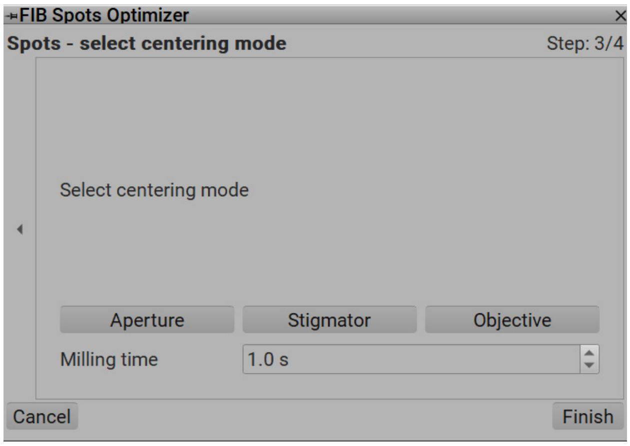
1. Field Emission Source
2. Condenser lens
3. In-Beam BSE
4. Third objective lens
5. Stigmators
6. Analytical objective lens
7. In-Beam SE
8. UH-resolution objective lens
9. Sample

FIB spot optimization wizard

TESCAN Essence™ features a FIB spot optimization 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. Using this wizard, the operator can pre-determine the optimal settings for a target application before processing the actual sample.

This wizard takes a user-selected parameter—like beam aperture centering, stigmation octupole settings or objective lens focus—then mills a matrix of FIB spots into bare silicon, using a typical range of values for the selected parameter. Based on the SEM image of the milled spots, the operator selects the optimal spot shape for the target application. This process can be repeated with a different parameter selected to determine whether or not the spot can be optimized further. Once the final values are determined, they can be saved as a preset for the target application.





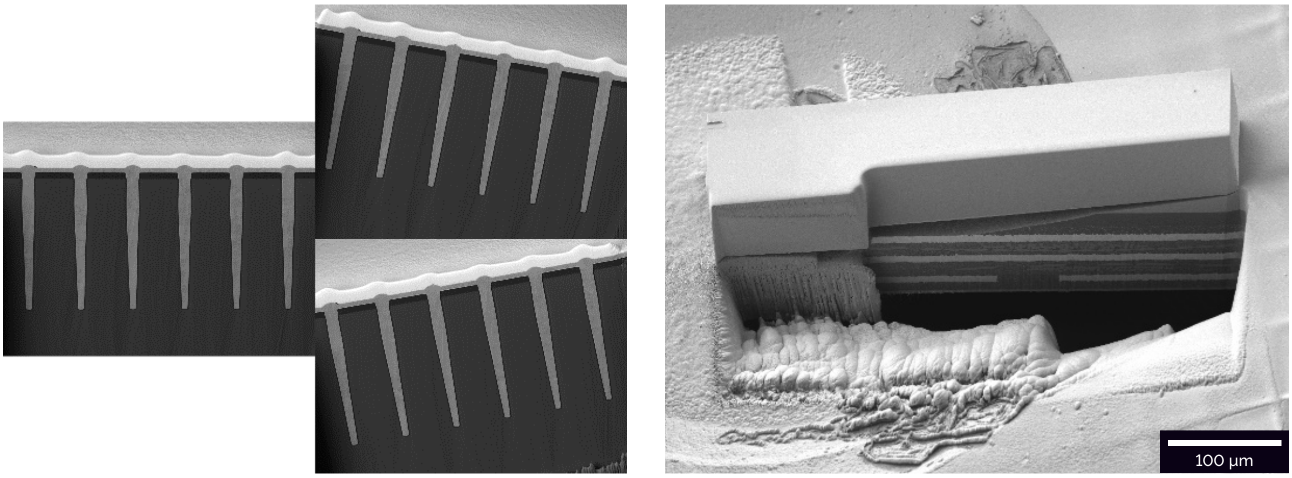
▲ (left) Matrix of FIB beam spots milled into silicon sample. (right) User interface showing available FIB Spots Optimizer parameters.

Ideal Applications for TESCAN SOLARIS X:

Milling and polishing of large cross sections

High FIB milling rates can induce artifacts, known as curtaining and rippling, on the resulting cross sections. TESCAN SOLARIS X offers a technology that greatly improves surface quality, while maintaining simplicity and accuracy throughout the milling process: the rocking stage.

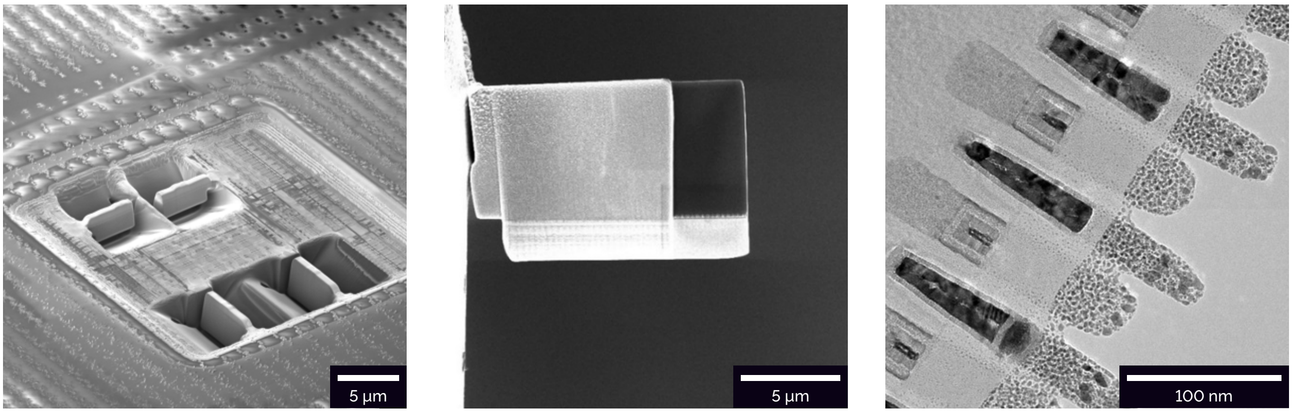
The rocking stage allows users to take advantage of TESCAN SOLARIS X's wide field of view and SEM optics for monitoring the milling process and accurate end-pointing. It provides forward tilt compensation for the taper angle and additional sequential tilting, also in the plane of the cross section. This enables simultaneous SEM observation when using FIB to mitigate curtaining effects. In addition, TESCAN has developed TRUE X-sectioning, a cross-sectioning technique that enables artifact-free cross sections at high ion beam currents, allowing users to fully leverage the benefits of the high sputtering rates delivered by Xe plasma FIB.



▲ (left) Xe plasma FIB polishing of TSVs by using Rocking stage. (right) TRUE X-sectioning: Silicon hard mask used for smooth cross-sectioning of sensor containing organic layers.

Ga^+ free TEM lamella preparation

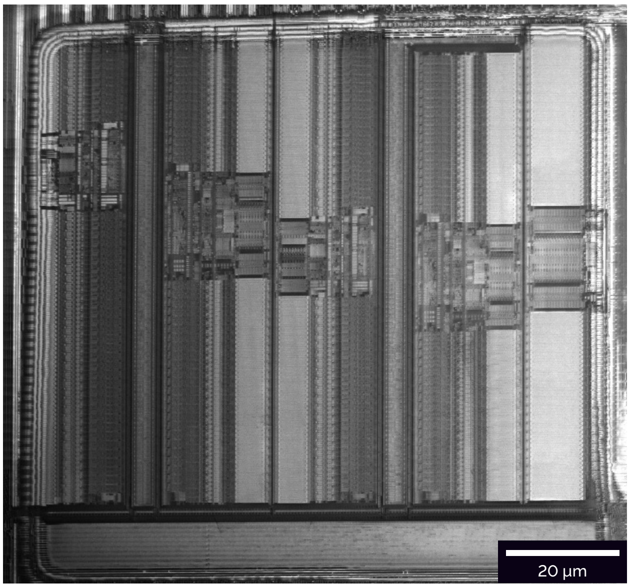
Low energy Ga^+ focused ion beam milling techniques developed years ago are routinely used to prepare specimens for aberration-corrected high resolution electron microscopy. These low energy polishing methods reduce ion implantation and/or amorphization damage as they decrease the specimen's thickness. Xe plasma FIB delivers similar benefits for specimen preparation; with the heavier mass Xe^+ ions produced by plasma FIB, the result is a larger sputter yield, without Ga ion implantation, for fast preparation of thin specimens with reduced surface damage.

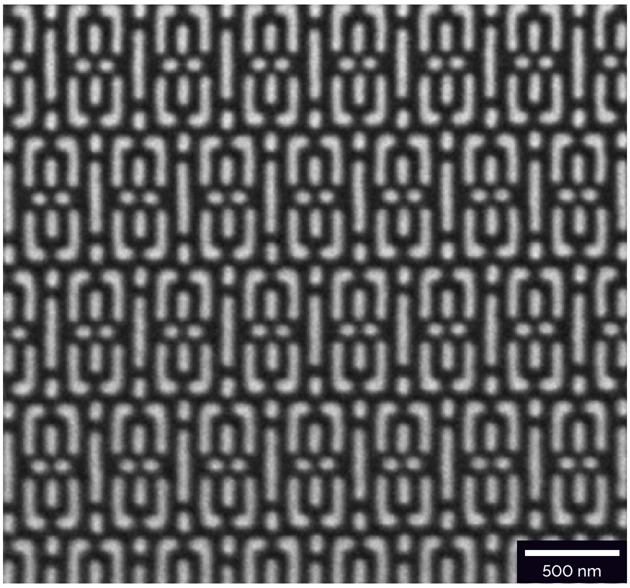


▲ (left) 3x TEM lamella liftout site prepared on 14 nm AMD Ryzen 3 sample; (center) Inverted TEM lamella preparation method; (right) 200 kV TEM brightfield image showing FinFET gate structure on resulting 20 nm lamella.

Gas-assisted top-down delayering of sub-14 nm devices

TESCAN SOLARIS X combines a proprietary gas chemistry with the Xe plasma FIB to enable top-down planar delayering of sub-14 nm node technologies for in-situ electrical nanoprobing or passive voltage contrast SEM imaging. Our proven recipes guarantee excellent, uniform planarity in windows with typical sizes of 100 × 100 µm² and smaller, opened at any location on the chip. A precise end-point detection software module provides full control of the entire process, including stops at desired metal or via layers.

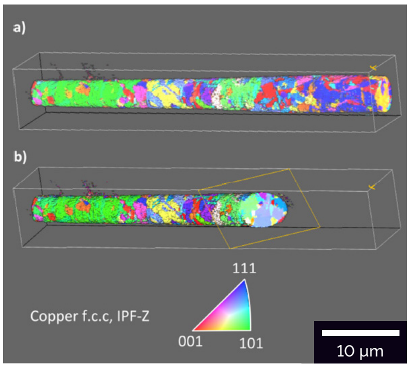


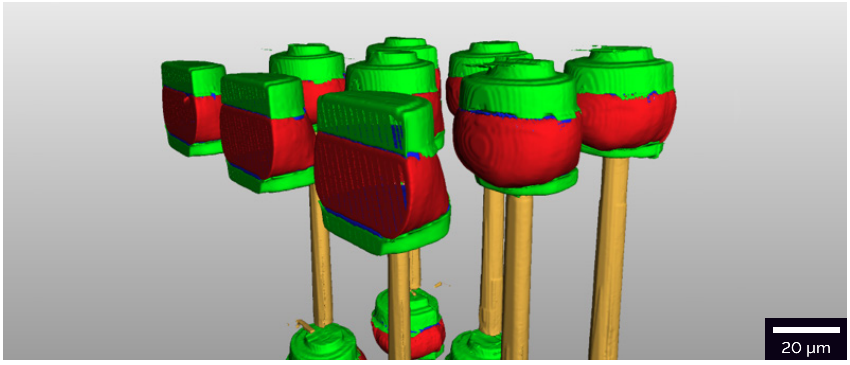


▲ (left) Delayered 100 x 100 µm^2 window in CACHE area. (right) Detailed 500 V SEM image showing the resulting surface flatness after delayering process.

Multiscale, multi-modal FIB-SEM tomography

TESCAN SOLARIS X, with our patented geometry for static 3D EBSD acquisition, makes it feasible to perform large-volume 3D sample reconstructions with extreme speed and precision. TESCAN SOLARIS X can be equipped with EDS and EBSD detectors and our novel FIB-SEM tomography software module, which together enable automated, simultaneous 3D EDS and 3D EBSD characterizations of complete bonding wires, solder balls, TSVs, diverse metal alloys, etc. Data is available as 3D chemical maps and full crystallographic sample information.





▲ (left) 3D EBSD reconstruction of a single 5 x 50 µm copper TSV; EBSD mapping with IPF-Z orientation coloring mode. a) Visualization of TSV surface; b) virtual cross section at an arbitrary angle. (right) 3D EDS reconstruction of solder balls and TSVs.

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:	i-FIB+
Ion Gun:	Xe Plasma FIB (ECR type)
Resolution:	< 12 nm at 30 keV
Ion Beam Energy:	3 keV to 30 keV
Probe Current:	1 pA to 3 μA
SEM-FIB Coincidence at:	WD_{SEM} = 5 mm

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