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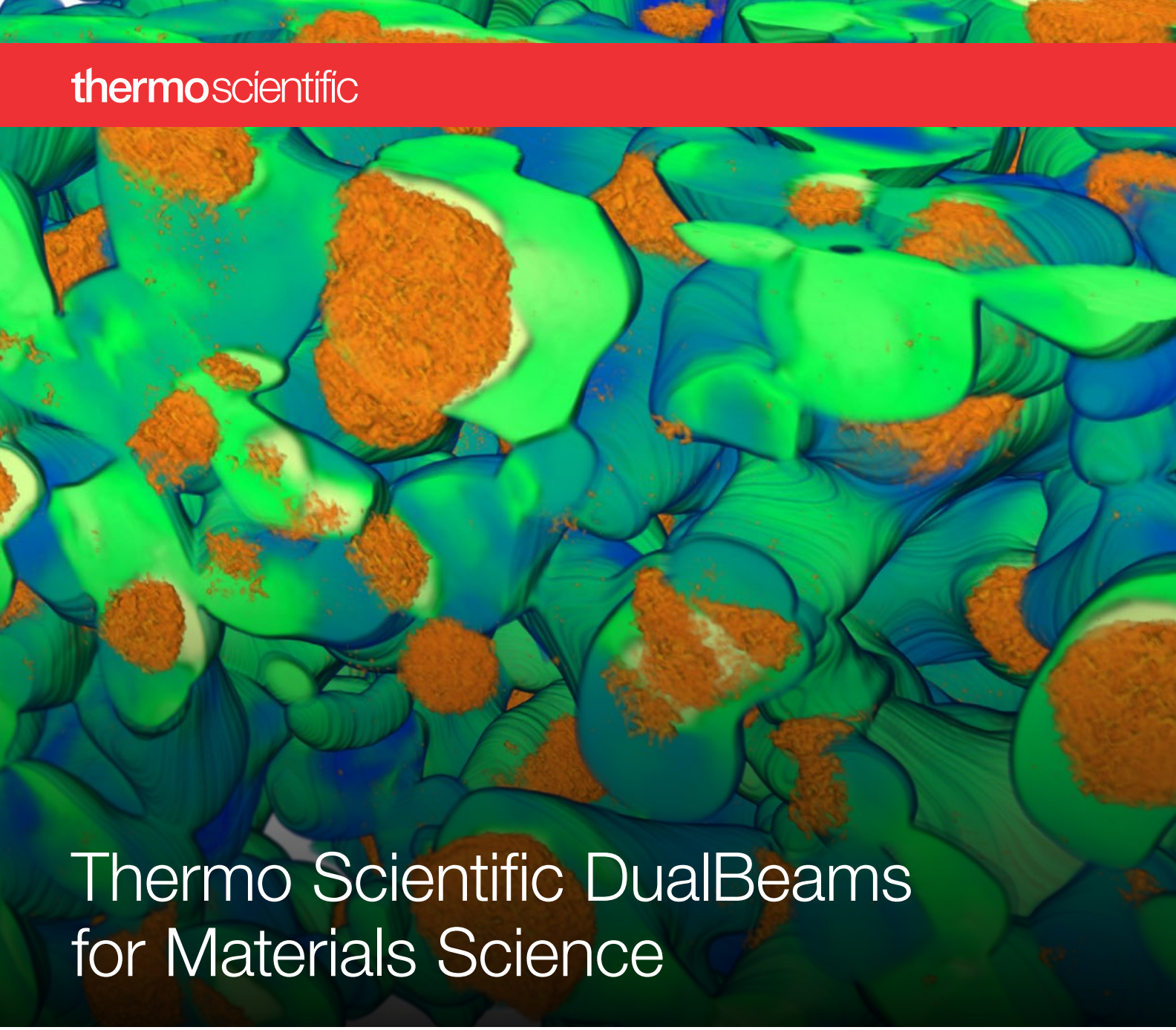

Thermo Scientific DualBeams for Materials Science

Industry leading focused ion beam technology combined with scanning electron microscopy for your structural characterization, S/TEM sample preparation and nano-prototyping needs.

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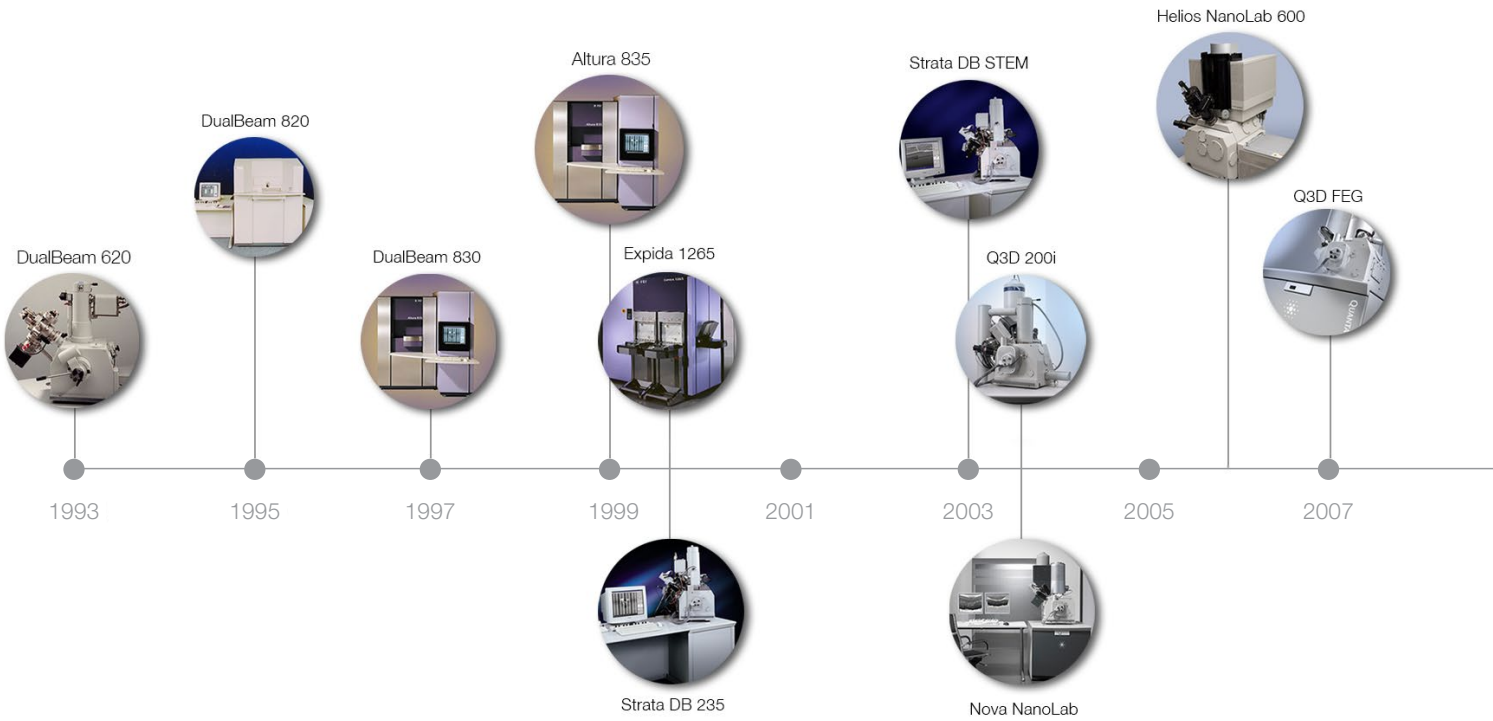
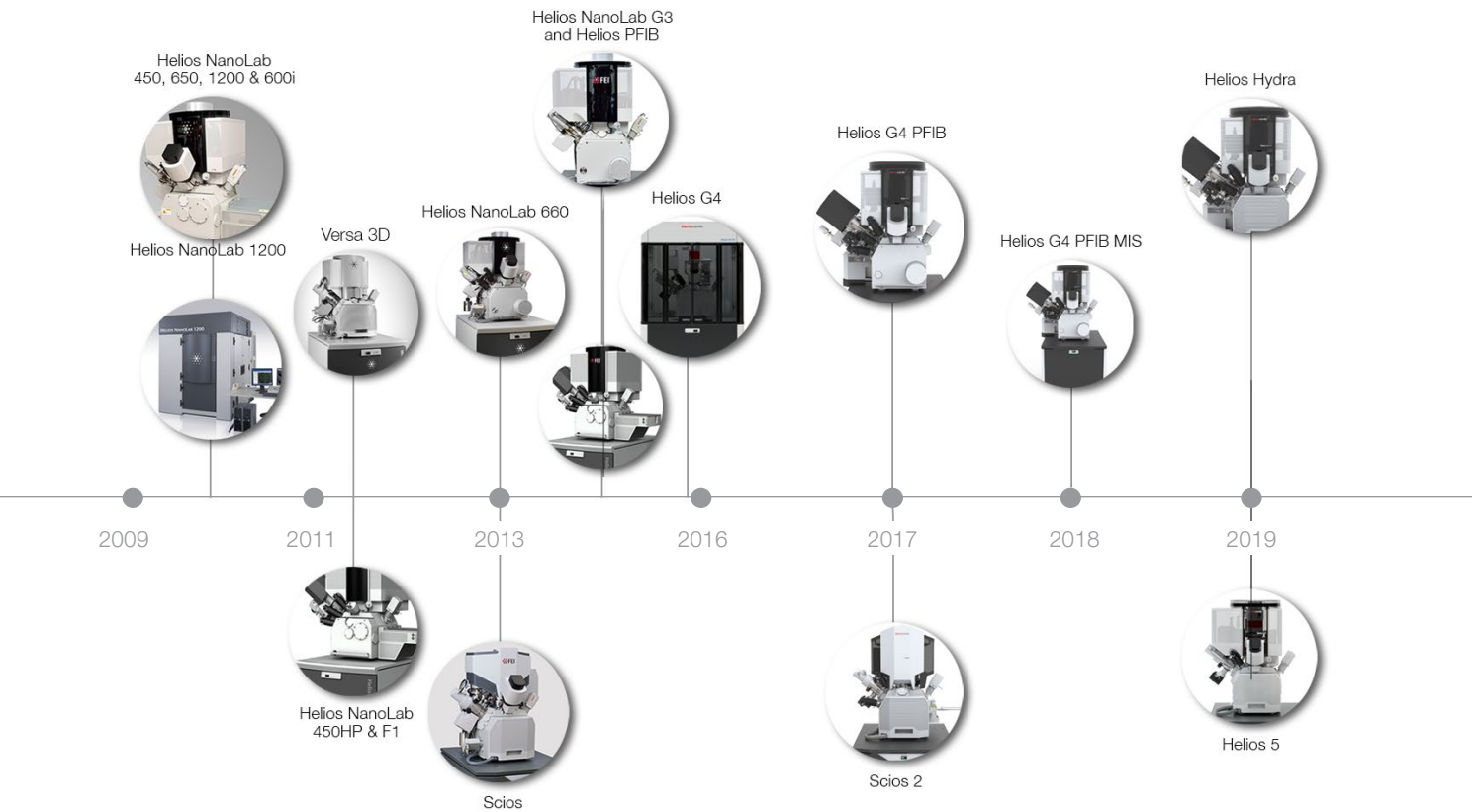
Introduction

Over 25 years ago, Thermo Fisher Scientific developed the first DualBeam™ system, pioneering the revolutionary combination of focused ion beam (FIB) and scanning electron microscope (SEM). While the FIB is capable of adding or removing material from a surface at the nanometer scale, the SEM is ideally suited to monitor this process in real-time, giving a clear visual representation of the FIB process. Since its inception, DualBeam technology has been embraced by the research and engineering communities alike for its ability to reveal sub-surface structural details and to prepare high-quality, site-specific samples for a wide range of materials.



With more than 2,000 systems installed worldwide, Thermo Scientific™ continues to be the DualBeam market-leader thanks to cutting-edge innovation and a deep well of unparalleled expertise gained through years of collaborative development with our customers. Our DualBeams don't just feature the most advanced hardware, they are guided by unique software that enables critical time-saving automation and ease of use, confidently bringing this powerful instrument within the reach of even novice users.



Applications

So, what can a DualBeam bring to your materials science research? 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. DualBeams deliver just that, with multi-scale, multi-dimensional insight down to the sub-nanometer range, giving you a thorough look at both the surface and interior of your sample. Not only that, but thanks to the FIB's ability to deposit material as well as remove it, DualBeams can be equipped to produce functioning prototypes of miniature MEMS and NEMS devices.

The instruments are also routinely used to create some of the highest quality samples for atomic-resolution scanning transmission electron microscopy (STEM) imaging, a technique that allows you to directly observe the fundamental building blocks of your materials. Thermo Scientific DualBeams have the highest quality beam profile on the market that, when combined with the unique Thermo Scientific AutoTEM™ Software for automated *in situ* lift-out, provide unmatched sample quality and throughput for rapid, high-quality characterization.

Scios 2 DualBeam

Helios 5 DualBeam

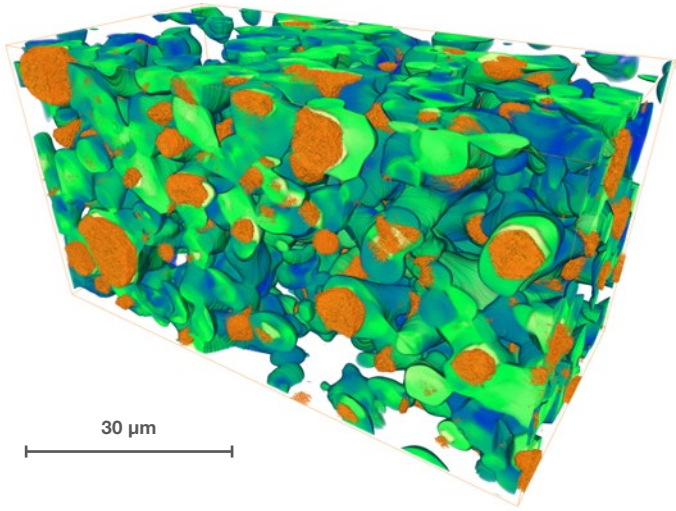
Helios PFIB DualBeam

Helios Hydra DualBeam

Products

Scios 2 DualBeam

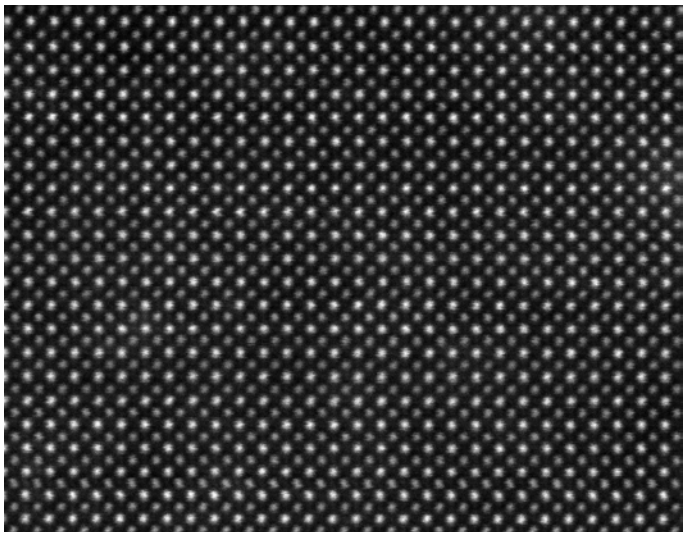
- Features gallium focused ion beam source
- Highest flexibility DualBeam with long working distance
- Low vacuum capability broadens the range of potential samples that can be observed with SEM
- Integrated user guidance for common DualBeam applications enables all users to fast-track their productivity
- Magnetic sample analysis is fully supported with an ultra-high-resolution non-immersion SEM column
- Automated multi-site cross-sectioning thanks to a broad range of novel software tools (see pages 8-11)



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 4 Software and Avizo Software.

Helios 5 DualBeam

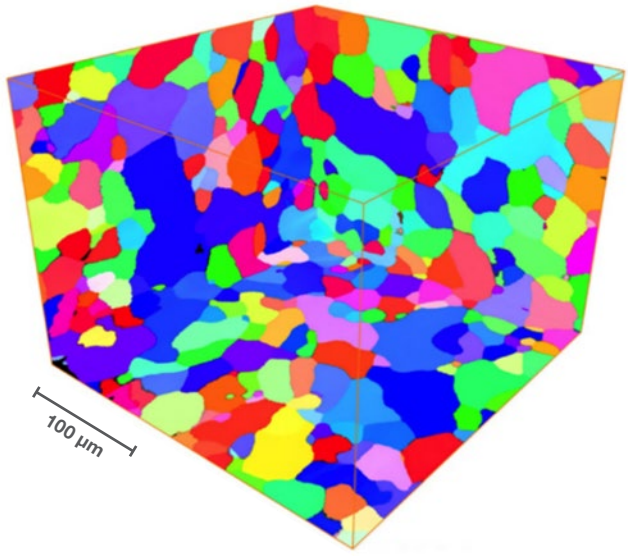
- Fastest and easiest S/TEM sample preparation for users with any level of experience
- Extremely high resolution and contrast imaging
- Fast and precise milling or deposition of complex structures as low as <10 nm in size
- Automated image tuning via the Flash tool
- High beam current density allows for up to 3x higher milling throughput than with other comparable instruments



High-resolution STEM image of an ultra-thin TEM lamella produced with the Helios DualBeam.

Helios PFIB DualBeam

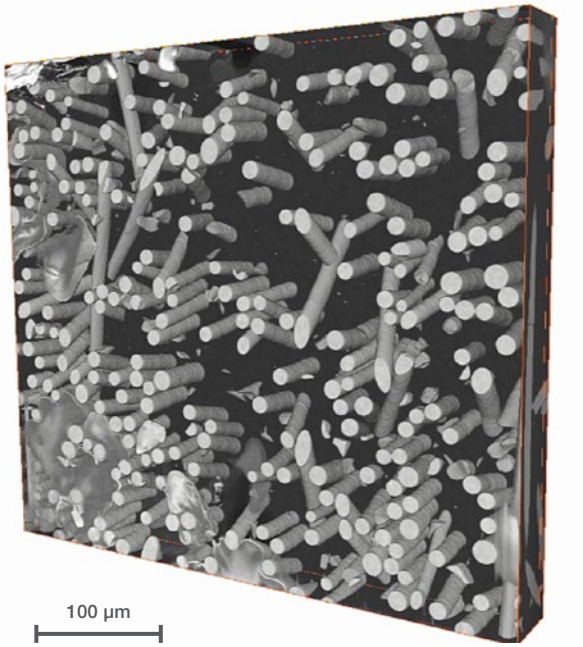
- Features xenon plasma focused ion beam (PFIB) source for rapid, large volume milling
- Fast and easy preparation of high-quality Ga^+ free S/TEM and atom probe tomography (APT) samples
- Unique automated TEM sample preparation workflow with Thermo Scientific AutoTEM™ 5 Software
- Extremely high-resolution and contrast imaging
- Fast, precise micromachining of complex structures for prototyping and *in situ* mechanical testing



3D electron backscatter diffraction (EBSD) reconstruction of zirconium alloy sample (250 x 250 x 220 µm³) produced with a Helios PFIB DualBeam, Auto Slice and View 4 Software and Avizo Software.

Helios Hydra DualBeam

- Novel multi-ion FIB source (xenon, argon, oxygen and nitrogen)
- Flexible experimentation thanks to unique, fast (<10 minute) ion species switching
- High-throughput milling and high-resolution imaging with proven Xe^+ ion beam
- Improved milling performance for carbon-based materials with O^+ ion beam
- Advanced S/TEM sample prep with the focused Ar^+ ion beam
- Optimize existing applications such as secondary ion mass spectrometry (SIMS) by finding the most appropriate primary ion beam



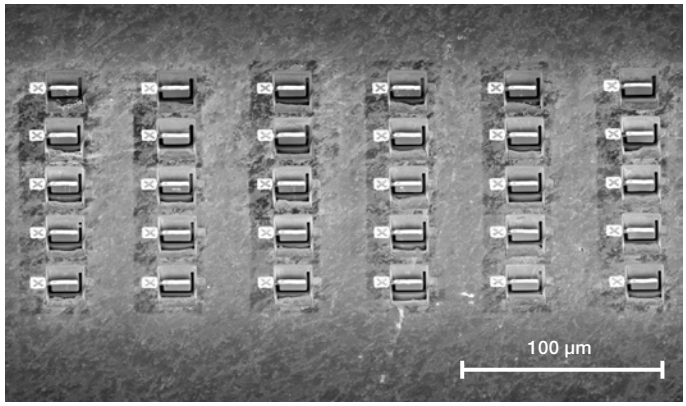
3D reconstruction of an automotive oil filter casing (polymer/glass fiber composite) acquired with a Helios Hydra DualBeam using a focused oxygen ion beam and Auto Slice and View 4 Software for automated serial sectioning. Horizontal field width = 350 µm.

Software and accessories

AutoTEM 5 Software

As sample preparation is considered to be one of the most important, but also most challenging and time-consuming, DualBeam use cases, Thermo Fisher Scientific has developed automation software to support complete *in situ* sample preparation. AutoTEM 5 Software enables fast and easy site-specific preparation of high-quality STEM/TEM samples for a large variety of materials.

- S/TEM sample preparation in less than an hour
- Robust, predictable results that can be acquired by experts and novice users alike
- Full support for both gallium FIB and plasma FIB sources
- Easy to use, intuitive user interface with hints and instructive graphics

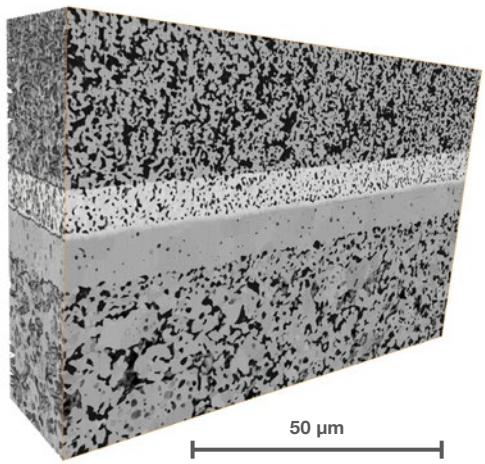


Aluminum sample, where a 5x6 array of STEM lamella has been prepared in 6 hours with AutoTEM Software, undercut and ready for lift-out. The software allows automatic defining of arrays and/or shifting of positions to user-defined locations.

Auto Slice and View 4 Software

Thermo Scientific Auto Slice and View™ 4 Software is a multi-modal 3D data collection tool that enables the creation of high-resolution 3D images and analytical maps (EBSD, EDS). Data is generated via the FIB milling and SEM imaging of serial sections (slices) of the sample.

- Intuitive, easy-to-use user interface with streamlined workflows
- Ability to acquire all information on every slice (imaging, EBSD, EDS, analytics, current, voltage, tilt, etc.)
- Regions of interest can be modified and adjusted during analysis
- Provides digital tilt-shift compensation for improved collection efficiency
- High-speed throughput with the ability to observe multiple sites

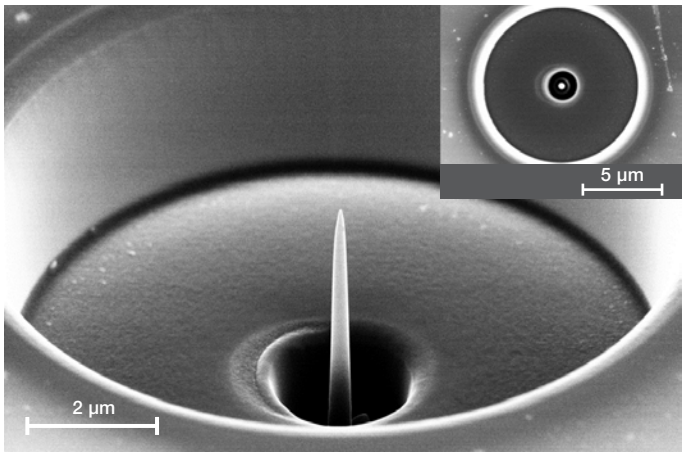


All layers of a solid oxide fuel cell collected in a single run with the Helios PFIB DualBeam and Auto Slice and View 4 Software. 3D reconstruction and visualization were performed with Avizo Software.

AutoScript 4 Software

A Python-based application programming interface (API) that offers control of Thermo Scientific DualBeam systems. It opens up the microscope to a world of advanced functions that can be employed for powerful automation.

- Improves reproducibility and accuracy of repetitive or tedious tasks
- Allows for unattended, high-throughput imaging
- Supported by the Python 3.5-based scripting environment

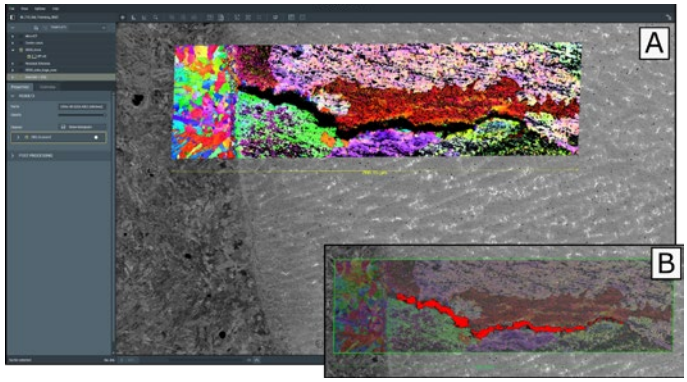


Drift-corrected nano-pillar milling using multiple beam currents. Horizontal field width ~ 10 µm.

Maps Software

An automation and correlative workflow software suite which can link observations from multiple sources including microCT, SEM, DualBeam and TEM instruments. With Thermo Scientific Maps™ Software, multi-scale context can be obtained, allowing you to inspect your complete sample in more detail. Additionally, Maps Software enables you to automatically acquire and stitch together large 2D tile sets.

- Easily set up multi-resolution acquisition on single or multiple samples
- Import imagery from any source to generate a correlative dataset
- Explore and interpret all your data efficiently and with context

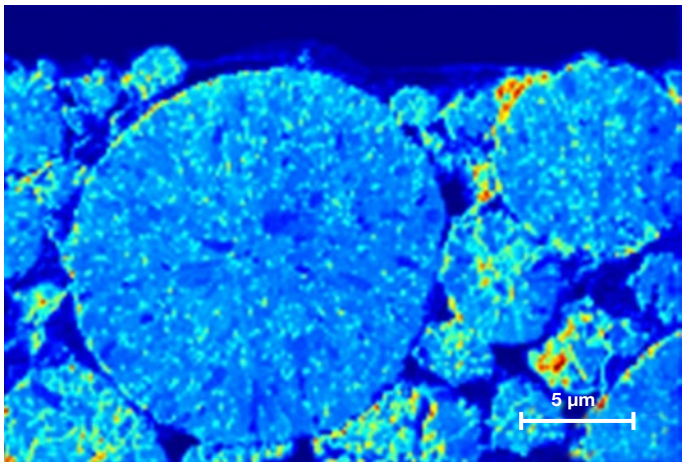


A) BSE image background with an EBSD map around a fractured region of the Inconel coupon. B) Same image as A, illustrating transparency of EBSD map on the BSE background image. Maps Software also provides the ability to threshold an image to highlight specific features. In this case, illustrating the difference in fracture aperture captured in EBSD versus BSE imagery.

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 DualBeam will be capable of:

- 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

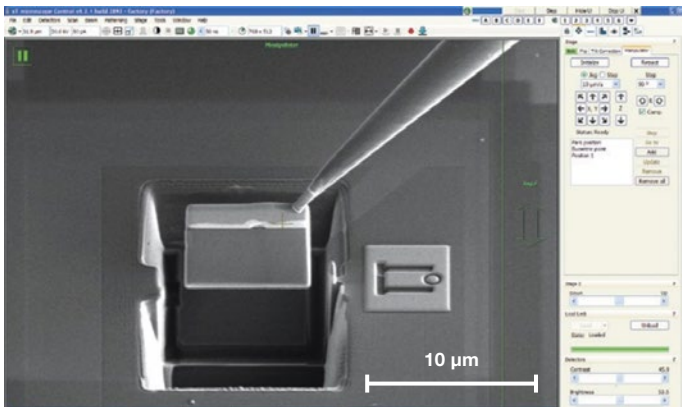


SIMS map showing lithium distribution over a sample cross-section. Horizontal field width ~ 29 µm.

EasyLift Nanomanipulator

The Thermo Scientific EasyLift™ Nanomanipulator allows you to extract lamella and attach them to a TEM grid, all within the DualBeam chamber. Thanks to consistent, repeatable software control, this enables precise, site-specific preparation of traditional or ultra-thin TEM lamellae.

- Low-drift, high-precision movements for *in situ* TEM sample lift out; critical for unique samples
- Controls are fully integrated into the DualBeam user interface

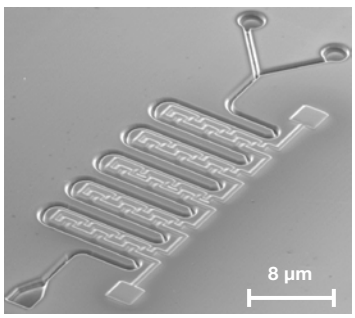


Control of the EasyLift Nanomanipulator is integrated into the DualBeam user interface. Movement of the probe can be done on screen with the mouse.

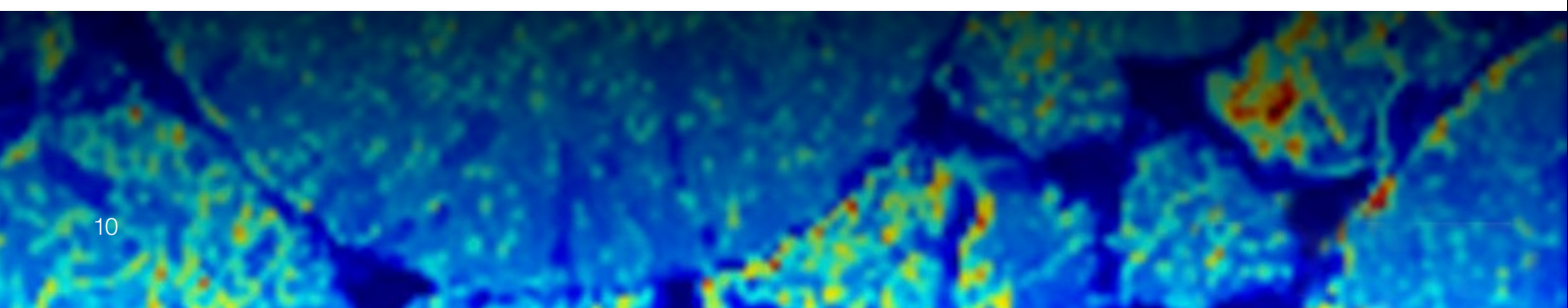
NanoBuilder Software

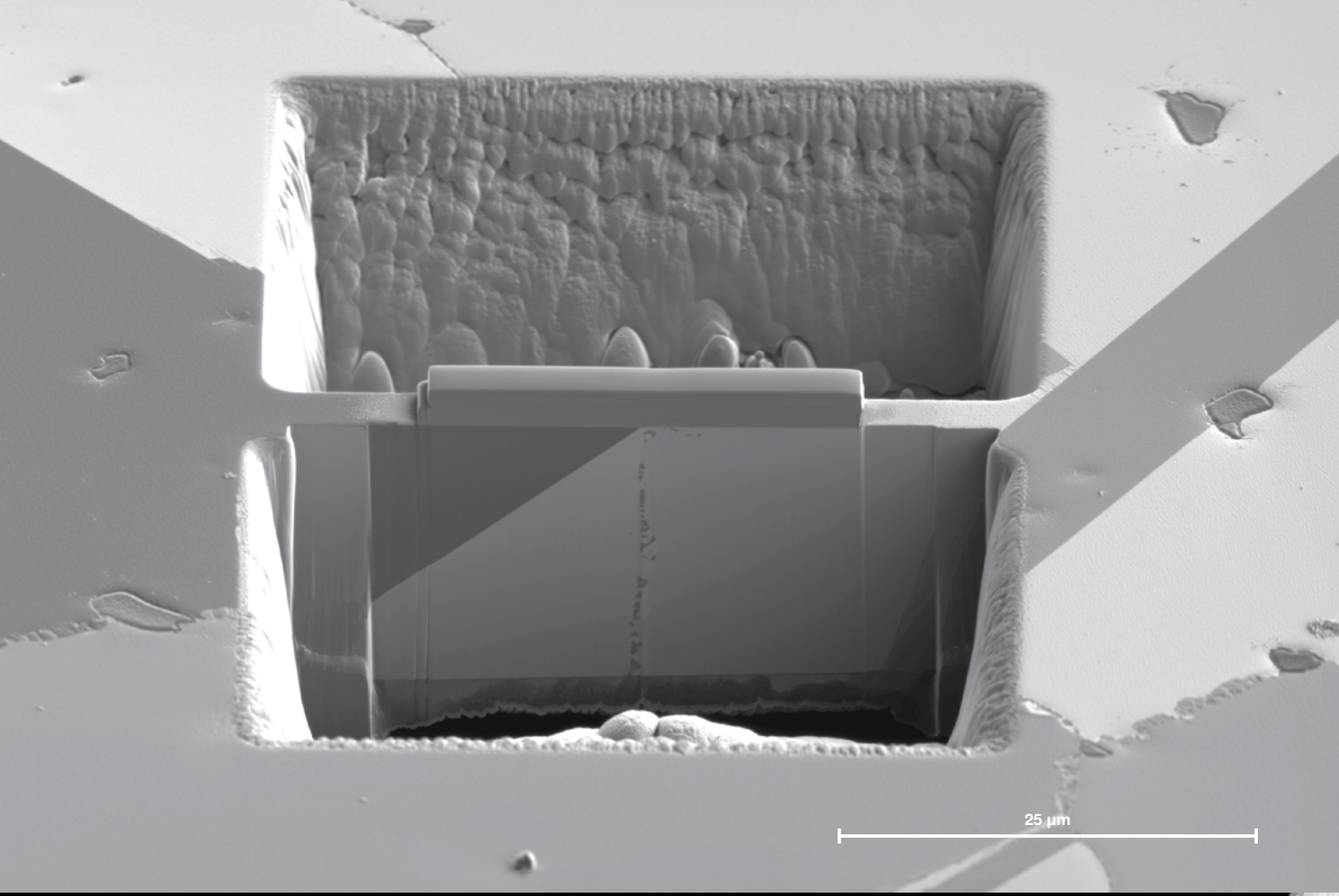
The nano-scale fabrication possible with DualBeam instruments requires a precise, layered application of FIB milling and deposition. NanoBuilder Software allows for the systematic planning of multi-layer nanostructures by dividing CAD files into ordered beam applications.

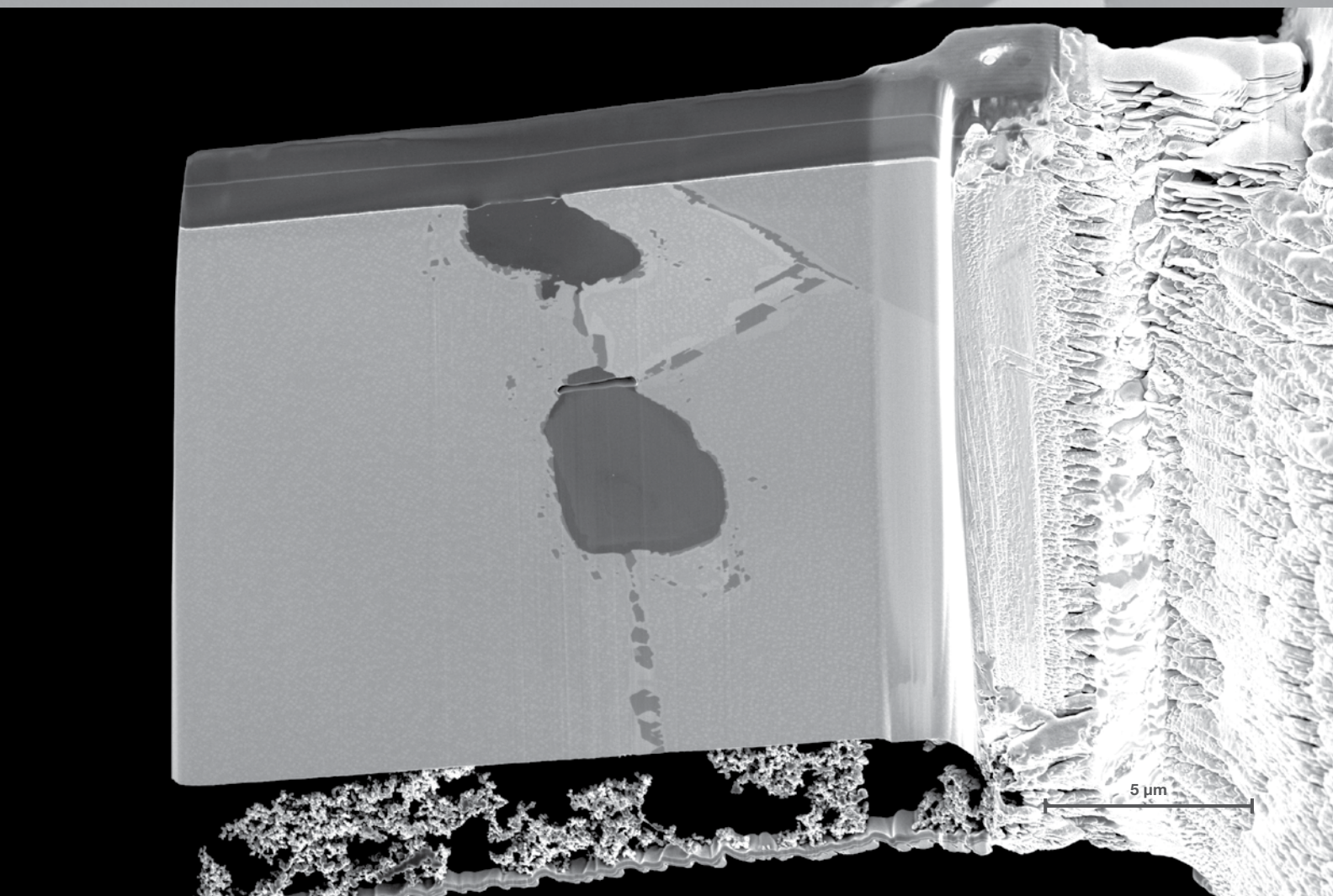
- Facilitates the generation of complex structures that were previously too tedious or impossible to build
- Accurate patterning of large and/or complex nanostructures on multiple sites



Nanofluidics building block created with NanoBuilder Software and the Helios DualBeam. Horizontal field width ~ 32 µm.




25 µm


5 µm

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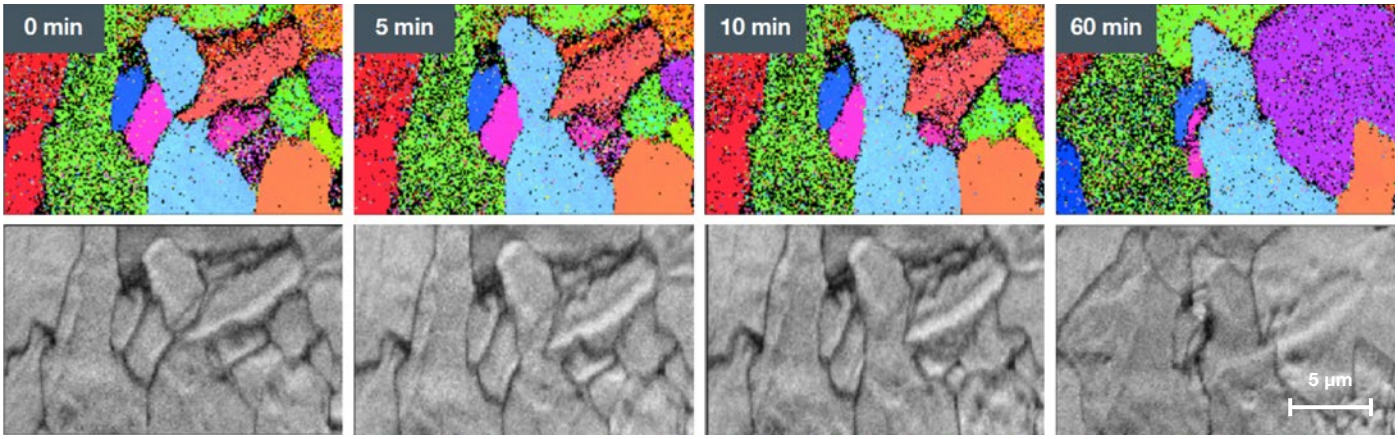
µHeater Holder

Direct observation of microstructures as they are affected by thermally active processes, such as recrystallization, grain growth and phase transformation, is oftentimes essential for a full understanding of the structure's material properties. The MEMS-based µHeater Holder allows samples to be prepared in the DualBeam and transferred to the heating stage without breaking vacuum, preserving the integrity of the sample.

- Rapid and precise heating in high vacuum, capable of reaching 1,200°C in 100 ms
- EDS and EBSD imaging at >1000°C enabled by the low thermal radiation of the heater
- Developed with high-resolution *in situ* imaging in mind, maintains highest DualBeam performance at elevated temperatures
- MEMS-based device design delivers consistent, reproducible and uniform temperature distribution over the heated area
- Full integration with microscope control software on DualBeam instruments

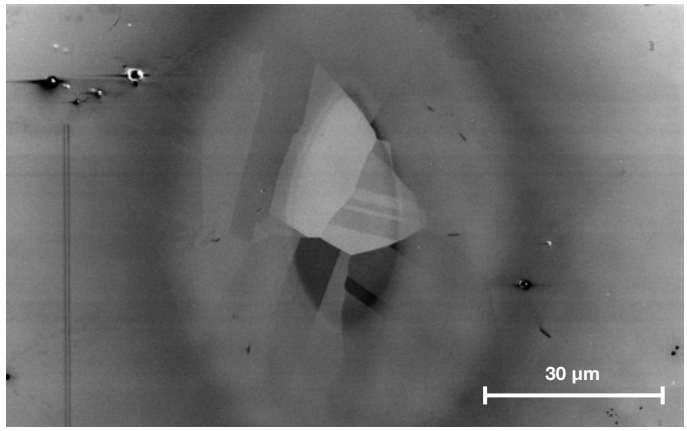


Microstructure evolution of deformed Ti_6Al_4V alloys obtained at 1100°C using the µHeater Holder, with EBSD inverse pole figure Z (IPF Z) colored images (top row) and corresponding image quality maps (IQM, bottom row). The horizontal field width of each image = 20 µm.

µPolisher System

This low-energy ion polishing solution for localized surface cleaning can be used for fine polishing of sample surfaces for electron backscattering experiments or high-quality surface preparation prior to high-resolution SEM imaging.

- Unique solution with the potential to enable a large number of novel, unexplored applications
- Extremely gentle surface polishing thanks to low energy milling with a static ion beam (20 - 500 eV)
- *In situ* solution enables experiments to be performed after cleaning without the need to break the vacuum
- Small spot size for precise local surface treatment without re-deposition
- Fully integrated in the microscope user interface, providing easy and intuitive operation



Stainless steel Type 316 cleaned with the µPolisher System for 2 minutes. The central spot reveals microstructure on a contaminated background. The horizontal field width of the image ~ 116 µm.

Find out more at **thermofisher.com/EM-Sales**

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