ZER0K NANOTECH

Vendor Tutorial featuring FIB:RETRO and SIMS:ZERO

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Tech Status:
Low Temperature Ion Source (LoTIS)

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LoTIS is a new Cs^+ ion source

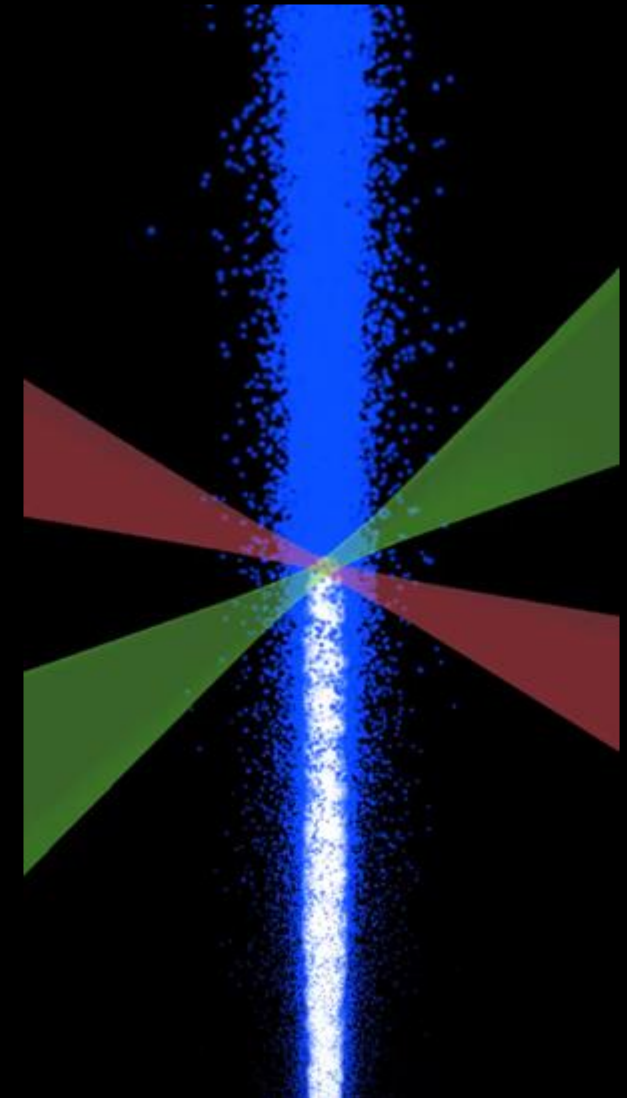
A LoTIS FIB instrument has been built and tested

- Successful circuit edits on 10 nm node chips
- Imaging and milling demonstrations

LoTIS Beam Performance

- Demonstrated 2 nm spots with 1 pA, at 10 kV beam
- Provides currents up to 5 nA (so far)
- Performs well at low-energy
- Yields large numbers of secondary ions

Available in FIB:RETRO and SIMS:ZERO variants



In-House FIB:RETRO

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Modified FEI/Micrion 'Vectra' platform

Equipped with process gases: Bromine, Tungsten, TMCTS, Oxygen

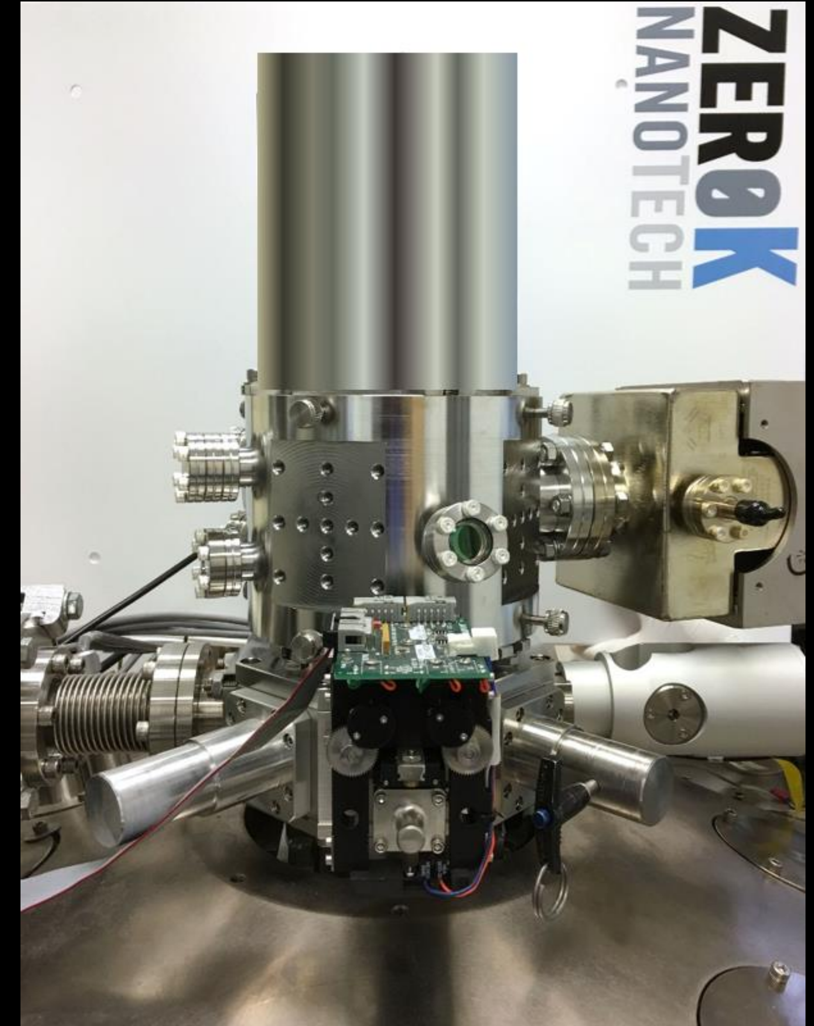
Demonstrated 2 nm spot sizes for few pA currents

- 2-3x better spot sizes and at 3x lower beam energy than LMIS

Provides currents up to several nA

Capable of generating secondary ion images as well
(no mass-resolving capability yet)

Performed 10nm circuit edits with Intel



LoTIS

5kV FIB imaging: LoTIS vs LMIS

ThermoFisher SCIENTIFIC

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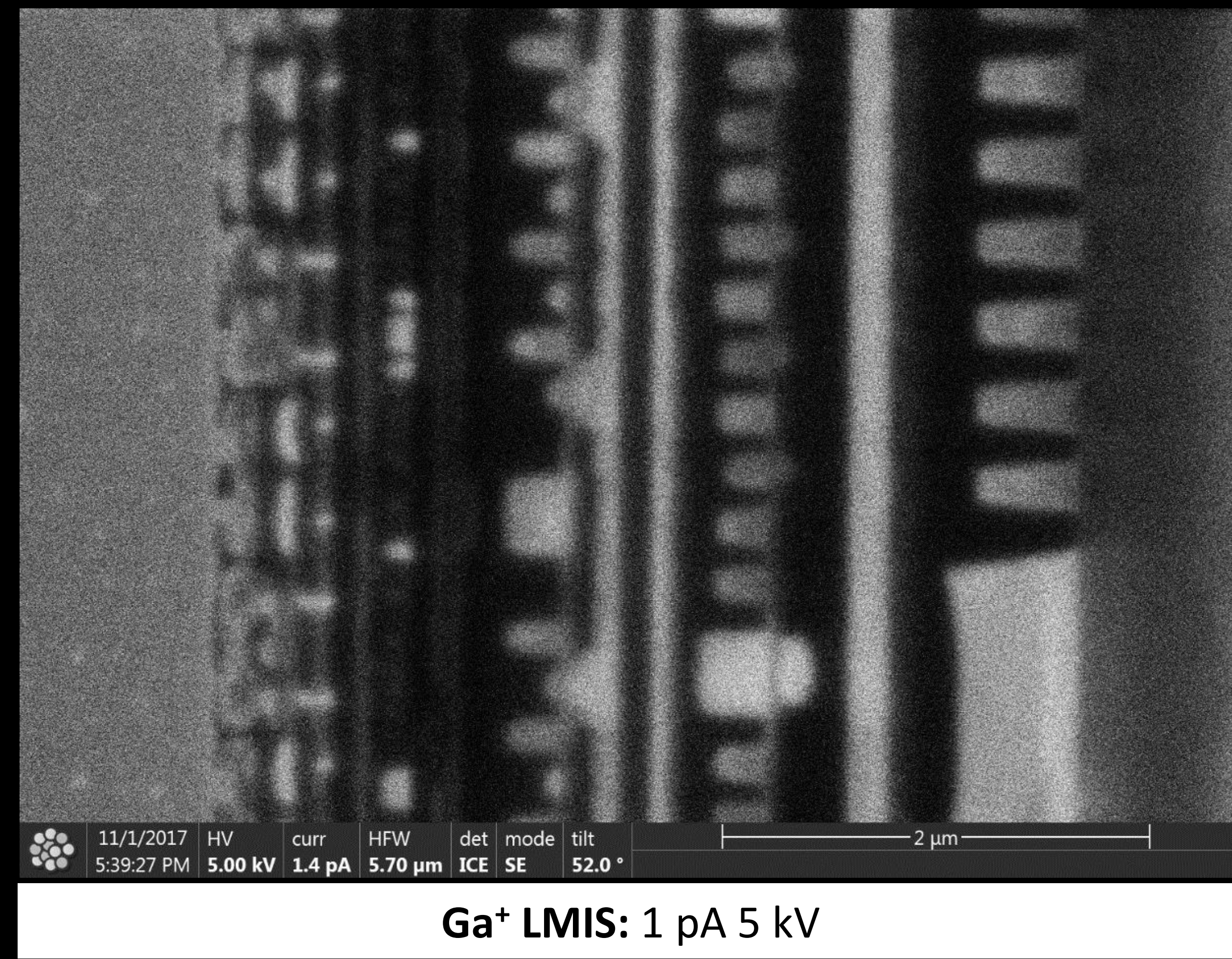
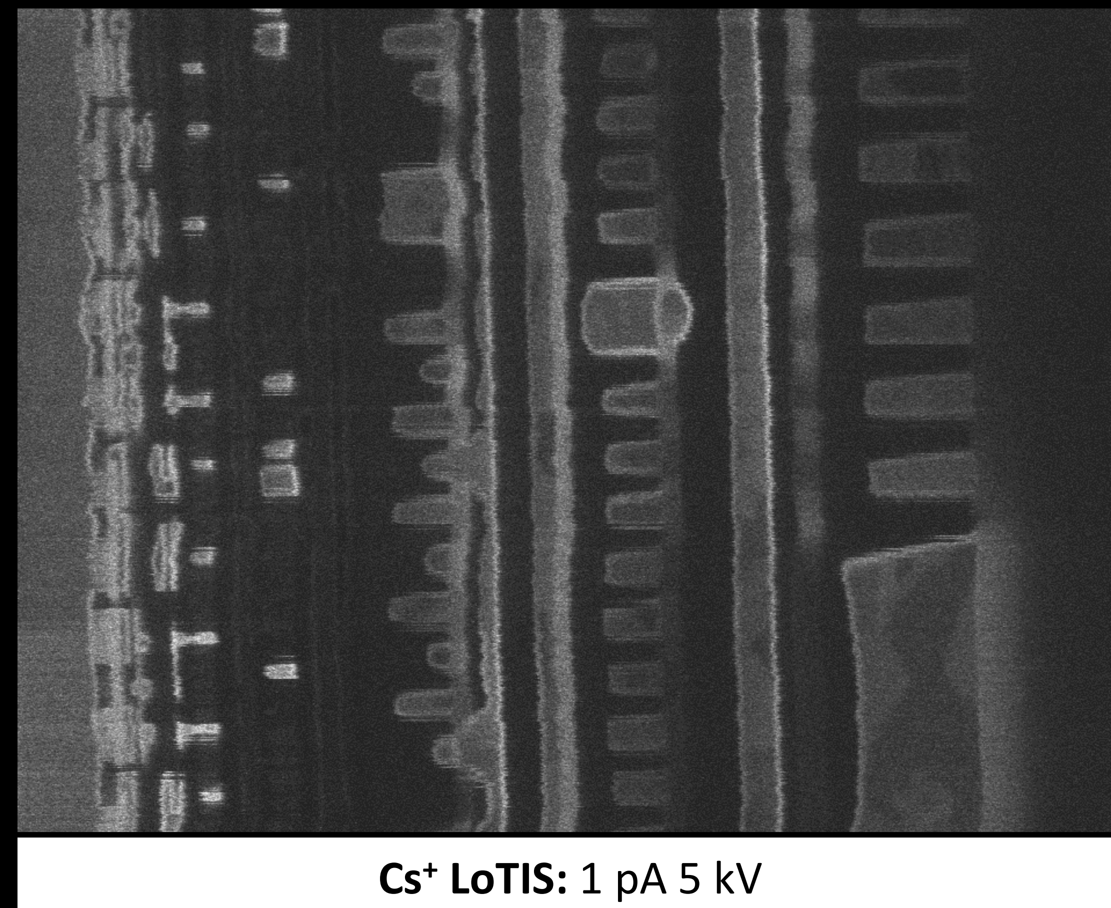


Ga^+ LMIS: 1 pA 5 kV



Cs^+ LoTIS: 1 pA 5 kV

Easily seen channeling contrast in LoTIS image.
Improved resolution at low energy (LoTIS: ~3-4 nm)

Secondary Electron, Ion Images

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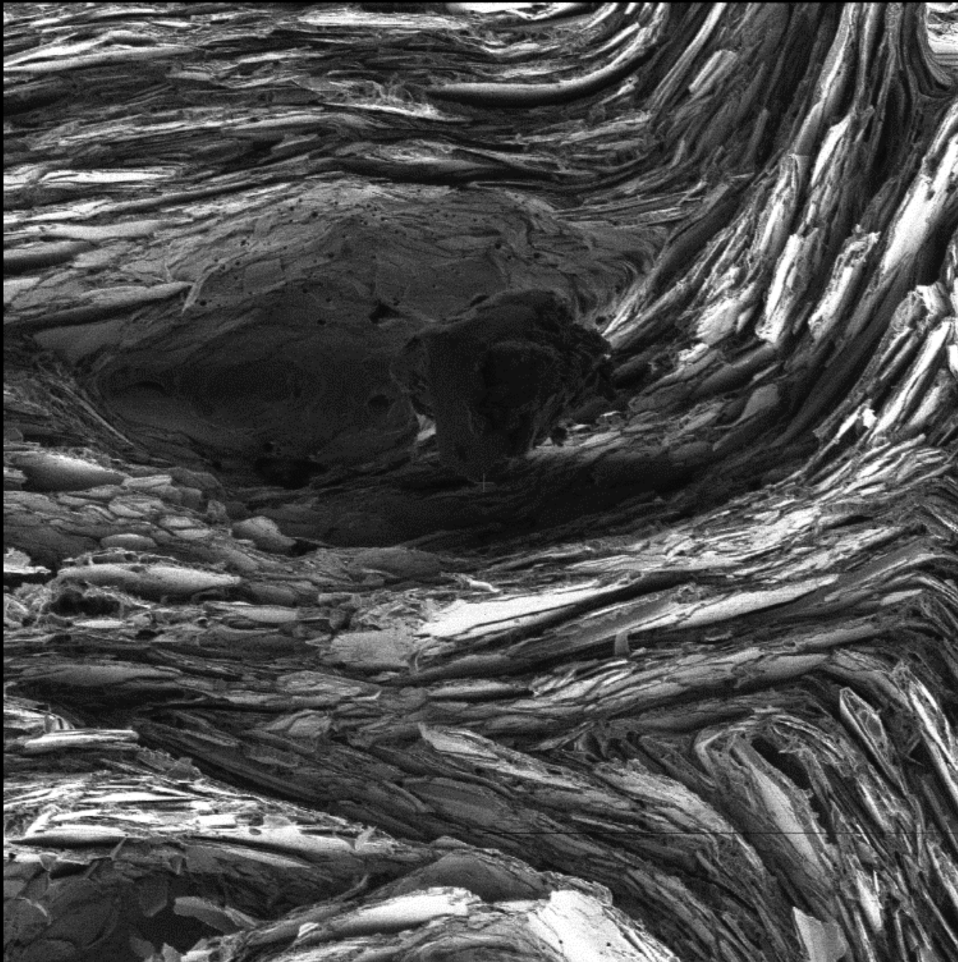

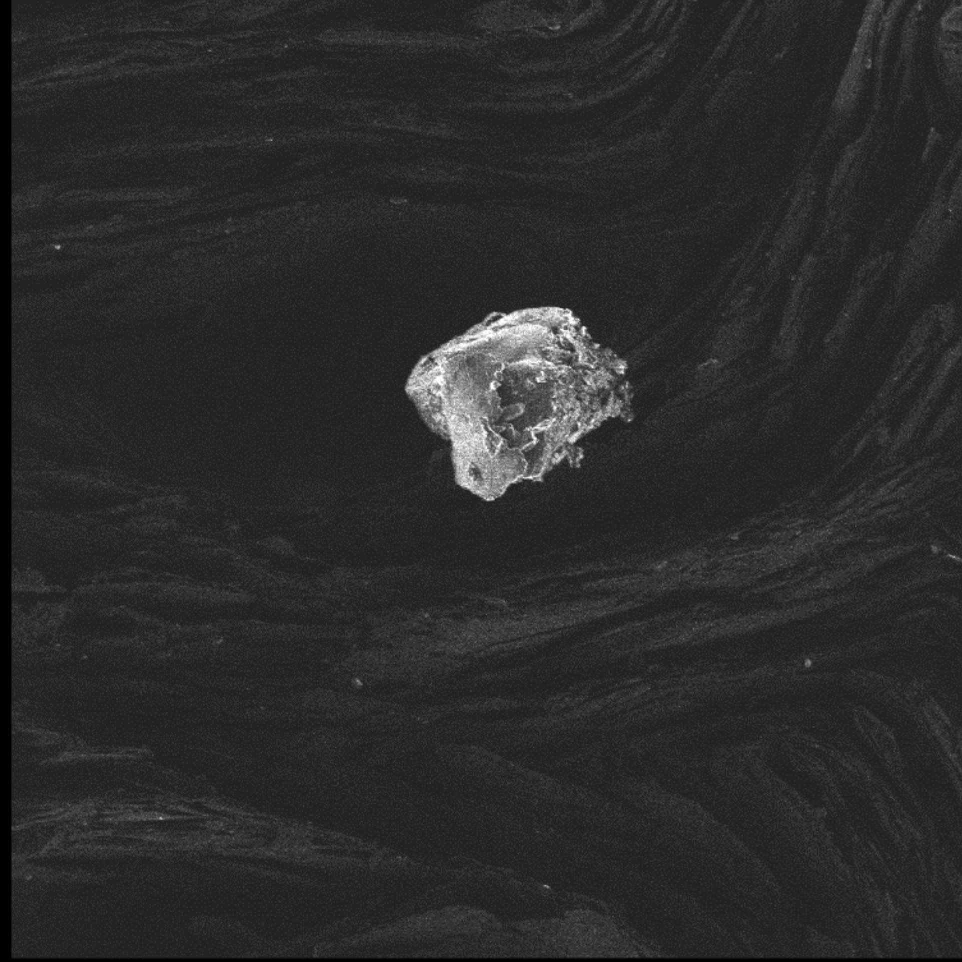

Pencil lead, 20 um FOV. Comparison of secondary electron (left) and secondary ion modalities (right).

Graphite has a low sputter rate, while the dust particle has a high sputter rate and/or high yield of positive ions.

FIB:RETRO Impacts

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Features

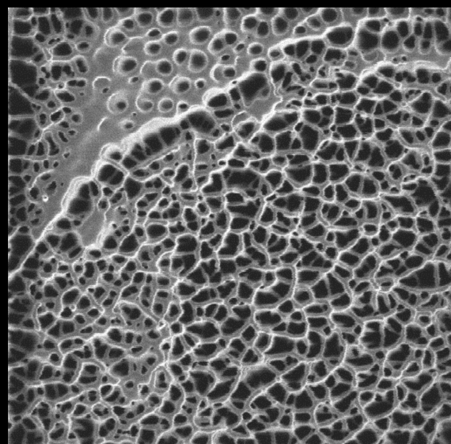
- Cs+ beam with 2 nm resolution
- Superior performance at low beam energy
- 10+ nA beam current
- Compatible with most ion beam columns & accessories

Benefits

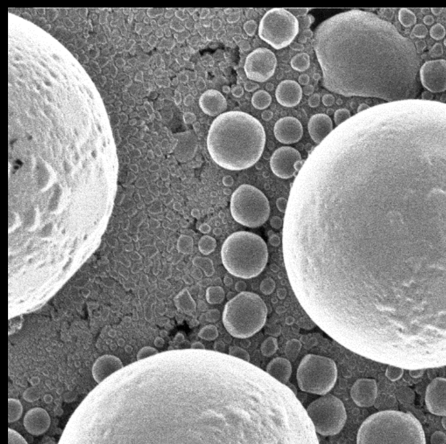
- Machine with higher precision than with Ga+
- Explore new applications with unprecedented performance
- Utilize currents up to several nA to handle a variety of tasks
- Extract additional value from existing capital equipment

Best Applications

- Nanomachining
- Circuit-Edit
- Low-invasiveness milling

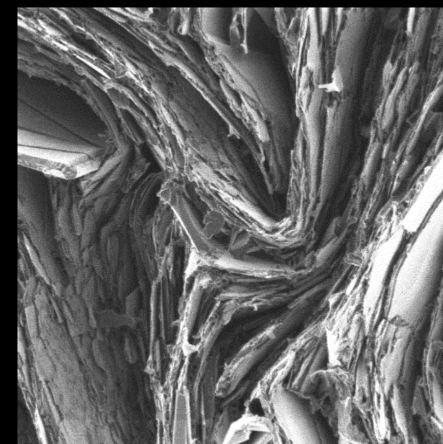


Fixed Cell Etch, 5 µm

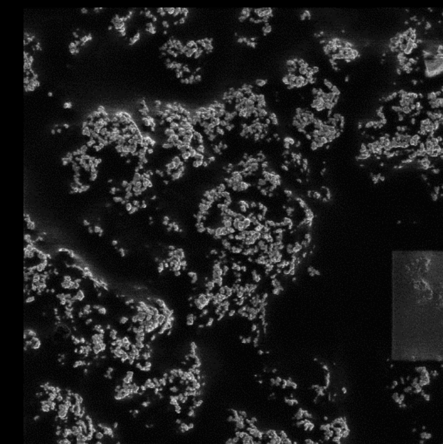


Tin Spheres 10 µm FOV

	Interaction		Focus
	Depth (nm)	Straggle (nm)	Spot Size (nm)
Ga+ (30 kV)	28	10	5
Cs+ (10 kV)	12	3.5	< 2

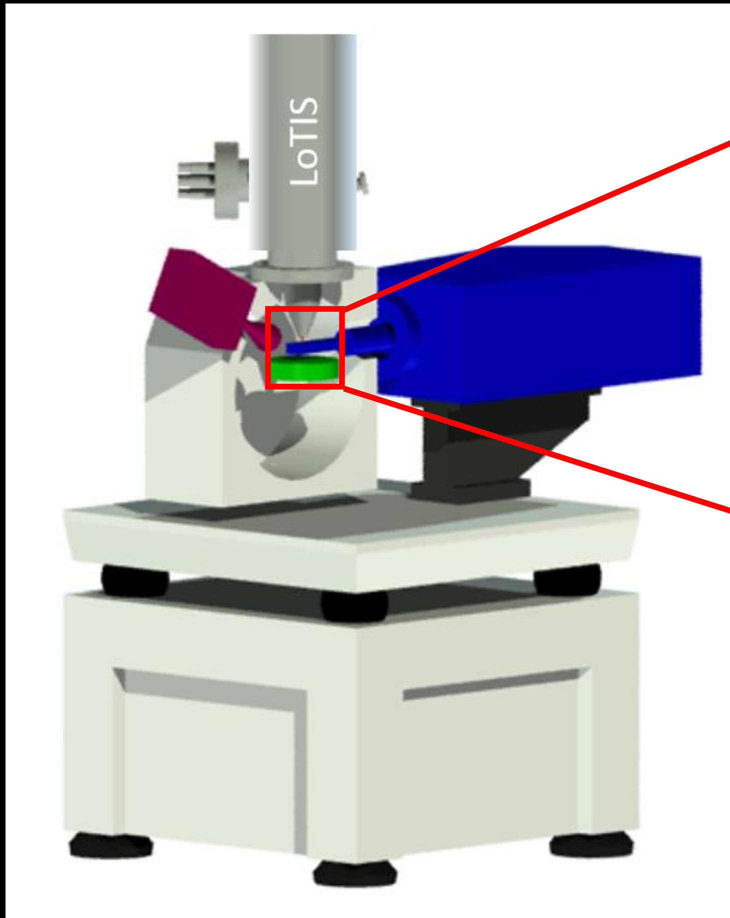


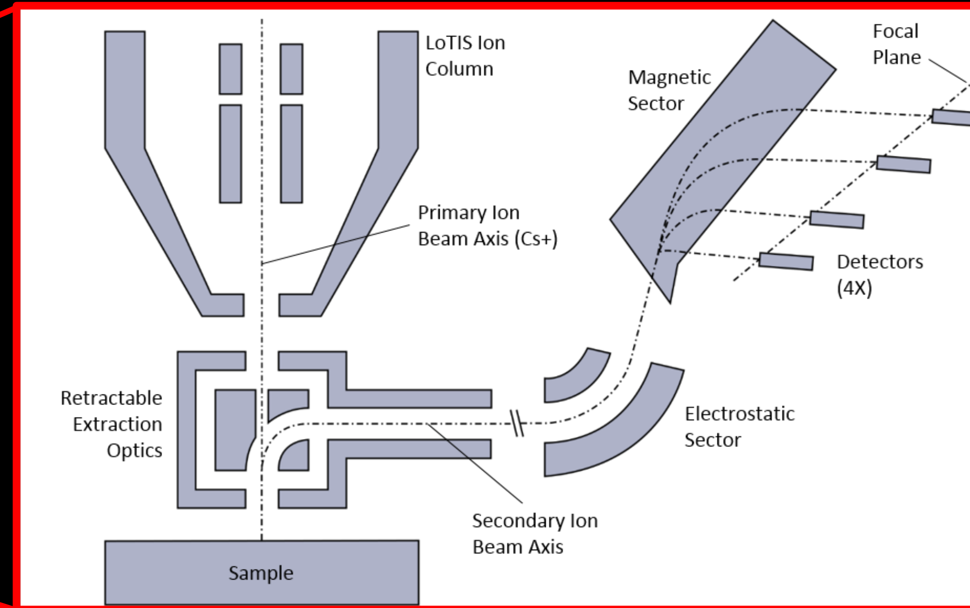
Graphite, 10 µm



Electrodag, 10 µm FOV

SIMS:ZERO Concept





Single-Beam FIB with high-efficiency collection of secondary ions

Multiple imaging modalities:

- Electrons, +Ions, -Ions

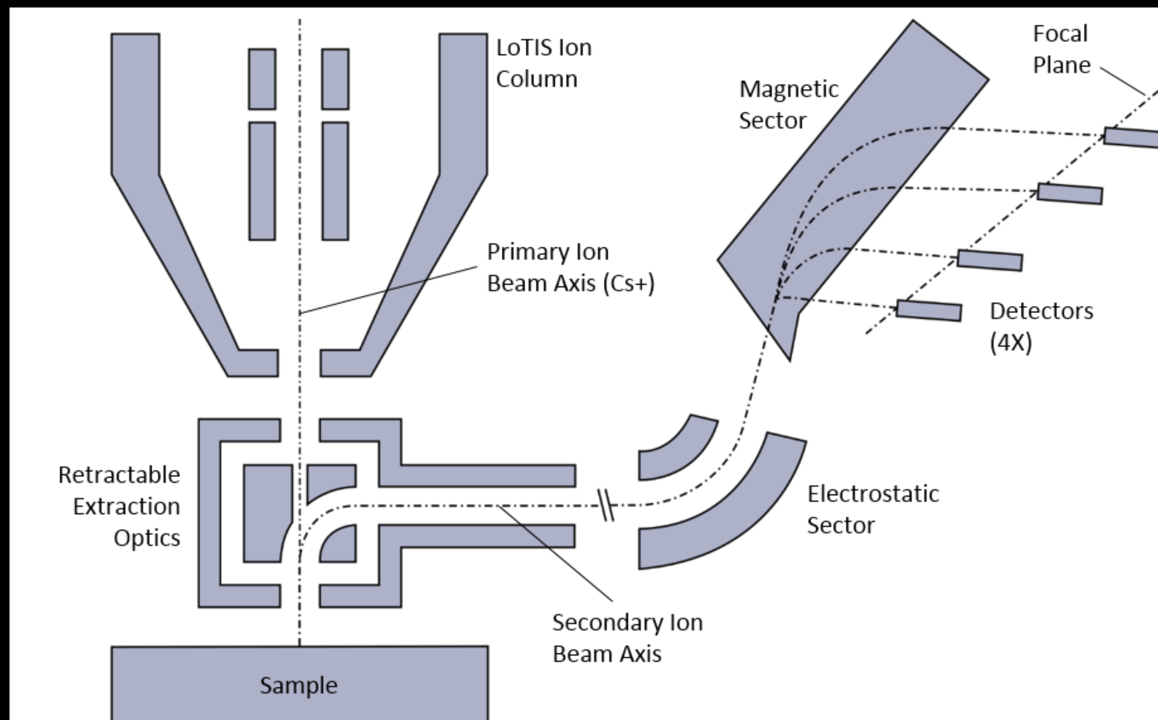
Superior performance

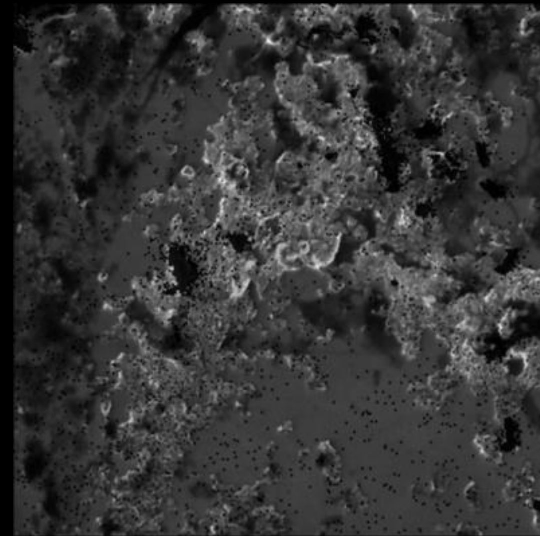
- 100x more current/area
- 10x better resolution

SIMS:ZERO Concept

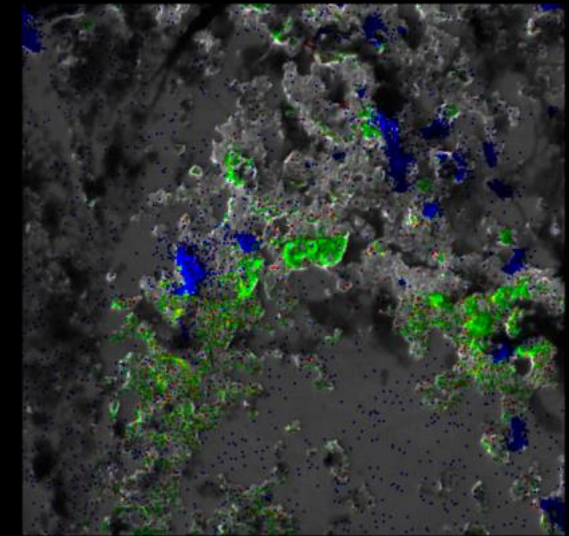
Secondary ion information reveals the sample's rich structure

Replaces EDX analysis





Secondary Electrons



Secondary Ions

SIMS:ZERO Application Example:
In-situ FIB Deposition Stoichiometry

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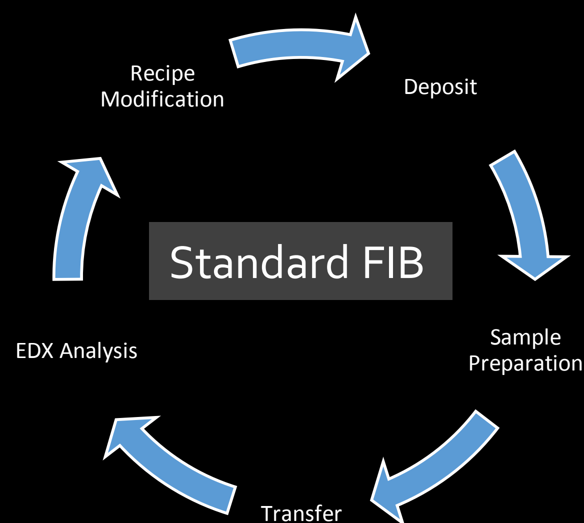
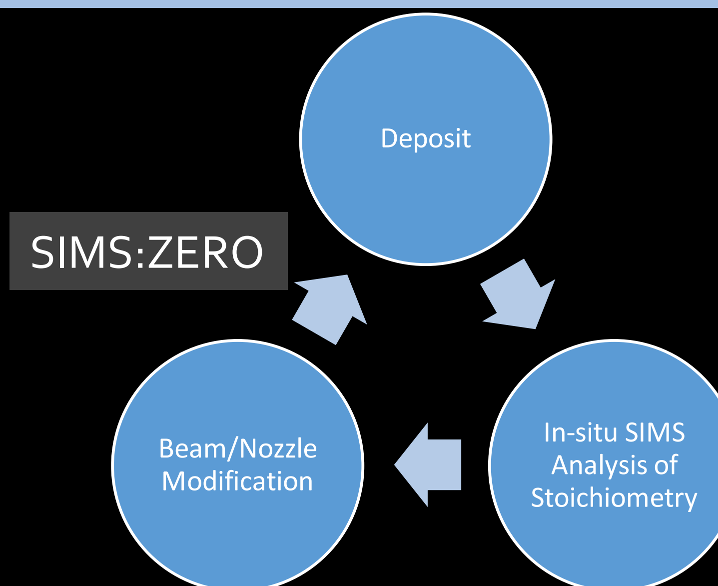
- Gas-assisted deposition of conductors and insulators is used in a variety of applications
- The deposition quality (e.g.: resistivity/conductivity) can be optimized through small adjustments to the ion beam and gas flow parameters
- Optimization of recipes is a time-consuming process because it requires EDX analysis and four-point probe measurements
- Yield could be improved by monitoring stoichiometry **at the time of deposition** to ensure consistency
- SIMS:ZERO enables a tight feedback loop for rapid optimization of recipes and stoichiometric monitoring during deposition





SIMS:ZERO Application Example:
Process Control with Secondary *Ions*

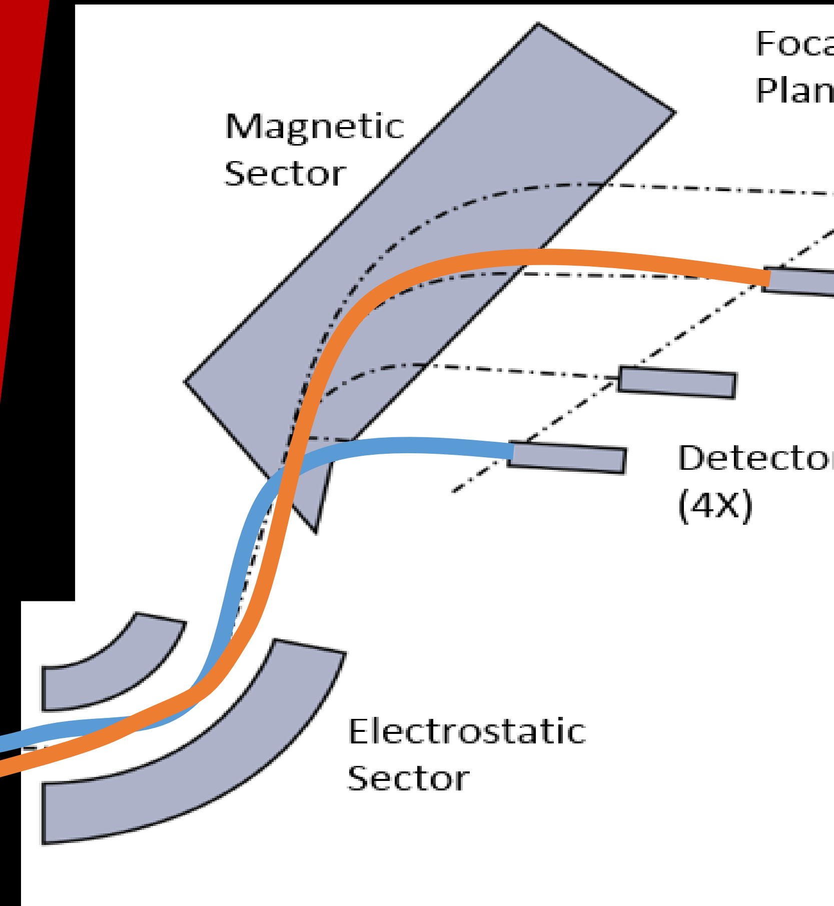
Endpointing: ceasing milling precisely when the desired target material has been removed.

Today, mill-stops often achieved by monitoring a secondary electron signal and stopping milling on threshold value crossings

SIMS:ZERO method not require a fortuitous correspondence between material and secondary electron yield

Multiple “binary” ion signals to feed into mill stop condition

LoTIS
Ion
Beam



Stop Target

Bulk Material

SIMS:ZERO Impacts

Features

- Cs^+ beam with nanometer resolution
- Full-featured FIB system
- Highest-Resolution SIMS
- Parallel readout of all masses

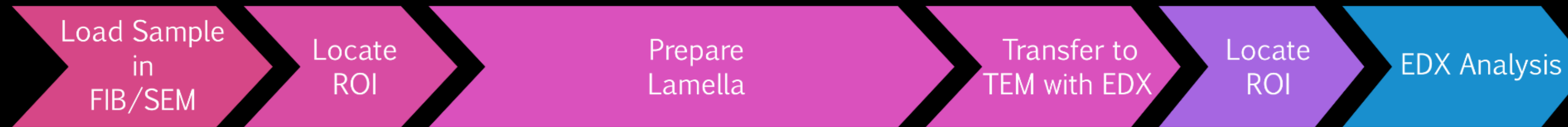
Benefits

- Obtain EDX-like spectra… without lamella Prep!
- Gather SIMS data 100x faster
- Machine with higher precision
- Endpoint using mass spectra
- SIMS process control during nanofabrication

Industry

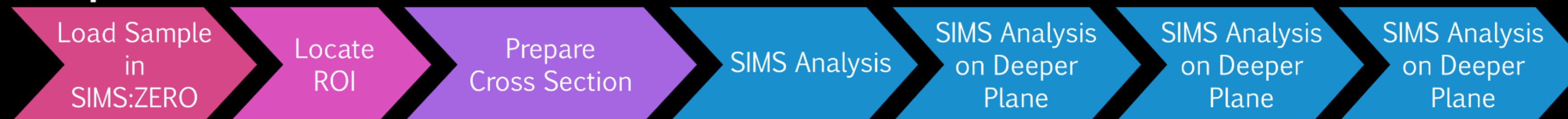
- Semi
- Semi/Bio/Energy
- Semi/Various
- Semi
- Various

Existing Workflow - Thin Sample EDX



Only one shot : analysis limited to a single depth

Optimized Workflow - SIMS:ZERO



More Information

Visit:

https://www.zeroK.com

Open Access Publications:

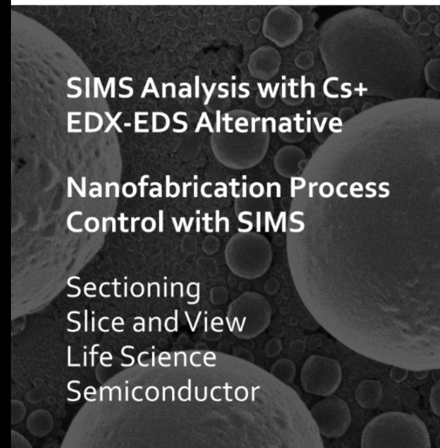
https://doi.org/10.1088/2399-1984/aa6a48
https://doi.org/10.1063/1.4816248
https://doi.org/10.1088/1367-2630/13/10/103035

Summary

Nano
Machining
Analysis

High Resolution SIMS + FIB

SIMS:ZERO



Cs+ ion beam with nanometer resolution	Obtain EDX-like spectra... without lamella prep!
10+ nA beam current	Gather SIMS data 100X faster
Full-featured FIB system	Machine with higher precision
Highest resolution SIMS	Endpoint using mass spectra
Parallel readout of all masses	Nanofabrication process control using SIMS

FIB:RETRO

Low Temperature Ion Source technology available as a retrofit to existing FIB instrumentation

Cs+ ion source retrofit for high performance FIB	Smaller spot size & damage volume than Ga+
Li+ ion source for battery research	Compatible with most FIB columns