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TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

NSC Nano Structuring Center

A demonstration of milling and imaging with the new

Cs^+ LoTIS-FIB

[Low Temperature Ion Source (LoTIS)]

www.zeroK.com

Data Courtesy of: T Loeber, S Wolffe, and B. Laegel of T.U. Kaiserslautern

Introduction

These slides compare the milling and imaging performance of zeroK's new ion source technology (Cs^+ LoTIS) to the Ga^+ LMIS used in so many instruments today

Images labeled "SEM" and "Ga^+ Ion" were acquired using a Thermo Fischer (FEI) Helios Dual Beam run by researchers from TU Kaiserslautern

"Cs+ LoTIS" images were acquired with zeroK's LoTIS-FIB system

- FIB systems incorporating this new ion source technology are now available
- All LoTIS images and milling were performed with a 10 kV beam energy with a few pA current (except as noted)

Depth of Focus Comparison

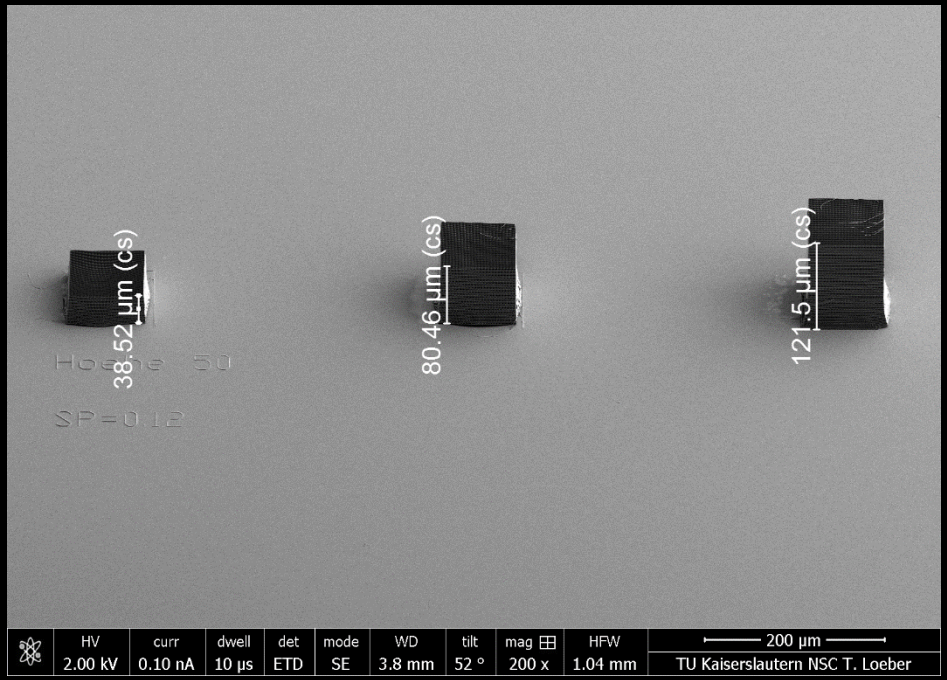
(Results on slides that follow)

“Wood Pile” Nanostructures

- Heights: 40 µm, 80 µm, 120 µm
- In the following slides we acquire an image containing both the top and bottom of such the 120 µm (tallest) structure
- We can compare the depth of focus of various beams by comparing the ‘blurriness’ of the top of the structure

A better depth of focus aids in the milling and imaging of ‘deep’ or ’tall’ structures.

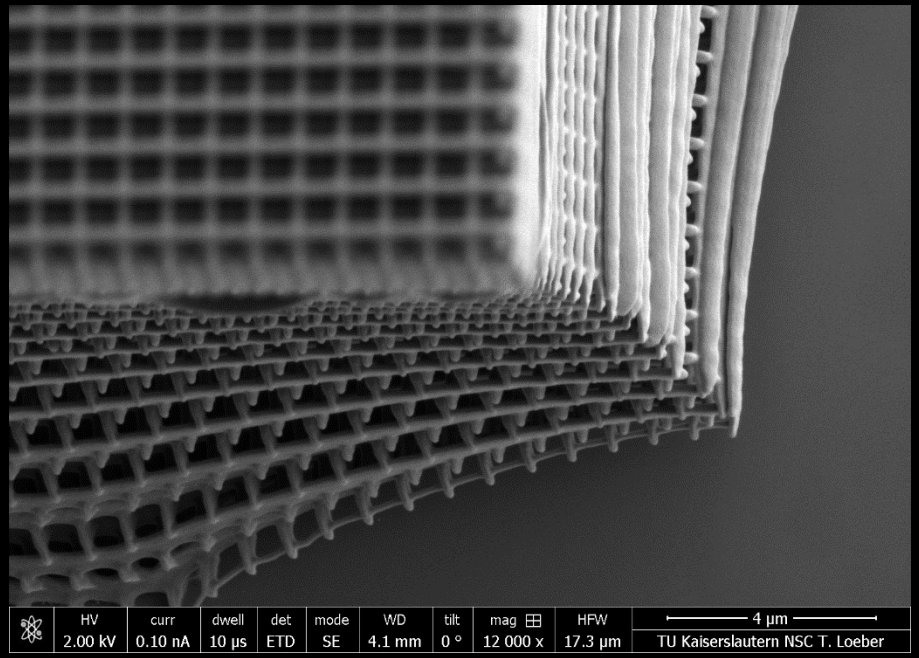
FEI: SEM image



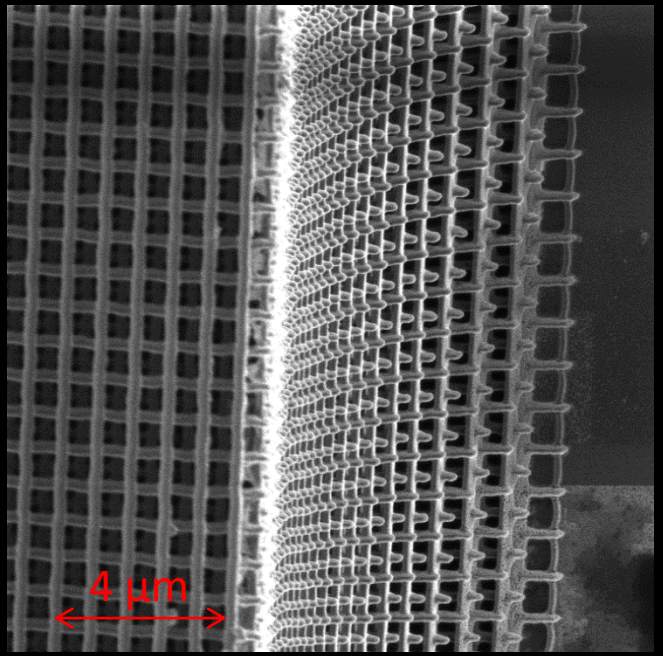
Depth of Focus Comparison

→LoTIS depth of focus substantially better than SEM

SEM



Cs+ LoTIS



“Wood Pile” Height 120 µm

Depth of Focus Comparison

→LoTIS depth of focus substantially better than Ga

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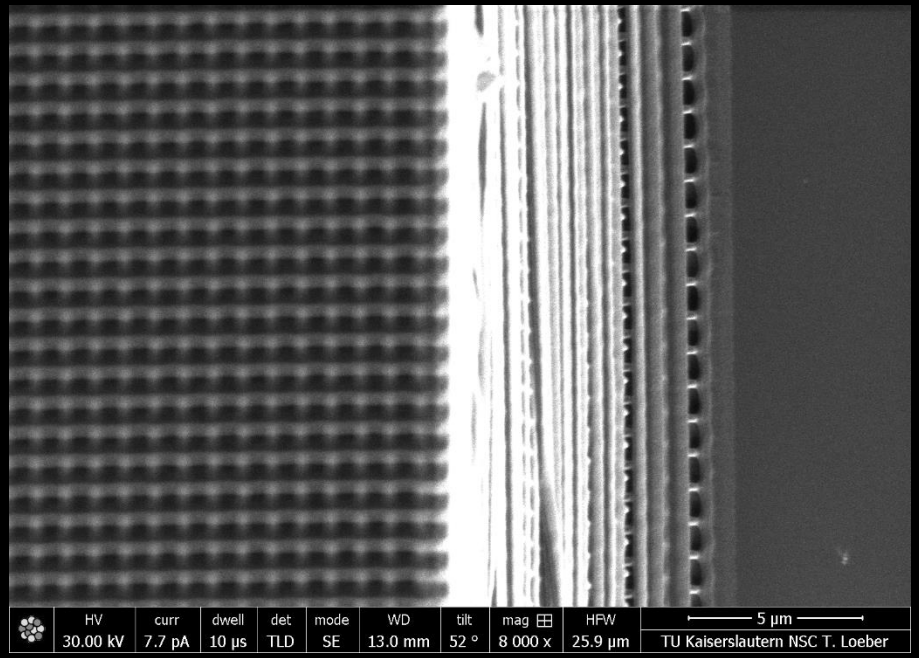
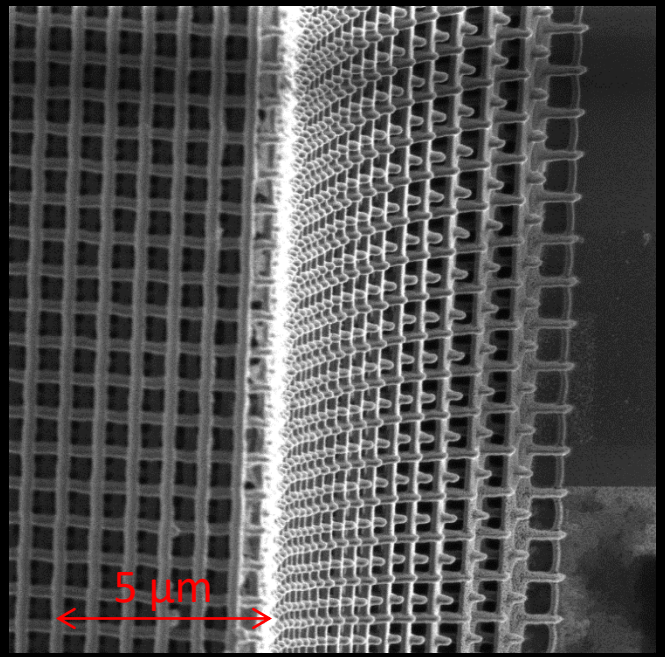
Ga^+ LMIS



Cs^+ LoTIS



"Wood Pile" Height 120 µm

Cs^+ LoTIS Interaction Volume
(Theoretical/SRIM Calculations)

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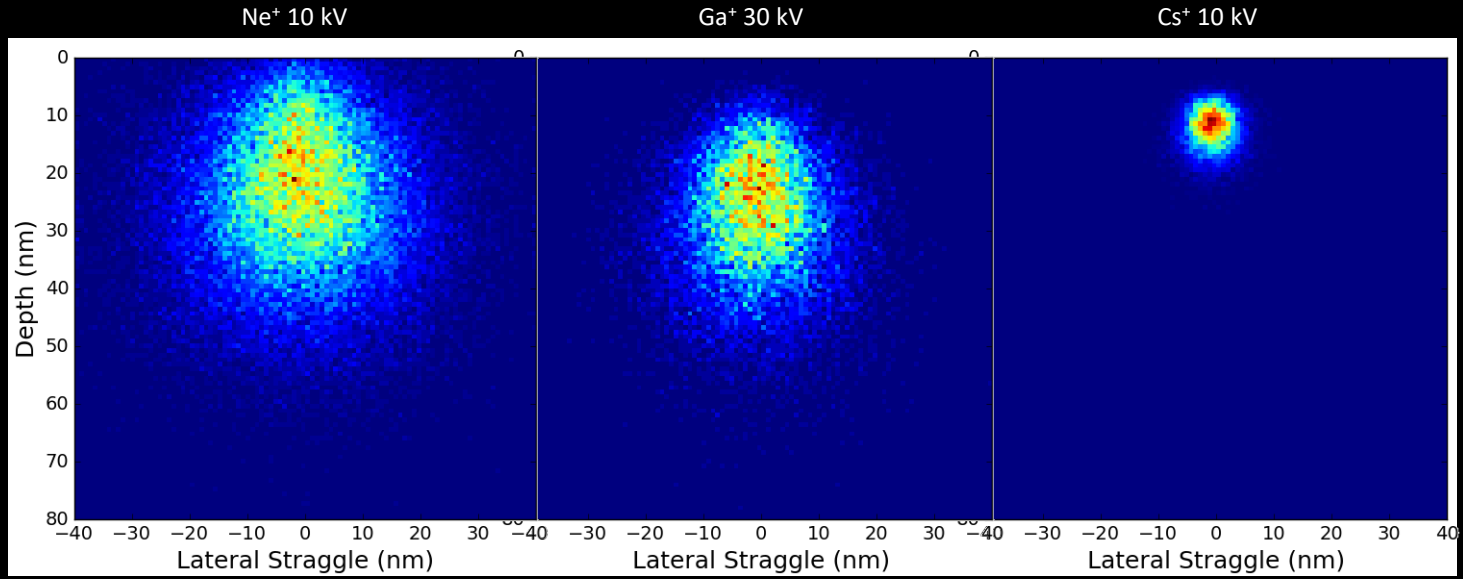
Comparison of where ion finally resides for three typical beams into Si

Cs^+ has significantly reduced straggle and implant depth than other beams

From this: LoTIS is expected to improve milling performance, and leave less residual material from the primary beam in milled structures



Cs^+ LoTIS Theoretical Milling Rates

→Similar to Ga, better then He/Ne

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Milling rate of 10 kV Cs^+ LoTIS about 15% lower than 30 kV Ga^+ for Si

Cs^+ LoTIS milling rates 90% higher than Ne^+

LoTIS Gas chemistry-driven processes:

- XeF_2 tests shows similar etch enhancement to Ga^+
- Gas-assisted deposition of insulators (TMCTS) and conductors (Tungsten) shown to work

Ne 10 kV	Ga 30 kV	Cs 10 kV
1.00-1.38 at/ion	2.20-2.40 at/ion	1.90-2.15 at/ion

Metal Grain Contrast

→LoTIS offers enhanced resolution and differing contrast

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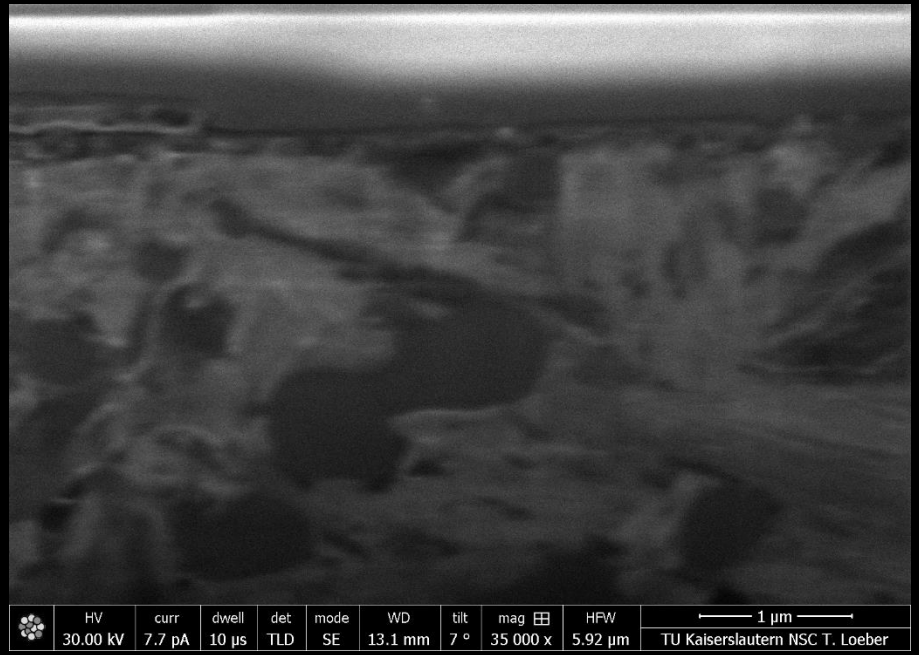
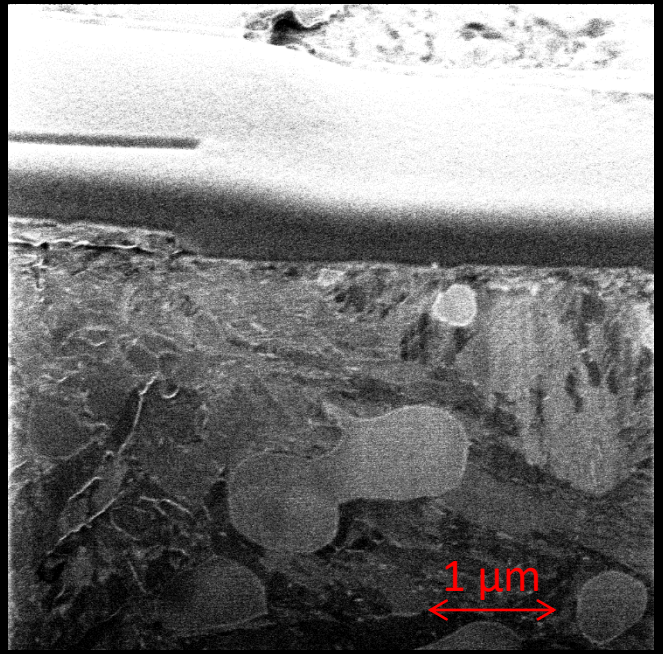
Ga^+ LMIS



Cs+ LoTIS



Metal Material Contrast:

Sample: P1369 GaAs wafer with GaAs and AlGaAs layers

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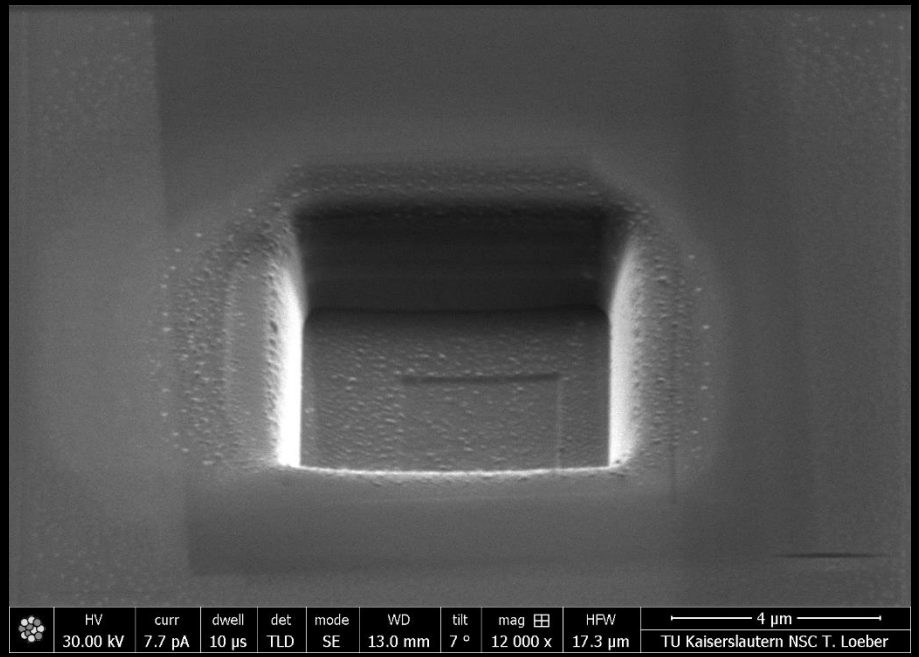
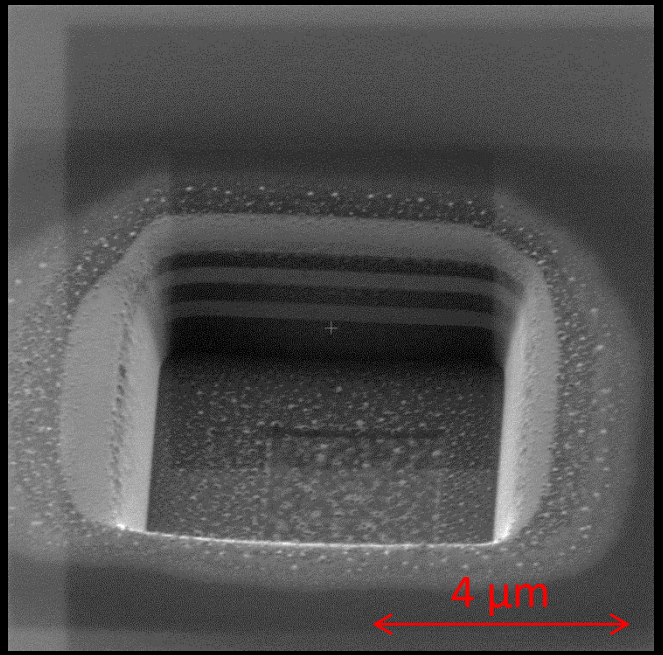
Ga^+ LMIS



Cs+ LoTIS



Setup: Sample was milled to depth using LoTIS (1 nA), then imaged with the beam indicated.
Cross section's are unpolished. This is a straight vertical sputter

Material Contrast:

→ Cs^+ LoTIS provides superior contrast

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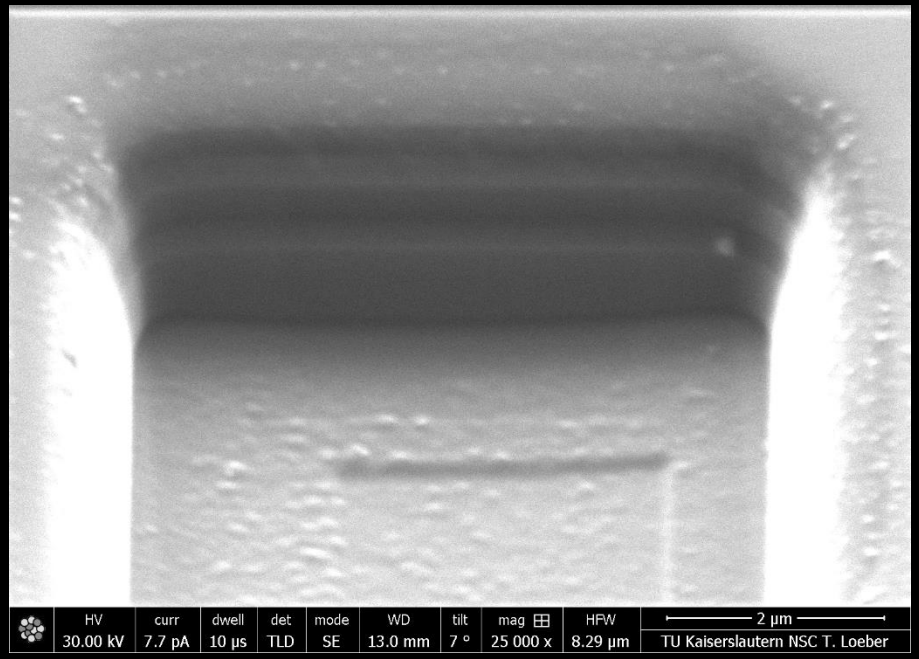
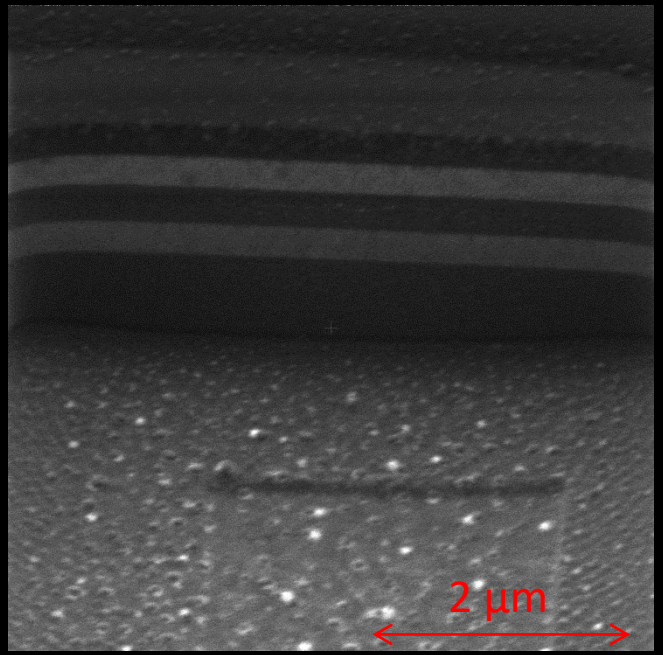
Ga^+ LMIS Image



Cs+ LoTIS Image



Sample was milled to depth using LoTIS, then imaged with the beam indicated.
Cross section's are unpolished. This is a straight vertical sputter

Material Contrast: GaAs and AlGaAs

→SEM Proves little/no contract between these materials

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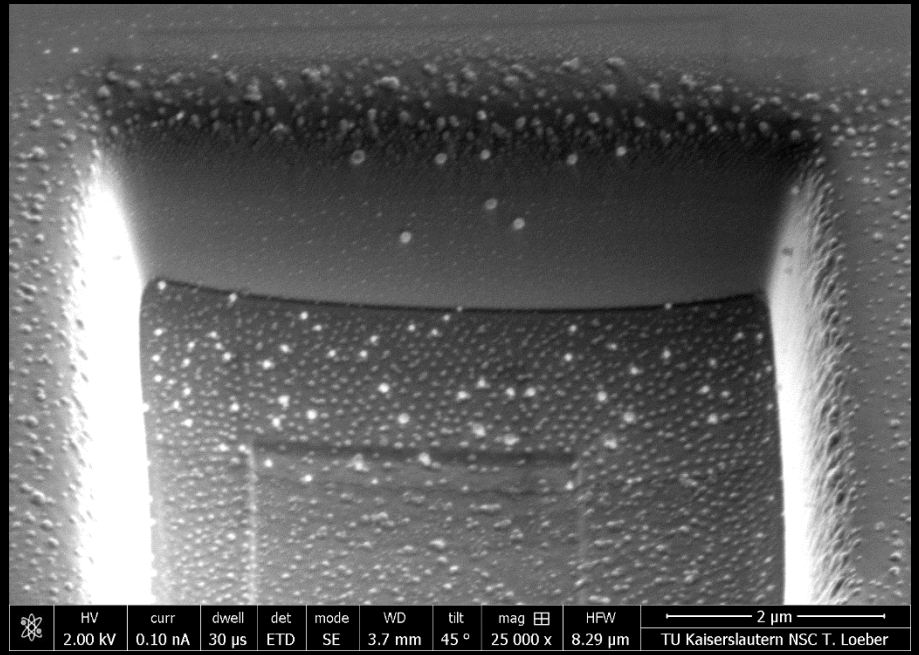
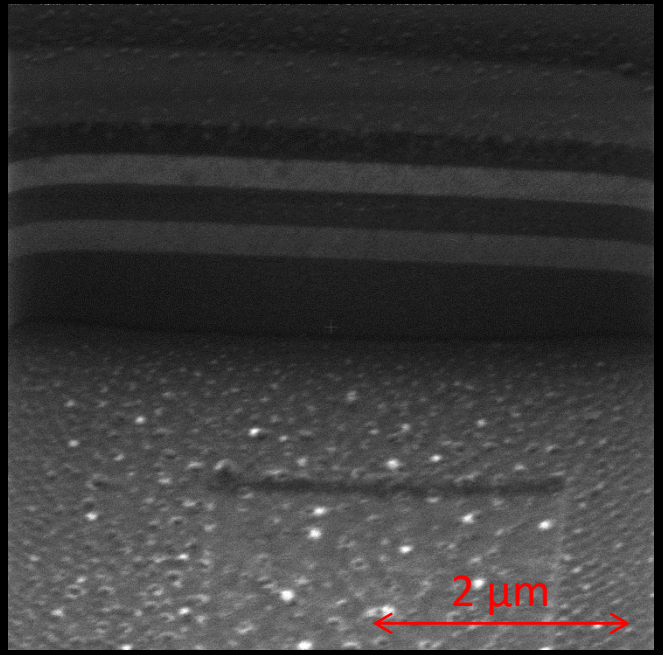
SEM



Cs+ LoTIS



Milling Homogeneity: 150 nm Au on Si

→Cs^+ LoTIS proves even touchdown

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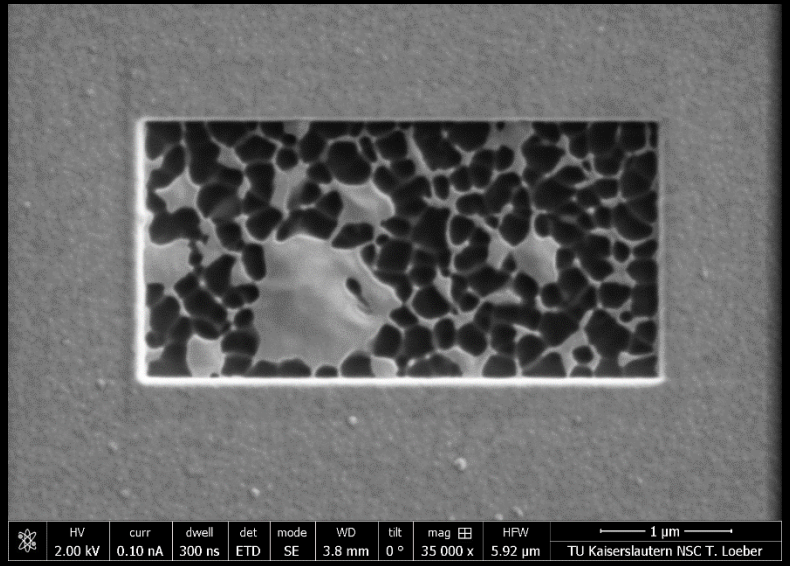
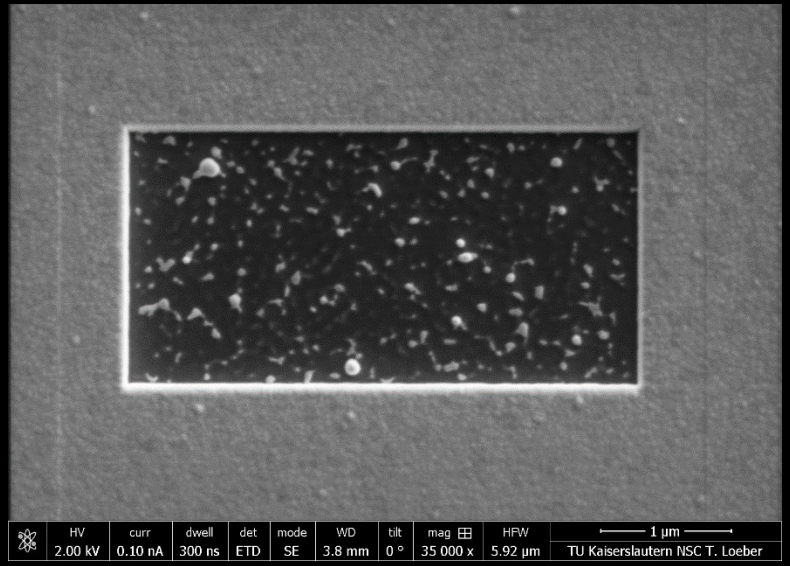
Milled with Ga^+ LMIS



Milled with Cs^+ LoTIS



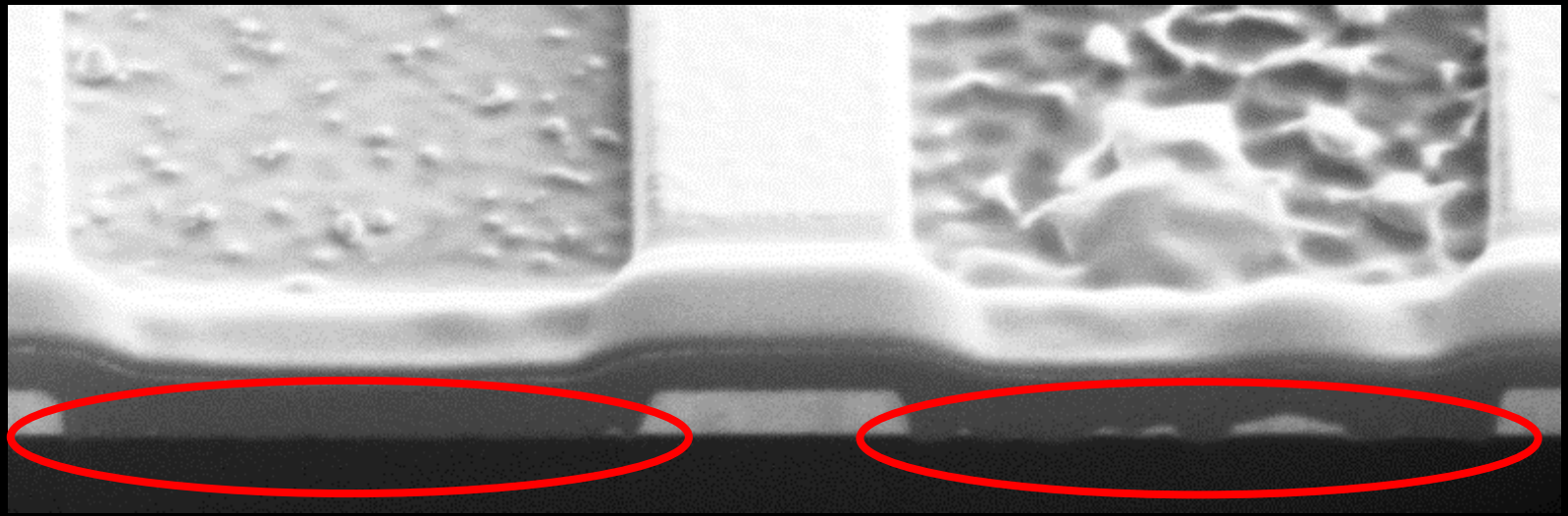
- milled rectangle ‘almost through’ the Au layer
- milling time Ga and Cs almost the same

Milling Homogeneity: 150 nm Au on Si

(Cross-Section of previous slide)

Milled with Cs^+ LoTIS

Milled with Ga^+



Cs^+ LoTIS proves near-complete sputtering of Au layer with much less sputtering of Si layer beneath than Ga^+

Milling Accuracy: 110 nm Au on Si

→ LoTIS provides clean mill boxes with sharp corners

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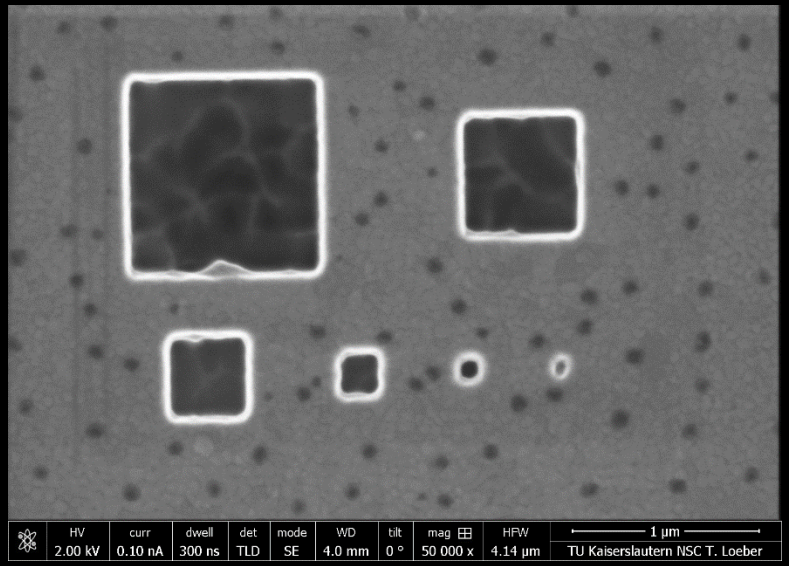
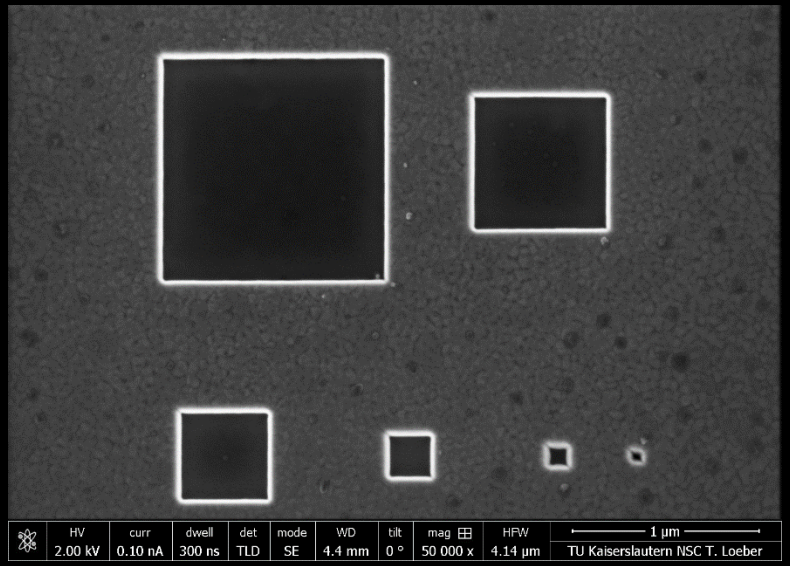
Milled with Ga^+ LMIS



Milled with Cs^+ LoTIS



- squares with 1, 0.6, 0.4, 0.2, 0.1 and 0.05 µm length
- milled through the Au layer
- milling time Ga and Cs almost the same

Milling Accuracy: 110 nm Au on Si

→ LoTIS Can mill very narrow trenches

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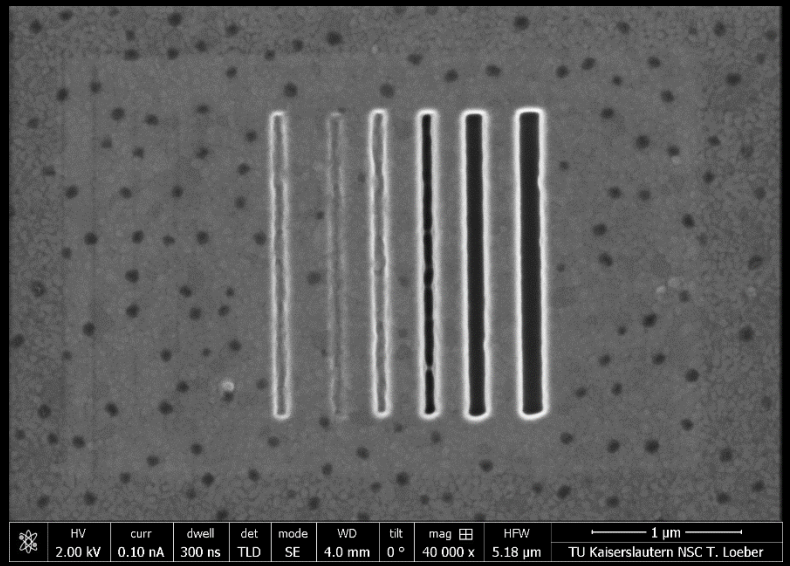
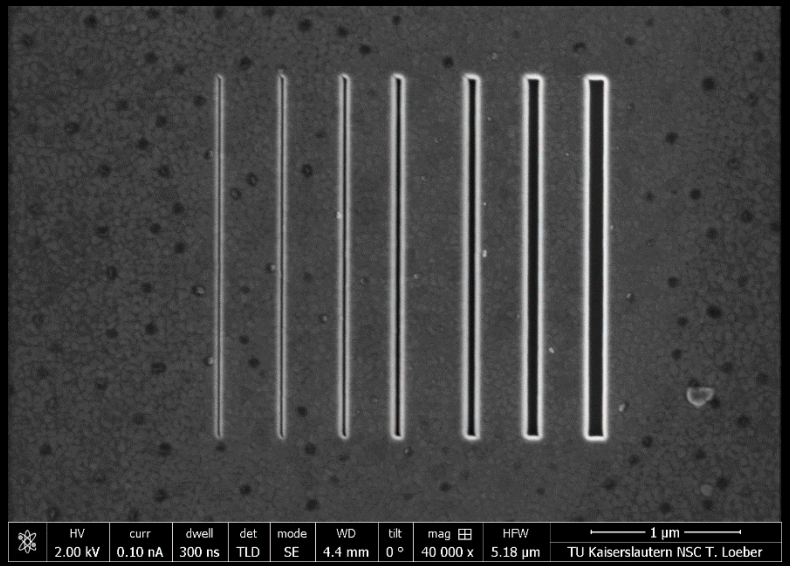
Milled with Ga^+ LMIS



Milled with Cs^+ LoTIS

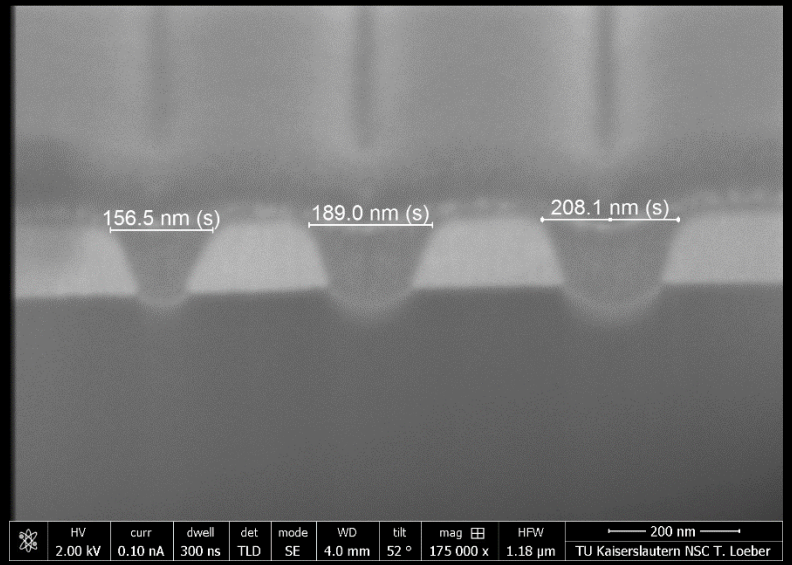


- lines with “single pixel”, 8 nm, 20 nm, 40 nm, 80 nm, and 100 nm width
- milling dose kept constant for all lines (except SPL)
- milling time Ga and Cs almost the same

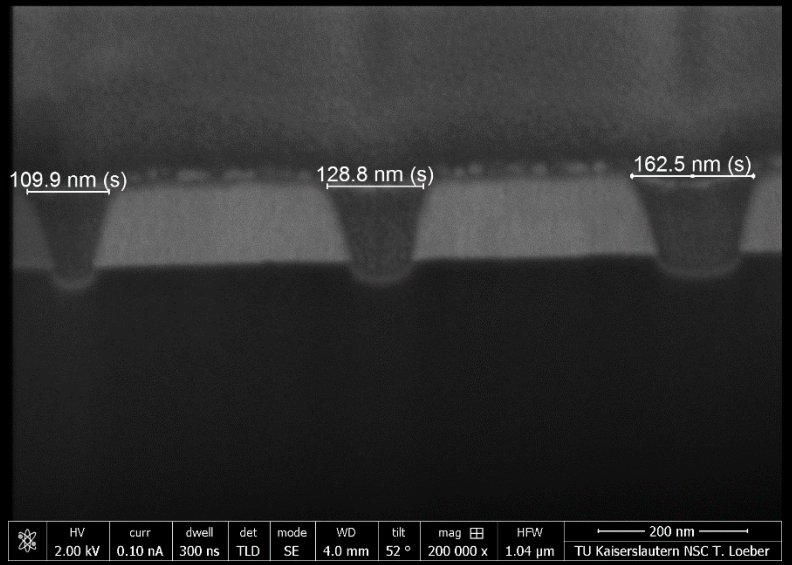
Milling Accuracy: 110 nm Au on Si

(cross section of trench from previous slide)

Milled with Ga^+ LMIS



Milled with Cs^+ LoTIS



LoTIS Milled trenches:

- Steeper walls
- Less ‘rounding’ at top
- Less material mixing and cleaner interface at bottom