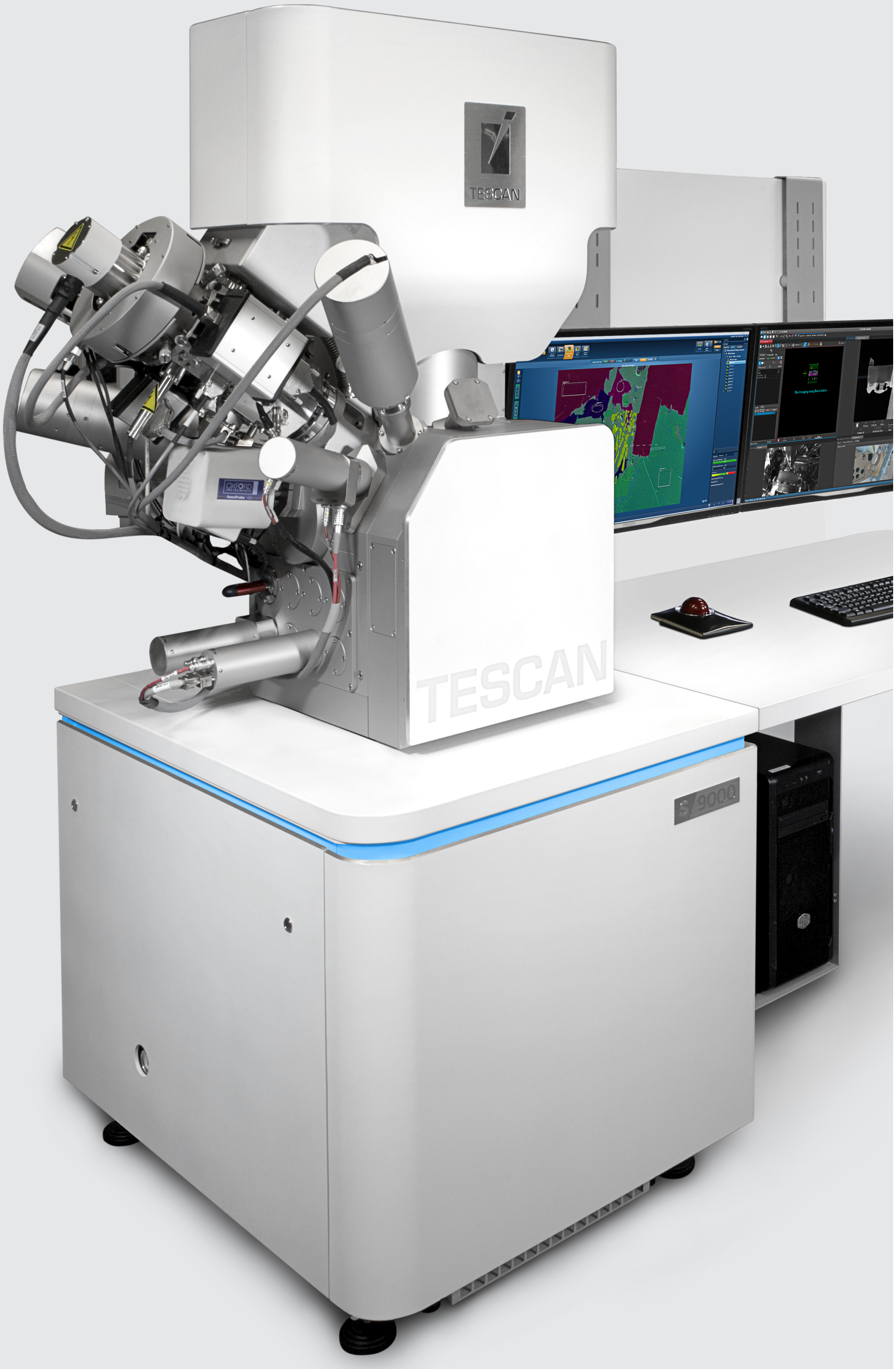
TESCAN

S9000G

TESCAN
PERFORMANCE IN NANOSPACE

New generation of FIB-SEM microscope



- Ga FIB Up to 100 nA — Ga FIB up to 100nA
- Triglav — Triglav Electron Column
- UHR SEM — Ultra High Resolution SEM
- 1.0 nm at 1 keV — Resolution
- 0.7 nm at 15 keV — Resolution
- Selective Signal Detection
- TEM lamella preparation
- Cross-sectioning
- FIB-SEM Tomography
- Planar delayering

The most advanced capabilities in nanofabrication for ultimate quality in challenging sample preparation

TESCAN S9000G is a gallium FIB-SEM system aimed at advanced ultra-thin TEM sample preparation, and other challenging nanofabrication tasks, that demand ultimate resolution and the latest in ion optics and nanomachining capabilities. The TESCAN S9000G features the Triglav™ SEM column for ultra-high resolution with excellent performance, especially at low electron beam energies, and improved in-beam detection system with filtering electron signal collection capabilities that opens the window to new contrasts and enhanced surface sensitivity. The TESCAN S9000G is equipped with the Orage™ FIB column that delivers not only the highest standard in precision for nanofabrication, but also the possibility to use high ion beam currents; thus, making it feasible to conduct large-volume sample analyses. Excellent resolution and performance at low ion beam energies enable the preparation of electron-transparent TEM specimens of sub-20 nm semiconductor devices with ultimate quality. In addition, high ion beam currents up to 100 nA enable site-specific, large-volume FIB-SEM tomography of biological specimens and materials with excellent contrast. The TESCAN S9000G is controlled by the new Essence™ SW interface, which is designed with an easy-to-learn, application-oriented and customizable layout as well as SW modules with automation capabilities for sample preparation. All features are aimed at maximizing control and throughput with exceptional ease.

- **World-class quality in sample preparation:**

  The cutting-edge ion optics design in the Orage™ FIB column guarantees high resolution over the entire beam energy range, versatility, and best conditions for sample preparation. However, its excellent performance at low energies is what makes this column a world-class instrument for performing the most challenging nanofabrication tasks, including the preparation of ultra-thin TEM specimens of sub-20 nm processes with ultimate quality after final low-kV polishing.

- **Maximum versatility in sample preparation to your lab:**

  Whether used at low ion beam currents for fabricating delicate nanostructures, or high currents for fulfilling large-volume milling requirements, the Orage™ column – capable of generating maximum currents of up to 100 nA while preserving beam quality – offers incomparable versatility to satisfy a wide range of FIB applications.

- **Nanofabrication with ultimate quality:**

  Keeping up with an ever-increasing number of FIB milling applications that demand low beam energies, the Orage™ column operates at energies down to 500 eV thus providing the possibility of gentle milling to complete tasks such as TEM sample final polishing with minimal amorphization. Surface preparation is possible for EBSD microanalysis, or delicate surface final polishing in delayering applications of sub-20 nm chips for the purposes of architecture characterization.

- **Making the most of ion beam capabilities:**

  A fast, efficient and high-performance gas injection system (GIS) is essential for all FIB applications. The new OptiGIS™ has all these qualities and the S9000G can be equipped with up to 6 units of OptiGIS, or optionally, with an in-line multi-nozzle 5-GIS system that gives maximum versatility in multi-purpose installations. In addition, different proprietary gas chemistries and proven recipes for planar IC delayering are also available.

- **Maximum precision and optimal FIB performance with ease:**

  The Orage™ FIB column is fitted with an ultra-stable HV supply and precise piezo-driven aperture changer, which allows fast switching between FIB presets and excellent repeatability. In addition, a semi-automated spot-optimizing wizard allows users to easily select the best beam spot that optimises FIB milling conditions for a particular application.

- **Improved and extended imaging capabilities:**

  The in-beam detection system in the next generation Triglav™ column has been optimized resulting in more than a three-fold enhancement of signal detection efficiency. In addition, the detection capabilities have been extended and energy-filtered axial BSEs signal collection is now possible. This makes it possible to explore with new contrasts and provides enhanced surface sensitivity by selectively collecting low-loss BSEs.

- **Enhanced surface sensitivity and meaningful contrast:**

  Electron-signal selective detection capabilities available in the next generation Triglav™ column gives users complete control on surface sensitivity and the option to explore with different contrasts. Images containing topographic or material contrast, or both, can be acquired simultaneously for maximum insight of the sample in minimum time.

- **Fast 3D microanalysis:**

  The new and enhanced in-lens detection system enables fast image acquisition, which in combination with high ion beam currents up to 100 nA, results in fast data acquisition for 3D ultrastructural studies and 3D microanalytical sample characterisation. EDS and EBSD data can be simultaneously obtained during the FIB-SEM tomography and post-processed with dedicated software to obtain 3D sample reconstructions that provide researchers in life sciences or nanomaterials with unique insight and concrete answers.

- **Best conditions for microanalysis guaranteed:**

  The new generation of Triglav™ also comes with adaptive spot shape optimization, which results in improved resolution at high electron beam currents. Such a feature is beneficial for fast analytical techniques such as EDS, WDS, 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.

- **Large wafer analysis:**

  Optimal 60° objective geometry design, and a large chamber enables SEM and FIB analyses of up to 8” wafers at any location.

- **Complex applications easier than ever:**

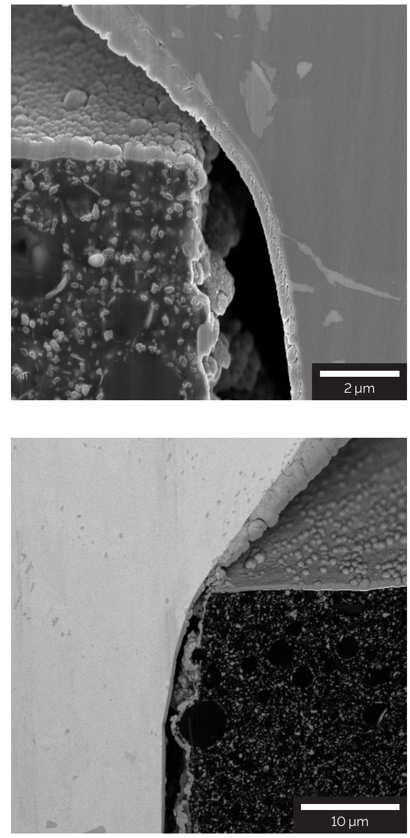
  The new TESCAN Essence™ software platform is a simplified, multi-user user interface with a layout manager that enables fast and easy access to main functions. This user-friendly interface can be customized to best fit particular applications, user skill level and preference. A wide range of SW modules, wizards and recipes make the FIB-SEM applications an easy and simple experience for both novice and expert users, thus boosting productivity and contributing to increase throughput in the lab. The new TESCAN Essence™ also offers the Advanced DrawBeam™, vector-based scanning generator for fast and precise FIB machining and Electron Beam Lithography.

Ultimate resolution and enhanced detection capabilities for sample characterization

The next generation Triglav™ SEM column is based on Trilens™, a three objective lens system. Such electron optics makes it possible to significantly reduce optical aberrations for ultra-high resolutions, and on the other hand, enables an Analytical model for field-free imaging suited for observation of magnetic samples and live monitoring of FIB operations. Unmatched large field of view for smooth, fast, and easy navigation across sample is also an advantage delivered by this column. Improved stability and newly-developed electronics enable users to set parameters rapidly and easy. The in-beam detection system in the next generation Triglav™ column has been optimized resulting in more than a three-fold enhancement of signal detection efficiency.

In addition, the detection capabilities have been extended, and energy-filtered axial BSEs signal collection is now possible. This makes it possible to enhance surface sensitivity by selectively collecting low-energy axial BSEs.

Moreover, the imaging system was optimized giving better contrast at all currents and improved resolution in the transmission mode (0.6 nm at 30 keV).



▲ **Fig:** Detail of under-bump metal layers using different detectors for different type of contrasts. In-Beam SE for topographic contrast, In-Beam f-BSE for combined material and topographic contrast.

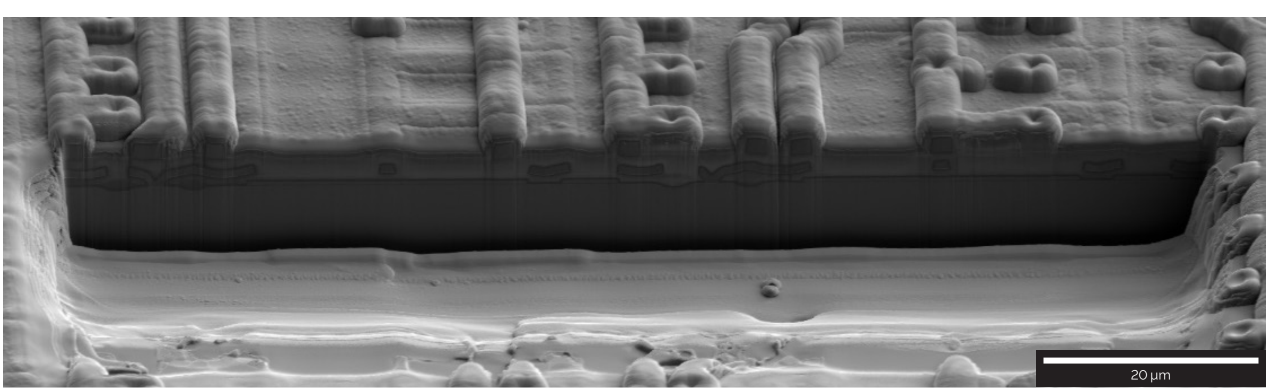
World-class quality in sample preparation

The outstanding imaging capabilities are just one part of what the TESCAN S9000G can offer; its capabilities for nanoengineering are equally remarkable. The TESCAN S9000G features the Orage™ FIB column, the next generation of Ga source FIB column with cutting-edge ion optics delivering ultra-fine resolution throughout the entire range of beam energies, and excellent low-energy beam performance.

Significant better resolution and excellent performance at low beam energies is an advantage and quality guarantee for performing delicate milling tasks and challenging nanopatterning applications that require ultimate precision. This includes the preparation of ultra-thin TEM specimens of thicknesses of less than 15 nm with ultimate quality by means of the most advanced preparation techniques and TEM lamella geometries.

Accelerating FIB nanomachining

The Orage™ column achieves ion beam currents up to 100 nA enabling fast sputtering rates for increased volume-wise analytical capabilities, superior throughput and minimum time frames to complete analyses.



▲ **Fig:** Fast bulk trench milling: 100 × 30 × 20 µm^3 completed in 20 minutes.

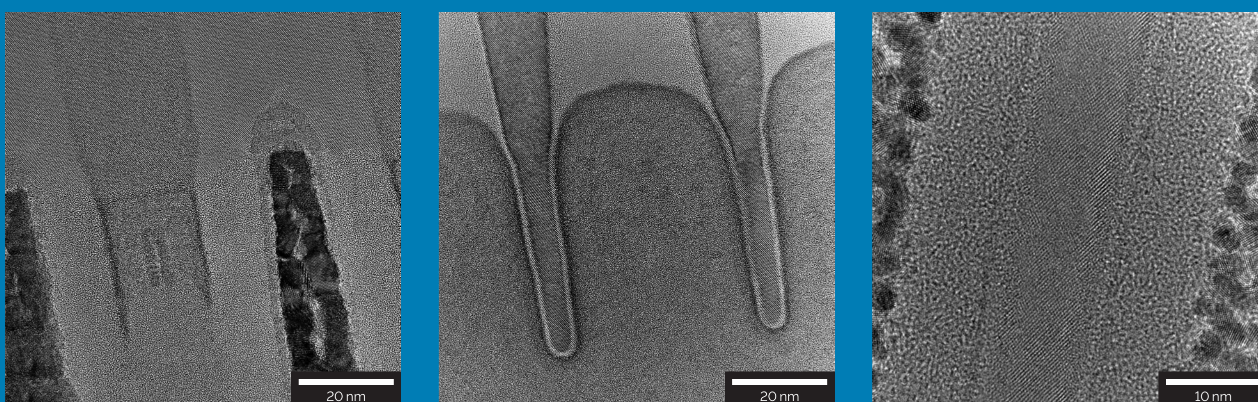
Applications

Physical failure analysis of semiconductor devices

Advanced TEM specimen preparation of sub-20 nm node processes

Preparing ultra-thin TEM specimens from sub-20 node process semiconductor devices is an extremely challenging FIB application that allows isolating defects with high localisation. This requires advanced preparation techniques that demand the highest performance for both SEM and FIB columns. On the one hand, excellent in-beam SE detection capabilities are crucial for keeping control of such complex nanofabrication. On the other hand, only an exceptional low-kV performance of the FIB column will be able to cope and guarantee ultimate quality in TEM specimens. The TESCAN S9000G has all that it takes to prepare TEM samples using advanced techniques such as the double cross-section for which specimens thinner than 10 nm can be prepared. The TESCAN S9000G is the ideal platform to prepare different TEM lamellae geometries:

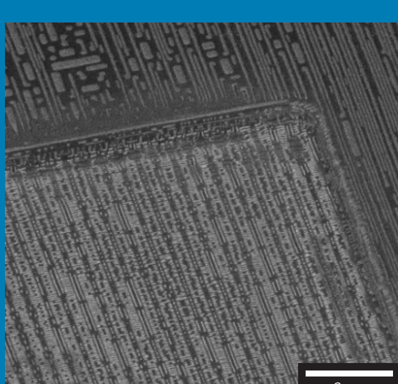
- Double cross-section TEM lamella
- Standard top-down thinning
- Inverted thinning
- Planar lamella
- Semi-automated serial TEM sample preparation



▲ **Fig:** TEM images of thin specimens prepared from a 10 nm node technology-based IC: (a) Gate-cut (b) Fin-cut (c) Cross TEM lamella showing thickness of < 10 nm.

Planar IC delayering

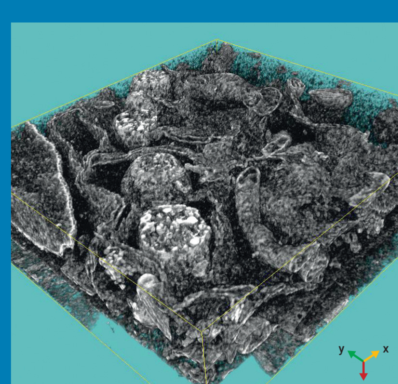
Delayering consists in strategically removing a set of layers to isolate a structure of interest. It is a key sample preparation technique in today's semiconductor industry especially for sub-20 nm technology chips. Gallium FIB delayering on semiconductor chips is useful in applications such as reverse engineering, cyber-security and physical failure analysis workflows for eventual lamella preparation. These applications are more focused on studying the information of unique architectural or material characteristics. It is extremely effective in terms of initial planar removal of multiple layers and then performing TEM lamella preparation in areas of interest.



◄ **Fig:** Overview of a delayered 10 nm node technology-based chip.

FIB-SEM tomography of Biological Specimens

FIB-SEM tomography is a 3D sample reconstruction technique that alternates FIB-slicing with SEM imaging through a serial and automated process. It provides unique highly-localised information on the internal ultrastructure of materials and specimens with nanoscale resolution that cannot otherwise be obtained by other conventional microanalytical techniques. The TESCAN S9000G makes it feasible to perform 3D sample reconstructions with speed and extreme ease of biological specimens. 3D microanalysis of materials providing elemental and crystallographic volume characterization is also one of the key applications of the TESCAN S9000G.



◄ **Fig:** 3D ultrastructural reconstruction of studied mammalian cell. 776 slices forming volume of approximately 6 × 8 × 6 µm³. Sample courtesy of Dr. Xuejun Sun, Dept. of Exp. Oncology, Cross Cancer Institute, University of Alberta, Canada.

Technical Specifications

Electron Optics:

Electron Gun:	High brightness Schottky emitter
Electron Optics:	Triglav™ column equipped with the three-lens compound TriLens™ objective
Resolution:	**Standard mode:** **In-Beam SE** 0.7 nm at 15 keV 1.4 nm at 1 keV **In-Beam f-BSE** 1.6 nm at 15 keV **Beam Deceleration mode (option):** **SE (BDM)** 1.0 nm at 1 keV / 1.2 nm at 200 eV **STEM mode (option):** 0.6 nm at 30 keV
Maximum Field of View:	4.3 mm at $WD_{Analytical}$ 5 mm 7.0 mm at WD 30 mm
Electron Beam Energy:	200 eV to 30 keV / down to 50 eV with the BDT option
Probe Current:	2 pA to 400 nA

Ion Optics:

Ion Column:	Orage™ Ga FIB column
Ion Gun:	Ga Liquid Metal Ion Source
Ion Beam energy:	0.5 keV to 30 keV
Probe Current:	< 1 pA to 100 nA
Resolution:	< 2.5 nm at 30 keV (at SEM-FIB coincidence point)
SEM-FIB Coincidence at:	WD 5 mm for SEM - WD 12 mm for FIB
SEM-FIB Angle:	55°

Detectors:

Detectors (standard):	SE In-Beam SE TriBE™ detection system – For angle-selective BSE signal collection with energy-filtering detection capabilities consisting of three detectors: ▪ In-Beam f-BSE – Annular, scintillation-based axial detector fitted with a bias grid for energy-filtering BSE signal collection ▪ Mid-Angle BSE – In column detector that collects mid-angle electrons ▪ Retractable BSE – Annular in-chamber scintillation-based detector for wide-angle BSE collection
Optional Analytical Techniques:	LE-BSE, Water-cooled BSE, 4Q BSE, HADF R-STEM, EDS, WDS, EBSD, TOF-SIMS, SITD, CL, Raman Spectroscopy (RISE)
Accessories:	**Standard:** Decontaminator/plasma cleaner. **Optional:** Nanomanipulators, Load Lock (Manual/Automatic), Rocking Stage, Optical Stage Navigation, Flood Gun, Control Panel, Peltier Cooling Stage, Beam Blanker for SEM column, Cradle Stage, EDX Piezo Shutter
Gas Injection System:	Single nozzle OptiGIS™ (up to 6 units) and in-line multi-nozzle 5-GIS. Variety of gas chemistries including proprietary gas for planar delayering.
Chamber:	Internal dimensions: 340 mm (width) × 315 mm (depth) × 320 mm (height) Number of ports: 20+ Chamber and Column Suspension: active vibration isolation (integrated)
Specimen Stage:	Compucentric, fully motorized XY = 130 mm (–65 mm to +65 mm), Z = 90 mm Rotation = 360° continuous, Tilt = –60° to +90°