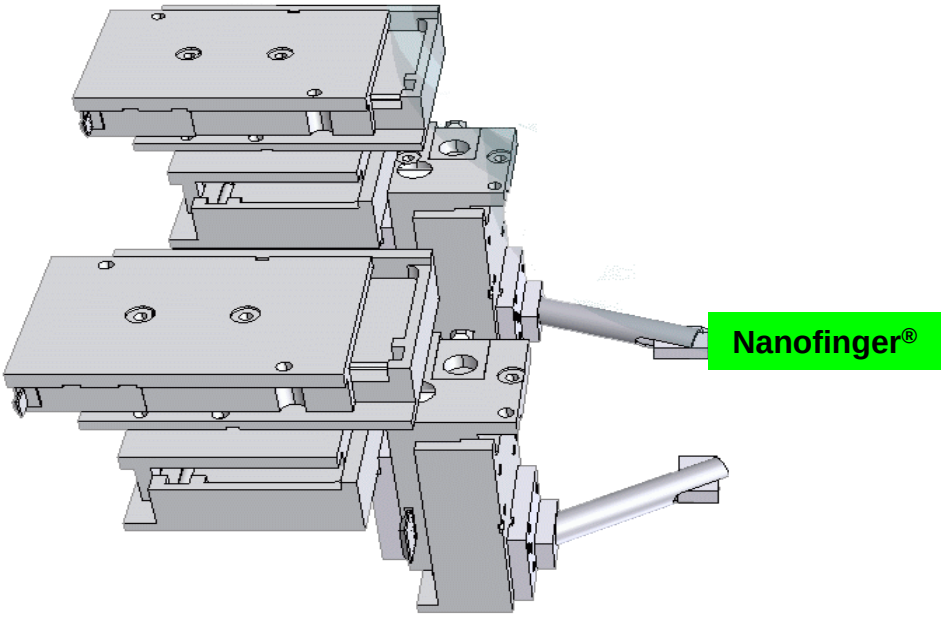
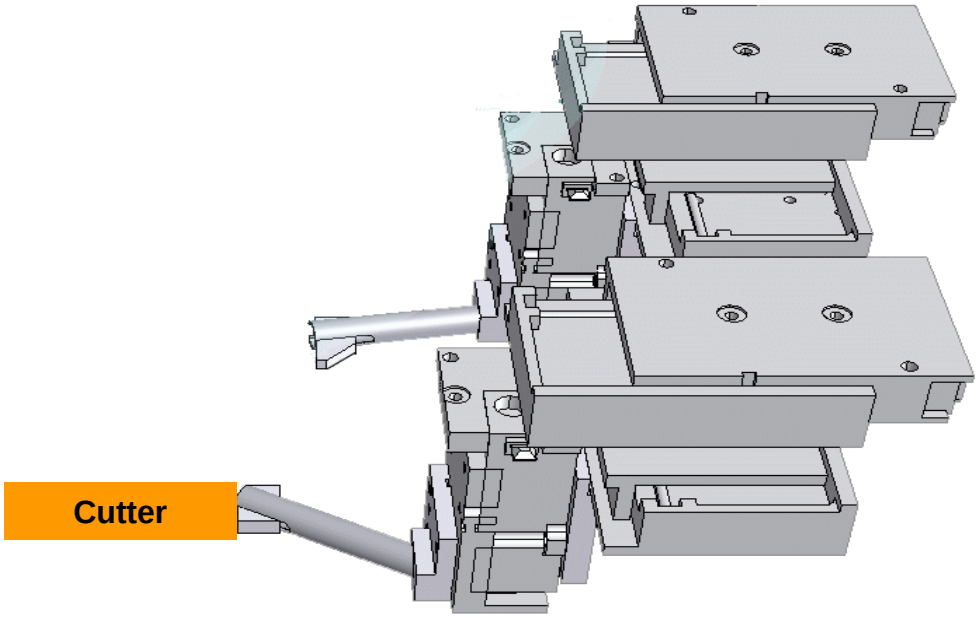
NanoCutting:

Nano-Cutting of structures inside SEM/FIB systems with the Nanoworkbench from Klocke Nanotechnik

NanoCutting

Nanoworkbench Configuration:





1. Nanomanipulator equipped with: 1D-Nanofinger® as Scout

2. Nanomanipulator equipped with: Cutting/Milling or Slicing tool (diamond or metal)

- Standard Software Package: Macro Executor, Live Image Positioning, Assistants, Sequencer

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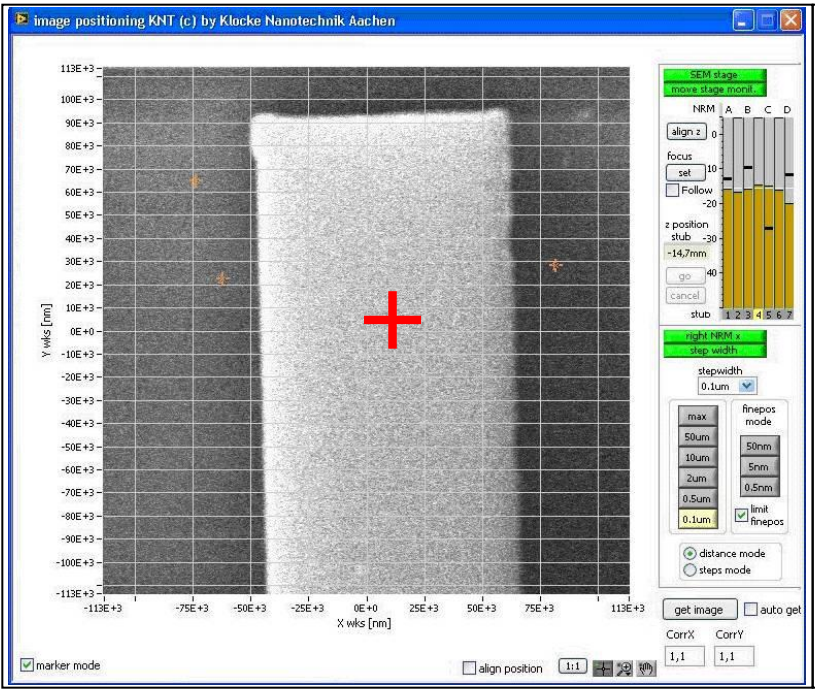
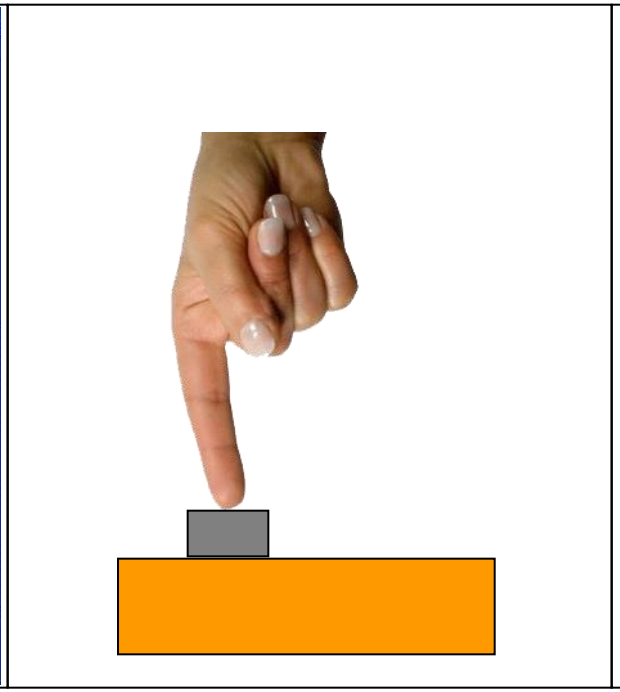
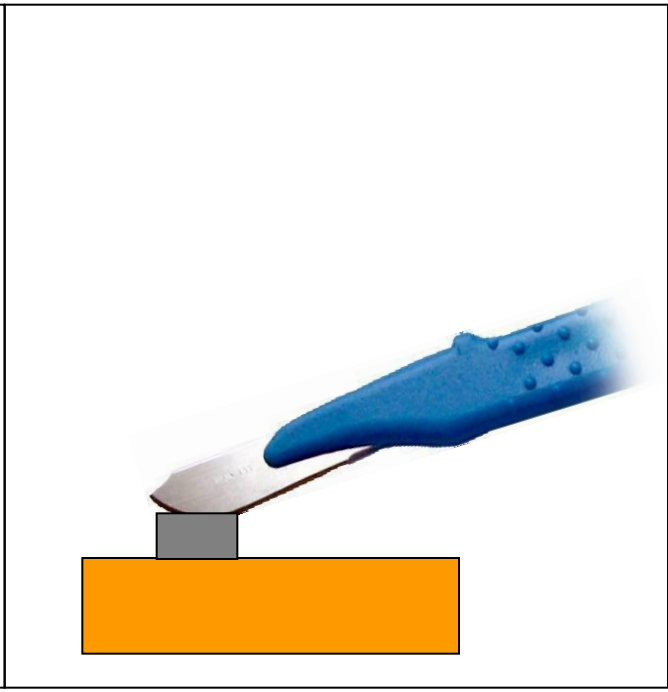
Operation Sequence







Live Image Positioning:

Select target, define structures

1D-Nanofinger®:

finds target

Cutter:

prepares structures

Cutting a conductor path on a semiconductor chip

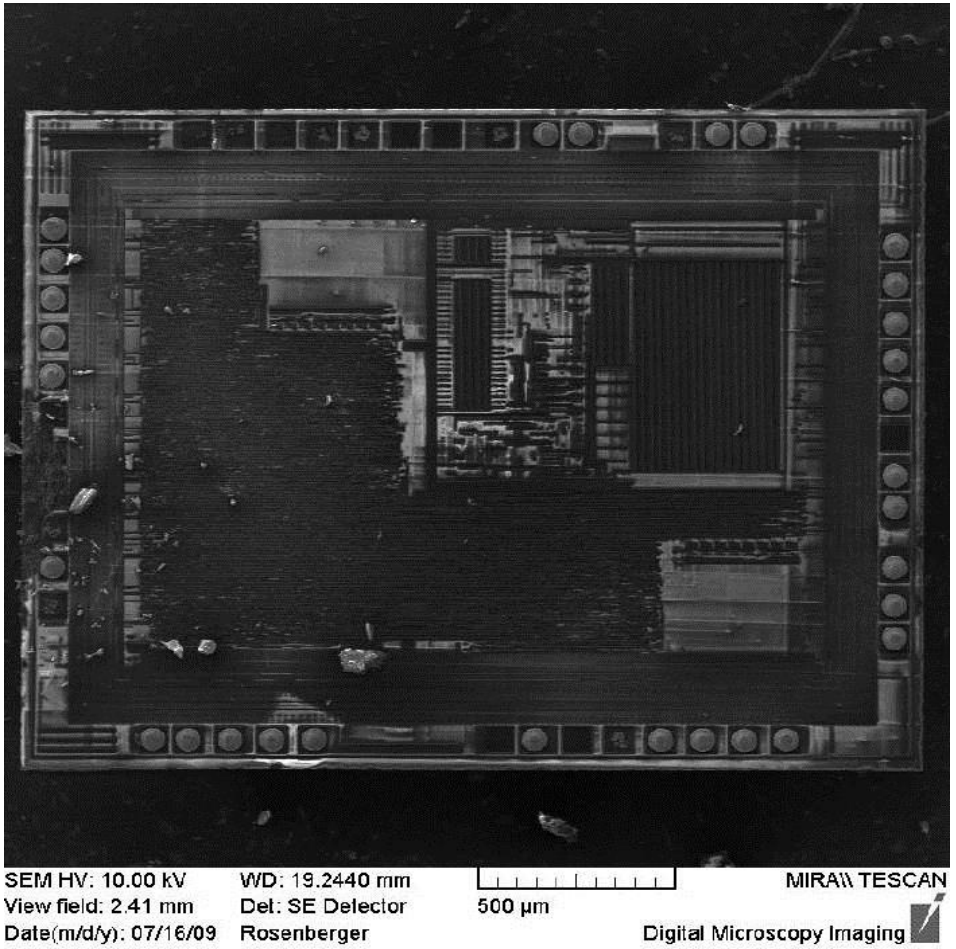
- On a semiconductor chip are several strip lines
- Cutting of a conductor is sometimes necessary, e.g. for measurements
- A nanorobotic manipulator from Klocke Nanotechnik with a cutting tool is used for precise cutting on a semiconductor chip
- The thickness of the Al conductor is < 200 nm
- Preparation for cutting is done within minutes
- Cutting itself not more then 2 min

NanoCutting

Cutting strip lines

The chip
with several strip lines

- Overview

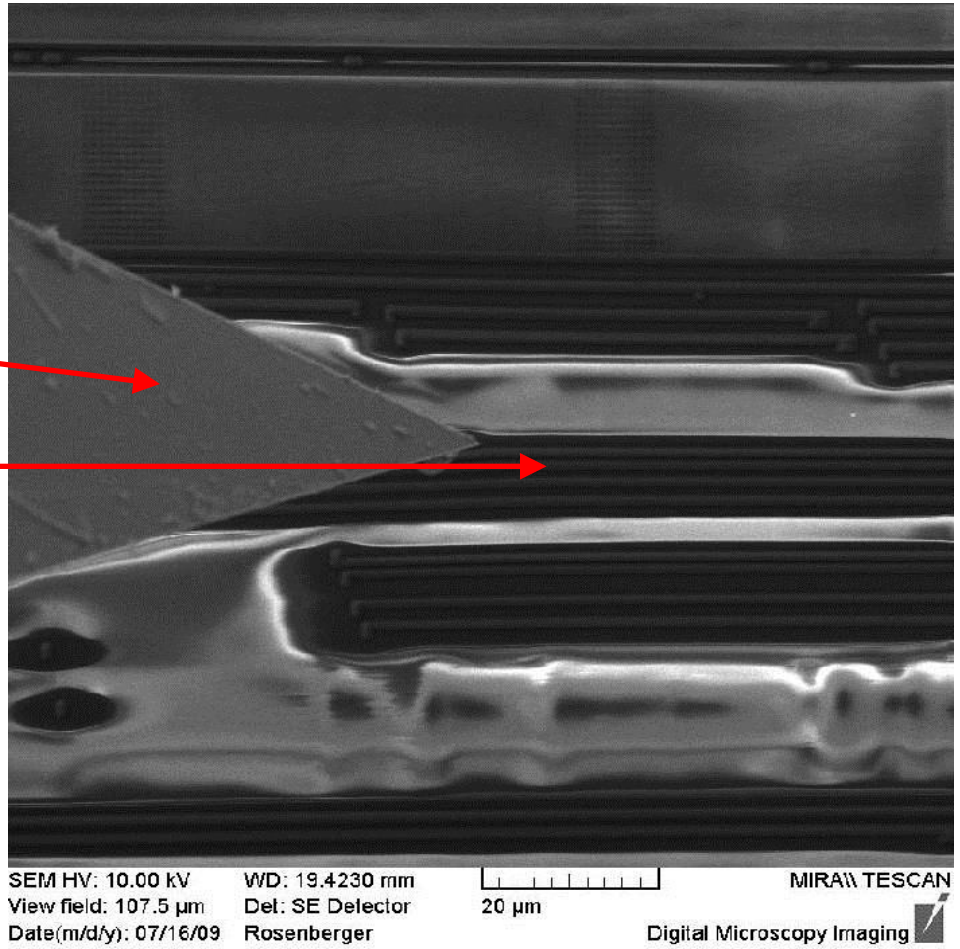


NanoCutting

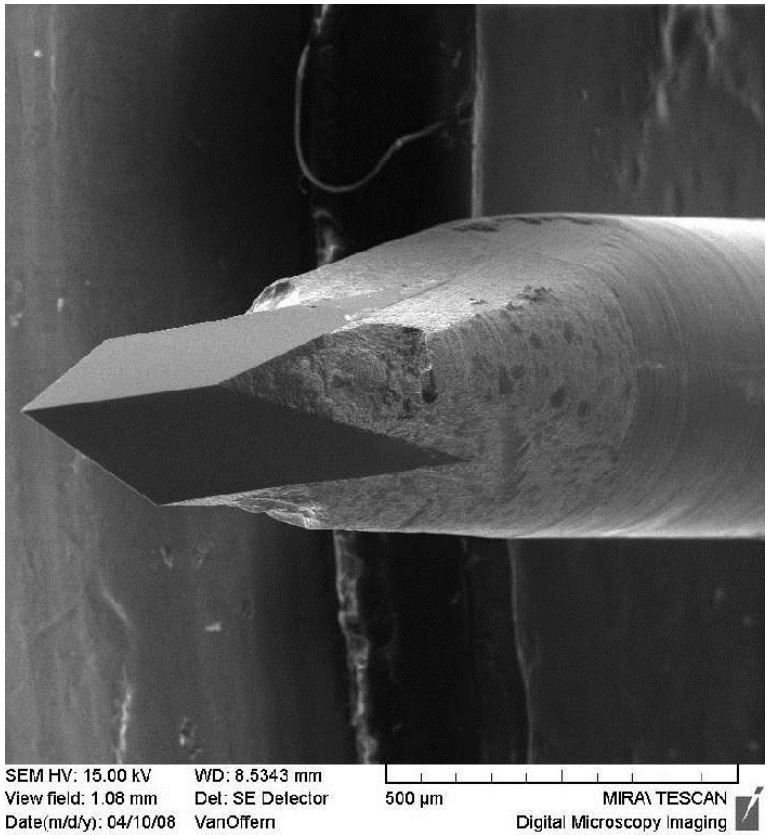
Cutting strip lines

The cutting tool nearby the selected conductor before cutting

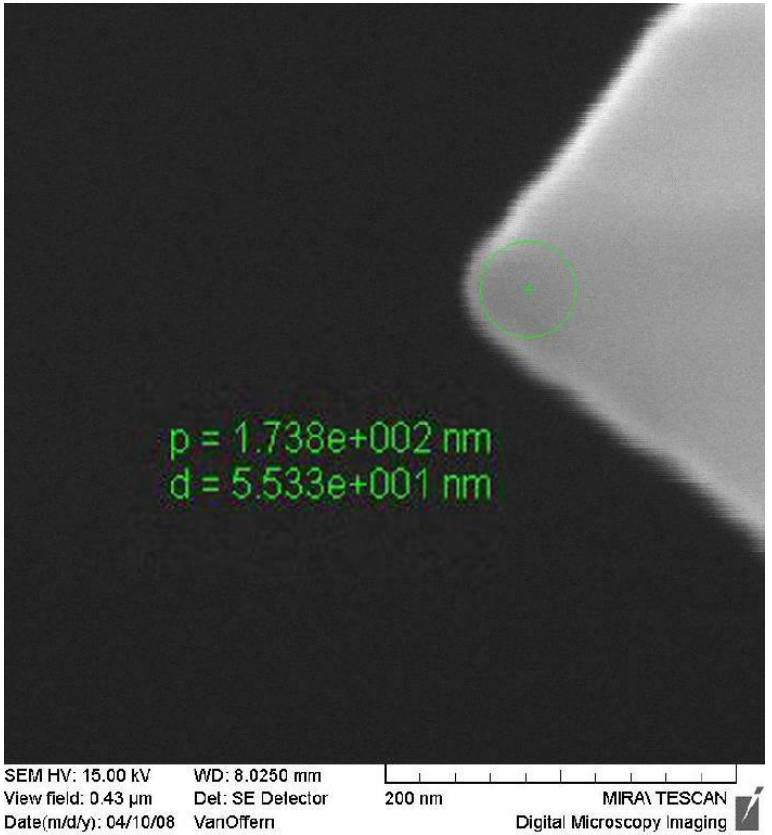
- Cutting tool
- Conductor before cutting



Cutting Tool



Cutting edge diameter = 55 nm

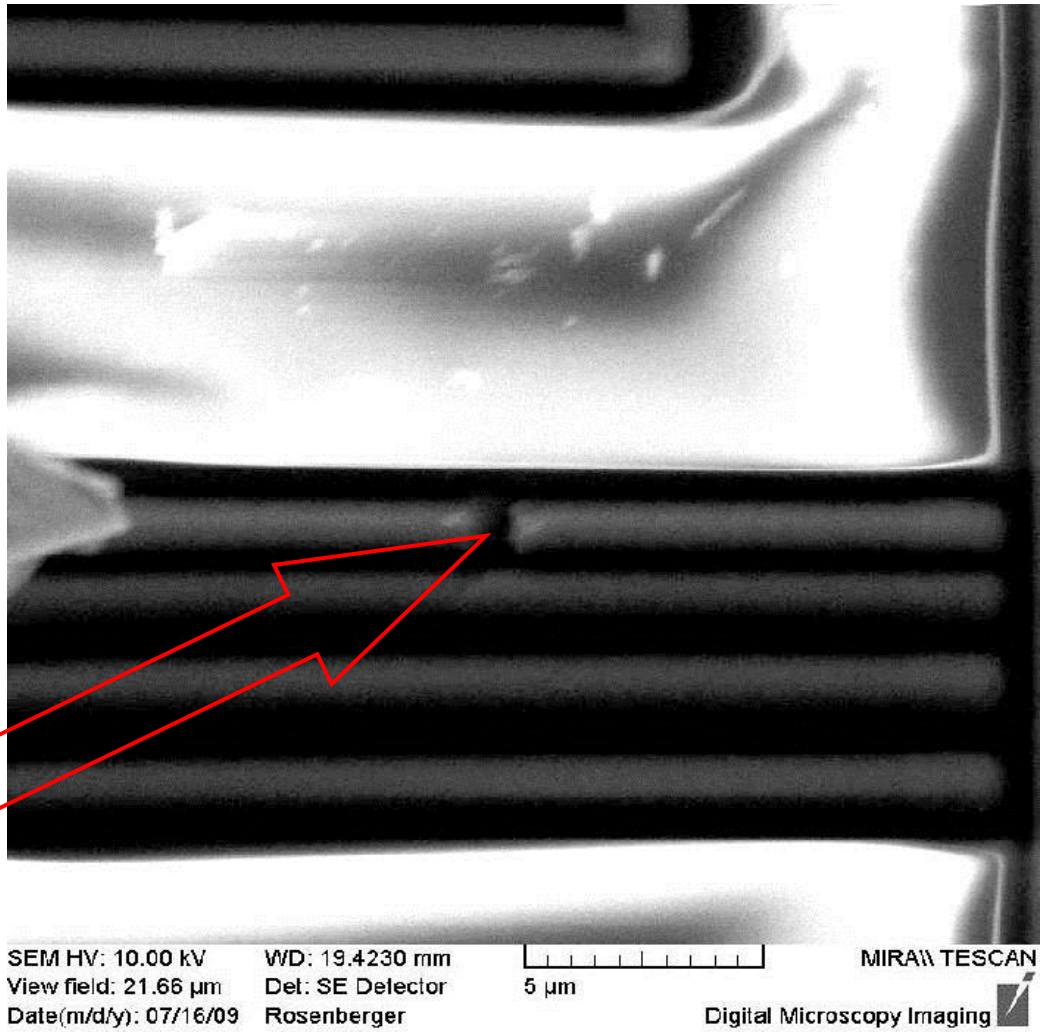


NanoCutting

Cutting strip lines

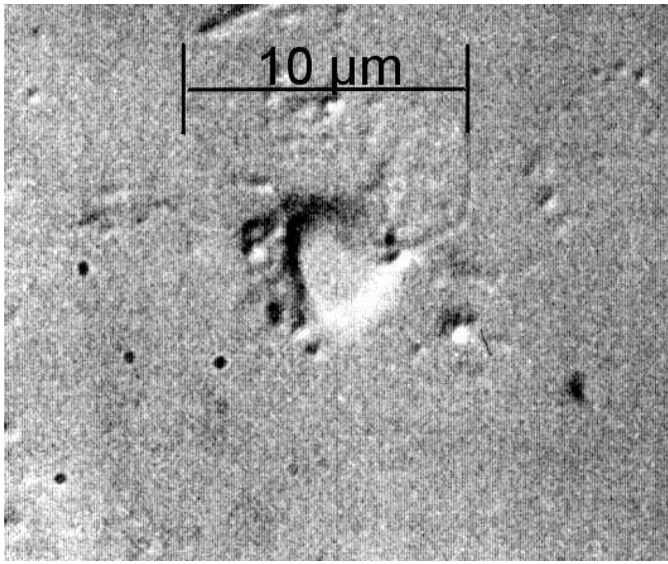
After cutting the conductor

- Cutting process needs about 2 min
- **Circuit editing without ion beam!**



Nano-Jackhammer:

- With tool tip accelerations of more than 50 G
- Programmable step amplitudes
- Nano-Jackhammer mode by periodic accelerations



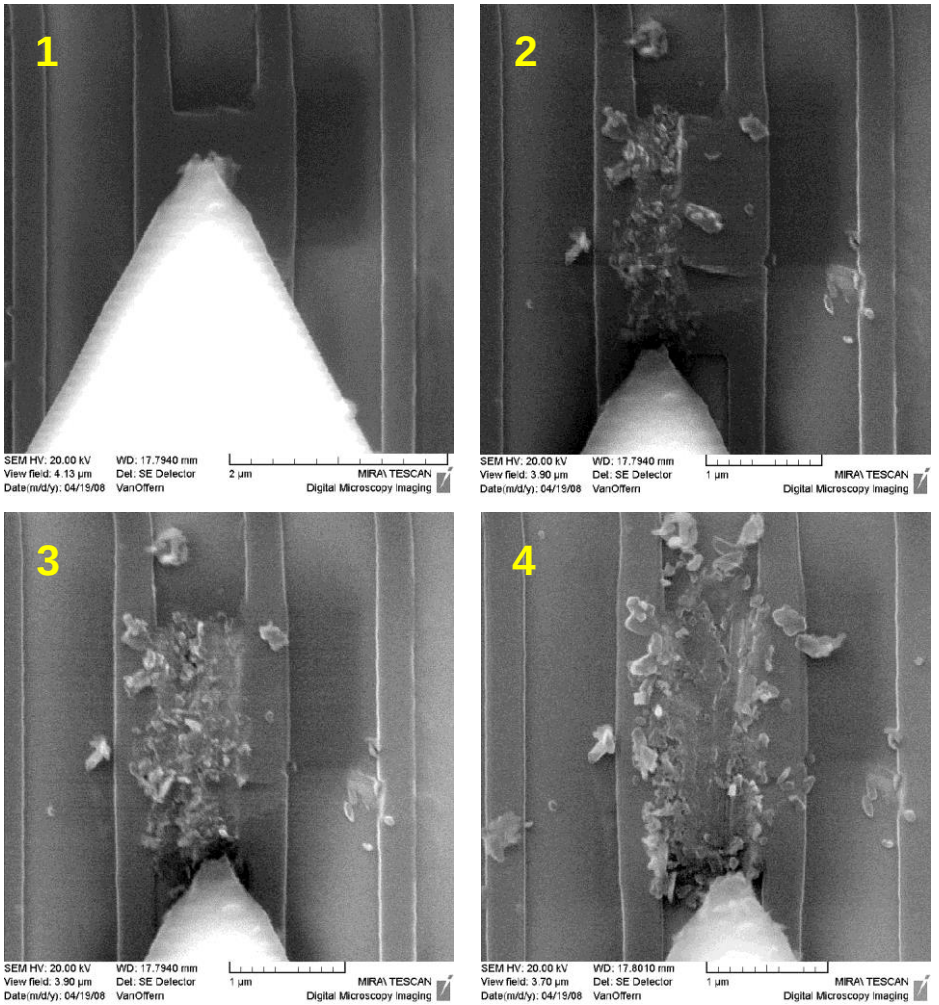
Tip imprint into diamond, diameter = 6 microns

NanoCutting

Nano-Jackhammer Module

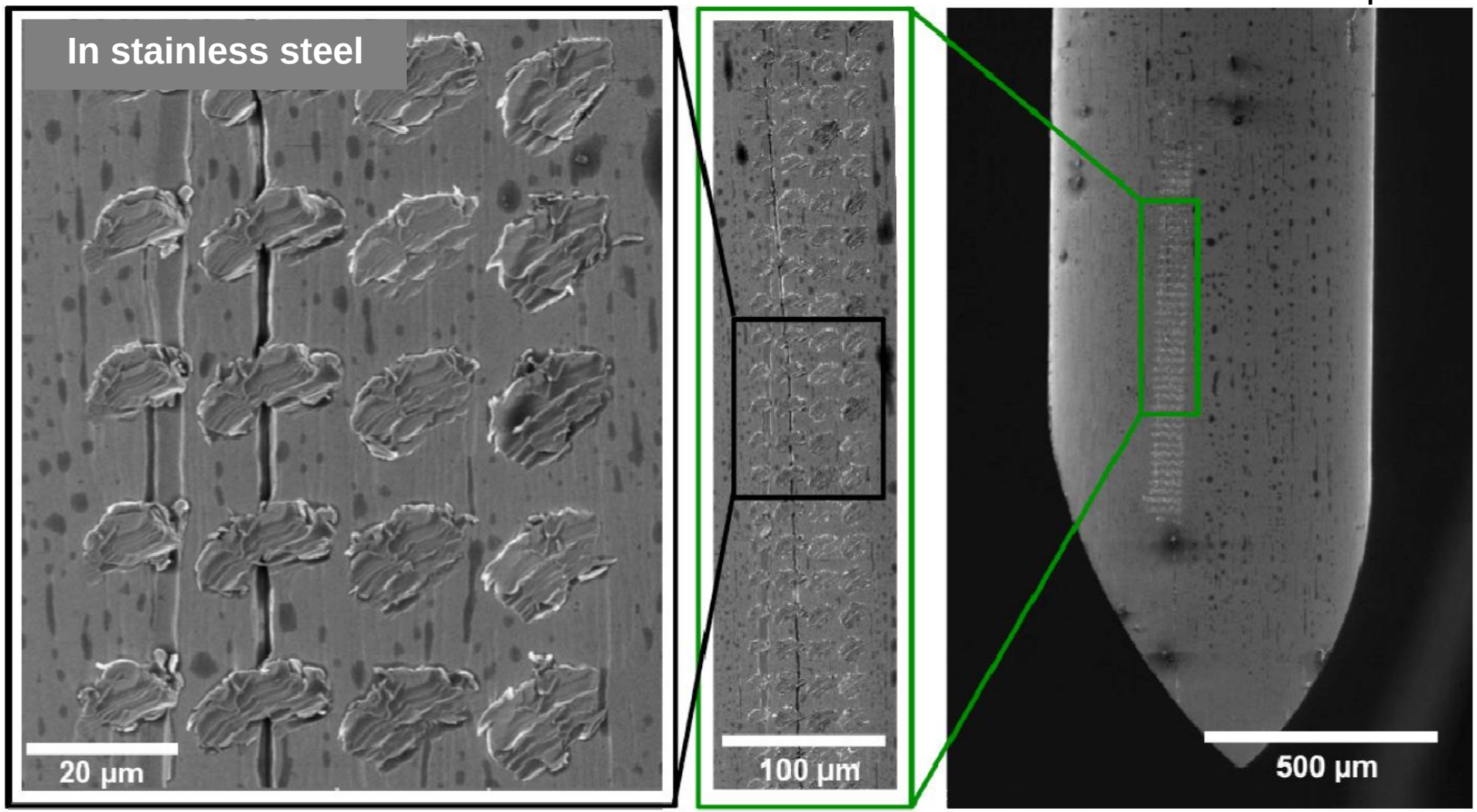
Nano - Jackhammer module

- Cutting of a **hard ceramic** sample on coarse scale:
- 4 “Jackhammer-lines” are sufficient to cut down to the substrate
- Much faster than FIB



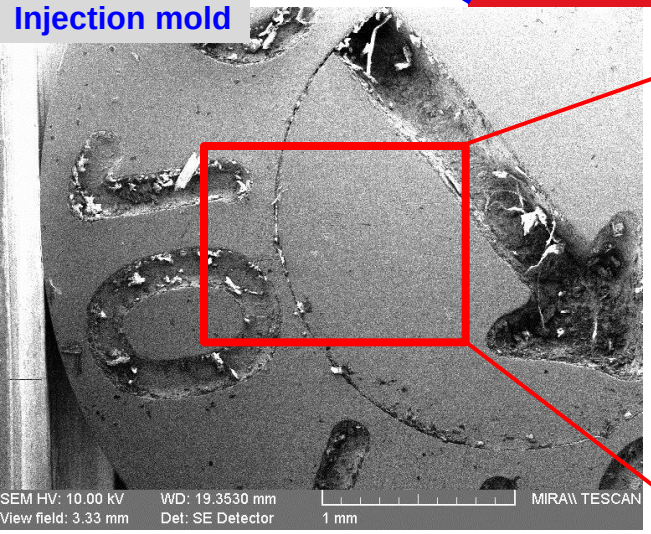
NanoCutting

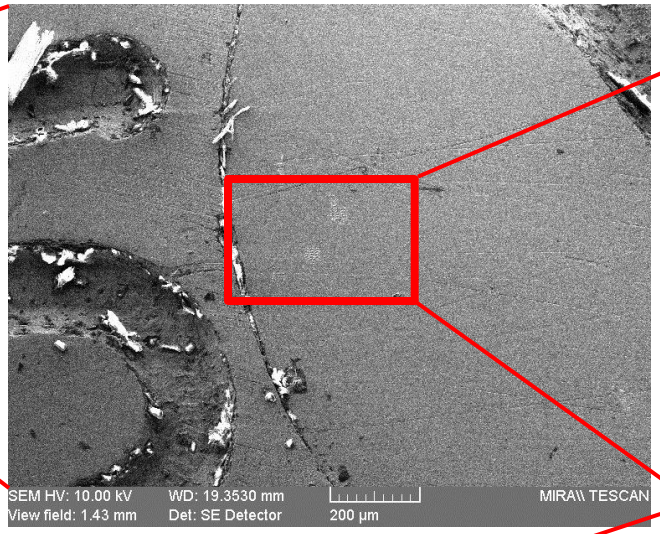
Nano-Imprints



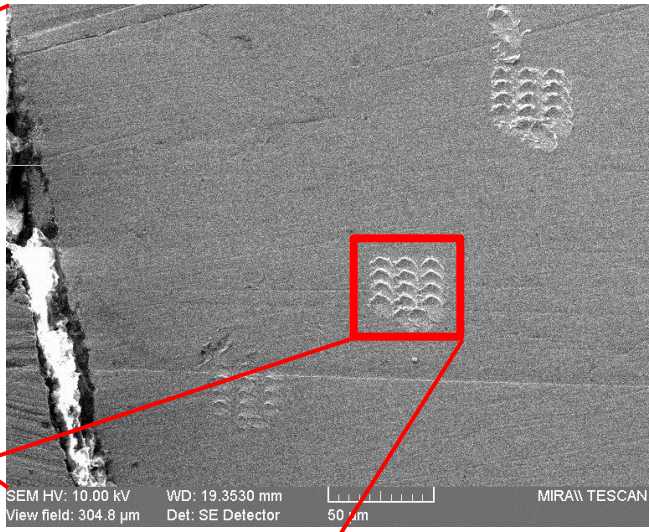
Plastic Bottles

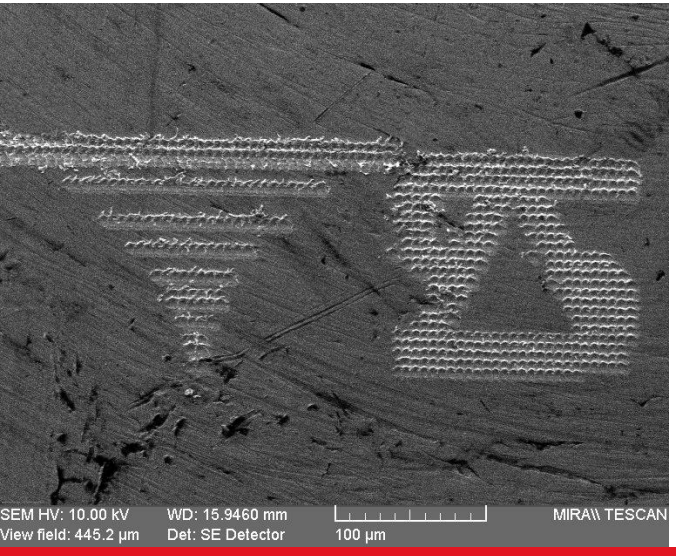
Injection mold



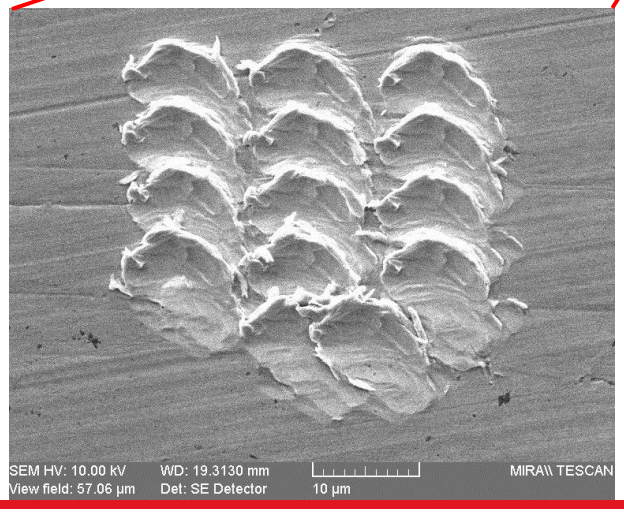


Nano-Imprints



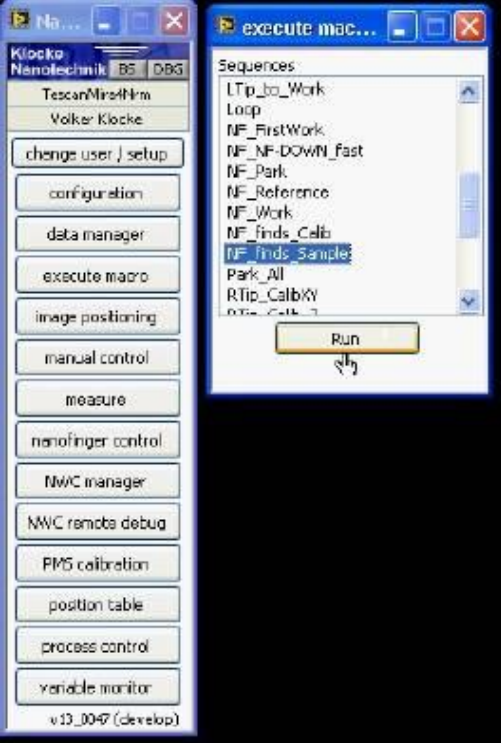


Hidden Logos against piracy of products



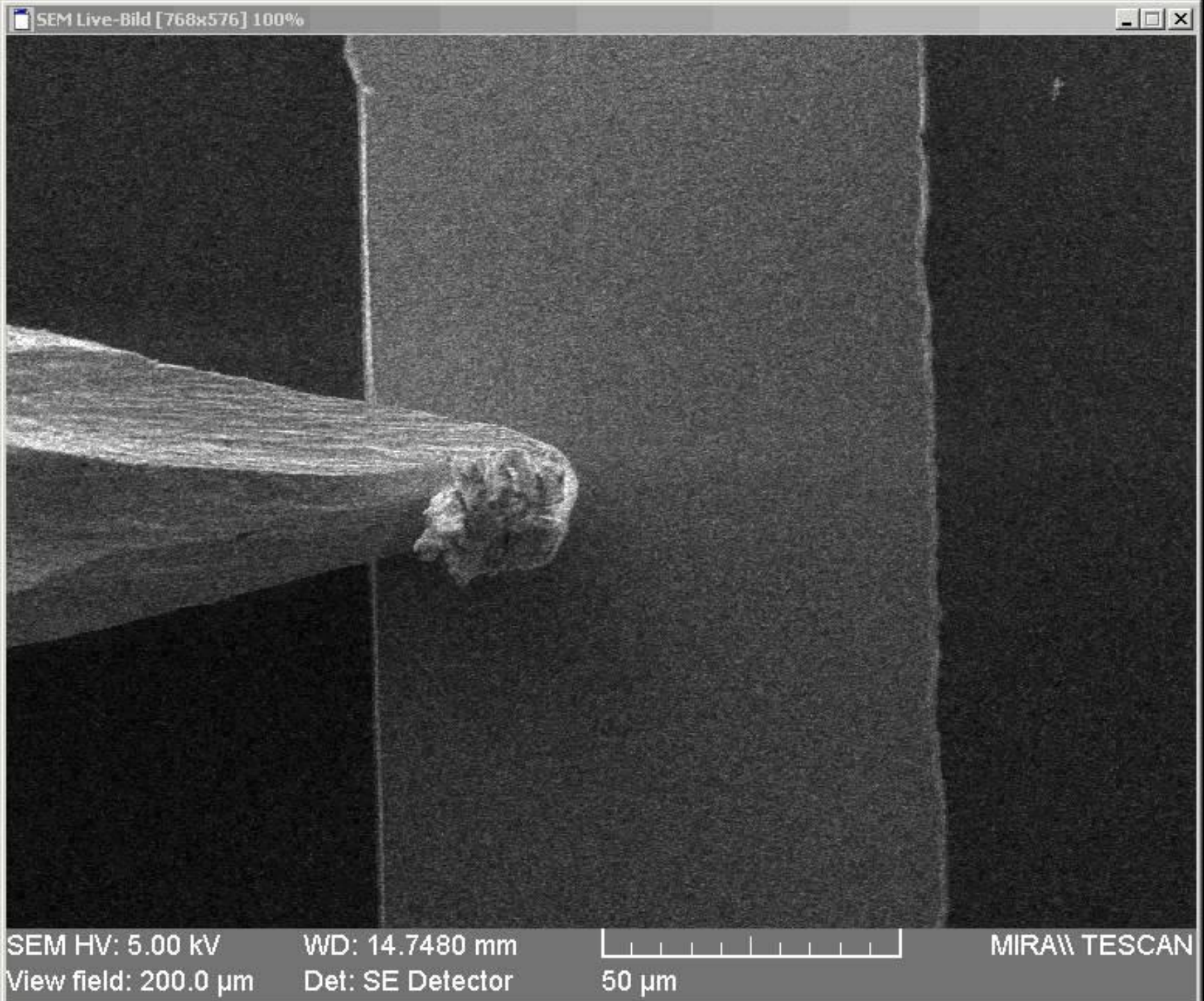
Nano-Milling in Silicon

Nano-Milling of structures with the Nanoworkbench from Klocke Nanotechnik



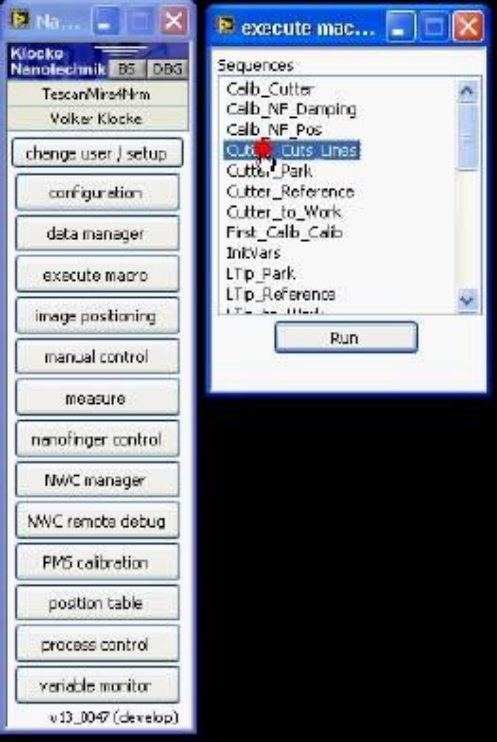
NanoControl Macro:

Nanofinger finds sample



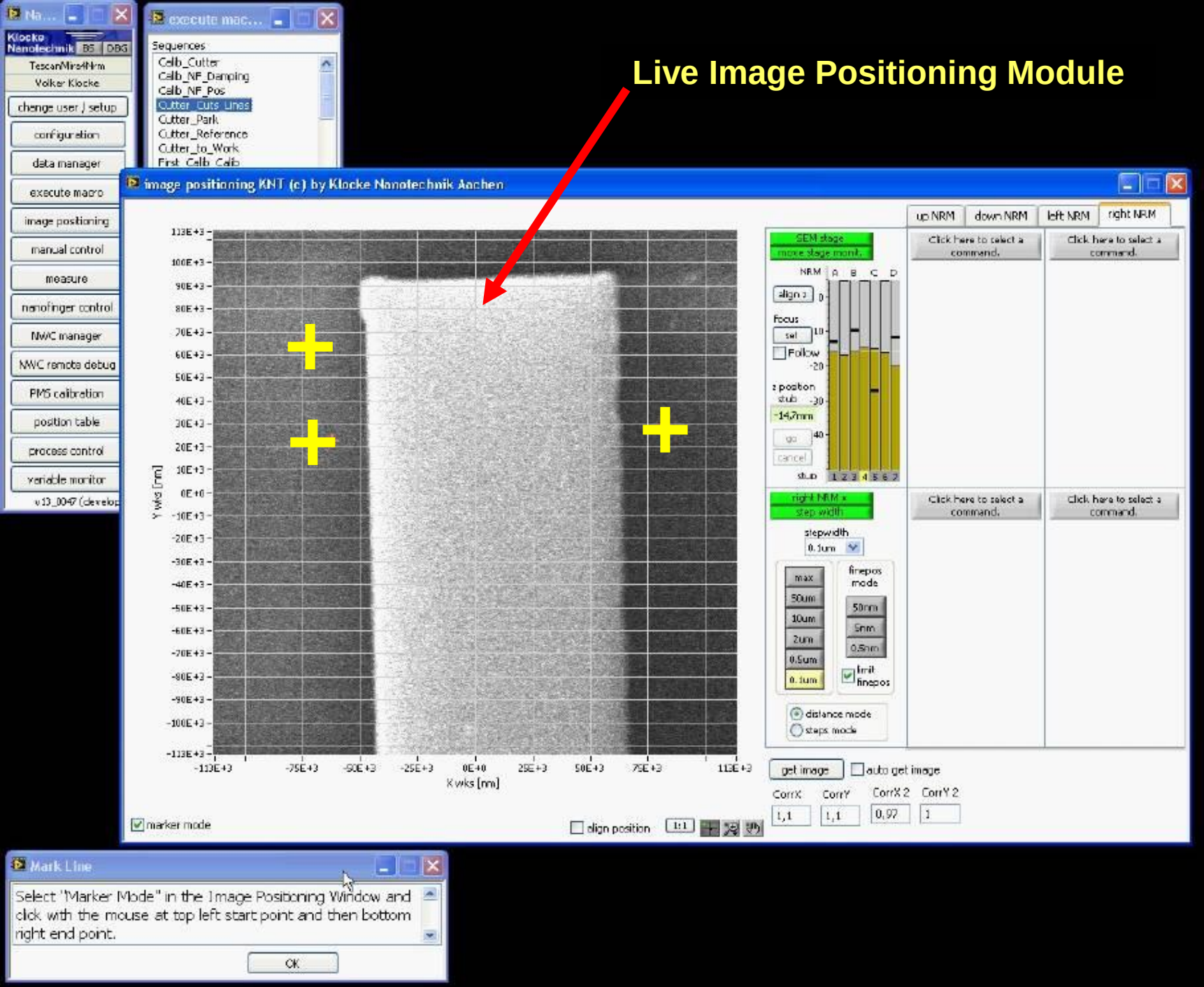
SEM – image

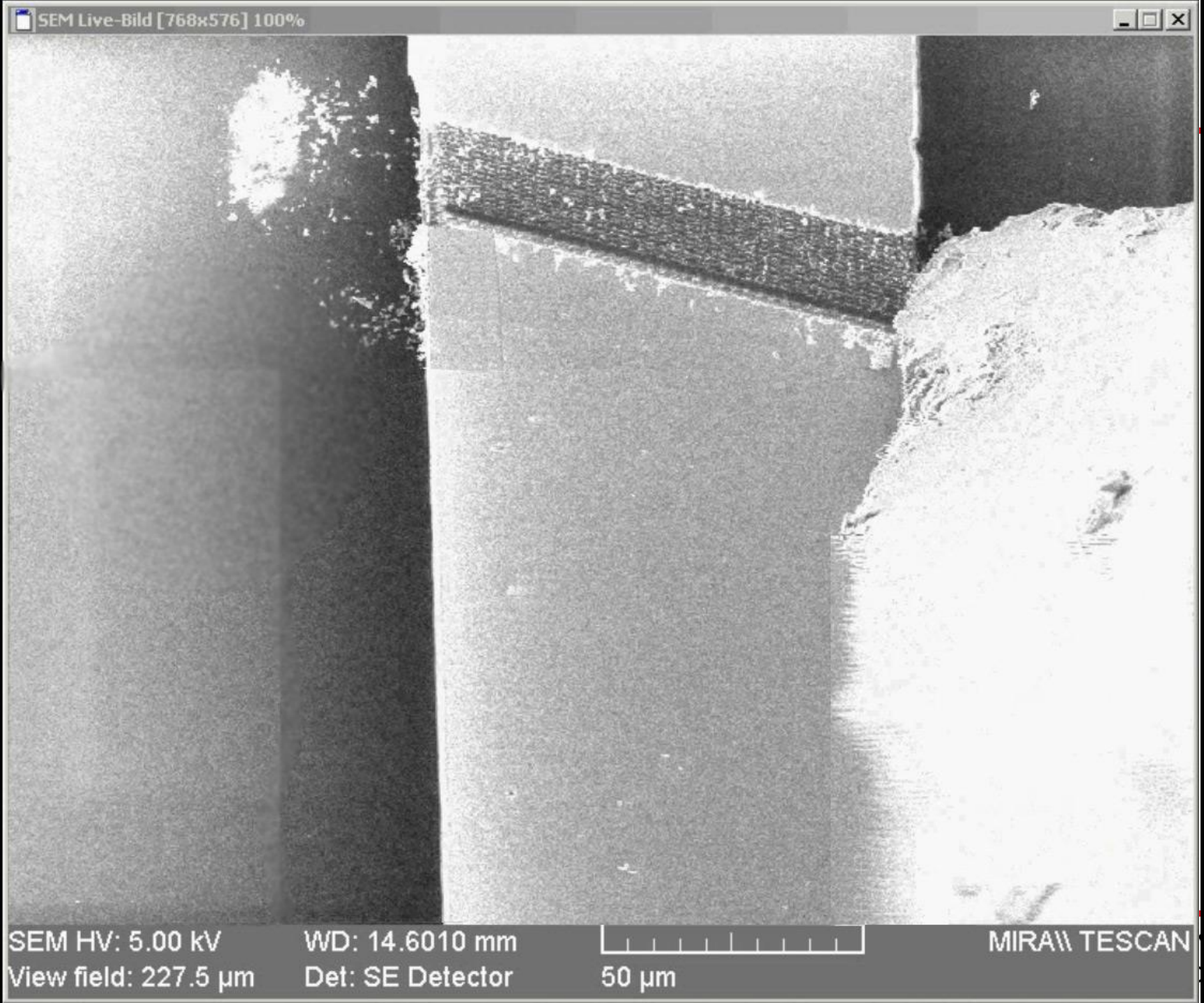
Nanofinger removal



NanoControl
Macro:

Select process
Cutter_Cuts_Lines


Live Image Positioning Module
NanoControl
Wizard:
Mark Start and End of Line
plus one marker for Line-Array Width
Klocke Nanotechnik
TescanMira4Nrm
Volker Klocke
change user / setup
configuration
data manager
execute macro
image positioning
manual control
measure
nanofinger control
NWC manager
NWC remote debug
PMS calibration
position table
process control
variable monitor
execute mac...
Sequences
Calib_Cutter
Calib_NF_Damping
Calib_NF_Pos
Cutter_Cuts_Lines
Cutter_Park
Cutter_Reference
Cutter_to_Work
First_Calib_Calib
image positioning KNT (c) by Klocke Nanotechnik Aachen
up NRM
down NRM
left NRM
right NRM
SEM stage
move stage mont.
Click here to select a command.
align z
focus
set
Follow
z position
stub
-14,7mm
go
cancel
right NRM x
step width
stepwidth
0.1um
max
50um
10um
2um
0.5um
0.1um
finepos mode
50nm
5nm
0.5nm
limit finepos
distance mode
steps mode
get image
auto get image
CorrX
CorrY
CorrX 2
CorrY 2
1,1
1,1
0,97
1
Y wks [nm]
X wks [nm]
marker mode
align position
Mark Line
Select "Marker Mode" in the Image Positioning Window and click with the mouse at top left start point and then bottom right end point.
OK



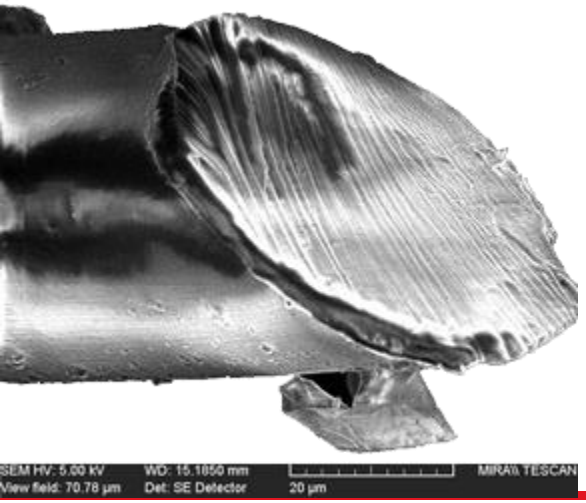
SEM – image

Nano-Milling in Silicon

2 seconds per line, about 900 times faster than FIB

NanoSlicing of Textile Wires

Nano-Slicing of structures with the Nanoworkbench from Klocke Nanotechnik

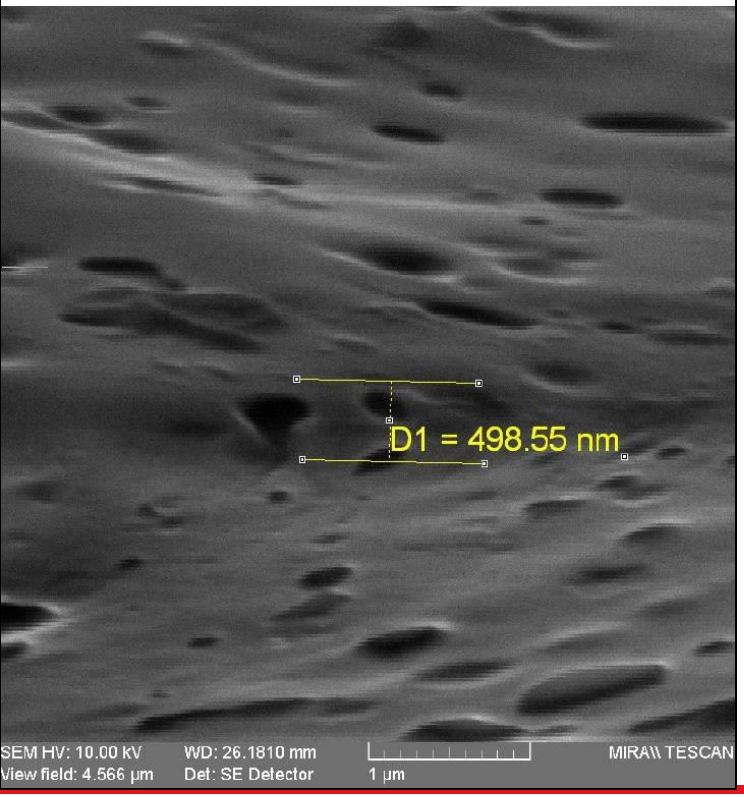


Application Note NanoSlicing

Tool and samples

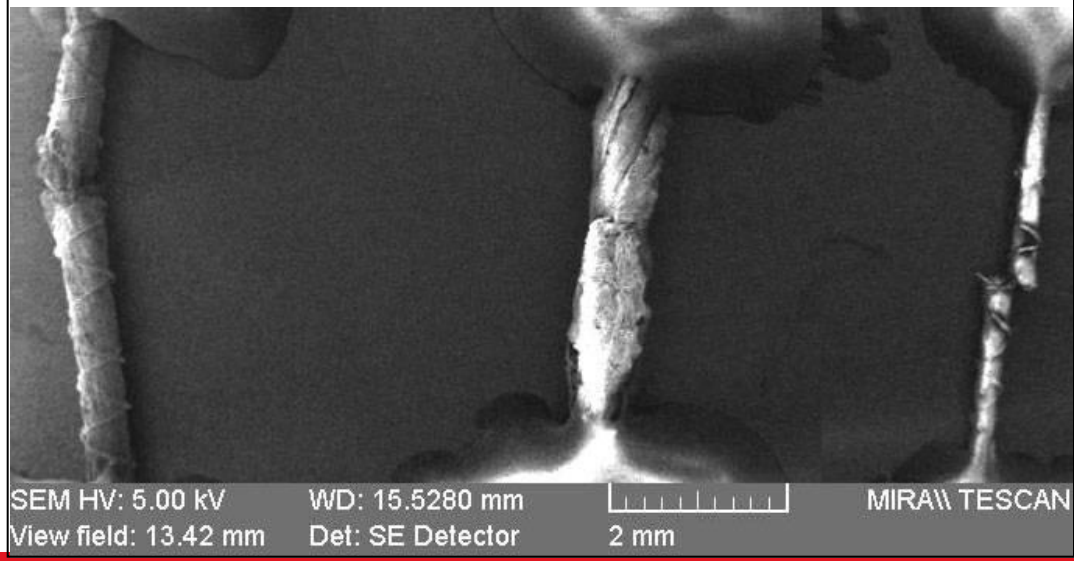
The Tool:

A cutter sharper than 500 nm:



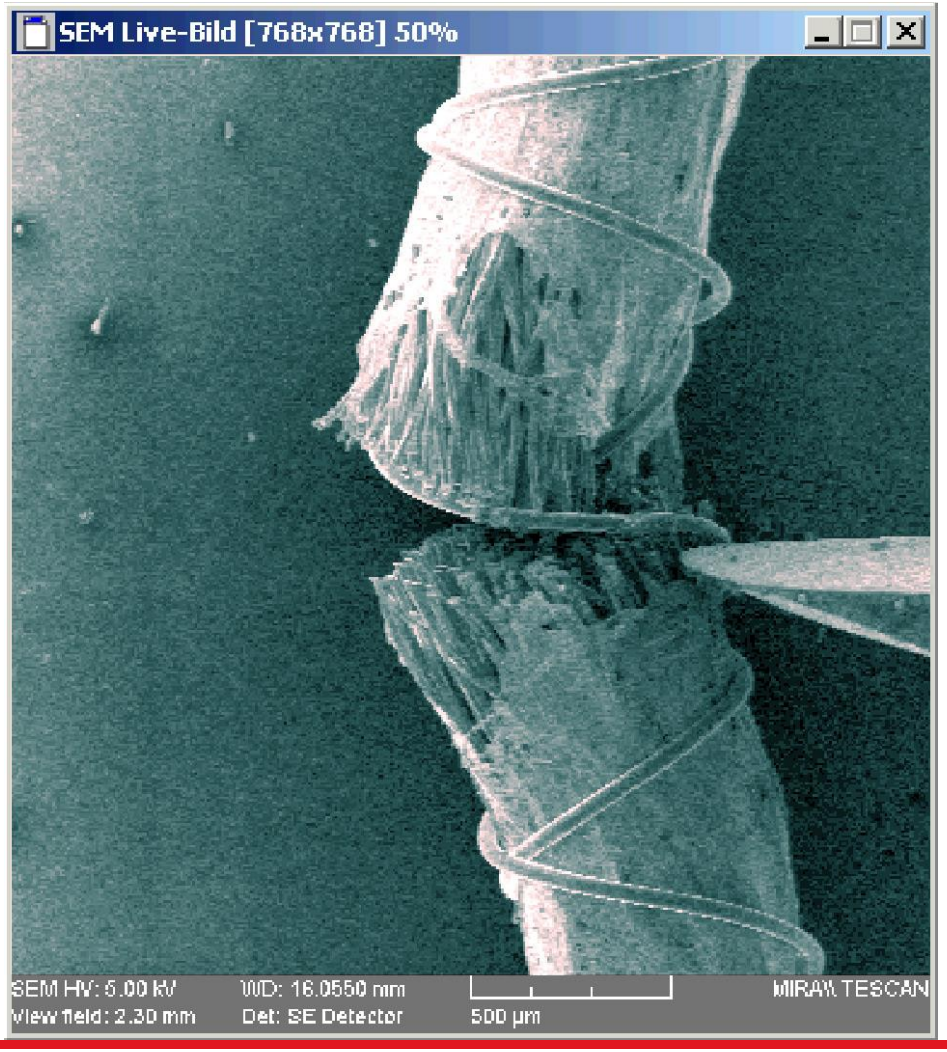
The samples:

Textile wires with different diameter, material and nano-structure



Application Note NanoSlicing

Slicing a sample



The automatic Slicing process: *

- A **slicing** algorithm was selected out of a set of options

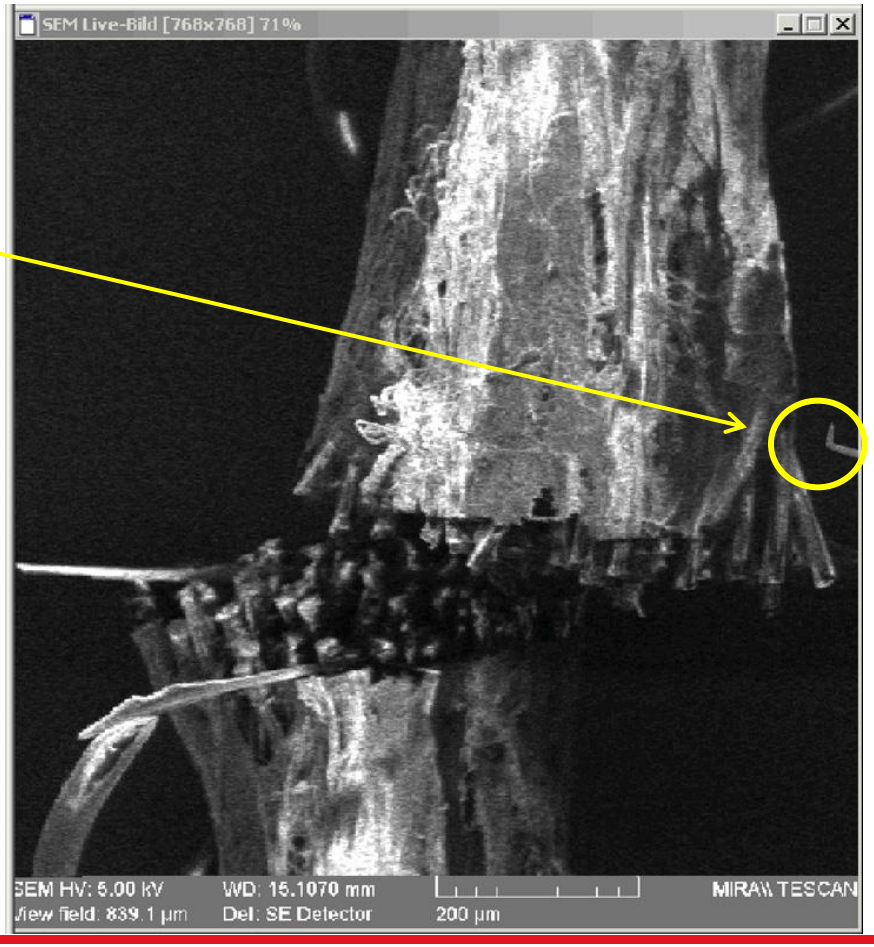
*** realized by Cartesian manipulator and simple process teaching**

Application Note NanoSlicing

Digging into the sample

Inspection after slicing, now by digging into the sample:

- A needle with a small hook intrudes the sample and grabs the fibers
- The bundle is fanned out allowing to **walk into** the internal structures with the SEM images.
- Also the outer cleading can be visualized from its **inner** side.

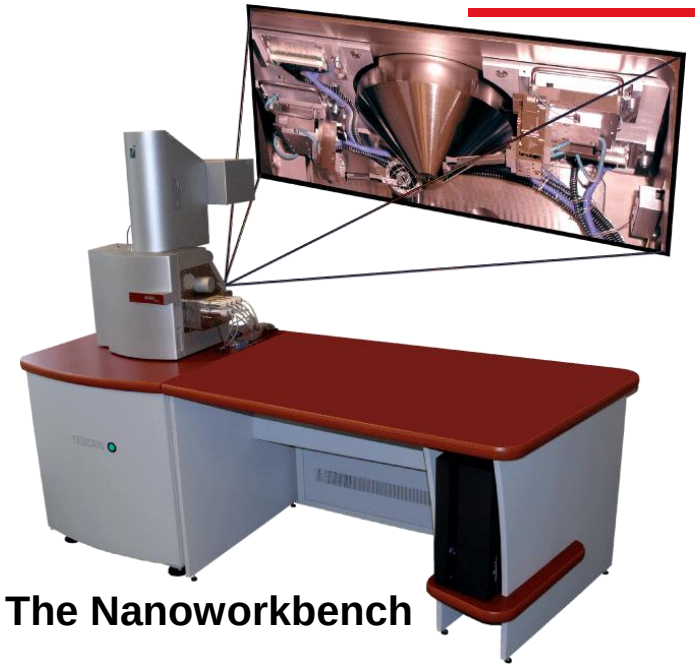


Summary

- With the Nanoworkbench from Klocke Nanotechnik cutting of material on fine and coarse scale is very fast and easy.
- The Live Image Positioning module allows to direct the cutting tool in XY to the target area just by mouse-click into the SEM image.
- The Nanofinger® operating as Scout allows a fast and secure automatic approach of the cutting tool to the sample, also on isolators.
- Automatic macros and absolute positioning in superior precision allow to program the cutting mode, range and areas.

The Nanoworkbench

and its Application Packages



The Nanoworkbench

NanoCutting …

is one out of several “Standard Application Packages”

of our Nanoworkbench.

The Nanoworkbench enables the **hand-eye coordination**

as used at Light Microscopes now in any SEM/FIB,

together with automation of the SEM/FIB **(@ZEISS, FEI, TESCAN)**

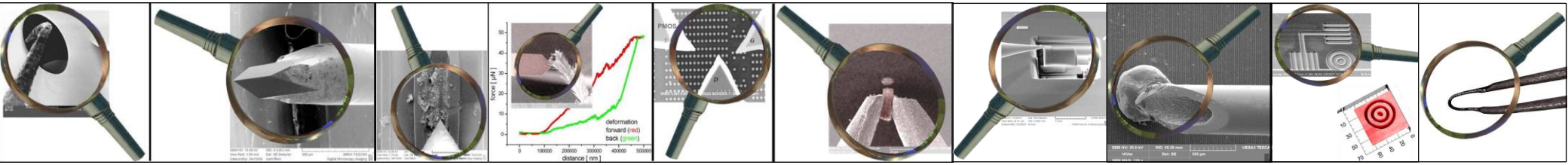
At Light Microscopes it is natural for everybody to use tool sets like tweezers, knives, hooks, probes and several different measurement tools, so it is with the Nanoworkbench.

The Nanoworkbench

One Product for all applications

The Nanoworkbench Standard Packet includes:

- The basic application package “Nanomanipulation” and
- one additional “Application Package” out of:

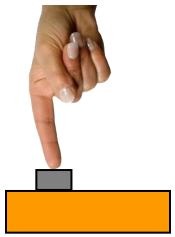


Manipulation, NanoCleaning, NanoProbing, TEM-Lamella, 3D-Nanofinger
NanoCutting, Force-Distance, Particle sorting, NanoFriction Spot-Heating

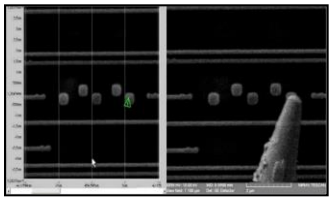
Each application package includes a standard tool, a standard sample and pre-defined processes as source-code and origin for own projects.

- **The following set of modules for easy usage an application control:**

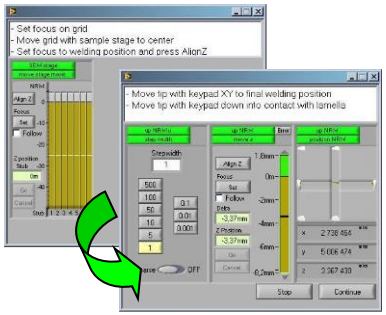
The Standard Packet



Nanofinger® as Scout, guiding the Nanoworkbench Tools,



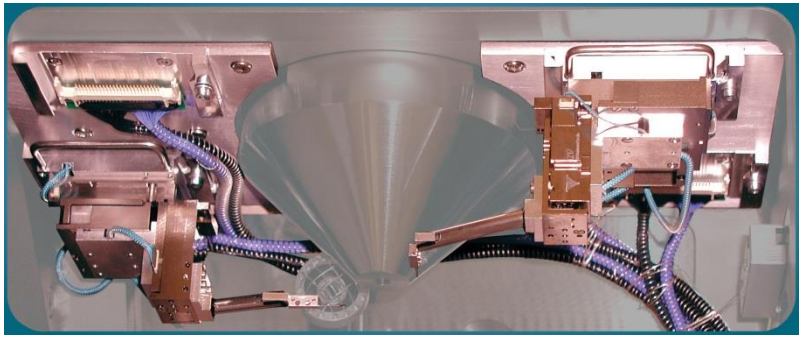
Live Image Positioning,



Assistants (Wizards),

Hand-eye coordination:

Sequencer for automation,
Macro Executor,
Remote Control,
…



2 Nanorobotics Manipulators with docking stations

More information?

Please ask for the leaflet “Nanoworkbench”

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