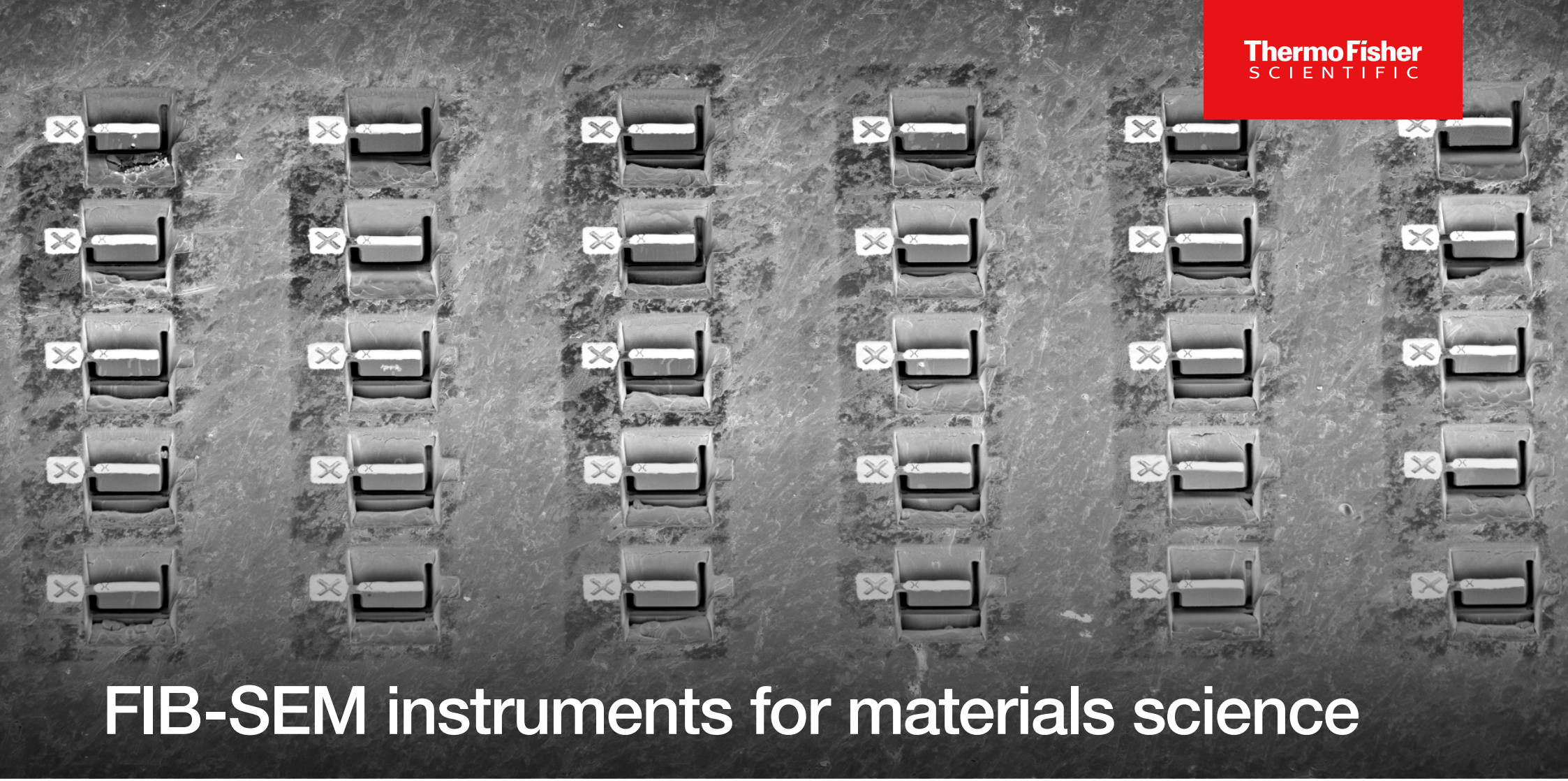


FIB-SEM instruments for materials science

Focused ion beam combined with scanning electron microscopy

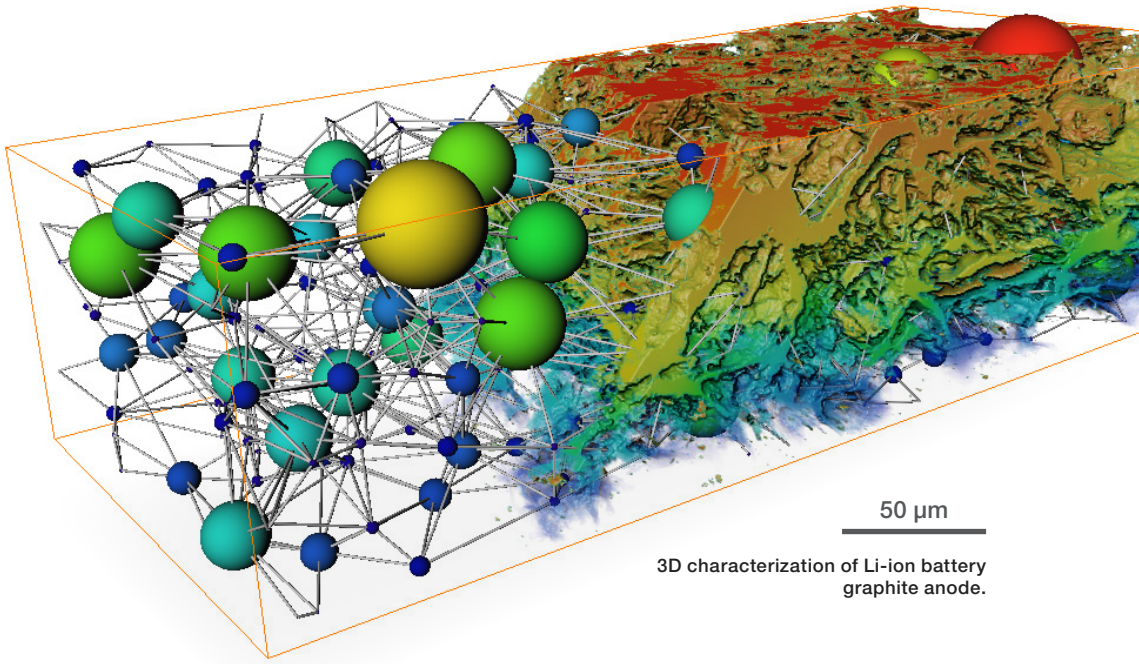
thermo scientific

The world faces increased demand for more efficient transportation, enhanced solutions for clean energy, and original synthetically engineered materials. These demands drive research and development to produce materials that are reliable and better performing. Consequently, materials scientists face complex analytical tasks to support this global demand.

Researchers engaged in failure analysis, product quality verification, battery research, and new product development can use FIB-SEMs to gain a deeper understanding of the relationship between structure and composition, unique properties, and, ultimately, material performance.

Thermo Scientific™ FIB-SEMs provide nanometer-scale data about a material by various combinations of the precise sample modification of the FIB, the fast milling of the femtosecond laser, and the high-resolution imaging of the SEM. DualBeam instruments provide high-resolution imaging with high materials contrast; fast, easy, precise, high-quality sample preparation for (S)TEM imaging and atom probe tomography (APT), and high-quality subsurface and 3D characterization. Plasma FIBs (PFIBs) provide large-volume 3D characterization, gallium-free sample preparation, and precise micromachining. TriBeam instruments combine a SEM with either a FIB or a PFIB and add a femtosecond laser to provide fast access to deep subsurface regions for analysis and sample extraction and to enable high-throughput, high-quality millimeter-scale cross-sectioning and statistically relevant subsurface and 3D characterization with nanometer resolution.

FIB-SEM applications



3D characterization of Li-ion battery graphite anode.

Novel material development often requires structural analysis at the nanometer scale. For scientists and engineers working in this field, obtaining the right data can be challenging when using conventional analytical instruments.

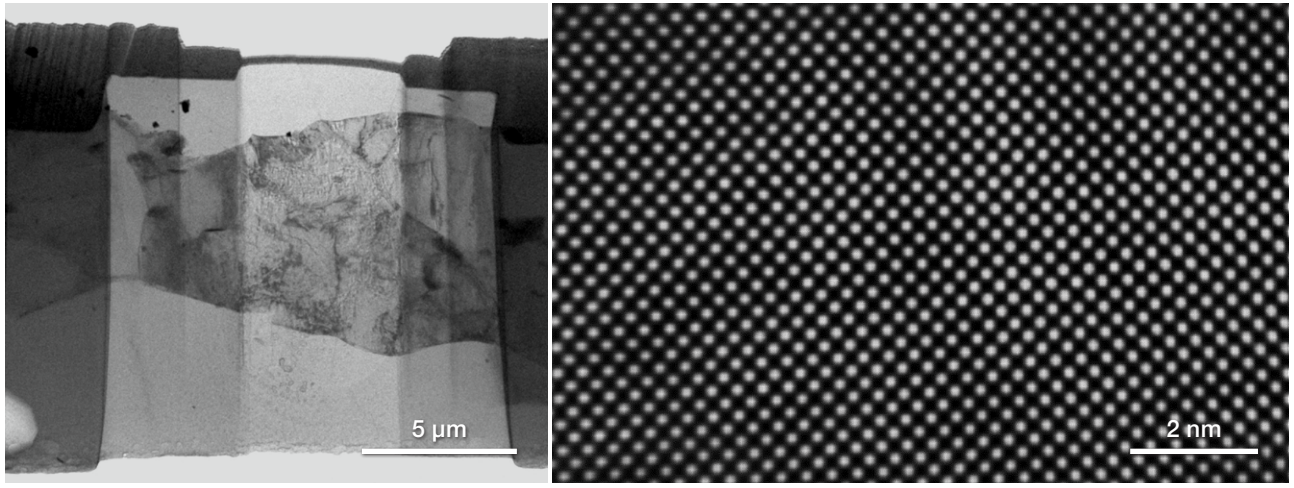
While they provide basic insights about the sample, these conventional instruments are often slow and lack the necessary resolution, data modalities, and statistical relevance of the data that are critical to accurately identify the materials' structure. Thermo Scientific FIB-SEMs offer state-of-art electron and ion beam technology combined with innovative automation software to deliver high-quality milling and sub-nanometer imaging performance for TEM sample preparation and large-volume sub-surface and 3D characterization.

Batteries

The performance of advanced new batteries depends highly on their structure. Battery optimization is a very demanding and time consuming task, which is even further complicated by the air- and beam-sensitive nature of materials containing lithium. Thermo Scientific FIB-SEMs provide high-throughput milling capabilities and sub-nanometer multi-modal imaging in one instrument.

This eliminates the need to transfer the sample between instruments, which, in turn, improves the characterization throughput and reduces the risk of sample oxidation.

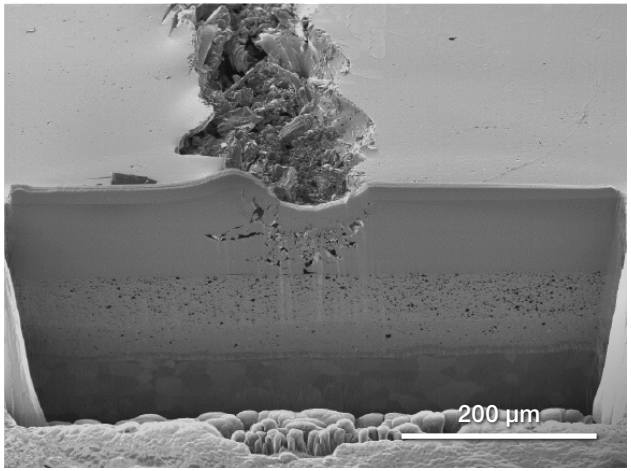
As the result, our FIB-SEM instruments provide high-quality data, even for challenging samples such as lithium (see the images below).



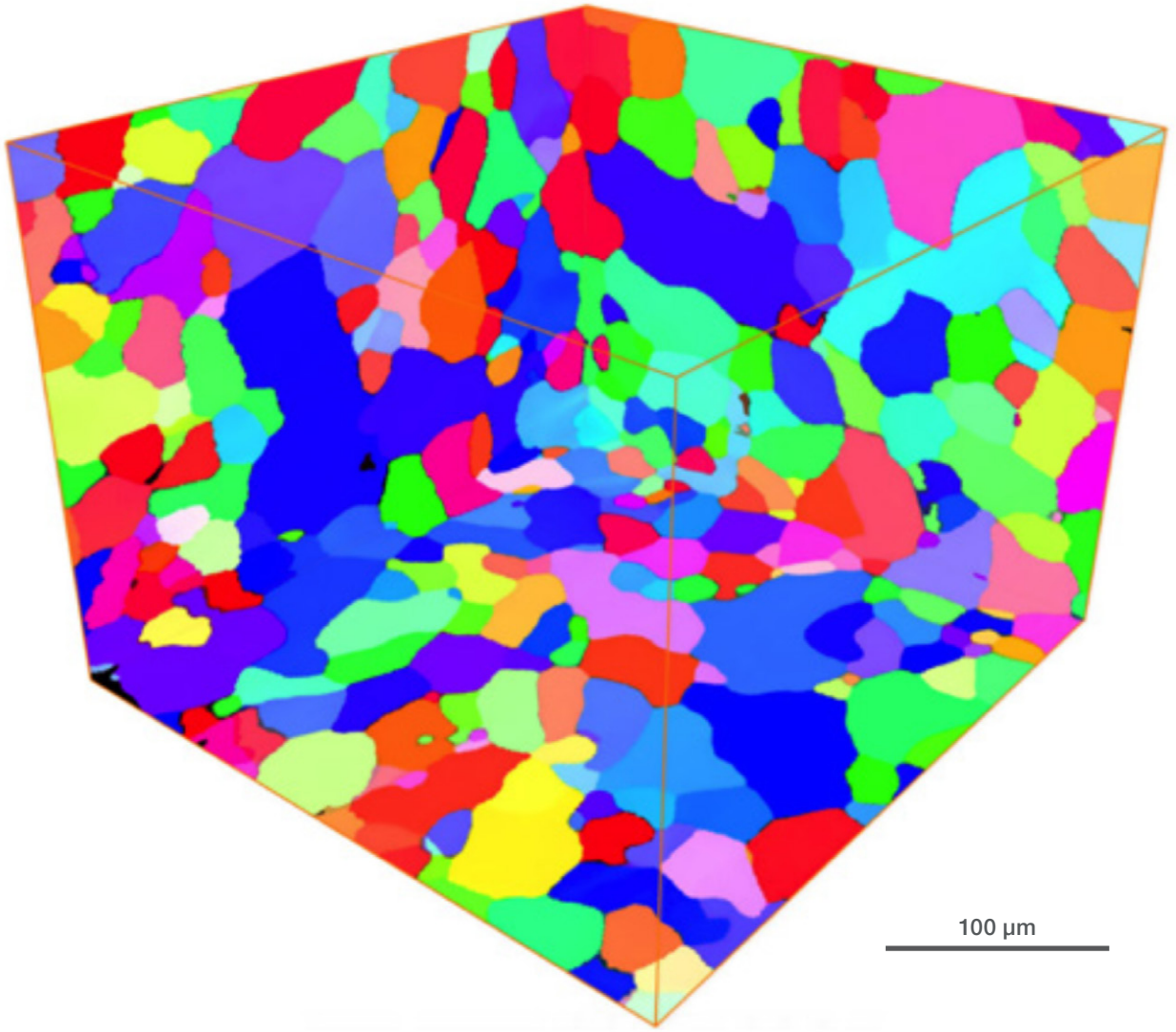
TEM lamella image of lithium (right), high-resolution TEM image of lithium (left).

Metals and alloys

Modern cutting-edge metals are increasingly engineered at the nanoscale to enhance their durability, reliability, and cost. Common characterization techniques provide either sufficient resolution or large 2D area but not both. It becomes a significant bottleneck for researchers investigating failure mechanisms in nanostructured materials where grain size is at the sub-micron scale, while the failure (crack) is in the order of hundreds of microns. The advanced automation software and high-throughput milling capabilities of Thermo Scientific FIB-SEMs enable millimeter-scale 2D and 3D characterization and deep subsurface sample extraction and failure analysis with nanometer resolution
(see the images below).



Site-specific cross-sections for scratch testing and adhesion in paint coatings on steel.



3D EBSD reconstruction of zircalloy sample (250×250×220 µm³) produced with Helios PFIB DualBeam, Auto Slice and View Software, and Avizo Software for Materials Science.

S/TEM sample preparation

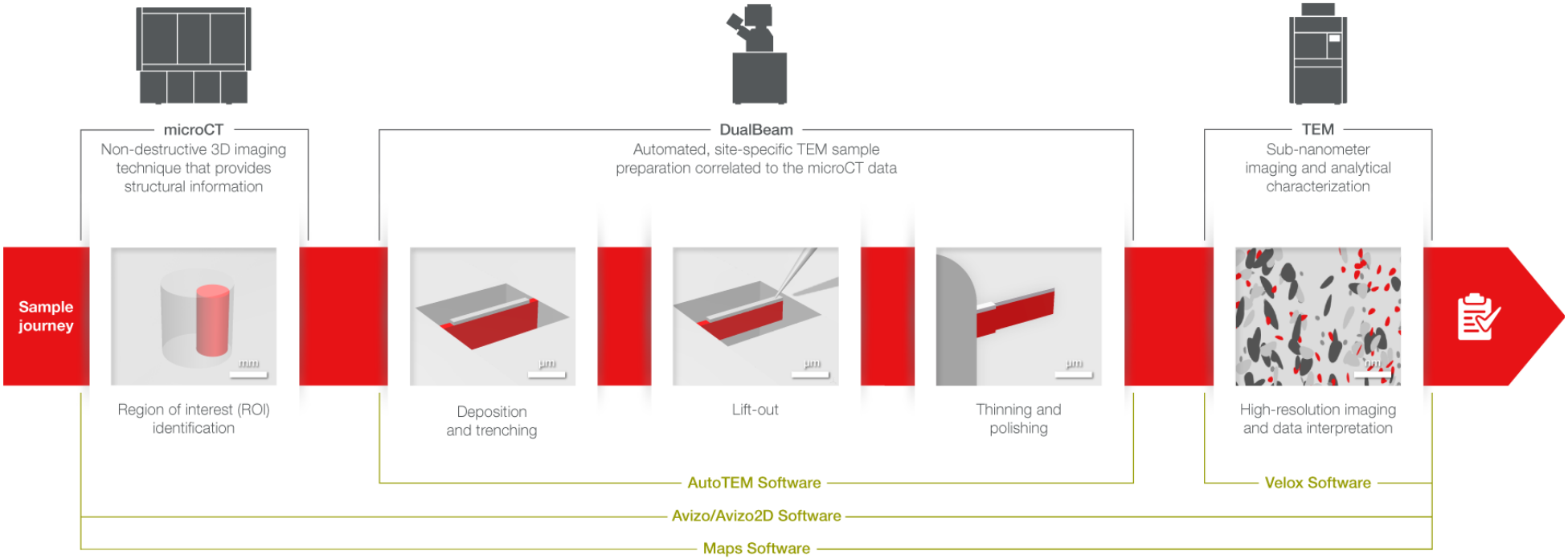
Sample preparation for scanning/transmission electron microscopy (S/TEM) analysis is considered to be one of the most critical but challenging and time-consuming tasks in materials characterization labs.

Conventional methods used to prepare ultra-thin samples required for S/TEM are slow, typically requiring many hours or even days of effort by highly trained personnel.

This is further complicated by the variety of different materials and the need for site-specific information.

Our FIB-SEMs are routinely used to create some of the highest quality samples for atomic-resolution S/TEM imaging, a technique that allows you to directly observe the fundamental building blocks of your materials. When combined with the unique Thermo Scientific AutoTEM™ Software for automated *in situ* lift-out, these instruments provide very high sample quality and throughput for rapid, high-quality characterization.

For more than 30 years, Thermo Fisher Scientific has been continuously developing and optimizing sample preparation instruments and introducing software that enable *in situ* TEM sample preparation that allows researchers to accelerate their research and fast-track innovation. Our TEM Sample Prep Workflow automates the most time-consuming and error-prone steps. Our novel workflow combines FIB-SEMs with software to enable fully automated, unattended, *in situ* lamella preparation and lift-out. Using this workflow, even novice users can reliably and repeatedly produce quality samples in 45 minutes instead of hours or days.



Automated S/TEM sample preparation in a multiscale workflow.

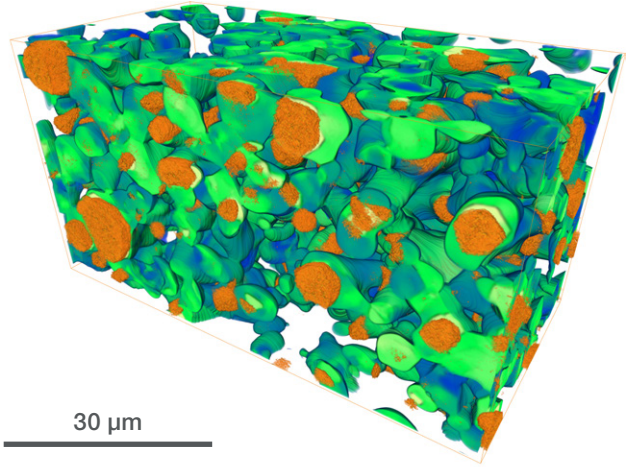
Structural analysis

With an ongoing drive to improve the quality of fabricated materials and devices, materials researchers increasingly need structural and compositional information at the nano-scale. FIB-SEMs deliver multi-scale, multidimensional insight down to the sub-nanometer range, giving you a thorough look at both the surface and interior of your sample.

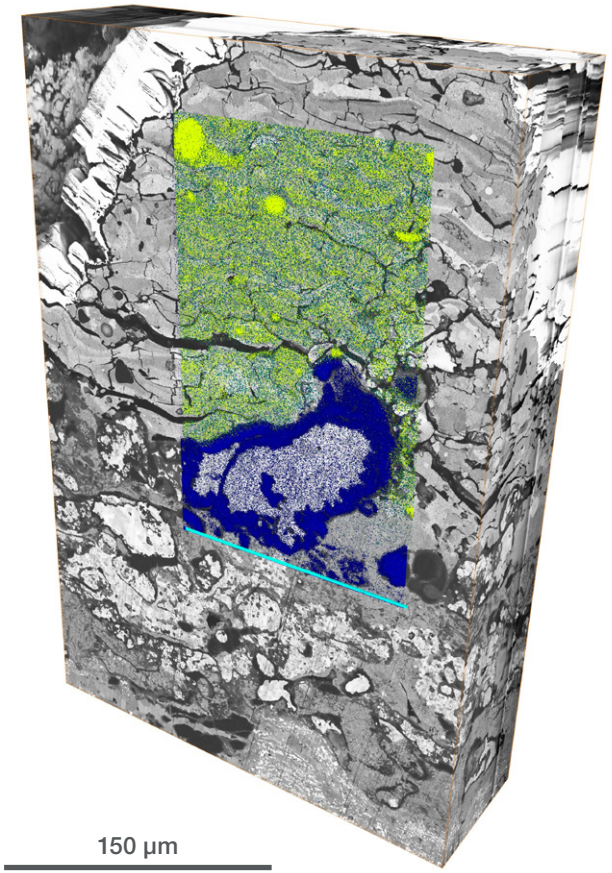
When combined with Thermo Scientific Auto Slice & View™ Software, FIB-SEMs provide 3D insight into sample structure by selectively removing (milling) the material for subsurface characterization. Digital reconstruction generates multi-modal 3D datasets that can consist of a variety of signals, including backscattered electron (BSE) imaging for maximum materials contrast, energy dispersive spectroscopy (EDS) for compositional information, and electron backscatter diffraction (EBSD) for microstructural and crystallographic information.

The SEM capability of FIB-SEMs offers nanoscale details across a wide range of working conditions, from structural information obtained at 30 keV in STEM mode to charge-free, detailed surface information at lower energies.

With unique in-lens detectors, FIB-SEM systems are designed for simultaneous acquisition of angular/energy-selective secondary-electron and BSE data. Fast, accurate, and reproducible results are provided by our unique SEM column design, which features fully automated lens alignments.



3D reconstruction of W-Mo-Cu sample using a combination of backscattered electron (green-blue) and energy dispersive X-ray (orange) data. Generated using a Scios DualBeam, Auto Slice and View Software, and visualized with Avizo Software.

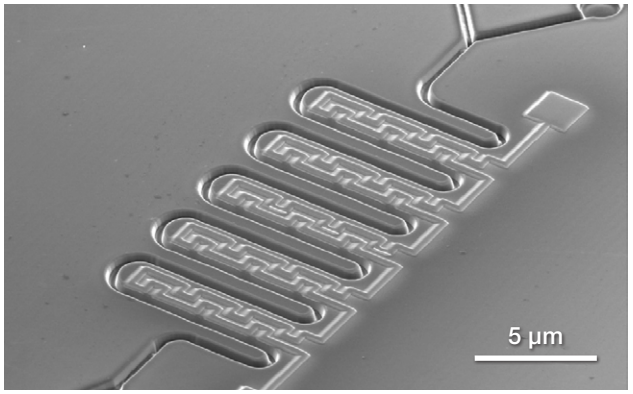


3D reconstruction of thermal barrier coating from an afterburner nozzle of a ramjet aero engine showing the microstructure state at end-of-life of the engine exhaust system. Overlaid EDS map shows elemental distribution on the top coat and bond coat interface: blue is aluminum, yellow is magnesium, and turquoise is yttria. The data have been produced with a Thermo Scientific Helios™ 5 PFIB, Auto Slice & View 5 Software and Avizo Software for Materials Science.

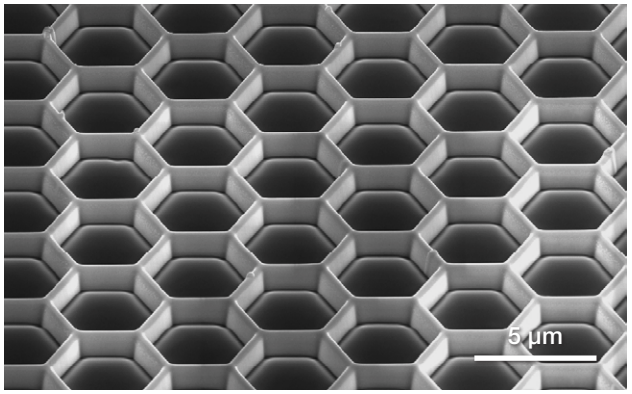
Nanoprototyping

Thanks to the FIB's ability to deposit material as well as remove it, FIB-SEMs can be equipped to produce functioning prototypes of miniature MEMS devices.

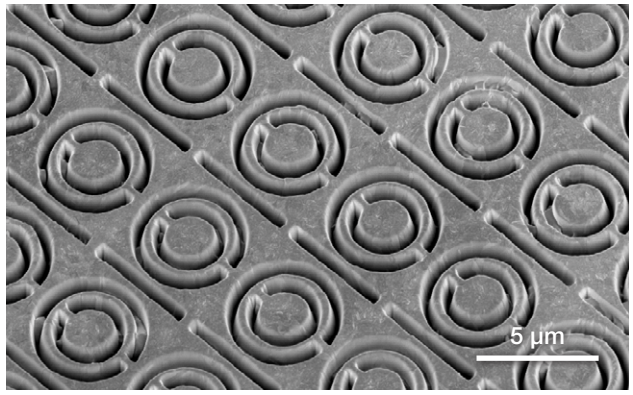
The nanopatterning capabilities of FIB-SEM systems can substantially reduce research and development time. Rapid prototyping with the FIB enables functionality testing before the final device layout is established for batch fabrication. Beam-induced deposition of different materials can be combined with FIB milling without the need for additional aligning lithography steps; patterns can be directly added to deposited structures or existing patterns can be modified. The final patterned substrates are immediately available for further processing or characterization.



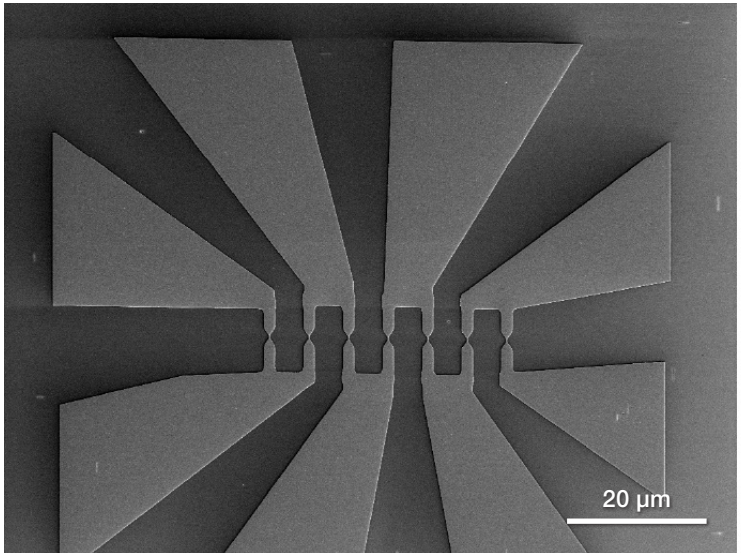
A nano-fluidic system made with a multi-layered pattern in NanoBuilder Software. Each layer may consist of a deposition or milling sequence to selectively add or remove material.

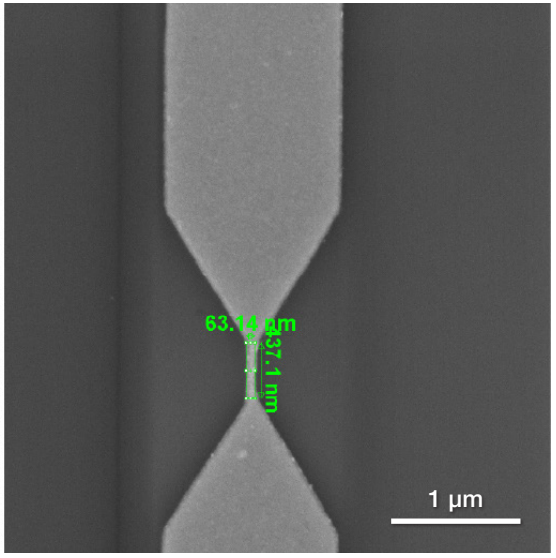


Secondary electron image of a honeycomb structure milled into a silicon substrate using a focused ion beam.



A split-ring oscillator pattern milled directly with a focused ion beam. The FIB used a vector scanning method in order to optimize milling direction for each part of the pattern.





Left: Electromigration structure created with NanoBuilder Software. Right: Close up of a single channel. Critical dimensions as low as 10 nm are possible.

Instruments

Since we introduced the first DualBeam in 1993, Thermo Fisher Scientific has continually improved the performance of these instruments while expanding the list of applications that can benefit from their unique capabilities.

Learn more about our FIB-SEMs

DualBeams

Scios 2 DualBeam

- Full support of magnetic and non-conductive samples
- High throughput subsurface and 3D characterization
- Advanced ease of use and automation capabilities

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Helios 5 DualBeam

- Fully automated, high-quality, ultra-thin TEM sample preparation
- High throughput, high resolution subsurface and 3D characterization
- Rapid nanoprototyping capabilities

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Plasma FIBs

Helios 5 Hydra DualBeam

- 4 fast switchable ion species (Xe, Ar, O, N) for optimized PFIB processing of a wide range of materials
- Ga-free TEM sample preparation
- Extreme high-resolution SEM imaging

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Helios 5 PFIB DualBeam

- Ga-free STEM and TEM sample preparation
- Multi-modal subsurface and 3D information
- Next-generation 2.5 µA xenon plasma FIB column

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TriBeams

Helios 5 Laser

- Fast, millimeter-scale cross sections
- Statistically relevant deep subsurface and 3D data analysis
- Shares all capabilities of the Helios 5 platform
- Available in configuration with Ga FIB, Xe PFIB or Multi-ion species PFIB

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Software

FIB-SEM instruments with AutoTEM Software can be used to facilitate fully automated, *in situ* TEM sample preparation, enabling and technologies and advancing research in batteries, polymers, metals, and more.

AutoTEM 5 software user interface: workflow steps at the bottom and settings on the right side. Intuitive UI with user guidance and instructive graphics helps to create highest quality samples for users with any experience level.

Using FIB-SEM instruments with AutoTEM Software to prepare samples for TEM analysis:

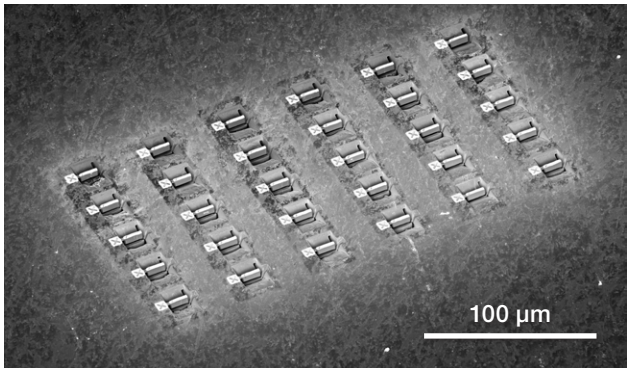
- Makes the process easier to learn than traditional methods
- Reduces the possibility of manual errors
- Increases consistent repeatability of preparation
- Decreases sample prep to as low as 45 minutes instead of days

AutoTEM 5 Software automates the entire process of lamella preparation, from chunking to *in situ* lift-out, thinning, and final low-kV polishing.

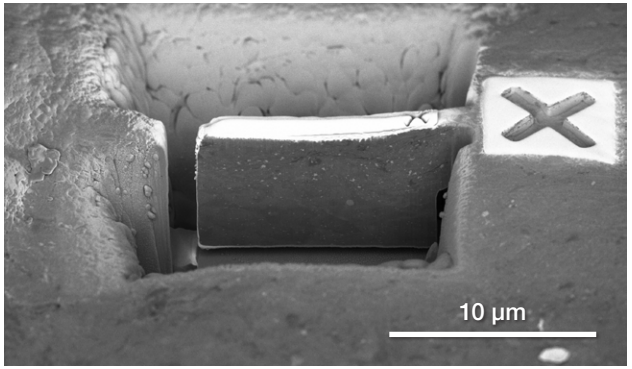
The incorporation of AutoTEM 5 Software on FIB-SEM instruments accelerates sample preparation for a broad range of materials. The highly configurable workflow enables preparation of the most challenging sample types.

As Thermo Fisher Scientific celebrates 30+ years of developing sample preparation instruments and software, the introduction of AutoTEM 5 Software and options to perform *in situ* TEM sample preparation on FIB-SEM instruments highlights how this solution can fast-track your research and innovation.

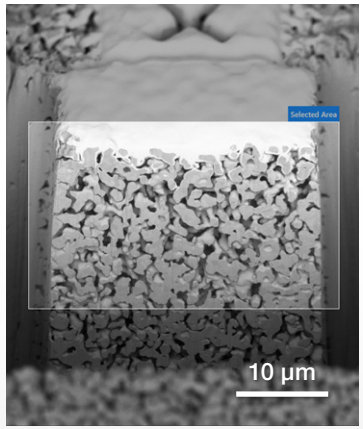
Learn more about our AutoTEM Software



Aluminum sample, where a 5x6 array of (S)TEM lamellas has been prepared with AutoTEM software fully unattended, undercut and ready for lift-out in 6 hours. The software allows automatically defining the array and shifting individual locations, to more precisely position the lamella.



Example of a sample after chunking and undercut, ready for *in situ* lift-out. The large fiducial on the side is used for chunking automation, while the smaller one on the lamella will be used later for final thinning automation.



Auto Slice & View Software

- Automated serial sectioning for DualBeam systems
- Multi-modal data acquisition (SEM, EDS, EBSD)
- On-the-fly editing capabilities
- Edge-based cut placement

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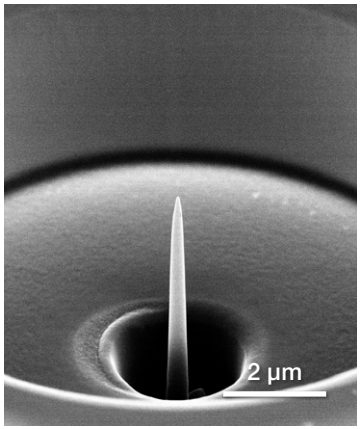

AutoScript Software

- Scripting of repetitive or tedious tasks
- Powerful automation for specific research needs
- Unattended, high-throughput imaging and patterning

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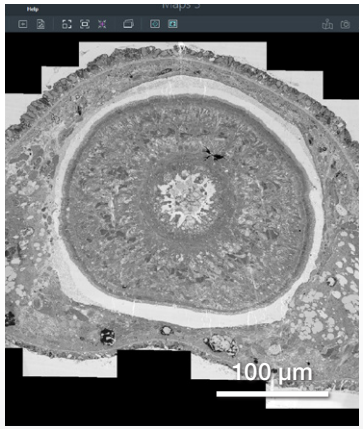

Maps Software

- Acquire high-resolution images over large areas
- Easily find regions of interest
- Automate image acquisition process

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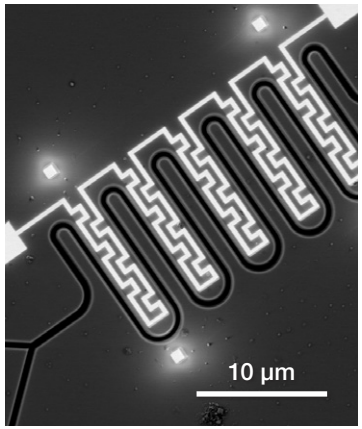

NanoBuilder Software

- CAD-based prototyping
- Fully automated job execution, stage navigation, milling, and deposition
- Automated alignment and drift control

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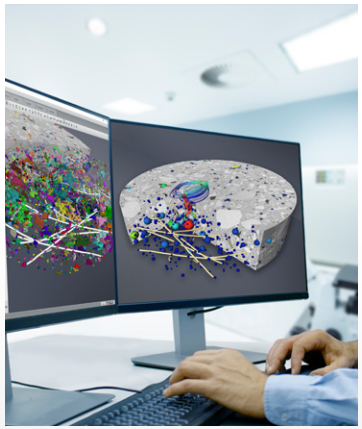

Avizo Software

- Support for multi-data/multi-view, multi-channel, time series, very large data
- Advanced multi-mode 2D/3D automatic registration
- Artifact reduction algorithms

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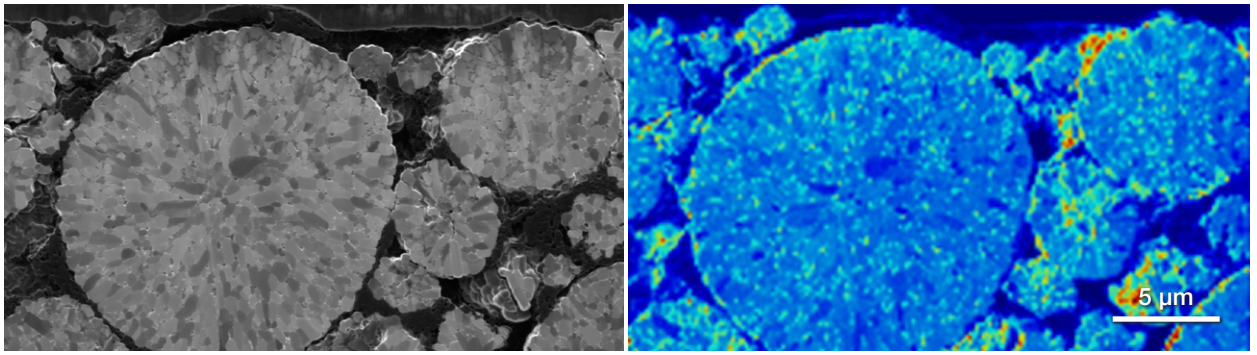
Accessories

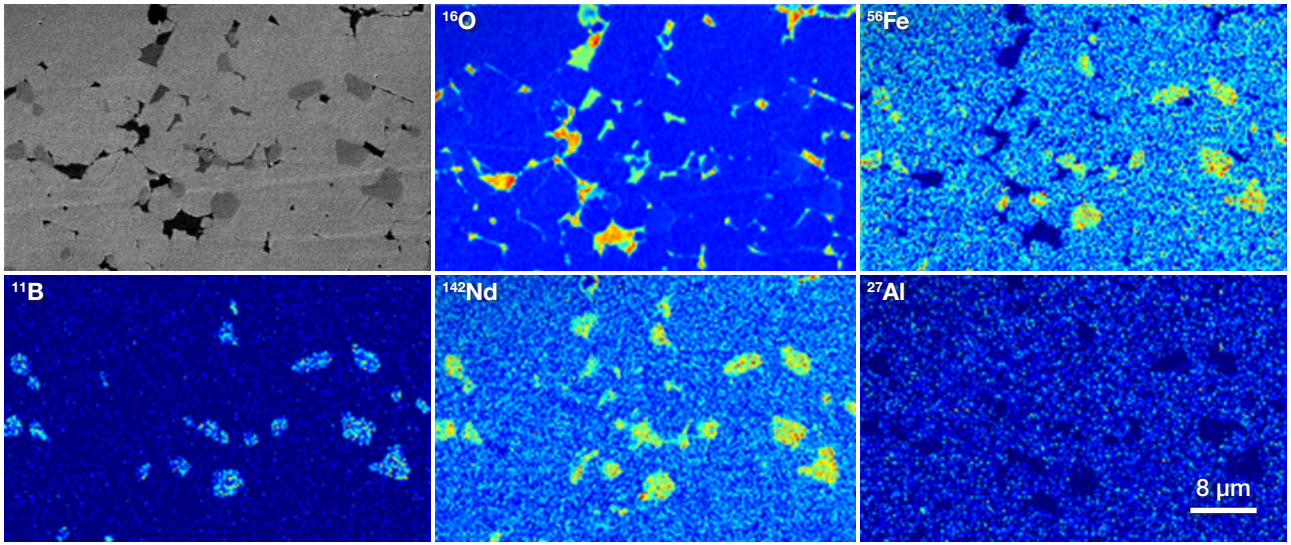
ToF-SIMS Detector

Characterization and high-resolution analysis of very light or sparse elements can be challenging, if not impossible, for traditional analytical techniques like EDS. A time-of-flight secondary ion mass spectrometer (ToF-SIMS) is capable of providing this sensitive high-resolution surface analysis, revealing detailed elemental and isotopic information as well as depth profiling analysis. With the addition of a ToF-SIMS detector, your FIB-SEM will be capable of the following:

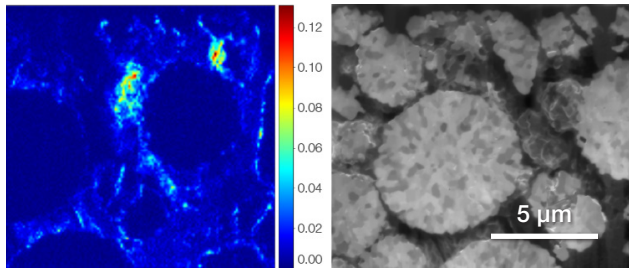
- High-resolution analytical characterization
- Detection and mapping of all elements in the periodic table
- Elemental analysis at parts per million (ppm) levels
- Separation and analysis of all isotopes and characterization of their spatial distribution



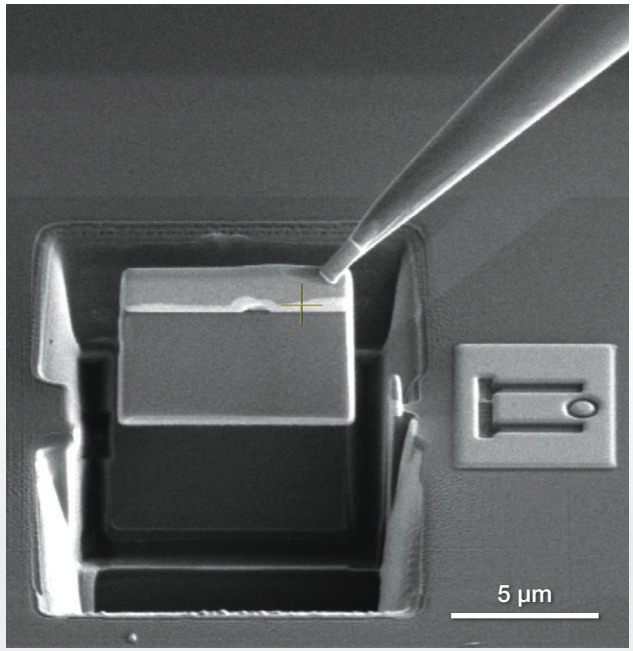
SEM image of a lithium battery cathode cross-section (top) and corresponding SIMS map showing the lithium distribution (bottom).



SIMS enables the simultaneous detection of light and low-concentration elements along with heavy elements.



Cross-section of a lithium battery cathode with polyvinylidene fluoride (PVDF) binder material. While it is challenging for EDS to map the fluoride distribution it can be efficiently imaged using SIMS mapping (right image).

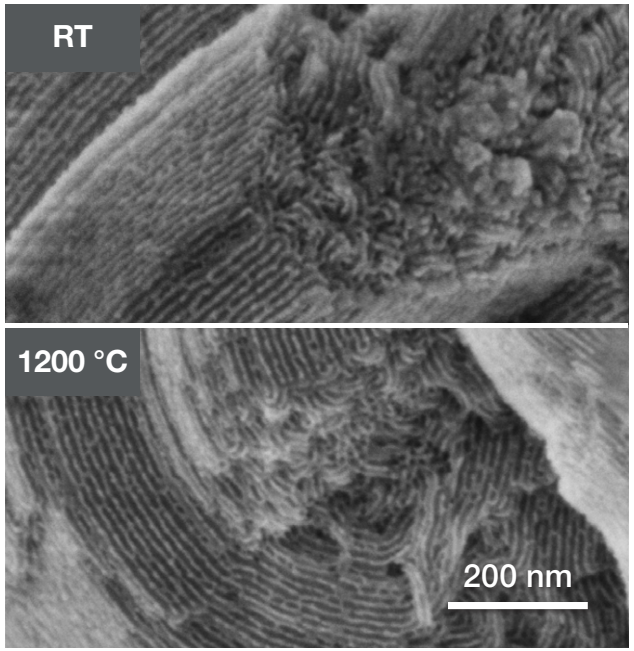


Control of the EasyLift is integrated into the DualBeam UI. Movement of the probe can be done on screen with the mouse.

EasyLift Nanomanipulator

- Enables precise, site-specific preparation of ultra-thin TEM lamellae
- Promotes operator confidence for *in situ* TEM sample lift-outs—critical for one-of-a-kind samples
- Pairs with AutoTEM software for consistent, repeatable preparation and lift-out of ultra-thin TEM samples

Download datasheet



Sample SBA-15. High resolution preserved at 1200 °C. SEM images at 1keV.

µHeater Holder

- Rapid and precise heating in high vacuum; fast heating of materials to 1,200°C in 100 ms
- EDS and EBSD imaging at >1,000°C; enabled by the low thermal radiation of the heater
- Stable solution for *in situ* nm-scale imaging; developed for high-resolution imaging

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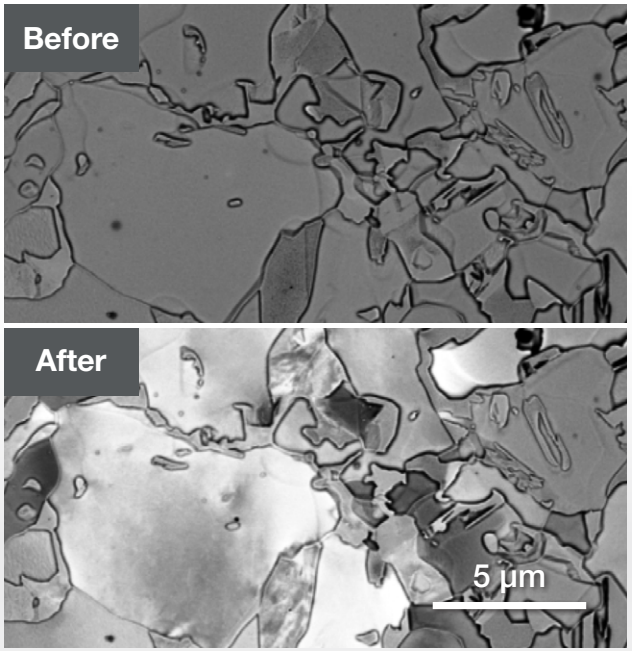

TRIP Steel surface cleaned for 2 minutes. Strain contrast becomes clearly visible after the treatment.

µPolisher System

- Unique solution with potential to enable large number of novel, unexplored applications
- Very-low-energy milling with a static ion beam (20–500 eV) for very gentle surface polishing
- *In situ* solution, allowing for experimentation after cleaning without breaking the vacuum

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Service and support

Your partner in service, across the lifetime of your system

When you use a Thermo Scientific microscope, our service organization remains beside you at every step. Whatever success looks like to you, we will meet you where you are to deliver impeccable care, prioritizing technical excellence and your unique objectives. Whether you are discovering new materials, developing energy-saving electronic devices or recovering challenging resources, Thermo Fisher Scientific provides the cutting-edge product innovations and commitment to service that create an exceptional experience.

App training

We offer a robust training infrastructure developed though our NanoPort organization. It encompasses over 100 scientific staff, as well as more than 30 dedicated individuals managing for Documentation & Training. We are fully committed to empowering your researchers to maximize their time and the efficacy of your instruments.

Scientific Workflows App

Our Scientific Workflows App is a free, cloud-based app that provides continuous workflow updates to enable it to predict the best workflow based on given system configuration and sample/grid type. Based on process results (operator observations), the app provides workflow improvements (recommendations) to optimize your process.

Download for Android

Download on the App Store

RAPID screen-sharing service

RAPID (Remote Access Program for Interactive Diagnostics) is a secure screen-sharing service that allows our team to view your perspective, just as if they were on-site.

- Troubleshoots technical concerns on your Thermo Scientific system
- Puts you in control from start to finish
- Included with most Thermo Scientific service agreements

Learn more about RAPID

> “RAPID is probably the biggest thing we go to first…that has helped us so much, and in a lot of cases, we can resolve things right away.”
>
> —Teresa Sawyer,
> Oregon State University

Accelerate and Advance for Materials Science FIB SEM

A comprehensive workflow needs comprehensive support across the lifetime of your instrument. During the warranty and post-warranty periods, the Accelerate and Advance offerings for materials science FIB-SEMs, including PFIB systems, can help you improve the speed and reliability of your workflow, optimize the overall performance of your system, and achieve faster time to data.

- Improve predictable service events with remote system monitoring
- Increase user efficiency with lamella preparation and workflow training
- Improve system utilization with quarterly reviews
- Consistent system maintenance with preventative and corrective services
- Fast on-site response time
- Optional uptime commitment

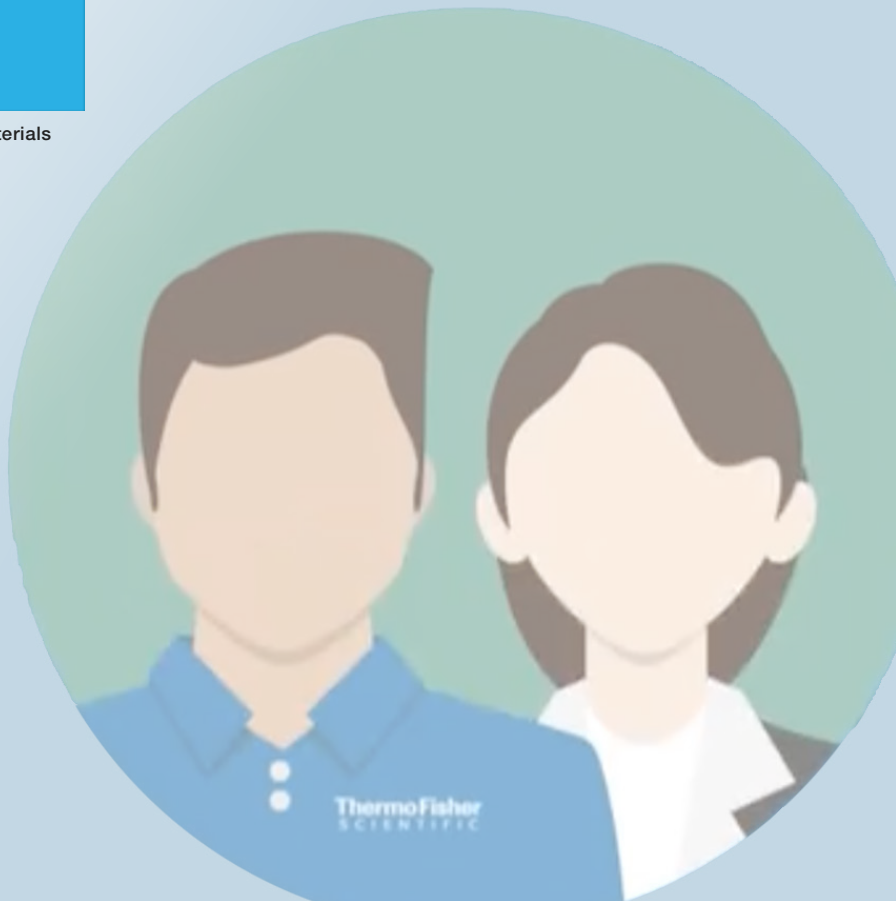
Accelerate and Advance for Materials Science SDB and AutoTEM Software A comprehensive solution for lamella preparation

Thermo Scientific AutoTEM Software offers a guided workflow for lamella preparation. AutoTEM Software is targeted for customers who prefer a standardized and automated lamella preparation experience. The Accelerate and Advance offerings provide support and training to help you manually prepare a variety of lamellas, including challenging lamellas that cannot be achieved by an automated workflow.

You do not have to invest in both the AutoTEM Software solution and Accelerate and Advance offerings; however, when these uniquely valuable solutions are combined, they create a comprehensive support solution for all your lamella needs.

Discover our Service offerings

Accelerate and Advance services for FIB-SEMs used in materials science research. Duration 2.32

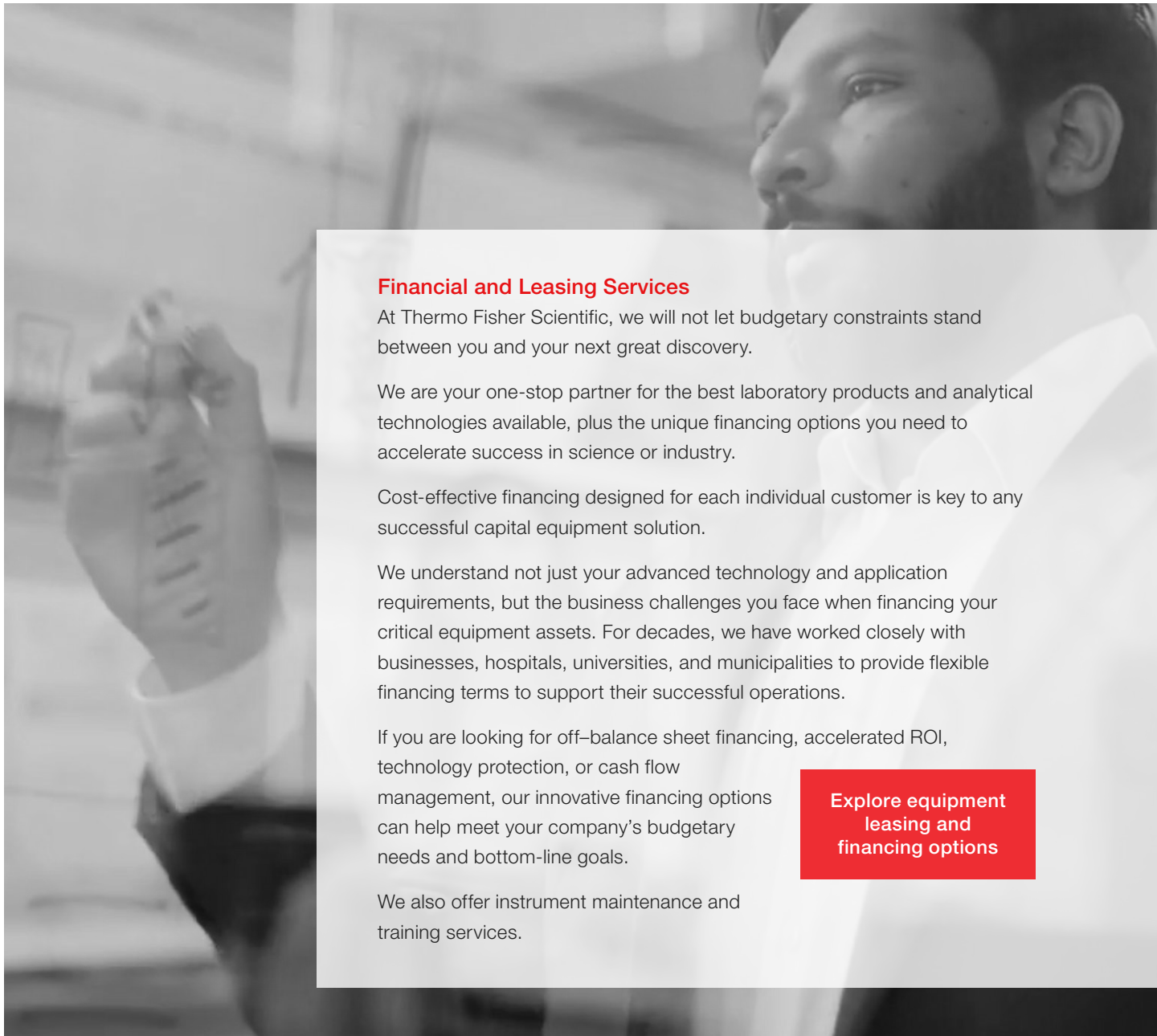


About Thermo Fisher Scientific

We are the world leader in serving science. Our Mission is to enable our customers to make the world healthier, cleaner and safer.

Step ahead. Step beyond. Duration 1.33

Our innovative solutions for electron microscopy, surface analysis, and microanalysis help materials science researchers advance their sample characterization to gain deeper insight into the physical and chemical properties of materials from the macroscale to the nanoscale. Our multiscale, multimodal solutions cover a broad range of applications across dozens of industries and research fields, serving customers in academia, government, and industry. Our TEMs, DualBeam™ FIB-SEMs, comprehensive portfolio of SEMs, XPS, and microanalysis solutions, combined with software suites, take customers from questions to usable data by combining high-resolution imaging with physical, chemical, elemental, mechanical, and electrical analysis across scales and modes.



Financial and Leasing Services

At Thermo Fisher Scientific, we will not let budgetary constraints stand between you and your next great discovery.

We are your one-stop partner for the best laboratory products and analytical technologies available, plus the unique financing options you need to accelerate success in science or industry.

Cost-effective financing designed for each individual customer is key to any successful capital equipment solution.

We understand not just your advanced technology and application requirements, but the business challenges you face when financing your critical equipment assets. For decades, we have worked closely with businesses, hospitals, universities, and municipalities to provide flexible financing terms to support their successful operations.

If you are looking for off–balance sheet financing, accelerated ROI, technology protection, or cash flow management, our innovative financing options can help meet your company's budgetary needs and bottom-line goals.

Explore equipment leasing and financing options

We also offer instrument maintenance and training services.

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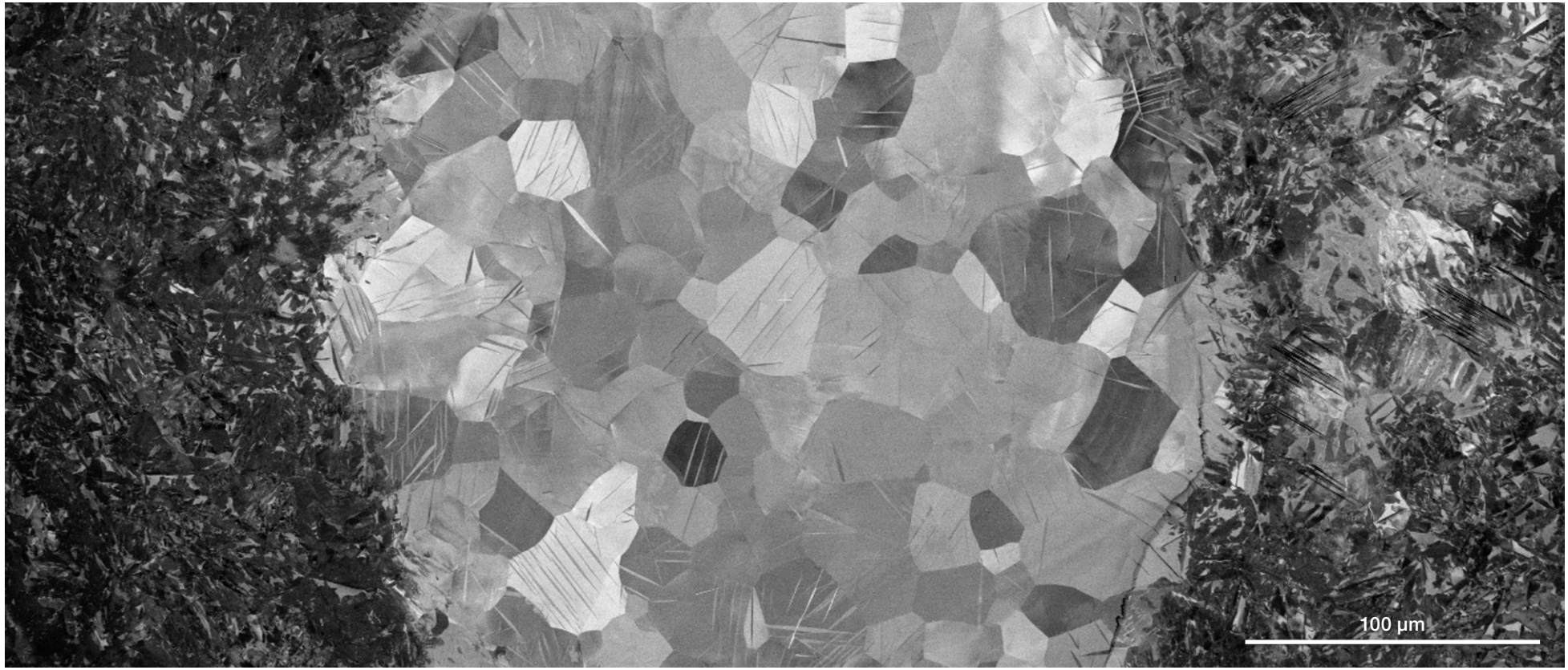

Surface polishing of Ti alloy using SpinMill on Helios 5 PFIB System.

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