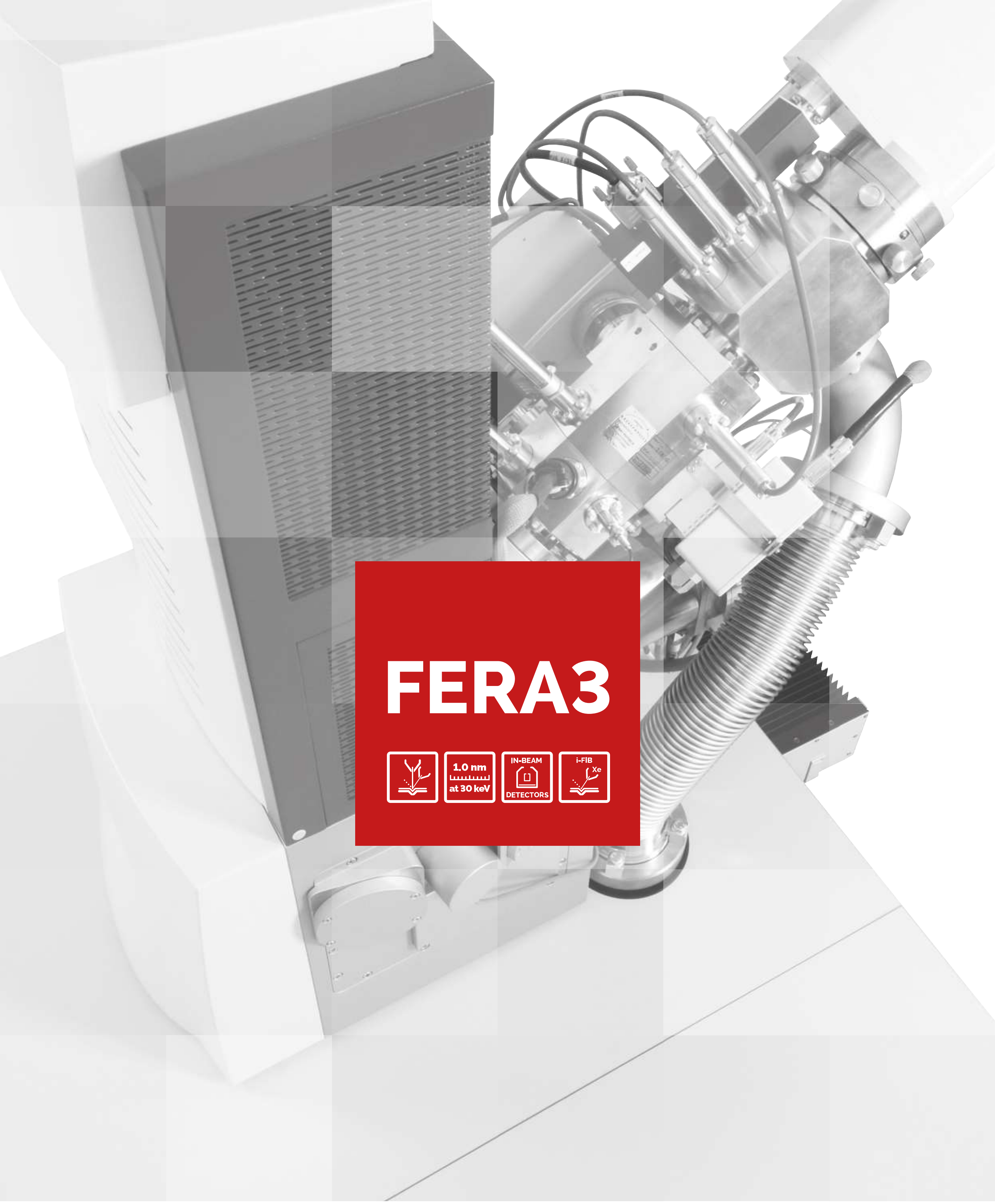


# FERA3

1.0 nm at 30 keV
IN-BEAM DETECTORS
i-FIB Xe

TESCAN
PERFORMANCE IN NANOSPACE

# The world's first fully integrated plasma source FIB with SEM

## TESCAN FERA3 Plasma Source FIB-SEM

The world's first fully integrated Xe plasma source FIB with SEM enables extremely high ion currents up to 2 μA thus increasing sputtering rate more than 50 times compared to conventional Ga source. This predetermines FERA3 for milling big volumes of materials that were time consuming or impossible so far.

## TESCAN Focused Ion Beam Scanning Electron Microscopes

This new generation of scanning electron microscopes equipped with focused ion beam column provides users with the advantages of the latest technology, such as new improved high-performance electronics for faster image acquisition, ultra-fast scanning system with compensation of static and dynamic image aberrations or built-in scripting for user-defined applications, all while maintaining the best price to performance ratio.

They were designed with respect to a wide range of FIB-SEM applications and needs in today's research and industry. The excellent resolution at high beam current values as well as the powerful software make TESCAN FIB-SEMs excellent tools for a wide range of analytical applications in different fields of research and industry.


## Highlights

- Automatic set up of the coincidence point of the electron and ion beams
- The Draw Beam Software gives to the end user access to the most advanced patterning and 3D characterization capabilities such as powerful multilayer pattern editing tool, corrections of proximity effect, live imaging of the milling process, etc.
- Sophisticated software for SEM/FIB/GIS control, image acquisition, archiving, processing and analysis
- Possible simultaneous SE and SI signals acquisition

## Modern Electron Optics

- A unique Wide Field Optics™ design with a proprietary Intermediate Lens (IML) offers a variety of working and displaying modes, for enhanced field of view or depth of focus, etc.
- Real time In-Flight Beam Tracing™ for performance and beam optimization. It includes also direct and continual control of beam and beam current
- Fully automated electron optics set-up and alignment
- Fast imaging rate up to 20 ns
- Unique live stereoscopic imaging using the advanced 3D Beam Technology opens up the micro and nano-world for an amazing 3D experience and 3D navigation

## High Performance Ion Optics

- Sophisticated high performance plasma FIB-SEM system for both extremely fast and precise cross sectioning and material removal

## Analytical Potential

- All the chamber models provide superior specimen handling using a full 5-axis motorized compucentric stage and ideal geometry for microanalysis
- Choice of extra-large XM and GM chambers both with robust stages capable of accommodating large samples
- Numerous interface ports with optimized analytical geometry for microanalysis as well as for attaching many other detectors
- First-class YAG scintillator-based detectors
- Selection of optional detectors and accessories
- Fast and easy obtaining of the clean chamber vacuum
- Investigation of non-conductive samples in the variable pressure mode versions
- Integrated active vibration isolation ensures an effective reduction of ambient vibrations in the laboratory
- Observation of magnetic samples
- Non-distorted EBSD pattern

## Beam Deceleration Technology (BDT)

TESCAN launches the new and innovative Beam Deceleration Technology (BDT), which consists of the Beam Deceleration Mode (BDM) and a state-of-the-art In-Beam detector designed to detect high-angle BSE under standard operating conditions and the SE signal in the BDM. Imaging at low voltages is advantageous for a wide range of specimens, including non-conductive materials, semiconductors and lithographic resists which are prone to radiation damage.

Keeping the primary beam at low energy allows the microscope user to determine very fine surface details which would not be observable at higher beam energies. It is highly recommended to combine the BDT with a decontaminator device.

## SITD - Secondary Ion TESCAN Detector

The new scintillator-based secondary ion detector (SITD) further extends the analytical possibilities of TESCAN FIB-SEMs. Together with the standard secondary electron detector (SE), the two standalone detectors with optimized geometry allow simultaneous acquisition of FIB generated positive secondary ion (SI) and secondary electron signals (iSE). This is advantageous, since the FIB imaging is always destructive.

With the secondary ion signal, a new type of contrast emerges. Secondary ions are emitted from a surface layer that is about ten times thinner than the information depth of ion induced secondary electrons, so the signal is very surface sensitive. Furthermore, the brightness of the SI signal is higher for heavier materials (it occurs the opposite for secondary ions generated with an Ga ion source FIB). This is true with the exception of material oxides. Oxygen increases significantly the secondary ion yield – in SI images, oxides become very bright, which makes the SITD an excellent tool for detection of corrosion.

## User-Friendly Software

- User-friendly, Windows-based user interface, multiple user levels, multiple user accounts, multi-user environment localized in many languages
- Easy-to-use control of all SEM parameters, simultaneous FIB/SEM imaging
- Live imaging with multiple window support, highly customizable live image parameters
- Image management using Image Manager, report creation, on-line and off-line image processing
- Project management using Project Manager
- Embedded automated diagnostics (self-test)
- TCP/IP remote control, network operations and remote access/diagnostics
- Free SW bug fixes and updates

## Software Tools

- Modular software architecture enables several extensions to be attached
- Several optional modules and dedicated applications optimized for automatic sample examination procedures
- DrawBeam software module turns the focused ion beam provided scanning electron microscope to a potent instrument not only for electron beam lithography, but also for electron beam deposition and electron beam etching as well as for ion beam deposition and ion beam milling
- 3D Tomography software option allows fully automated procedure of serial SEM imaging of FIB-prepared cross-sections and subsequent 3D reconstruction and visualization

| | |
|---|---|
| **Image Processing** | ☑ |
| **Histogram** | ☑ |
| **Analysis & Measurement** | ☑ |
| **Object Area** | ☑ |
| **Hardness** | ☑ |
| **Tolerance** | ☑ |
| **Multi-Image Calibrator** | ☑ |
| **Switch-Off Timer** | ☑ |
| **3D Scanning** | ☑ |
| **X-Positioner** | ☑ |
| **Live Video** | ☑ |
| **DrawBeam Advanced** | ☑ |
| **Easy SEM™** | ☑ |

| | |
|---|---|
| **Particles Basic** | ☐ |
| **Particles Advanced** | ☐ |
| **Image Snapper** | ☐ |
| **3D Tomography** | ☐ |
| **3D Tomography Advanced** | ☐ |
| **Sample Observer** | ☐ |
| **3D Metrology (MeX) *** | ☐ |
| **Input Director** | ☐ |
| **TESCAN TRACE GSR** | ☐ |
| **System Examiner** | ☐ |
| **Cell Counter** | ☐ |
| **AutoSlicer** | ☐ |
| **SYNOPSYS Client** | ☐ |
| **Coral** | ☐ |

☑ standard, ☐ option,
* third-party dedicated software by Alicona Imaging GmbH

## Rapid Maintenance

Keeping the microscope in optimal condition is now easy and requires a minimum of microscope downtime. Every detail has been carefully designed to maximize microscope performance and minimize the operator's effort.

## Automated Procedures

Automatic set up of the microscope and many other automated operations (such as working distance, brightness, etc.) are characteristic features of the equipment. There are many other automated procedures which significantly reduce the operator's tune-up time, enable automated manipulator navigation and automated analyses. SharkSEM remote control interface enables access to most of the microscope features, including microscope vacuum control, optics control, stage control, image acquisition, etc. The compact Python scripting library offers all these features.

# Plasma FIB-SEM configurations

The XM and GM configurations extend the analytical capabilities providing the ability of fine sample surface observation and modification even for extra-large specimens. In addition to electron and ion columns, the FERA3 Plasma FIB-SEM can be configured with a gas injection system, nano-manipulators, and a wide variety of detectors including the SE detector, BSE detector, SI (Secondary Ion) detector, CL (Cathodoluminescence) detector, EDX, and EBSD microanalyzers, etc.

## FERA3 XMH

An extra-large chamber model with a compucentric motorized manipulator operate at a high vacuum for investigation of conductive samples with extraordinary imaging quality.

## FERA3 XMU

These variable pressure model supplements all the advantages of the high vacuum model with an extended facility for low vacuum operations, allowing for the investigation of non-conductive specimens in their natural uncoated state.

## FERA3 GMH

An analytical giant chamber model with a compucentric motorized manipulator operate at high vacuum allowing for the investigation of conductive samples with the possibility of extending the scanning electron microscopy investigation by microanalyses and/or other methods.

## FERA3 GMU

The analytical giant chamber variable pressure model extends the scanning electron microscopy investigation by microanalyses and/or other methods.

| Chamber | XM | GM |
|---|---|---|
| Internal size | 285 mm (width) × 340 mm (depth) | 340 mm (width) × 315 mm (depth) |
| Door | 285 mm (width) × 320 mm (height) | 340 mm (width) × 320 mm (height) |
| Number of ports | 12+ | 20+ |
| Chamber suspension | Integrated active vibration isolation system | |

| Specimen Stage | XM | GM |
|---|---|---|
| Type | compucentric | |
| Movements | fully motorized<br>X = 130 mm, Y = 130 mm, Z = 100 mm, Rotation = 360° continous | |
| Tilt | -30° to +90° | -60° to +90° |
| Max. specimen height | 92 mm with BDT rotation stage and 110 mm/139 mm with/without rotation stage | |

| Detectors | XMH GMH | XMU GMU |
|---|---|---|
| SE Detector | ☑ | ☑ |
| Retractable BSE Detector* | ☑ | ☑ |
| In-Beam BSE Detector | ☑ | ☑ |
| In-Beam SE Detector | ☐ | ☐ |
| In-Beam LE-BSE Detector | ☐ | ☐ |
| LE-BSE Detector* | ☐ | ☐ |
| LVSTD Detector | ⊘ | ☐ |
| HADF R-STEM Detector* | ☐ | ☐ |
| Secondary Ion TESCAN Detector (SITD) | ☐ | ☐ |
| CL Detector * | ☐ | ☐ |
| Rainbow CL Detector* | ☐ | ☐ |
| Beam Deceleration Technology (BDT) | ☐ | ☐ |
| EBIC | ☐ | ☐ |
| EDX **, *** | ☐ | ☐ |
| WDX ** | ☐ | ☐ |
| EBSD ** | ☐ | ☐ |
| TOF-SIMS**,**** | ☐ | ☐ |

| Other Options[1] | XMH GMH | XMU GMU |
|---|---|---|
| Probe current measurement | ☑ | ☑ |
| Touch Alarm | ☑ | ☑ |
| Chamber view camera | ☑ | ☑ |
| Active vibration isolation | ☑ | ☑ |
| Gas Injection System for 5 precursors | ☐ | ☐ |
| Gas Injection System for 1 precursor | ☐ | ☐ |
| Decontaminator/ plasma cleaner | ☐ | ☐ |
| Peltier Cooling Stage | ☐ | ☐ |
| Beam Blanker | ☐ | ☐ |
| Control Panel | ☐ | ☐ |
| Load Lock | ☐ | ☐ |
| Optical Stage Navigation | ☐ | ☐ |
| Nanomanipulators | ☐ | ☐ |
| Flood gun | ☐ | ☐ |
| Rocking stage | ☐ | ☐ |

☑ standard, ☐ option, ⊘ not available

* equipped with motorized mechanics

** fully integrated third party products

*** EDX detector has to be equipped with a shutter

**** only available on GM chamber

[1] Combinations of optional equipment must be discussed with TESCAN.

# FERA 3

## Electron Optics

| | |
|---|---|
| **Resolution** | |
| **In high-vacuum mode SE** | 1.2 nm at 30 kV<br>2.5 nm at 3 kV |
| **In high-vacuum mode In-Beam SE** | 1.0 nm at 30 kV |
| **In high-vacuum BDM (Beam Deceleration Mode)** | 1.8 nm at 3 kV<br>3.5 nm at 200 V |
| **In low-vacuum mode LVSTD** | 1.5 nm at 30 kV |
| **In-Beam BSE** | 2 nm at 15 kV |
| **STEM Detector** | 0.9 nm at 30 kV |
| **Electron optics working modes** | |
| **High-vacuum mode** | Resolution, Depth, Field, Wide Field, Channelling |
| **Low-vacuum mode** | Resolution, Depth |
| **Magnification** | Continuous from 1 × to 1,000,000 × |
| **Field of view** | 6.0 mm at $WD_{analytical}$ 9 mm<br>17 mm at WD 30 mm |
| **Accelerating voltage** | 200 V to 30 kV / 50 V to 30 kV with BDT (Beam Deceleration Technology) option |
| **Electron Gun** | High Brightness Schottky Emitter |
| **Probe current** | 2 pA to 200 nA |

## Ion Optics

| | |
|---|---|
| **Ion column** | i-FIB |
| **Resolution** | 25 nm at 30 kV at SEM-FIB coincidence point |
| **Magnification** | Minimum 150 × at coincidence point and 10 kV<br>(corresponding to 1 mm view field), maximum 1,000,000 × |
| **Accelerating Voltage** | 3 kV to 30 kV |
| **Ion Gun** | Xe Plasma Ion Source |
| **Probe Current** | 1 pA to 2 μA |
| **SEM-FIB Coincidence at** | WD 9 mm for SEM – WD 12 mm for FIB |
| **SEM-FIB angle** | 55° |

## Vacuum System

| | |
|---|---|
| **System pressure:** | |
| **Chamber – High-vacuum mode** | $< 9 \times 10^{-3}$ Pa* |
| **Chamber – Low-vacuum mode** | 7–500 Pa** |
| **Electron Gun** | $< 3 \times 10^{-7}$ Pa |
| **FIB Gun** | $< 5 \times 10^{-4}$ Pa |
| | * pressure $< 5\times10^{-4}$ Pa reachable |
| | ** with low vacuum aperture inserted |

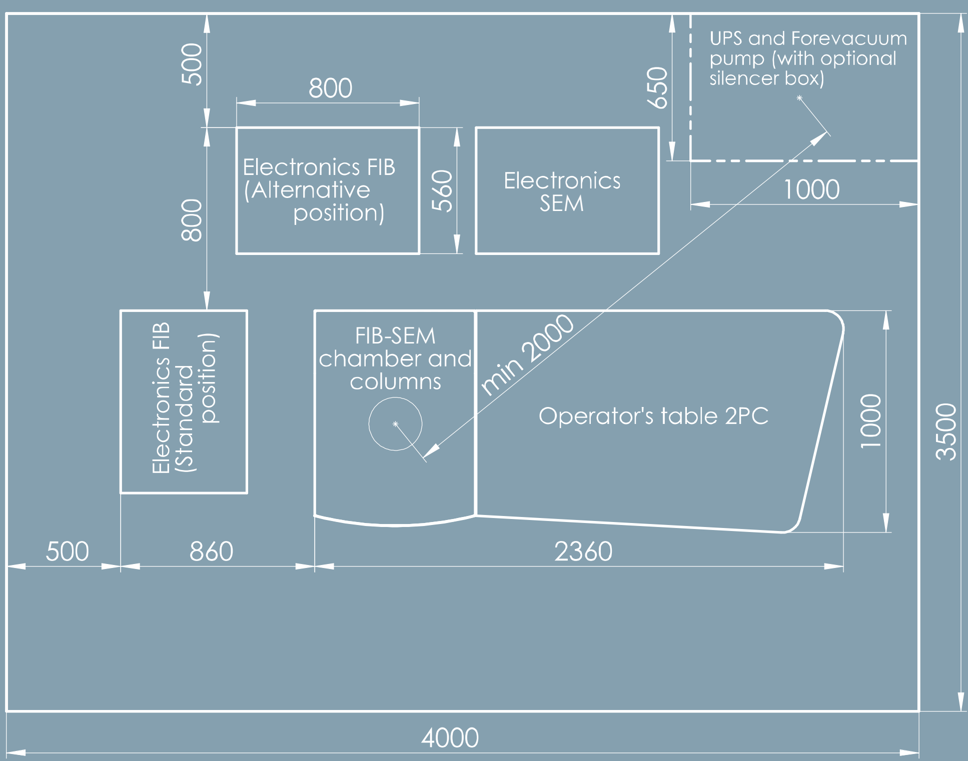
## System Control

| | |
|---|---|
| **System control** | All system functions are PC-controlled using the trackball, mouse and keyboard via the program FeraTC using Windows™ platform. |
| **Scanning speed** | From 20 ns to 10 ms per pixel adjustable in steps or continuously |
| **Scanning features** | Focus Window, Dynamic focus, Point & Line scan, Image rotation, Image shift, Tilt compensation, 3D Beam, Live Stereoscopic Imaging, Other scanning shapes available through DrawBeam Software |
| **Image size** | 16,384 × 16,384 pixels, adjustable separately for live image (in 3 steps) and for stored images (11steps), selectable square or 4:3 or 2:1 rectangle. |
| **Automatic procedures** | In-Flight Beam Tracing™ beam optimization, Spot Size and Beam Current Continual, WD (focus) & Stigmator, Scanning Speed (according to Signal- Noise Ratio), Gun Heating, Gun Centering, Column Centering, Compensation for kV, Contrast & Brightness, Vacuum Control, Look Up Table, Auto-diagnostics, Setup of FIB-SEM intersection point, Automated FIB emission start |
| **Remote control** | Via TCP/ IP, open protocol |

## Requirements

| | | |
|---|---|---|
| **Installation requirements** | Power 230 V/50 Hz or 120 V/60 Hz, 2300 VA<br>No water cooling<br>Compressed dry nitrogen for venting: 150 – 500 kPa<br>Compressed air: 600 – 800 kPa<br>Compressed xenon for plasma source: 300 kPa | |
| **Environmental requirements** | Environment Temperature: | 17 – 24 °C |
| | Relative humidity: | < 65 % |
| | Acoustic noise: | < 60 dBC |
| | Active vibration isolation: | < 10 µm/s below 30 Hz<br>< 20 µm/s above 30 Hz |
| | Background magnetic field: | synchronous $< 3 \times 10^{-7}$ T<br>asynchronous $< 1 \times 10^{-7}$ T |
| | Room for installation: | 3.5 m x 4 m minimum<br>minimum door width 1.0 m |
| | Altitude: | max. 3000 m above sea level |

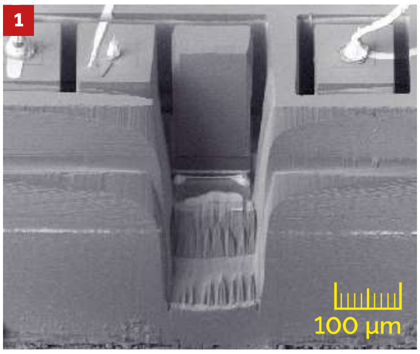
## Footprint of the microscope FERA3 XM/GM (all dimensions in mm)

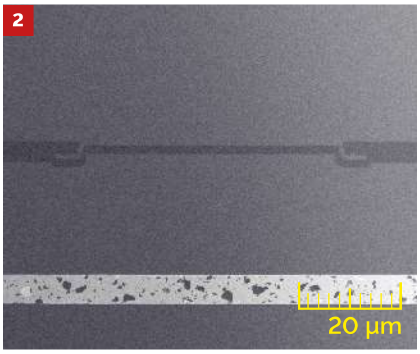


# Common applications

The use of a xenon plasma source for the focused ion beam allows FERA3 to satisfy high resolution FIB requirements (imaging, fine milling/polishing), but first of all achieving high ion currents needed for ultra-fast material removal rates. Compared to existing FIB technologies with gallium sources, the material removal rate achievable for silicon with the plasma FIB-SEM is about 50 times faster. For this reason, FERA3 is well suited for applications requiring the removal of large volumes of material, particularly in the semiconductor packaging corridor where the TSV technology is used.

The FERA3 plasma FIB-SEM workstation integration of both an electron and focused ion beam places this tool in a class of its own, affording the end user the benefits of electron beam analysis and characterization. Generally, systems of this kind can be used not only for research in materials science and forensic investigations but mainly in the semiconductor industry for 3D metrology, defect and failure analysis or for the design of micro-electro-mechanical systems (MEMS).



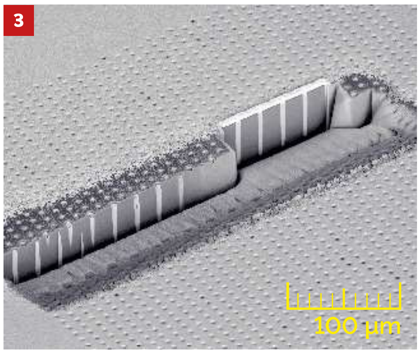




**Fig. 1,2:** Cross-section of MEMS sample **(1)**, revealing the structure located more than 200 μm below the surface. Detailed image of the structure **(2)** shows excellent quality of the polished surface without any visible damage or curtaining effect introduced by the ion beam. The total time necessary for obtaining this cross-section was 1 hour 20 minutes. Sample provided by courtesy of STMicroelectronics, Cornaredo, Italy.

**Fig. 3:** TSV cross-section milled in 45 minutes, using a Xe beam at 30 kV, 2 μA. With dimensions of 400 μm long, 100 μm wide and 50 μm deep. A deep fine polishing of the 4 vias took 30 minutes.

### TSV Analysis

In a three-dimensional integrated circuit (3D-IC), multiple chips are vertically stacked in a single package to deliver higher performance and functionality in a smaller area. The chips are electrically connected using deep holes called through-silicon vias (TSVs).

TSV is a vertical electrical connection (via) passing completely through a silicon wafer or die. TSVs are a high performance technique to create 3D packages and 3D integrated circuits, compared to alternatives such as package-on-package, because the density of the vias is substantially higher, and because the length of the connections is shorter.

Structural analysis of through-silicon-vias with a dual beam focused ion beam/scanning electron microscope can be achieved via/using different milling strategies. Among others, particular attention is given to methods to reduce the analysis time. From this point of view, the use of FERA3 brings significant advantages.

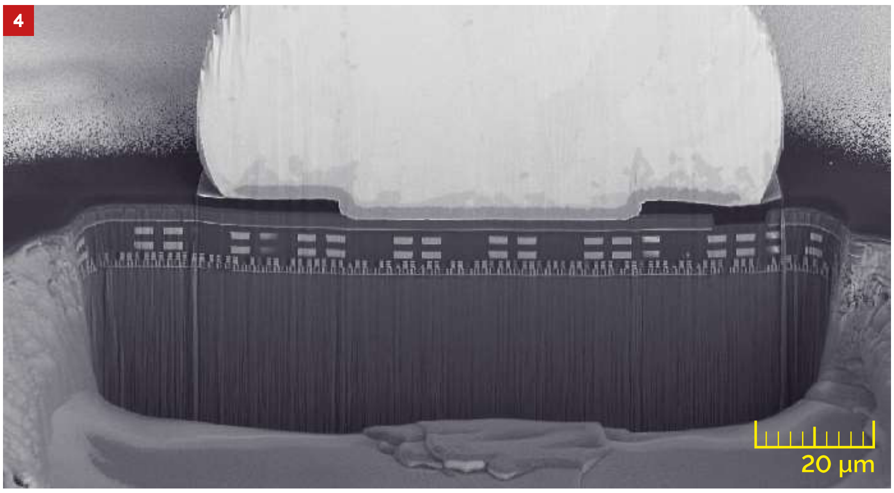



**Fig. 4:** Cross-section in a flip chip. Rough milling and fine polishing of an area of 120 x 120 μm² was performed in 15 minutes with a Xe ion beam. Sample provide by courtesy of IBM, Bromont, Canada.

### Flip Chip Failure Analysis

Flip chip, also known as Controlled Collapse Chip Connection, is a method for interconnecting semiconductor devices, such as IC chips and micro-electro-mechanical systems (MEMS), to external circuitry with solder bumps that have been deposited onto the chip pads. This differs from wire bonding, in which the chip is mounted upright and wires are used to interconnect the chip pads to external circuitry.

Failure analysis of semiconductor devices is necessary to clarify the cause of failure and provides a rapid feedback of this information to the design and manufacturing process stages. With the demand for higher reliability in the market and the development of devices with higher integration density and larger chip sizes, advanced technologies are required for failure analysis. The FIB/SEM technique is one of the failure analysis methods in this field. The ultra-fast sputtering rates offered by a Xe plasma ion source open up new possibilities in FA as large-scale micro-analyses are now feasible.

# Enhance your SEM analysis of TEM lamellae with the HADF R-STEM detector

The High Angle Dark Field Retractable STEM Detector (HADF R-STEM) combines the principles of TEM with that of SEM allowing every TESCAN SEM and FIB-SEM system to be turned into a (low energy) STEM platform. With the HADF R-STEM detector you can enhance the FIB-SEM analysis (SE, BSE, EDX, EBSD, SI, and TOF-SIMS) of your thin-sliced samples by adding the unique information carried by transmitted electrons.

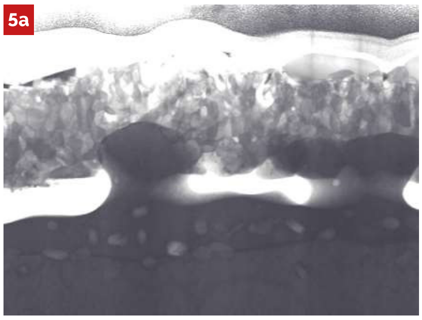
This detector represents a concrete and efficient solution for those research facilities that have no TEM infrastructure but nonetheless have the same needs for a sample analysis. The HADF R-STEM detector is undoubtedly a valuable tool for those laboratories involved in cutting-edge research in life sciences, materials sciences and the semiconductor industry.

- **Observation of multiple samples** without breaking the chamber vacuum
- **Simultaneous acquisition of bright field (BF), dark field (DF) and high angle dark field (HADF) signals** which provide valuable information such as Bragg-diffraction orientation contrast and material contrast
- **Lifting up and down of the sample relative to the detector** in order to reach the best imaging conditions
- **Tilting of the sample independently of the detector**
- **Improved geometry of the sample holders for EDX analysis**

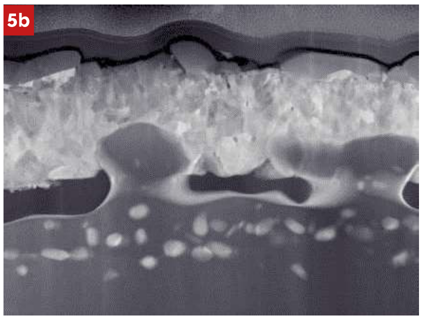
- Two different sample holders:
    **1) Multiple sample holder:** for up to 8 TEM standard grids
    **2) TEM lamella holder:** a system of exchangeable single grid holders optimised for easy handling and lift-out grids manipulations

This new detector has been designed with respect to a broad range of SEM applications in diverse fields of science and industry enabling for instance, the investigation of the ultrastructure of biological samples, rigorous failure analysis of logical devices in the semiconductor industry, or the characterisation and research in material engineering.

5a



5b



5c

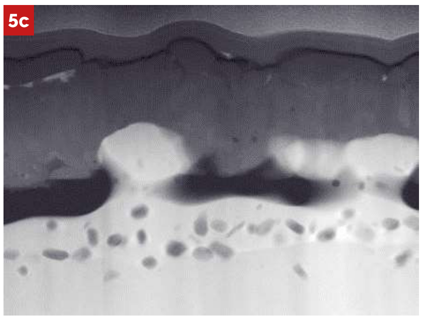


**Fig. 5:** A thin lamella was prepare to study the corrosion growth through Cr plating on steel. The images correspond with different HADF R-STEM signals: **(a)** Bright Field, **(b)** Dark Field, **(c)** High Angle Dark Field.

6

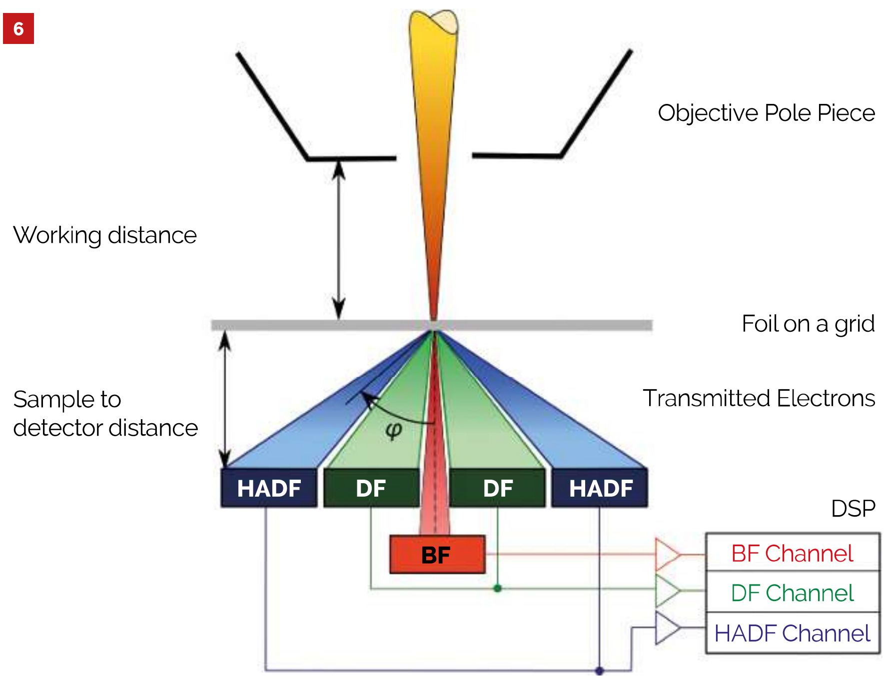



**Fig. 6:** Schematic drawing of the new HADF R-STEM detector with HADF imaging mode; φ is the scattering angle.

**DrawBeam and AutoSlicer are powerful and user-friendly software for the preparation of high quality lamellae with high throughput**

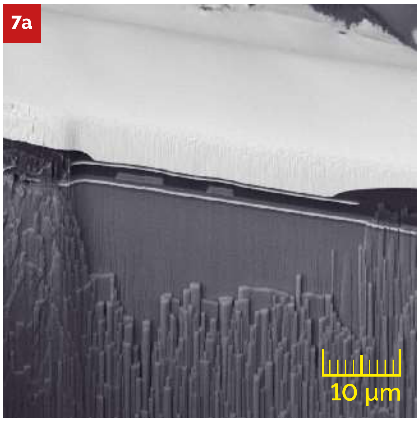
# Prepare top-quality surfaces for failure analysis with the Rocking Stage

FIB cross-sectioning and the preparation of thin lamellae for the TEM analysis are two of the most common and extended applications of FIB-SEM systems. Cross-sectioning is a valuable SEM technique for unveiling defects or structures not visible from the surface as they are often buried under surface layers of the sample while thin lamellae allow for the analysis of samples using the information given by transmitted electrons.

The microelectronic and semiconductor industries rely on high quality surfaces on cross-sections and lamellae for a successful failure analysis. The surface of the cross-section or that of lamellae need to be really smooth and artifact-free, otherwise the task of finding or identifying possible failures is very difficult as they can easily hide among surface defects.

Curtaining effects are unwanted surface artifacts that appear on cross-sections or lamellae prepared with FIB, a defect that is more common when milling at high ion currents. The origin of curtaining can be the topography of the sample or its composition, or due to characteristic grain and crystal orientation of the sample. Additionally, the beam tail effects are another source that lead to curtaining.

In reality, a defect-free surface is an elaborate and difficult task to achieve with the use of FIB-SEM alone and therefore different techniques to avoid curtaining need to be implemented. One of these techniques is the use of Rocking Stage which has proven to be not only effective against curtaining but also for the optimisation of cross-sectioning tasks



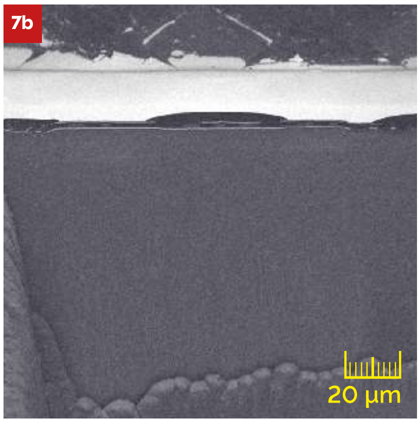
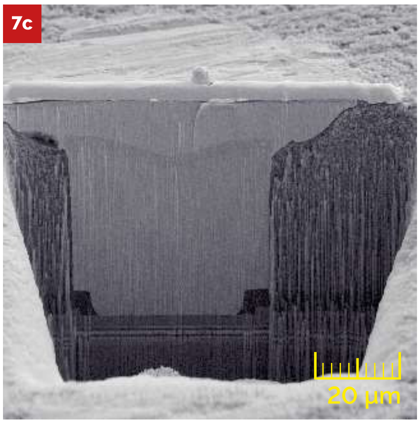
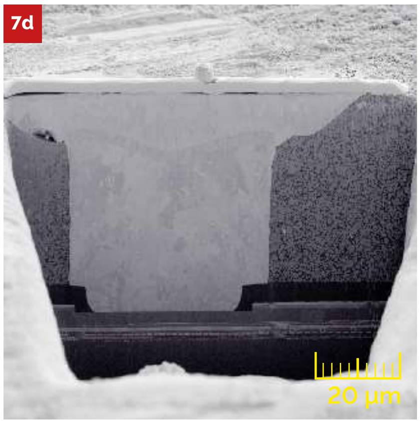




**Fig. 7: (a and c)** Curtaining can appear when milling at high ion beam currents. **(b and d)** Tilt-polishing with the Rocking Stage is an effective technique to get rid of the curtaining which results in smooth surfaces suited to perform failure analysis.




## Milling in different directions: Rocking Stage

It has been proven that tilting the sample (up to a maximum of ±10°) during milling is an effective strategy for reducing curtaining effects when preparing cross-sections. Milling in different directions is possible with a conventional 5-axis Eucentric stage for which the sample has to be rotated by 90° followed by the respective tilting angle. The disadvantage of this procedure is that the cross-section cannot be imaged with the SEM column as the electron beam axis is parallel to the cross-section.

TESCAN Rocking Stage enables FIB milling in different directions by tilting the sample about an axis perpendicular to the cross-sectioned surface. This procedure has the great advantage in which the entire milling process can be monitored in real time with SEM imaging.

## The benefits of the Rocking Stage include:

- Real time SEM imaging during the entire milling process for absolute control and monitoring of quality
- Reliable end-point detection
- Full integration with DrawBeam
- Multi-direction surface milling to prevent curtaining
- Piezo-drives for precise stage movements

# TOF-SIMS for superior compositional analysis of ultra-thin layers and nanoscale sample features

Time-of-flight secondary ion mass spectrometry (TOF-SIMS) is a high sensitive analysis technique that provides chemical characterisation of the surfaces of materials. This is achieved by using a focused ion beam at typical energies of 10-30 keV, which impinges the surface of the sample and, as a result, secondary ions (SI), ion clusters, and molecules are emitted from the uppermost atomic layers of the specimen.

## ■ With TOF-SIMS, smaller means better

The interaction volume generated by ions is of the order of few nanometres which is much smaller than ones generated by an electron beam - typically of the order of few microns. As a result, TOF-SIMS can achieve better lateral and depth resolution compared to other common chemical analytical SEM techniques such as EDX. TOF-SIMS provides a characterisation of the surface of materials by means of mass spectra, depth profiles and elemental/molecular maps. Mass spectra allow the identification and quantification of elements, and molecular species present in the surface layers of the sample, as well as the distinction of isotopes and species with similar nominal mass.

8

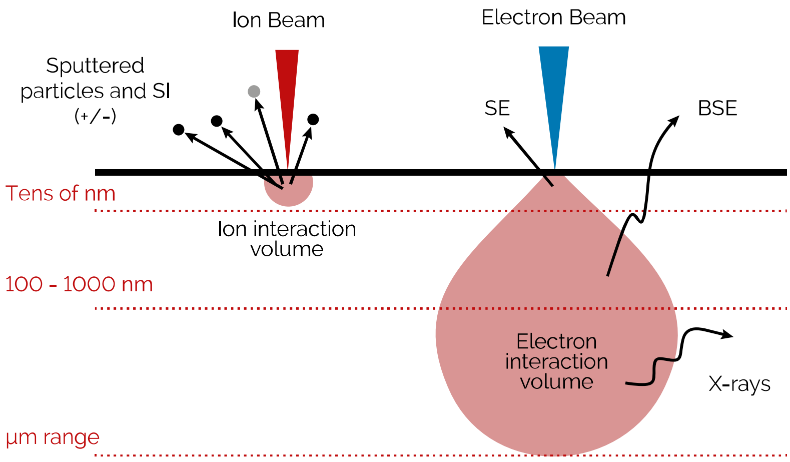



**Fig. 8:** Interaction volume generated by an ion/electron beam.

Depth profiling – an advantageous capability of this technique - is used to detect trace elements of dopants and other impurities at different depth ranges. All the elements in the periodic table can be detected including light elements such as hydrogen, beryllium, boron and lithium at very low concentrations of few ppm. In addition, 3D chemical characterisation with high mass resolution and high spatial resolution imaging is also possible.

## ■ Time-of-Flight

TOF-SIMS analysers are based on the principle that for a given ion energy, the velocity of each ion is mass-dependent. The secondary ions are extracted from the surface of the specimen and directed into a drift tube in which the ions are sorted according to their m/q ratio, and the time-of-flight is measured, i.e. the length of time necessary for the SI to move from the ion source to the detector. Ions with the same mass will have the same kinetic energy and thus lighter ions will have shorter time-of-flight than heavier ones. An accurate measurement of the time-of-flight determines the mass of each of the secondary ions or molecules revealing the elemental chemical composition of the sample surface.

9

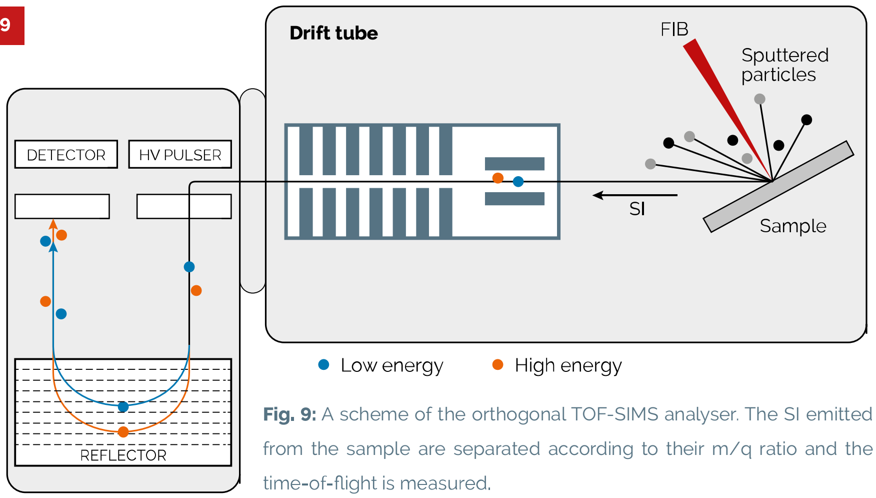
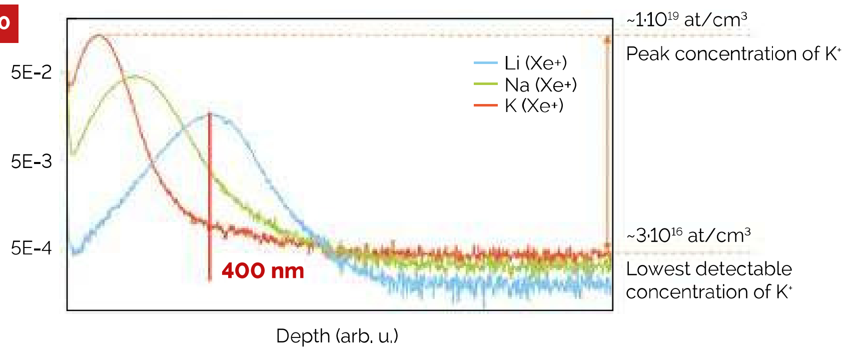



**Fig. 9:** A scheme of the orthogonal TOF-SIMS analyser. The SI emitted from the sample are separated according to their m/q ratio and the time-of-flight is measured.

## ■ A non-destructive analytical technique

TOF-SIMS uses a low primary ion beam current to impinge the surface of the sample in order to generate secondary species. This technique minimises damage and preserve the chemical structure of the sample. TOF-SIMS is suitable technique for the molecular characterisation of sensitive organic specimens or tissue that cannot be analysed with spectral techniques such as EDX.

10




**An orthogonal TOF-SIMS analyser can be fully integrated into any TESCAN FIB-SEM system. This combination represents a novel and cost-effective solution for enhanced sample analyses.**

**Fig. 10:** The detection limits for Li, Na and K are of less than 1 × $10^{17}$ atoms/$cm^3$ which is 2 ppm atomic obtained without any additional method for yield enhancement.

11a

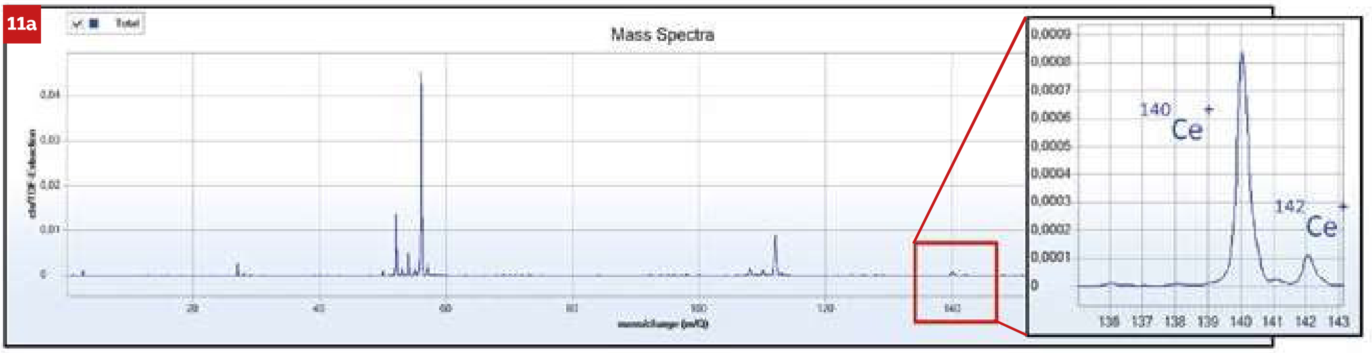
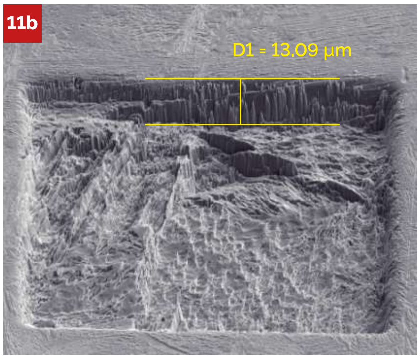
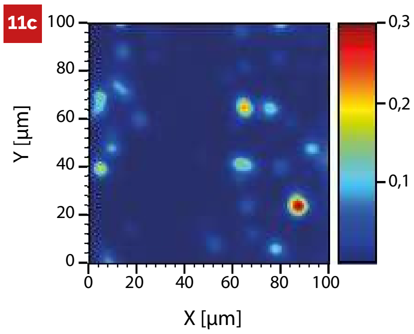



**Fig. 11:** A steel sample with traces of different isotopes of cerium with different relative abundances. The sample was analysed with FERA3 equipped with a TOF-SIMS analyser. **(a)** TOF-SIMS spectrum showing the presence of two Ce isotopes in the sample (showed in the zoomed square). **(b)** The crater in the sample after analysis, and distributions maps from top **(c)**, and side view **(d)** of the sample showing the presence of Ce in the sample. Sample courtesy of Prof. Jaromír Drápala from VŠB (Technical University of Ostrava, Faculty of Metallurgy and Materials Engineering).

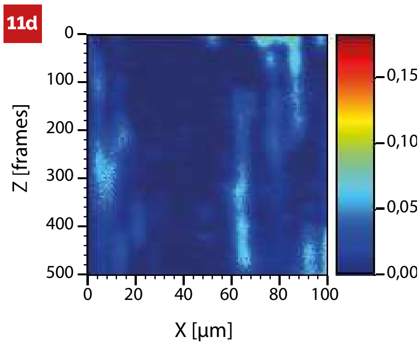
11b




11c




11d




## Applications

TOF-SIMS is the ideal characterisation technique for those fields of science and technology where the composition of surfaces, thin films or layers plays an essential role in performance. This is the case of nanomaterials, magnetic media, 3D IC packaging in semiconductors, corrosion, display technology, biomaterials, polymer surface modification, etc. TOF-SIMS also provides a powerful analytical technique for the battery manufacturing industry and research groups or industries involved in nuclear research.

## The main benefits of the integration of TOF-SIMS into FIB-SEM are:

- Identification and quantification of ions, molecular species and isotopes
- High mass resolution to distinguish species of similar nominal mass
- In-situ chemical composition analysis of the sample
- Surface analysis of insulating and conductive specimens
- No additional ionisation source necessary
- Non-destructive analysis
- Trace elemental analysis
- 3D chemical mapping and depth profiling
- Post-data acquisition analysis

## The implementation of TOF-SIMS analysis with a Xe ion source brings additional advantages over conventional Ga ion sources including:

- Improved secondary ion yields especially at high mass molecules and fragments
- Excellent detection limits of less than 2 ppm with Xe ion sources which in the case of light elements such as Li, Na and K are of less than 1 × $10^{17}$ atoms/$cm^3$
- No interference in the spectrum coming from primary gallium (Ga+ features interfere with peaks of other elements such as Ce, Ge and Ga itself)
- In addition, the lateral resolution achieved with a Xe ion source is less than 100 nm.

TESCAN
PERFORMANCE IN NANOSPACE

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