Simplify your TEM lamella sample preparation

ZEISS Crossbeam Samplefab

TEM preparation FIB-SEM with
industry-leading automation yield

zeiss.com/samplefab

Seeing beyond

Dedicated, robust solution for fully automated, unattended multi-site TEM lamella preparation

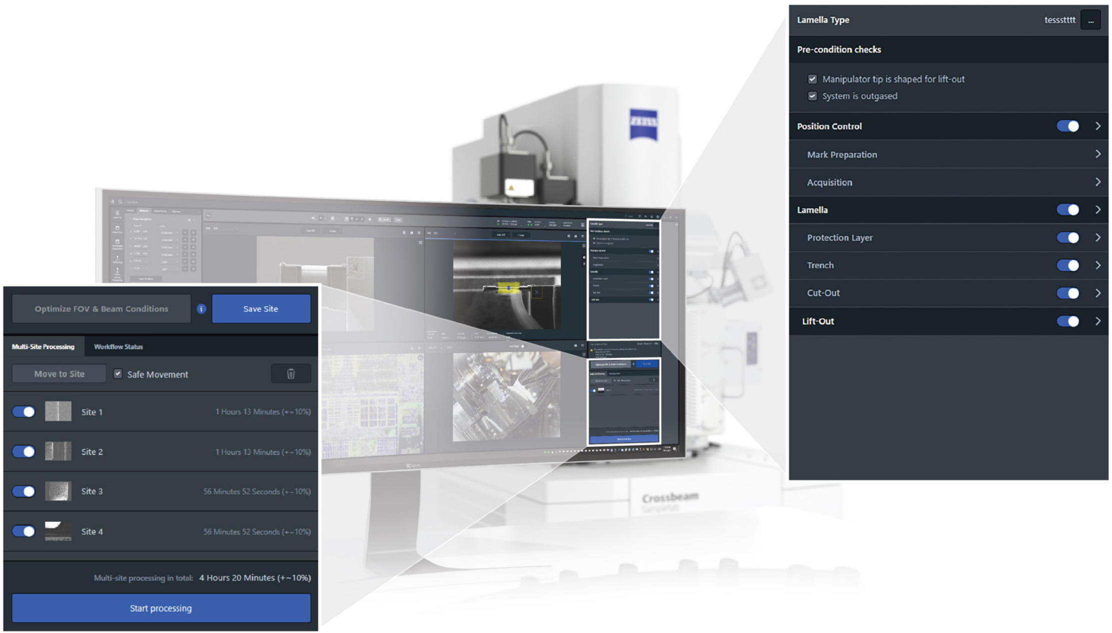
ZEISS Crossbeam Samplefab® is an integrated focused ion beam scanning electron microscope (FIB-SEM) for automated multi-site TEM lamella preparation. Built on a completely new and easy to use control software platform, Crossbeam Samplefab provides automated TEM sample preparation, and is engineered and tested for robustness and automation yield success.

As semiconductor devices become more complex, faster, smaller, and more efficient, the evolution of advanced materials and new manufacturing processes continues to deliver challenges which can be addressed only at the nanoscale in a transmission electron microscope (TEM).

TEM is one of the most important tools used in the physical analysis of semiconductors, and good results require excellent sample preparation. TEM sample preparation throughput is increasingly important to daily work in the semiconductor lab, and manual preparation is challenging and time-consuming.

It is critical for the success of laboratory work that this process be efficient, accurate, and uniform.

Crossbeam Samplefab addresses this need by providing an automation platform for TEM lamella preparation, allowing unsupervised operation for many hours at a time.



☑ Safe Movement

Site 1	1 Hours 13 Minutes (+~10%)
Site 2	1 Hours 13 Minutes (+~10%)
Site 3	56 Minutes 52 Seconds (+~10%)
Site 4	56 Minutes 52 Seconds (+~10%)

Multi-site processing in total: 4 Hours 20 Minutes (+~10%)

Lamella Type: tesssttttt

Pre-condition checks
☑ Manipulator tip is shaped for lift-out
☑ System is outgased

Position Control ●
- Mark Preparation
- Acquisition

Lamella ●
- Protection Layer ●
- Trench ●
- Cut-Out ●

Lift-Out ●

Robust solution for unsupervised, automated TEM lamella preparation

- Crossbeam FIB-SEM in a dedicated configuration with high specifications for TEM sample preparation
- New user-centric software for easy deployment of recipe-based workflows
- Full automation of chunking, lift-out, and thinning
- Exceptional hardware and software stability
- ZEISS unique lamella feedback control technique for stability and throughput during auto lift-out
- High automation throughput, allowing up to 10 lamellae in 8 hours
- Automation yield promise for hands-free chunking and lift-out
- Extended service and applications support

Navigation: Simple and efficient software controls

Simplified, contextual navigation and automation job queuing

Crossbeam Samplefab streamlines the automation workflow setup with a completely redesigned and easy to use control software. The new user interface is designed for simplicity and efficiency, without sacrificing the advanced controls required for recipe development on your specific sample.

TEM lamella location is selected relative to operator-defined fiducial marks. Each TEM sample can be assigned its own optimized recipe depending on the requirements of the sample and location.

Powerful, simplified user interface with outstanding UX design

- Navigation is intuitive and contextual with integrated ZEN Correlative Workspace
- Operators see only the controls they need to set up an automated sample preparation run
- Super-users can dive into every detail to exactly specify protocols and milling recipes
- Guided checklist provides confidence that all operator-led tasks have been successful

Setup: Tools for optimum efficiency

Premium hardware configuration reduces operator effort and improves weekly throughput by reducing daily overhead

Figure 1 *TEM grid loading station*

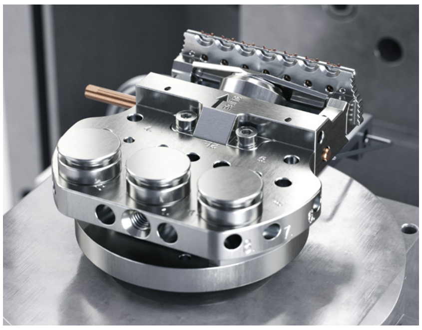


Figure 2 *TEM lamella preparation sample holder*

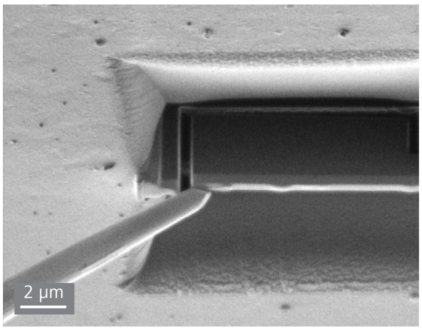


Figure 3 *OmniProbe 400 nanomanipulator tip*

Calibration and alignment

The time and effort required to recalibrate beams can limit the productivity of a FIB-SEM used to produce TEM lamella. The Gemini electron beam column calibration requires checking only at annual or semiannual field service visits.

The highly stable Ion-sculptor FIB column needs only occasional recalibration. Calibration frequency can vary depending on the application and work profile of the system, but typically a weekly interval is sufficient.

Crossbeam Samplefab provides system stability that reduces operator effort, leading to better tool utilization.

TEM grid loading

The ZEISS grid rail holds up to seven TEM grids. A loading station makes loading and unloading of grids to and from the grid rail easy and eliminates the risk of losing grids during this procedure (Figure 1).

TEM grid handing

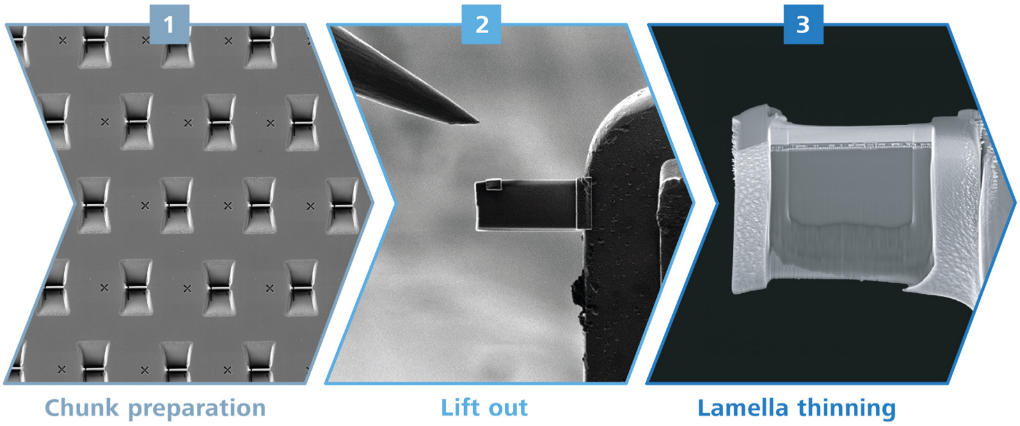
The TEM grid rail is compatible with a collection of sample holders offered by ZEISS for a variety of semiconductor applications (Figure 2).

Manipulator control

Market-leading OmniProbe nanomanipulator OP400, with ZEISS native software control, employs a robust automation algorithm for TEM lamella lift-out (Figure 3).

Fully-automated TEM lamella preparation workflow

The Crossbeam 550 Samplefab automation routine follows a standard TEM preparation workflow



1. Automated chunking/ bulk milling
First a protective layer is deposited on the surface of the sample, and the rough volume of interest is isolated from the bulk. A fiducial marker is used to precisely correct any sample displacements due to stage movements. This "chunking" process can be observed live with the SEM during milling, allowing immediate operator intervention if required.

2. Automated *in situ* lift-out and grid attach
Where *in situ* lift-out is required, the chunk is automatically lifted out from the bulk with the nanomanipulator and welded to the FIB half-grid. The automated lift-out and transfer to grid uses a ZEISS-proprietary "beam-barrier" method that is significantly more robust and efficient compared to image-recognition methods.

3. Automated thinning down to 100 nm
Thinning follows lift-out, or can be completed in bulk, depending on the application requirements. Thinning is typically a coarse polish, followed by a fine polish on the chunk surface to isolate and make the region of interest transparent for TEM imaging. As Crossbeam Samplefab electron optics do not require an immersion field for high-resolution imaging, the thinning process can be observed live with the SEM during FIB milling.

The user can choose to automate a complete workflow by linking any of the three steps of chunking (1), lift-out with grid attach (2), and thinning (3).

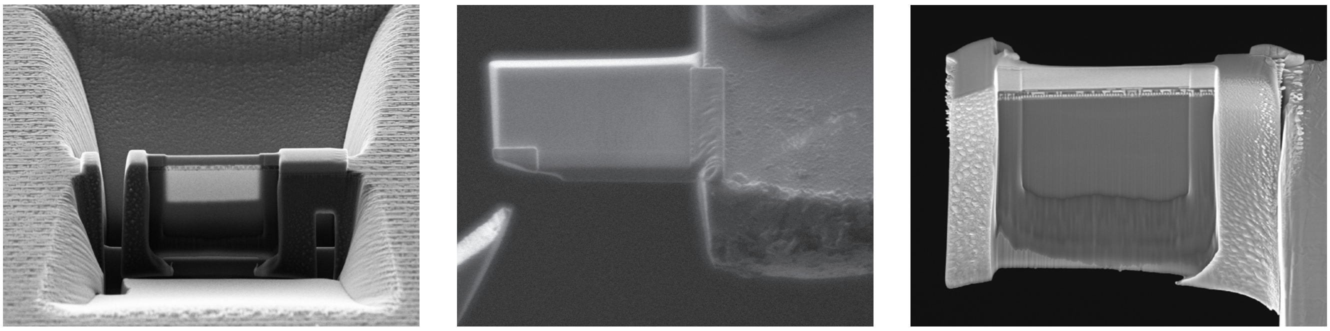


Figure 4 *(1,3) for* ex situ *lift-out (left), (1,2) for automated lift-out without automated thinning (center), (1,2,3) for complete automated TEM prep workflow from bulk sample to thinned lamella on the TEM grid (right).*

Fully-automated multi-site lamella preparation

The full process can be repeated for a multi-site automation run. To ensure that all target positions are reached precisely, the chunking fiducial markers are used for position correction. The wide beam-shifting range and field of view of the Gemini 4 electron beam column improves navigation efficiency and overall stability of the automation. The combination of these design factors contributes to an impressive throughput for silicon semiconductor samples of up to 10 lamellae in 8 hours* for the complete process (1,2,3).

Achieve reliable and precise endpointing

A final operator-guided polishing step may be required depending on your application. The final polish is critical as it defines the quality and targeting accuracy of your TEM lamella. To accurately hit the target feature and to precisely achieve the desired thickness, the Gemini electron optics allow continuous, real-time, high-resolution SEM monitoring during lamella thinning. Both beams are simultaneously on with no need for fast beam switching or beam blanking, enabling best-in-class endpointing performance. Comprehensive FIB controls combined with live SEM imaging enable extremely fine adjustments of the milling process on the fly while approaching the target, allowing fast responses to events like sample charging or lamella bending.

Automation yield promise

The automation workflow has been rigorously tested and optimized for stability and the results of hundreds of TEM lamella runs have been collected. Crossbeam Samplefab comes with an automation success promise that for silicon semiconductor samples, **statistically fewer than 1 in 10 lamellae require an operator intervention during automated chunking and lift-out** (1,2)

In the few cases where a manual intervention is needed, the operator may log in to secure the active lamella and in most cases restart the automation without losing or damaging the sample.

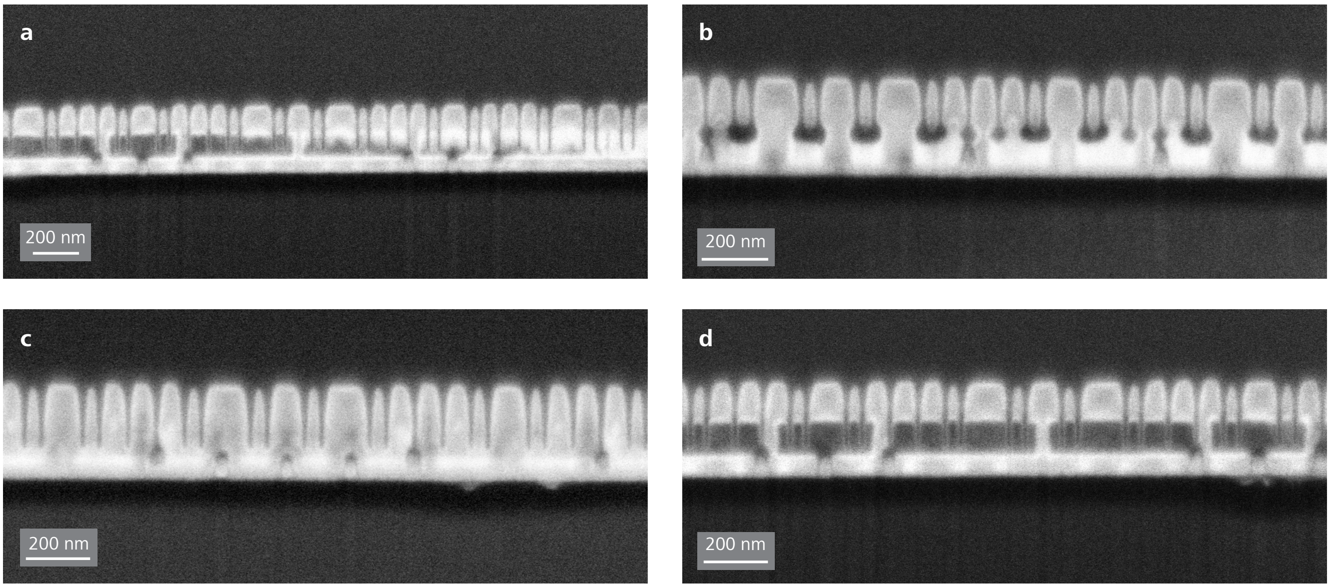


Figure 5 *Images saved at different time points during continuous SEM thinning monitoring.* ***Sample:*** *7 nm node SRAM.* ***Goal:*** *Gates exactly centered in a lamella across the transistor fins. a) Asymmetry indicated bad alignment of milling to device structures. Immediately corrected by adjusting milling angle with 0.01° accuracy. b) and c) All structures remain clearly visible at high resolution and high contrast while milling proceeds, making it easy to identify endpoint. d) Endpoint of thinning process reached, exactly at transistor gates.*

*Assumes 9 µm × 5 µm × 1 µm chunk, thinning window of 3 µm × 3 µm, with a silicon semiconductor sample.

Single chamber sample analysis

Rapid high resolution lamella imaging by *in situ* STEM

Crossbeam Samplefab can be equipped with scanning transmission electron microscopy (STEM) detectors for an instant transmission mode review of your lamella before transfer to the TEM, or as an adequate TEM alternative. *In situ* STEM can often provide sufficient data to make a technical decision or complete an engineering report without requiring the transfer of the sample to a TEM.

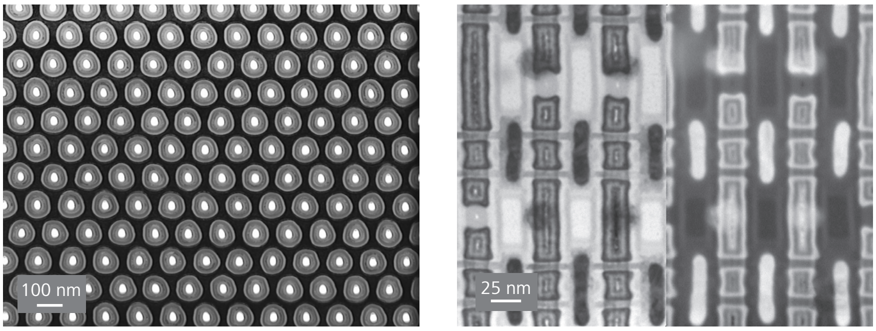


Figure 6 *30 kV STEM images of 3D NAND in darkfield STEM (left) and 7 nm-node SRAM (right) showing brightfield and darkfield STEM images acquired by Crossbeam 550 Samplefab.*

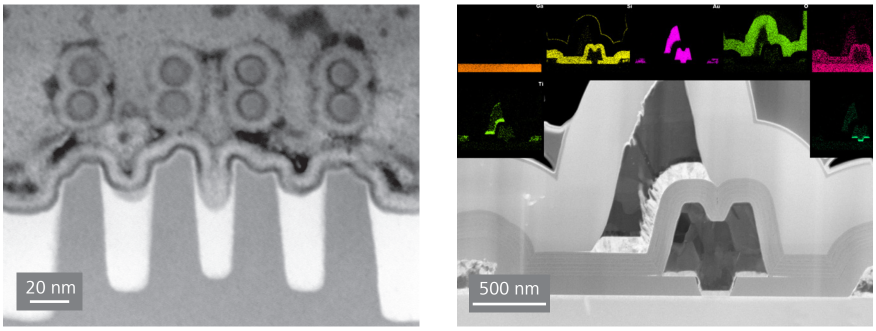


Figure 7 *30 kV brightfield STEM image of a gate-all-around test device (left), and a commercial GaN power device showing brightfield STEM and STEM EDS (right).*

Technical specifications

ZEISS Crossbeam Samplefab

SEM	Schottky Emitter 0.6 nm at 30 kV (STEM) 0.7 nm at 15 kV 0.6 nm at 15 kV / DCV* 1.2 nm at 1 kV TD** 1.4 nm at 1 kV 1.1 nm at 1 kV / DCV* 1.6 nm at 0.2 kV TD** Beam current: 3 pA – 40 nA
FIB	Liquid metal ion source (LMIS) lifetime: 3000 µA at 2 µA emission 3 nm at 30 kV (statistical method) 120 nm at 1 kV and 330 nm at 500 V Beam current: 1 pA - 100 nA
Detectors	Inlens SE, Inlens EsB, SESI (secondary electron/secondary ion detector), aSTEM (scanning transmission electron - optional), aBSD (backscatter detector - optional)
Chamber size & ports	Standard with 7 configurable ports
Stage	X/Y = 100 mm Z = 50 mm, Z’ = 13 mm T = -4° to 70°; R = 360°, continuous Repeatability: 500 nm in x/y at 0° tilt over full travel range
Sample manipulation	Integrated Manipulator: Oxford OmniProbe 400, 4 axes including rotation
Charge control (optional)	Flood gun Local charge compensation
Gases	UniGIS: Pt (standard), C, SiO_x, W, H_2O (optional)
Store resolution	512 × 384 to 32 k × 24 k pixels
Analytics options (optional)	EDS
Advantages	Your robust solution for unsupervised, automated TEM lamella preparation

Automated TEM sample preparation

Workflow	Fully automated multi-site workflow: 1. Chunking 2. Lift-out (with transfer to grid) 3. Thinning to 100 nm
Automation yield	A maximum of 1 in 10 lamellae require operator intervention during chunking & lift-out (steps 1, 2)
Throughput	10 lamellae in 8 hours for the complete process (steps 1, 2, 3) 9 µm × 5 µm × 1 µm chunk, thinning window of 3 µm × 3 µm on silicon semiconductor samples
Endpoint control	Continuous SEM imaging, simultaneously with FIB milling, and on-the-fly fine adjustment of milling for manual endpoint control

* Digital resolution (deconvoluted)

** Tandem deceleration (TD) – stage biasing

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