TESCAN

S9000X

TESCAN
PERFORMANCE IN NANOSPACE

New generation of FIB-SEM microscope

- iFIB+™ Xe plasma FIB column
- Triglav™ electron column
- UHR SEM
- Low-kV resolution
- Resolution
- Selective signal collection
- UniVac
- IC planar delayering
- Nanoprobing
- TEM lamella preparation
- Cross-sectioning
- FIB-SEM tomography

Ultimate resolution and maximum throughput in large-scale sample preparation and characterization

The TESCAN S9000X is the platform for the most challenging physical failure analysis applications in semiconductors and material characterization that require ultimate precision and extremely high-throughput. The TESCAN S9000X guarantees ultimate resolution and surface sensitivity essential to resolve nanosized structures while providing the best conditions for large-volume 3D sample characterizations. At the same time, it also delivers unmatched FIB capabilities that enable precise, damage-free, and extremely large-area cross-sectioning in packaging technologies and optoelectronic devices.

- **Extremely high-throughput for challenging large-scale milling tasks**

  The iFIB+™ Xe plasma FIB column can generate high FIB currents of up to 2 µA while maintaining beam spot quality that enables bulk milling at maximum ion beam currents. Thus, large volumes of materials 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.

- **Xe plasma FIB column with unmatched FoV enabling extremely large-area cross-sectioning**

  The new iFIB+™ column has the largest-in-class field of view (FoV) in the market of plasma FIB-SEM. With a maximum field of view of 1 mm at 30 keV and ultra-high sputtering rates of Xe ions at high currents, 1 mm-wide cross-sections in electronic packaging technologies and other large structures such as MEMS and displays can be completed in matter of a few hours. This is a concrete solution to simplify complex physical failure analysis workflows.

- **Versatility that extends your possibilities in FIB analysis and microengineering**

  The Xe plasma FIB offers a large ion beam current range enabling a wide range of applications in one single system. Large currents enable fast milling rates for large-volume bulk material removal, medium currents for large-volume FIB-tomography, low currents for TEM lamella polishing, and delayering, and ultra-low currents for damage-free polishing and nanopatterning.

- **Making the most of electron and 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 S9000X can be equipped with up to 6 units of OptiGIS or optionally with an in-line multi-nozzle 5-GIS system. In addition, different proprietary gas chemistries and proven recipes for physical failure analysis of packaging technologies are available.

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

  The new iFIB+™ column is fitted with an ultra-stable HV supply and precise piezo-driven beam aperture changer which allow fast switching between FIB presets. In addition, a semi-automated spot-optimising wizard allows users to easy select the best beam spot that optimizes FIB milling conditions for the particular application.

- **Robust detection system**

  Multi-detector system consisting of TriSE™ and TriBE™ enables collection of SE and BSE in the entire take-off angle range for maximum information of the sample.

- **Minimal surface damage and Ga-free sample preparation to preserved properties of samples**

  Ion implantation range and interaction volume of Xe ions is significantly smaller compared to those of Ga ions. This results in less 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 that can result in changes in physical properties of the specimen and interfere with for instance, electrical measurements.

- **Improved and extended imaging capabilities**

  The in-beam detection system in the next generation Triglav™ column has been optimized resulting in significantly improved 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.

- **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. Beam Deceleration Technology is also available to further improve resolution at low and ultra-low electron landing beam energies.

- **Ultra-fast 3D microanalysis**

  The new and enhanced in-lens detection system enables fast image acquisition, which in combination with high sputtering rates enabled by the Xe plasma FIB, results in ultra-fast data acquisition for 3D microanalysis. EDX and EBSD data can be simultaneously obtained during the FIB-SEM tomography, and post-processed with dedicated software, to obtain 3D reconstructions for unique microstructural, compositional and crystallographic information of whole solder balls, TSVs, metal alloys, etc.

- **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. This feature is beneficial for fast analytical techniques such as EDX, WDX, and EBSD.

- **Enhancement of detection limits in TOF-SIMS analysis**

  and no interference in the elemental spectrum (as opposed to Ga FIBs in which Ga+ peaks can interfere with the detection of other elements such as Ce, Ge and Ga itself).

- **Fast microanalysis without sacrificing spatial resolution.**

  The Triglav™ SEM column features a new Schottky FE gun that enables beam currents up to 400 nA and rapid beam energy changes. Real-time In-Flight Beam Tracing™ for performance and beam optimization includes direct and continual control of beam spot size and beam currents, which guarantee the best conditions for microanalysis.

- **Large wafer analysis**

  Thanks to optimal 60° objective geometry design and a large chamber, SEM and FIB analysis of 6" and 8" wafers at any location is possible.

- **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 based on 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.

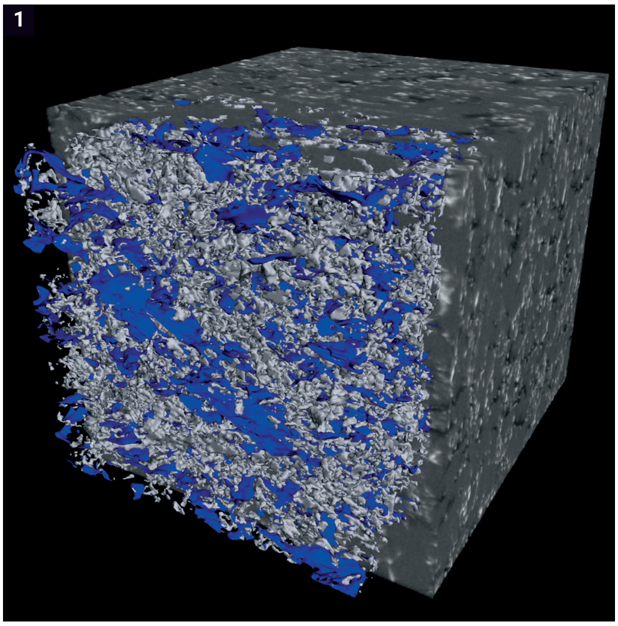


Fig. 1: 3D reconstruction of a SiAlON-graphene sample. The in-beam f-BSE detector provides great morphological detail of the structure of the composite. The FIB-SEM tomography of this SiAlON-graphene composite sample consisted in 1339 slides. The volume of the detailed reconstruction was 22 × 22.3 × 66.9 µm³. We thank Professor Servet Turan from Anadolu University for providing us with the SiAlON-graphene composite sample.

TESCAN Xe Plasma FIB: combining power and precision in one single instrument

Xe plasma FIB is a powerful microanalytical technique that has completely revolutionized the landscape and scope of FIB applications in science and industry as a whole. What makes Xe plasma special is that it is possible to achieve very high ion beam currents up to 2 μA without compromising beam quality, a feature which makes the TESCAN S9000X a suitable technique for large-volume milling tasks and the ideal choice to increase throughput and productivity in routine workflows in fabs and semiconductor foundries. Thanks to continuous developments in the Xe plasma FIB column, power and high-precision are no longer in conflict; small probes with resolution of less than 15 nm at 30 keV can be achieved.

In terms of sample preparation, Xe plasma FIB offers great advantages compared to Ga ion sources. The inert nature of Xe makes it the ideal ion specie to mill or to fabricate delicate structures that require to be Ga-free to not alter physical properties such as conductivity of samples – this is the case of Hall probes and atom probe tips fabrication. In addition, Xe ions cause less amorphous damage compared to Ga at 30 keV; this is advantageous for preparing high-quality thin TEM specimens.

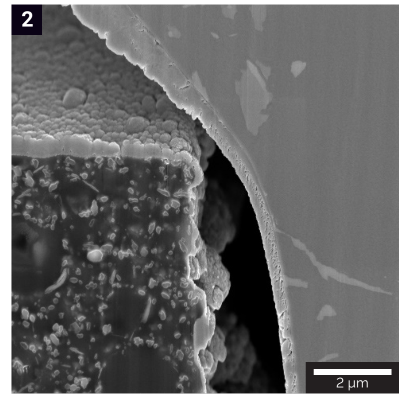
■ Benefits:

- ✓ Extensive ion beam current range gives incomparable FIB versatility
- ✓ Up to 50 × faster milling speed rates than conventional Ga FIBs
- ✓ Large FIB currents for fast milling rates without gas-assisted enhancement
- ✓ Highly-localised and well-controlled sample modification and nanoengineering
- ✓ Significant reduction in surface amorphisation and ion implantation
- ✓ No intermetallic compounds formed during milling
- ✓ Xe ions enhance detection limits in TOF-SIMS analysis
- ✓ Shortest time-to-data, Increased throughput, and productivity

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 resolution. On the other hand, it enables an Analytical Mode for field-free imaging suited for observation of magnetic samples, and live monitoring of FIB operations. The Analytical mode also provides large field of view for smooth, fast, and easy navigation across a sample. 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 optimised giving better contrast at all currents by an adaptive spot shape optimisation and improved resolution in transmission mode (0.6 nm at 30 keV).



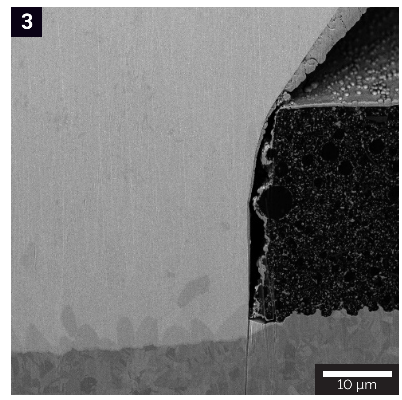


Fig. 2, 3: Detail of under-bump metal layers using different detectors for different type of contrasts. In-Beam SE for topographic contrast, In-Beam f-BSE for combined material and topographic contrast.

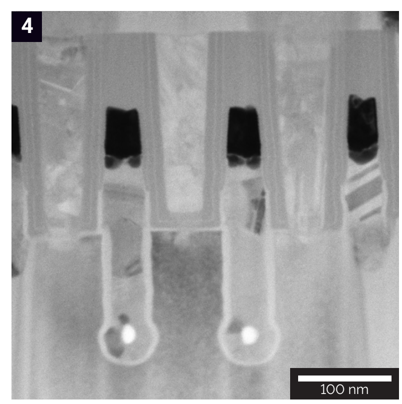


Fig. 4: STEM-BF image of an 80 nm-thick TEM specimen from a DRAM 65 nm node prepared with Xe plasma FIB. 5 nm-thick layers are well-resolved.

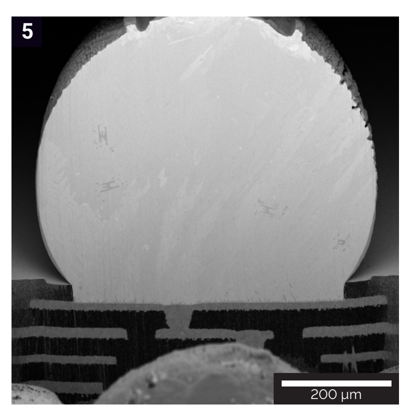


Fig. 5: 630 μm-diameter solder ball cross-sectioned using a Si mask for artefact-free surface.

Applications

Root-cause physical failure analysis of today's semiconductors devices has become an extremely complex task with ever smaller devices with higher density and functionality. This requires highly-reliable analytical platforms that can keep up with the increasing complexity of design and architectures of integrated circuits, optoelectronic devices and, in general, with the development of new nanotechnologies and nanomaterials. The TESCAN S9000X is a powerful FIB-SEM platform specifically designed to take up such challenges. The ultimate resolution, surface sensitivity and outstanding contrast is delivered by next generation Triglav™ imaging capabilities. On the other hand, the new iFIB+™ column comes to push even further the realm of applications of Xe plasma FIB and the capability for large-scale sample microengineering and 3D microanalysis while maintaining shortest time-to-result.

Enhance quality in the most challenging cross-sectioning

The TESCAN Rocking Stage, a 6-axis piezo-movement stage enables milling the sample from two different directions, a well-known technique for removing curtaining while making simultaneous SEM imaging possible. The Rocking Stage is fully integrated into the SW microscope, thus its implementation is easy and straightforward. In addition, TESCAN has developed and patented the TRUE X-sectioning, a cross-sectioning technique that enables artefact-free cross-sections at high ion beam currents allowing the user to fully profit from high sputtering rates delivered by Xe plasma FIB. The TRUE X-sectioning technique improves up to 50% preparation time compared to standard milling approaches with plasma FIB thus increasing throughput in FA workflows.

Benefits:

- Ultra-fast, large-area cross-section preparation
- Final polishing at high currents
- Excellent surface quality even in the most difficult materials at no cost in overall preparation time
- Easy to implement and automated
- Analysis can be performed on individual cut die or on entire wafers (up to 8")

Extremely large cross-sections

The TESCAN S9000X extends the capabilities of FIB by making large-scale sample analysis feasible. Cross-sectioning of areas up to 1 mm wide are now tasks that can swiftly and routinely be performed. TSVs, MEMS, solder bumps, Cu pillars, bonding pads, whole BGA areas, and other large structures can be effortlessly cross-sectioned with Xe plasma FIB for the purposes of physical failure analysis. The TESCAN S9000X has the capabilities that guarantee the smoothest and flawless cross-sections even for the most difficult materials, such as dielectrics and composite samples, where differences in milling rates of materials make cross-sections prone to FIB-induces artefacts.

Ultra-fast large-volume FIB-SEM tomography

FIB-SEM tomography is a 3D sample reconstruction technique that alternates FIB-slicing with SEM imaging in serial automated way. It provides unique information on the internal structure of materials and specimens that cannot otherwise be obtained by other conventional microanalytical techniques. The TESCAN S9000X makes it feasible to perform large-volume 3D sample reconstructions with extreme ease and speed. The TESCAN S9000X can be equipped with EDX and EBSD detectors and the 3D Advanced Tomography software module which enables you to perform automated and simultaneous 3D EDX and 3D EBSD characterizations of whole bonding wires, solder balls, TSVs, diverse metal alloys, etc. making 3D chemical maps and full crystallographic sample information available.

Benefits:

- Unique ultra-structural information of samples
- Large-volume highly-localised sample analysis
- Ga-free contamination in sample preparation
- SW modules for data rendering and different data visualization
- Small voxel and high contrast
- 3D EDX for 3D chemical mapping
- 3D EBSD for volume crystallographic microanalysis
- EquiPower™ guarantees excellent column stability

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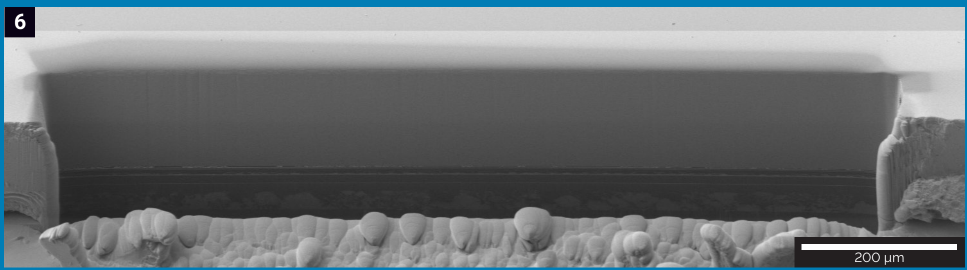

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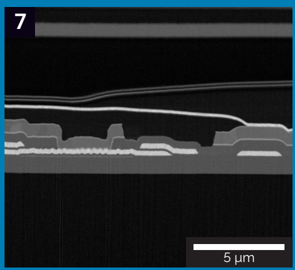

Fig: (6) Overview of a 1086 µm-wide cross-section in an OLED display, FoV 1.26 mm. **Fig: (7)** Detailed image of the cross-section showing Al contacts and SiO_2/SiN_x layer structure imaged with the Mid-Angle BSE detector at 2 keV.

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 BSE** 1.6 nm at 15 keV **Low Vacuum Mode*:** **BSE** (UH RESOLUTION) 2.0 nm at 30 keV **LVSTD** (ANALYSIS) 3.0 nm at 30 keV	**Beam Deceleration mode (option):** **SE(BDM)** 1.0 nm at 1 keV 1.2 nm at 200 eV **STEM (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:	iFIB+™ / High-resolution iFIB+™ (option)
Ion Gun:	Xe ion Plasma FIB
Ion Beam Energy:	3 keV to 30 keV
Probe Current:	1 pA to 2 μA / 1 pA to 1 μA
Resolution:	< 25 nm at 30 keV / < 15 nm at 30 keV (at SEM-FIB coincidence point)
Magnification:	Minimum 150× at coincidence point and 30 keV (corresponding to 1 mm field of view), maximum 1,000,000 x
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, scintillator-based axial BSE detector and fitted with a bias grid for low-loss BSE detection ▪ Mid-Angle BSE - Second in-column detector that collects mid-angle electrons with high efficiency ▪ Retractable BSE - Retractable annular in-chamber scintillator-based detector for collecting wide-angle BSEs pA meter Chamber view camera
Optional Detectors:	Beam Deceleration Technology (BDT), LE-BSE, LVSTD, Water-cooled BSE, 4Q BSE, HADF R-STEM, EDX, WDX, EBSD, TOF-SIMS, SITD, CL, Raman Spectroscopy (RISE)
Accessories:	**Standard:** Decontaminator /plasma cleaner **Optional:** Load Lock, Nanomanipulators, Flood Gun, Rocking Stage, Optical Stage Navigation, Control Panel, Beam blanker for SEM column, Peltier Cooling Stage, Cradle Stage, EDX piezo shutter
Gas Injection System:	Single nozzle OptiGIS™ and in-line multi-nozzle 5-GIS. Variety of gas chemistries including proprietary gases for planar IC 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 motorised XY = 130 mm (–65 mm to +65 mm), Z = 90 mm Rotation = 360° continuous, Tilt = –60° to +90°

*For variable pressure (UniVac) systems