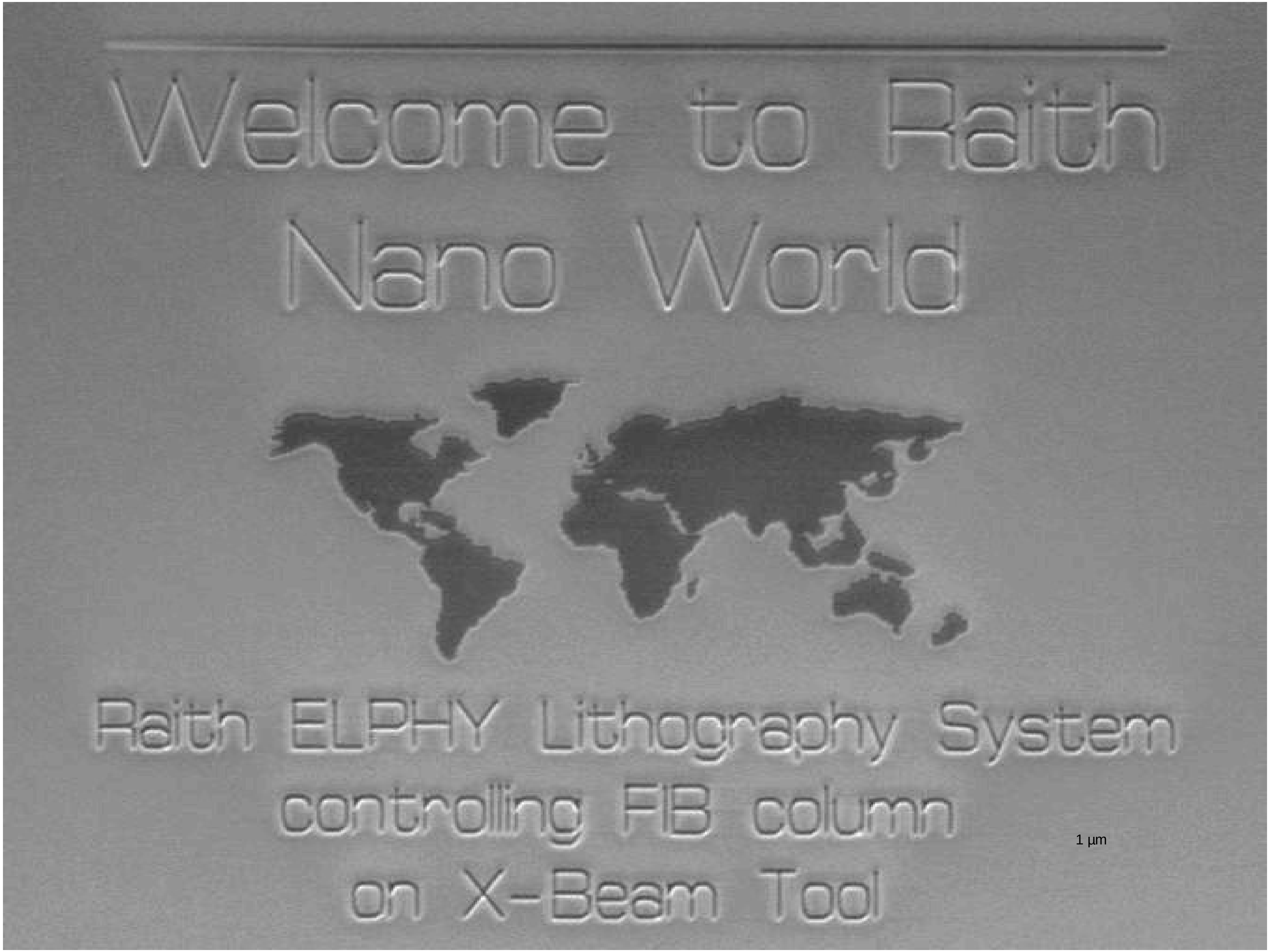

Welcome to Raith
Nano World
Raith ELPHY Lithography System
controlling FIB column
on X-Beam Tool
1 µm

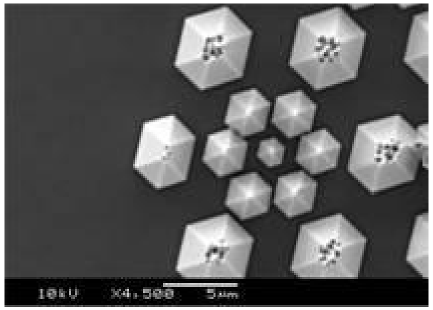
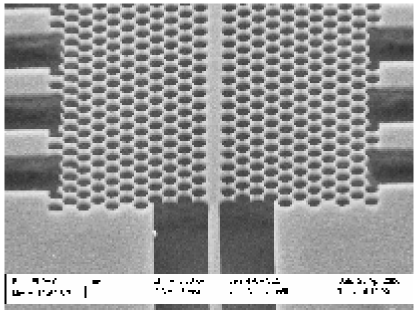
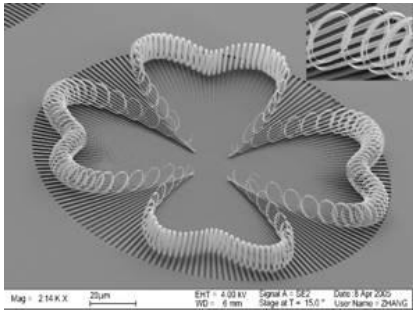
Outline

INNOVATION FROM A WORLD LEADER IN ELECTRON BEAM LITHOGRAPHY AND SEMICONDUCTOR NAVIGATION SOLUTIONS

Enabling new in-situ Nanofabrication Experiments using novel Electron- and Ion-Beam Lithography and Nanoengineering Workstations

Sven Bauerdick[1], Andre Linden[1], Michael Kahl[1], Lars Bruchhaus[1], <u>Frank Nouvertné[1]</u>, Jacques Gierak[2]

[1]Raith GmbH, Hauert 18, 44227 Dortmund, Germany
phone +49 231 975 000 0   fax +49 231 975 000 5
[2]CNRS / LPN, 1, Route de Nozay, F-91460 Marcoussis

Taken from Raith best picture award 2005 image gallery

Raith company profile

Annual turnover:

>16 Mio Euro

Headcount:

~ 70 @ headquarters

10 @ branch offices

Headquarters Dortmund, Germany

Headquarter staff members 2001

Raith

Raith company profile - Main activities

Nanolithography and Nanofabrication

for R&D and small batch production

Semiconductor Failure Analysis

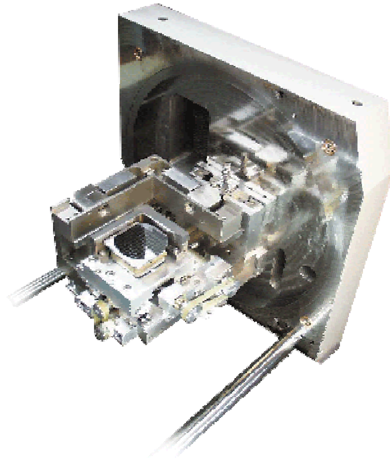
and Reverse Engineering

OEM supply, development and fabrication

(UHV goniometer 2“-12“, Beamblankers etc)

Raith E-Beam-Lithography Portfolio

Electron Beam Lithography **Attachments**



ELPHY *Quantum*	ELPHY *Plus*	Compact LIS
Universal Electron/Ion Beam Nano-Lithography System	Professional Electron/Ion Beam Nano-Lithography system	Compact Laser Interferometer Stage for SEM / analytical systems
single field applications	**Advanced applications with max. stability**	**Stitching capabilities required**

Raith E-Beam-Lithography Portfolio

Complete Electron Beam Lithography Systems

RAITH50

LaB_6 / W gun
up to 2 inch wafer
typ. cm^2 samples
< 50 nm lines

EBL „standard“ applications

eLiNE

TFE gun
up to 4 inch wafer
typ. cm^2 samples, chips
< 20 nm lines (UHR)

UHR-Lithography and Nanoengineering Tool

RAITH150

TFE gun
up to 8 inch wafer
up to 6 inch mask
< 20 nm lines (UHR)

Automated wafer (6“, 8“) exposure

Motivation for new tools

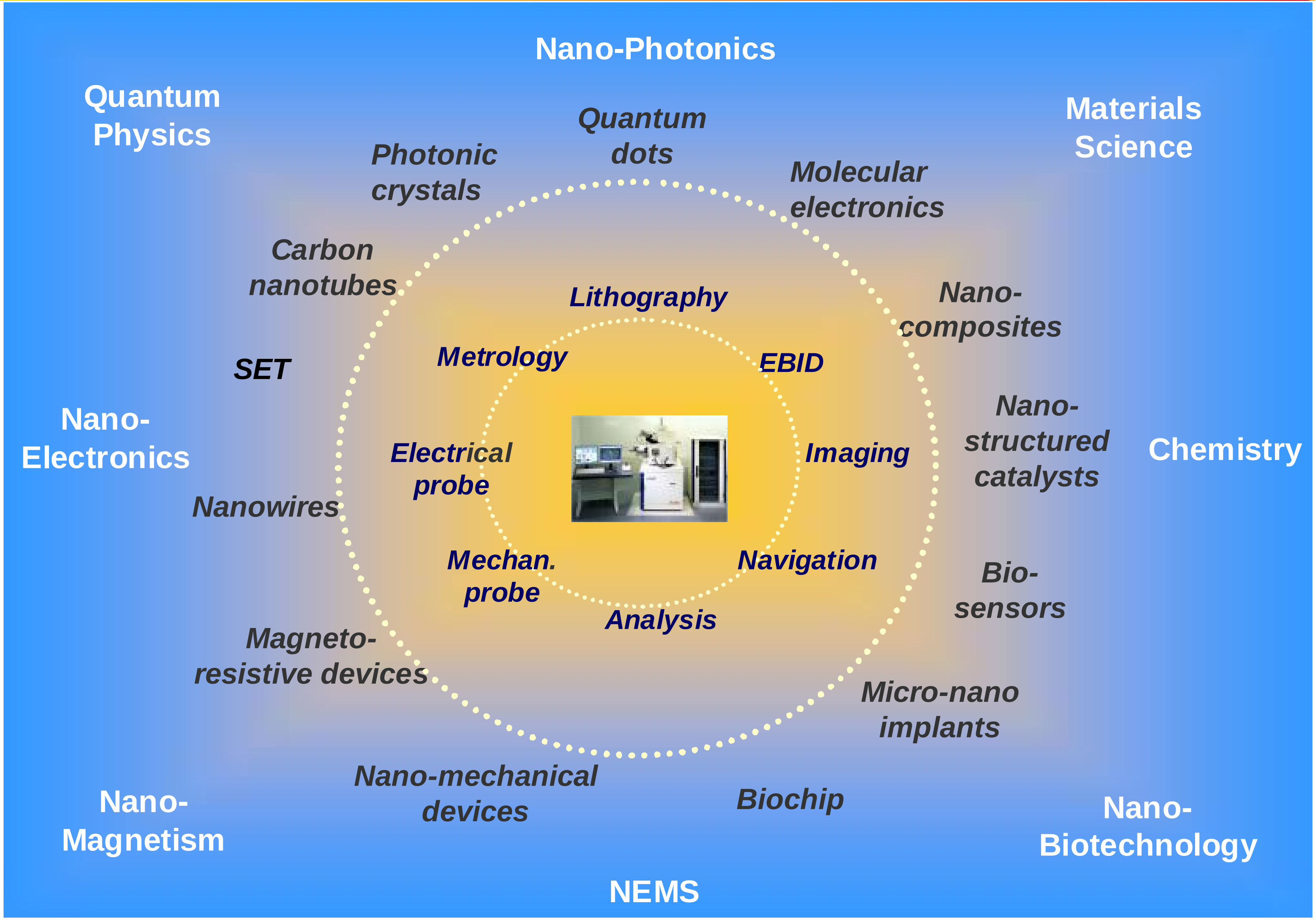
- **R&D task: Interfacing nano devices to macroscopic world**

System capabilities required to …

- **Fabricate:** Use nature, lithography process or combination of both
- **Relocate:** Apply intelligent sample navigation, imaging
- **Modify:** Employ shaping, adding, subtracting features and materials
- **Measure:** Analyze (topography, chemistry, dimensions ..), build contact to macroscopic measures (electrical, magn., ..)

… preferably in one single system only !

Applicational bandwidth in various scientific disciplines



eLiNE


NEW
ionLiNE
Raith

eLiNE product philosophy

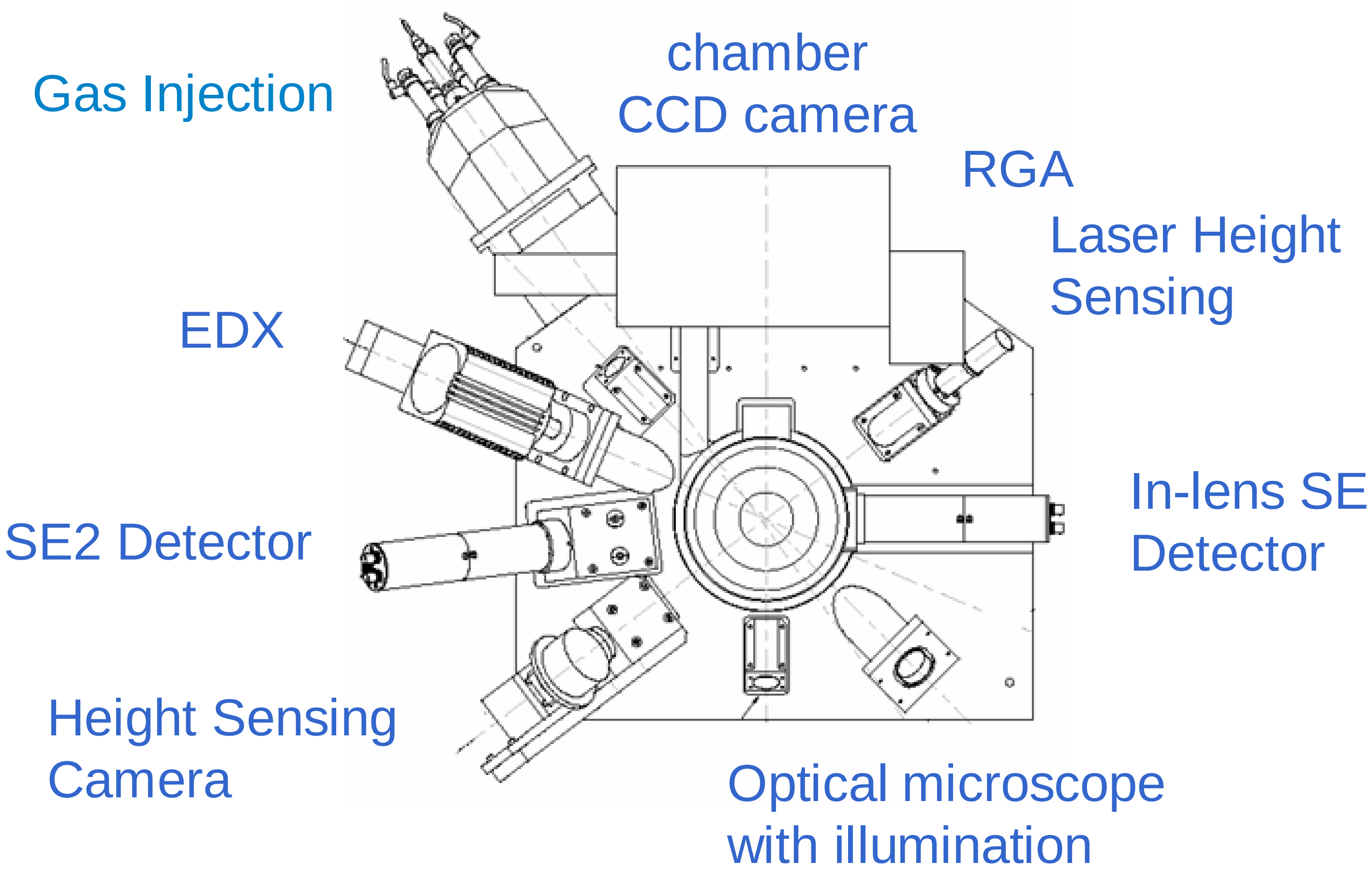
Base applications

- E-beam lithography
- Inspection and process control
- Nano Metrology and intelligent Sample Navigation

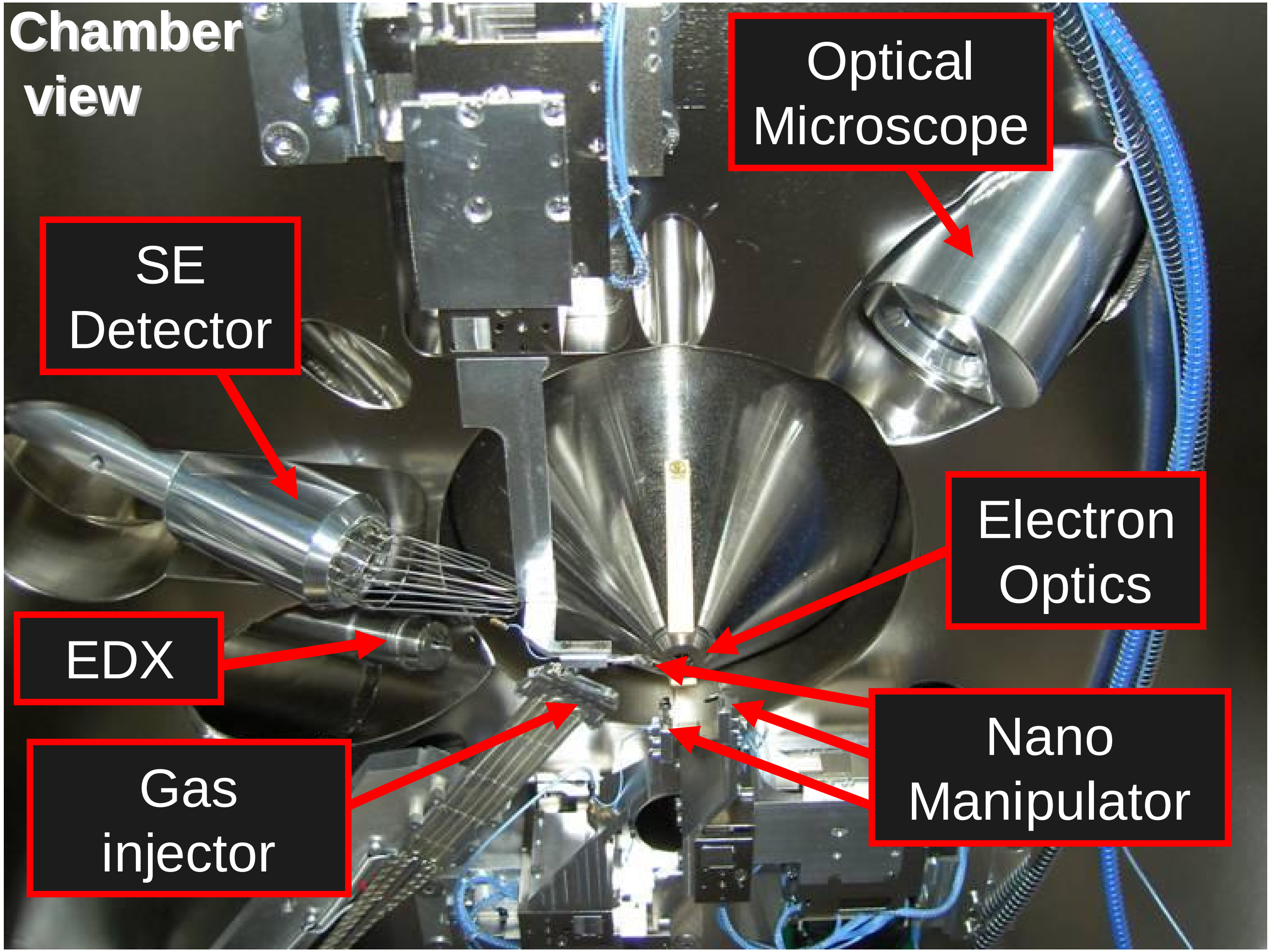
PLUS: Advanced Nanotechnology / Nanoengineering applications

- E-beam induced surface modification
  - Electron beam induced material deposition (EBID)
    (also referred to as e-beam CVD)
  - Electron beam etching
- Nano probing / manipulation
  - In Situ electrical measurements on Nano Devices
  - In Situ manipulation of Nano Structures
- X-ray analytics

e_LiNE conceptual configuration top view



Collision free system integration



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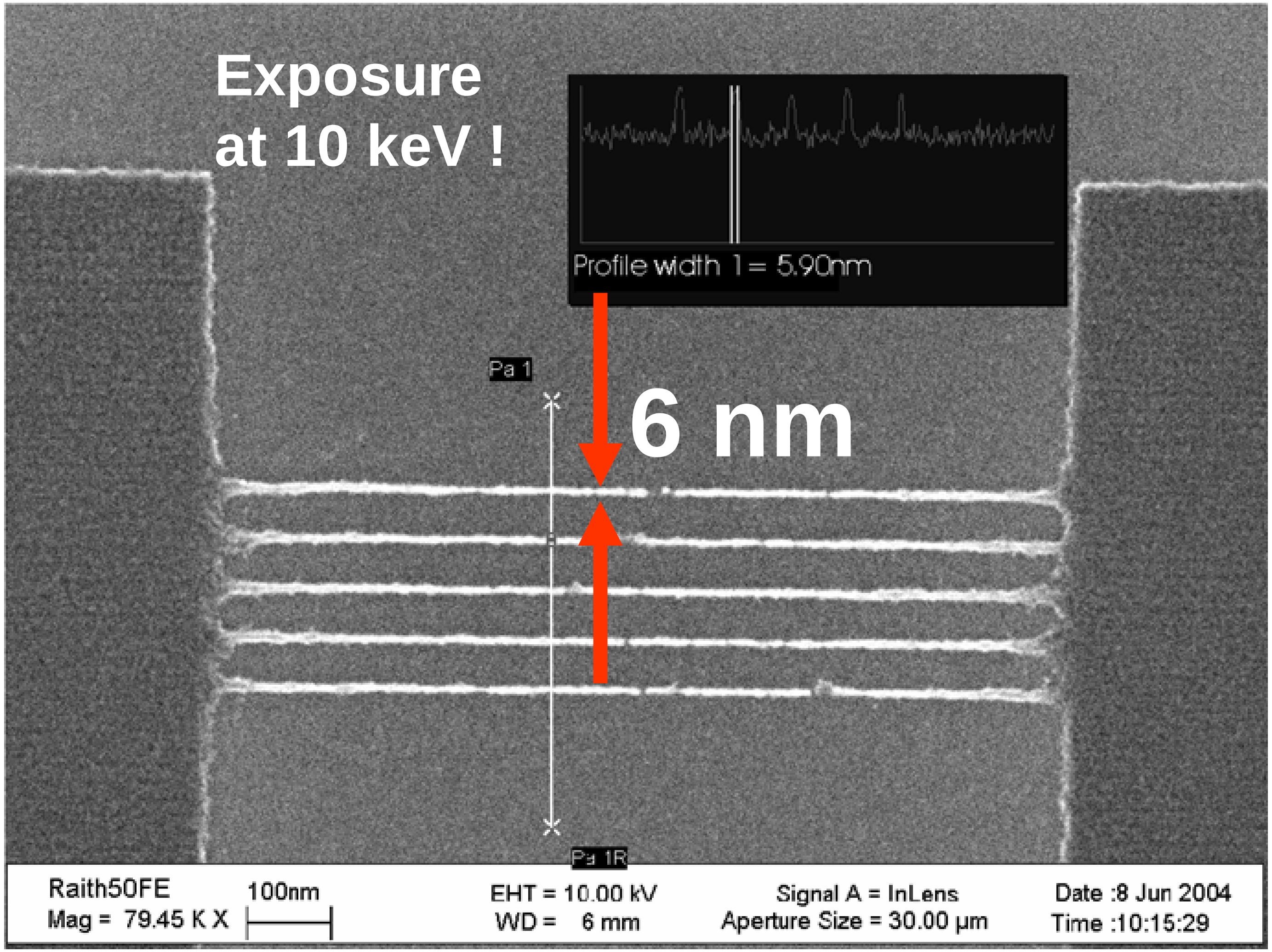
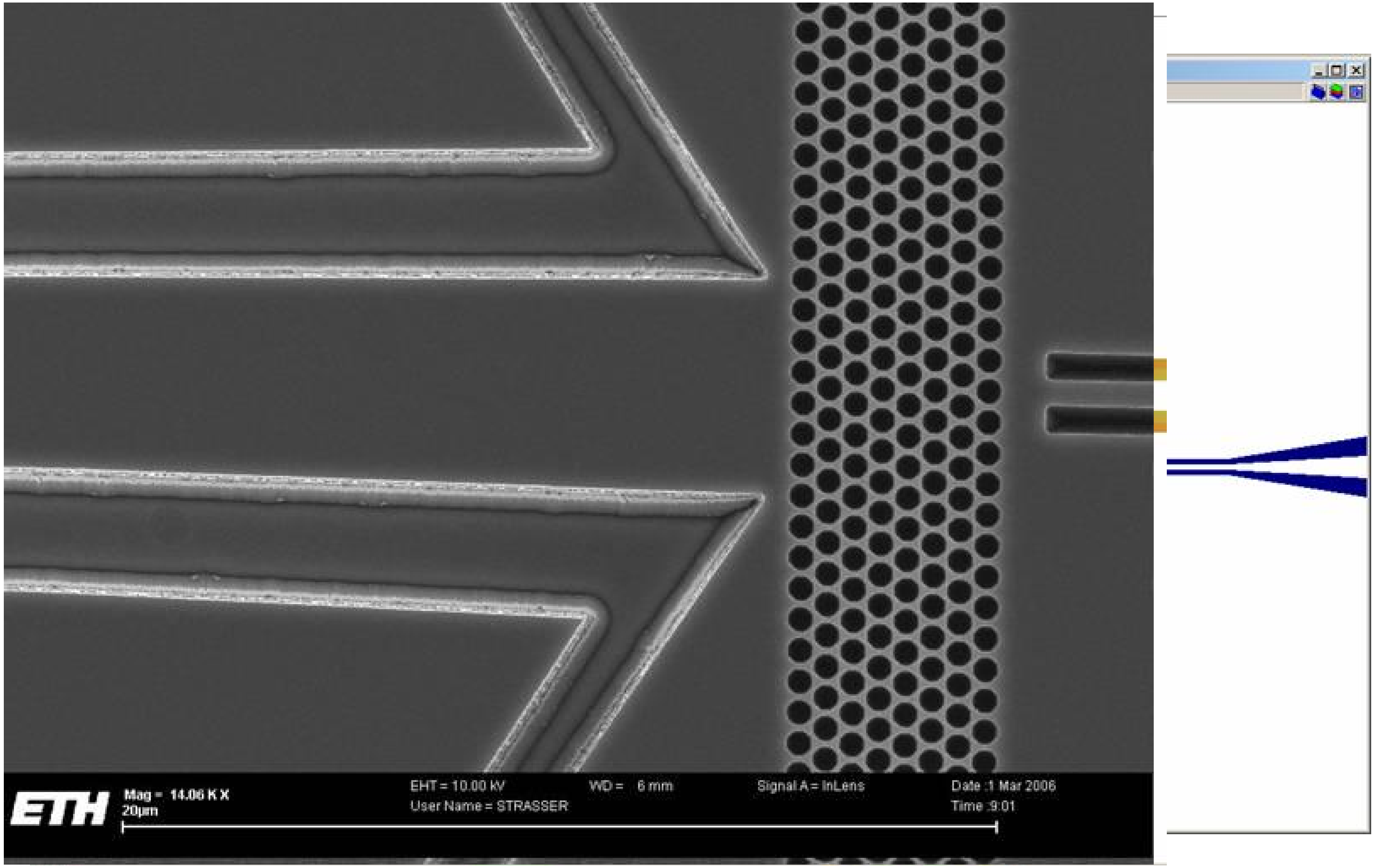
Applications – Ultra High Resolution



6nm lines exposed in HSQ resist at 10 keV only, D. Lucas, Raith inhouse

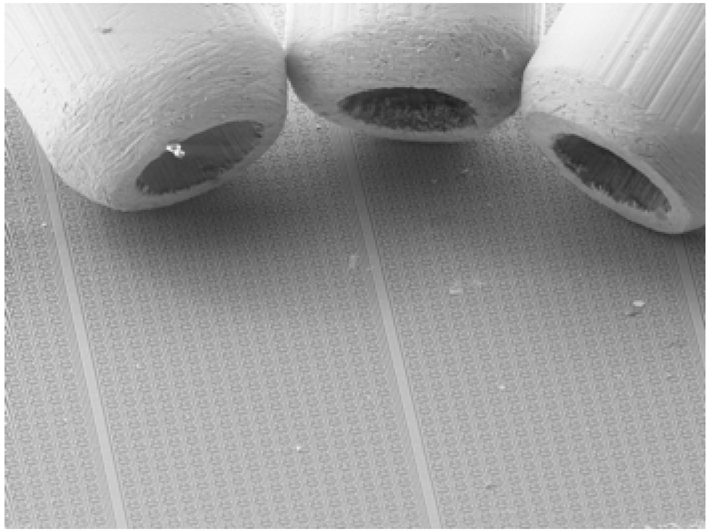
Raith

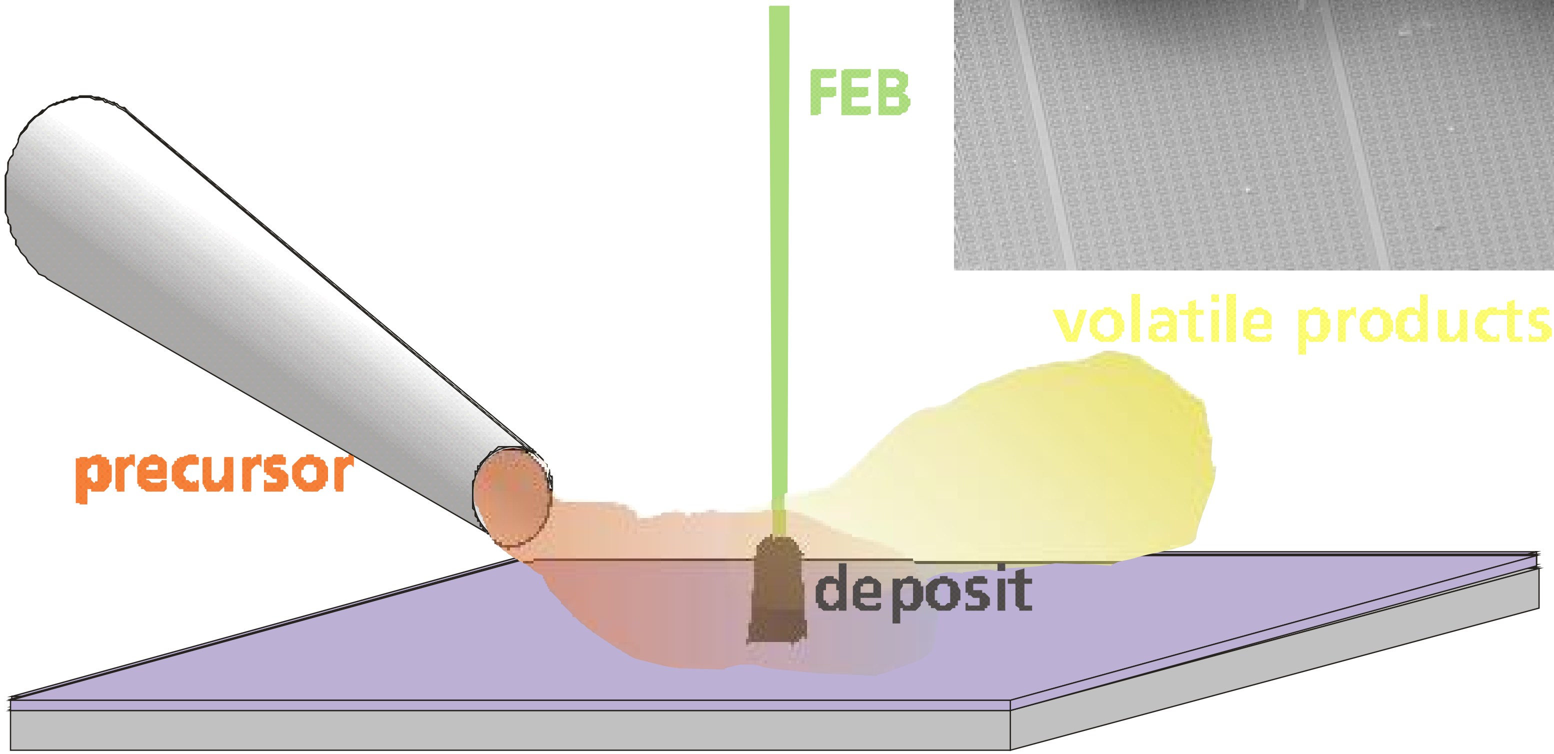


Proximity Corrected Exposure Result
GDSII-Design
Dose Distribution

Electron Beam Induced Deposition

- various parameters: energy, beam current, substrate, dose, pressure, ……





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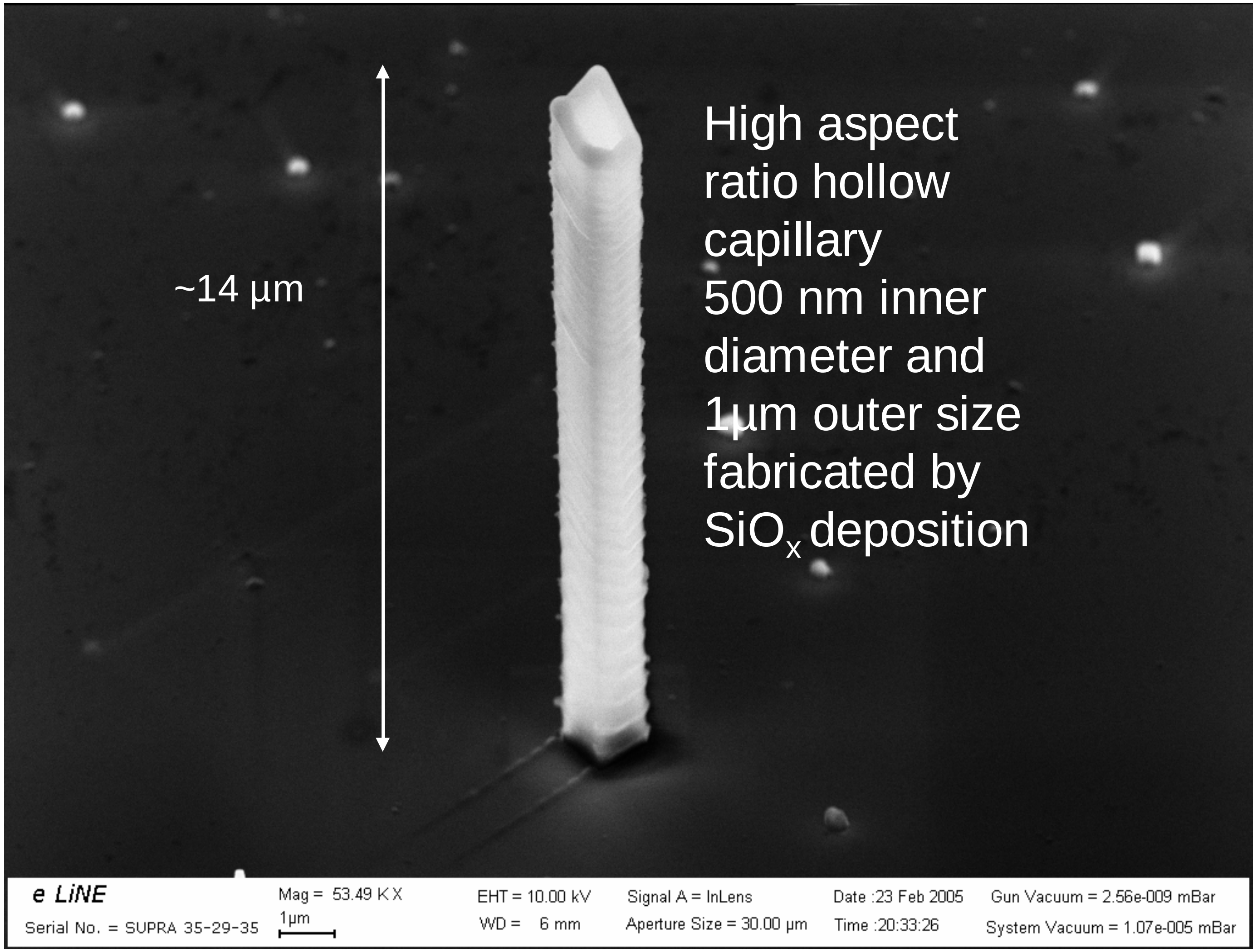
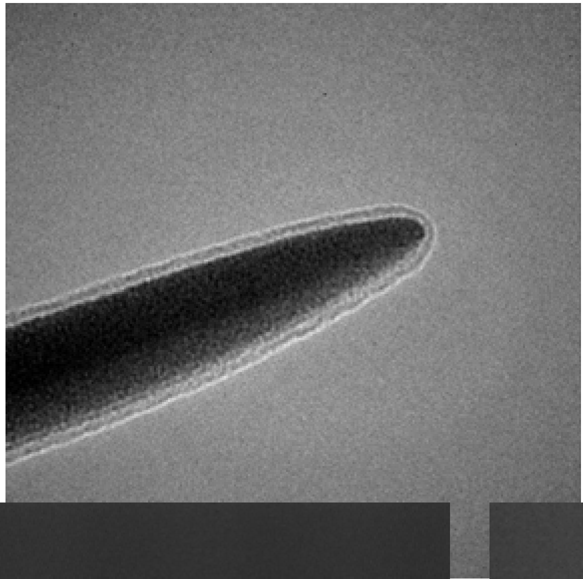
Electron Beam Induced Deposition



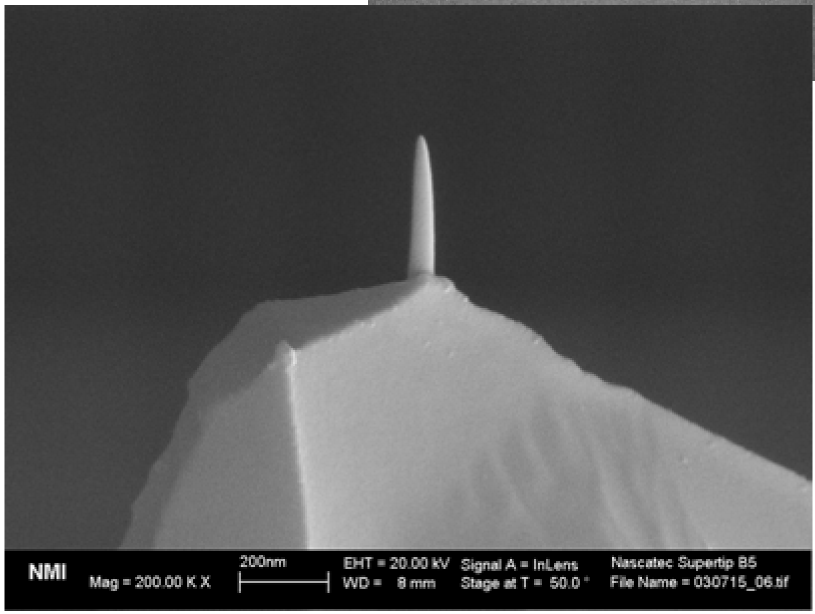
„Nano-Chimney“, A. Linden, Raith inhouse

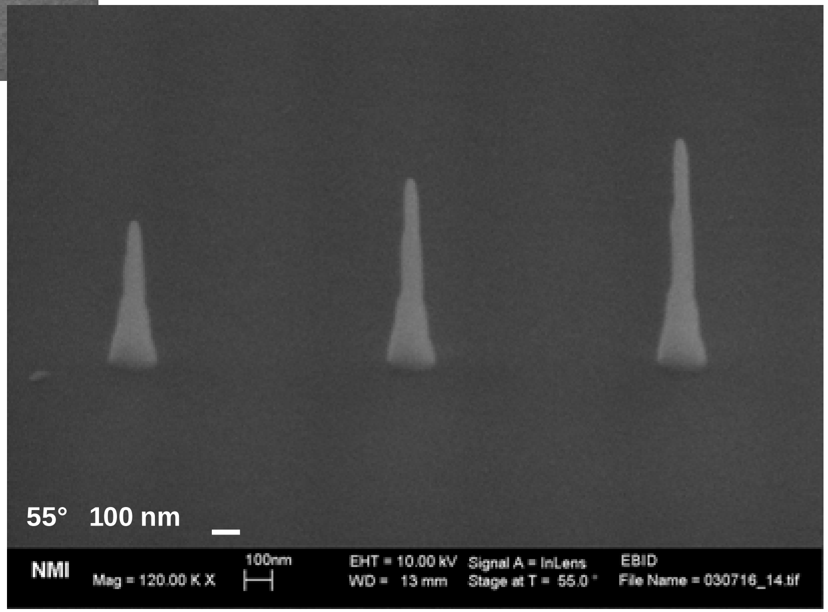
Electron Beam Induced Deposition



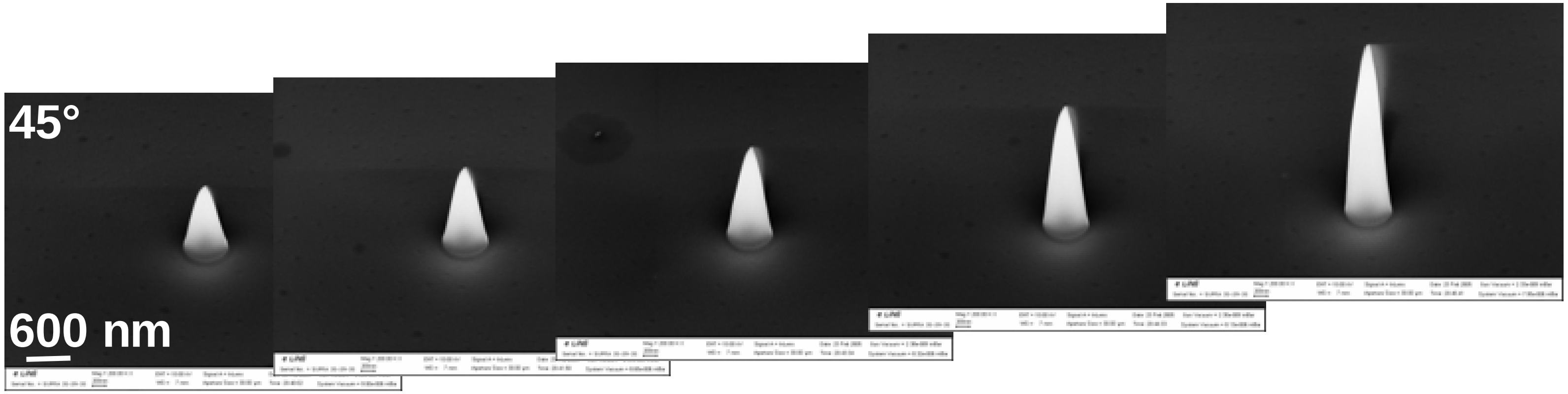
Nano tip curvature radius approx. 5 nm

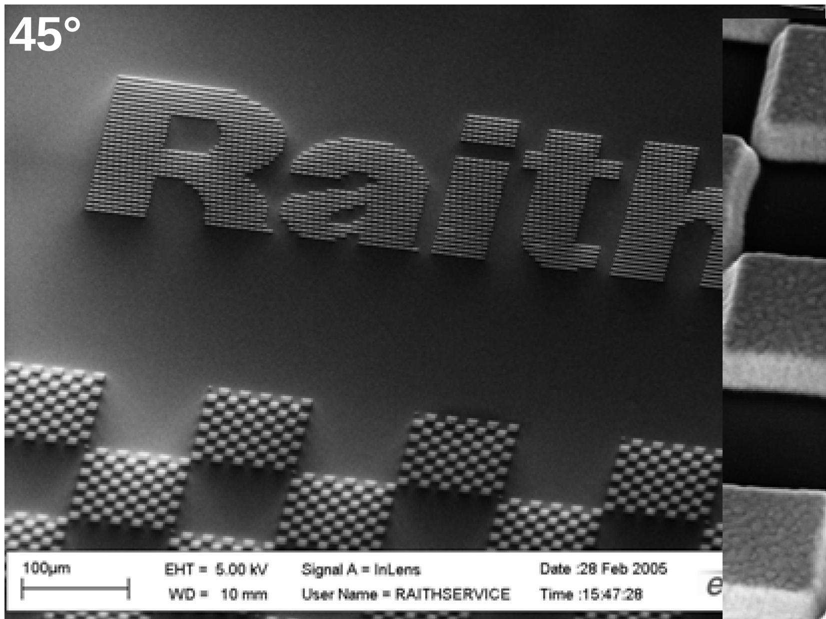
AFM supertips
(courtesy Nisch, NMI Reutlingen, Germany)

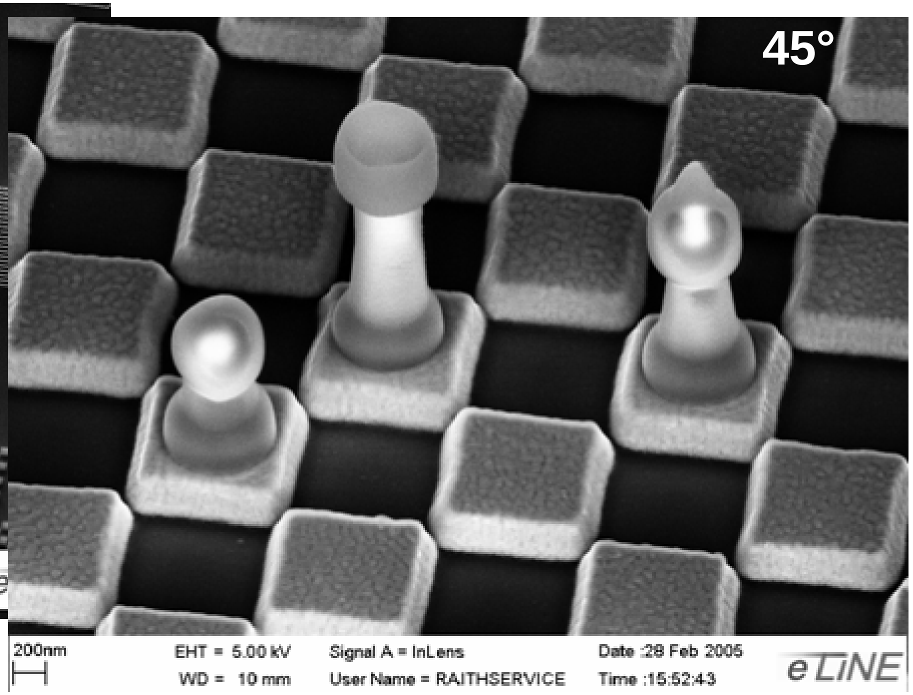




EBID of SiO_x

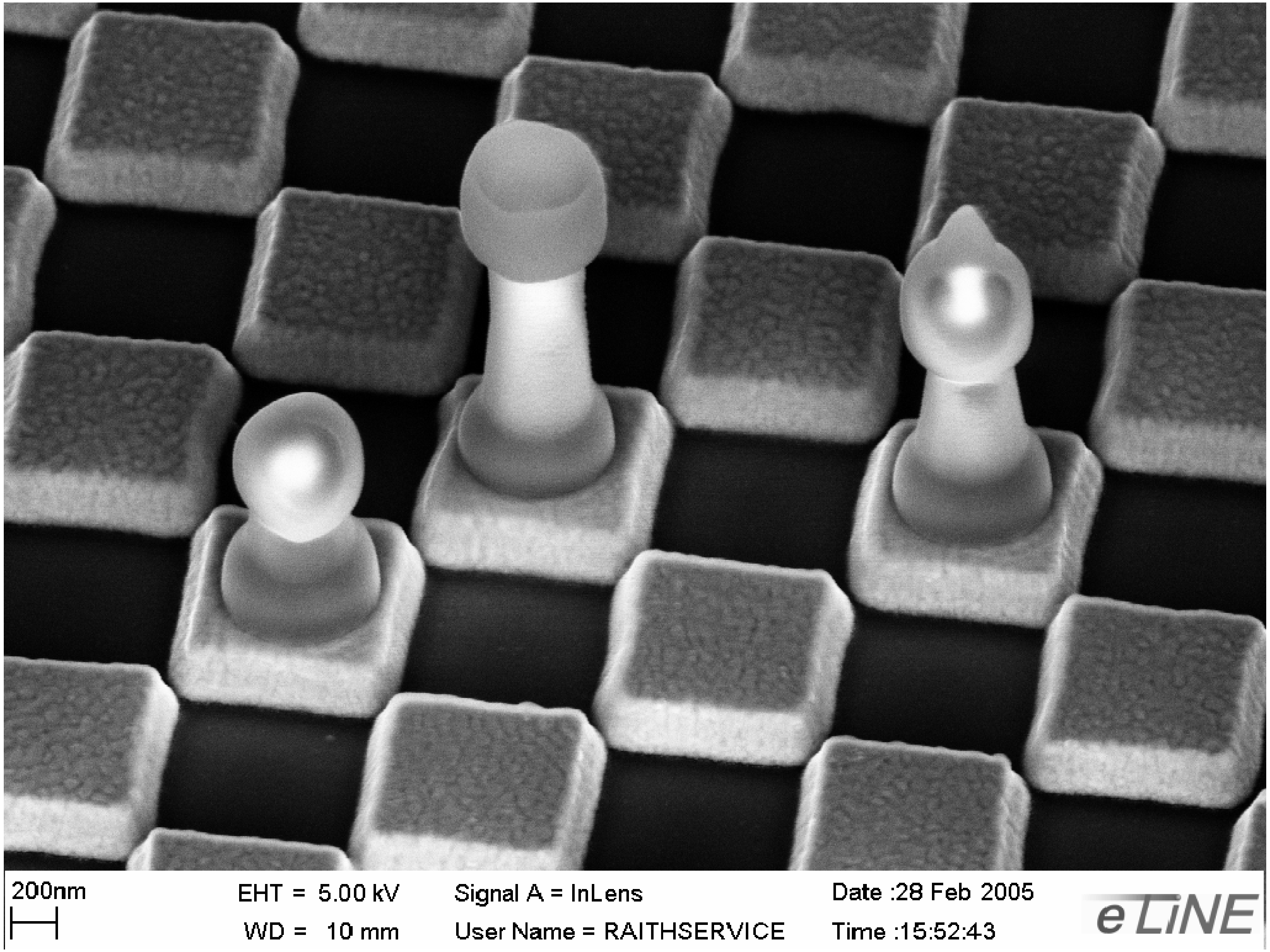






3D „Nano-Chess“, S. Bauerdick, Raith inhouse

Applications – Electron Beam Induced Deposition



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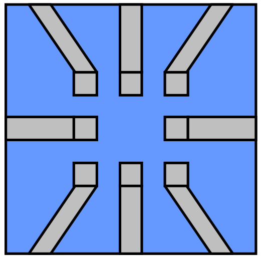
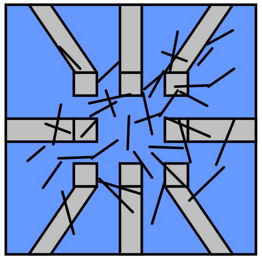
Latest applications – EBID

SiO_2 sample with Au electrodes

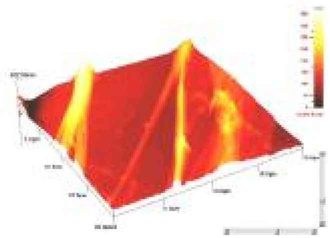


SWCNTs on SiO_2
in co-operation with ETH Zürich

Random placement of SWCNTs (1.3 nm diameter) on SiO_2 sample



Detection of applicable SWCNTs with the help of an AFM



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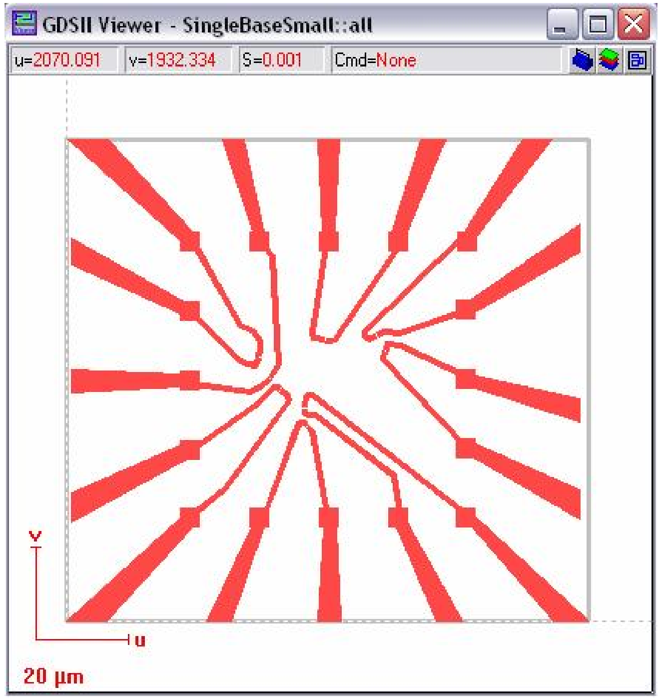
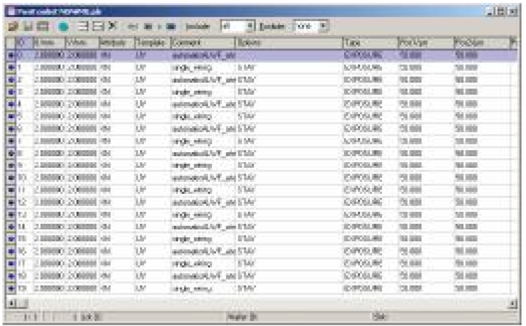
Latest applications – EBID

Automatic preparation of matching design



Import to GDSII-editor of *e_LiNE* software

Preparation of exposure batch job (positionlist)



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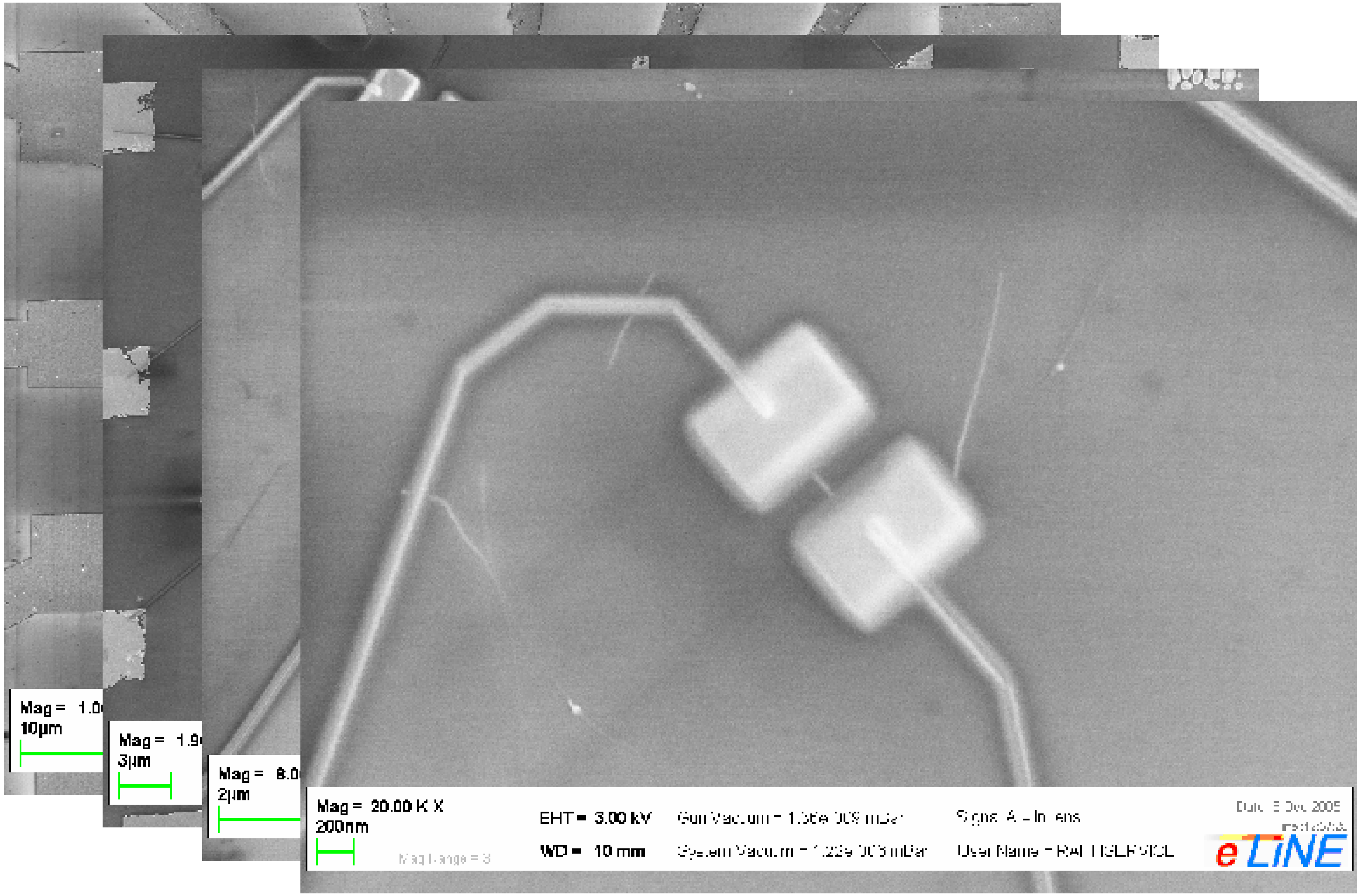
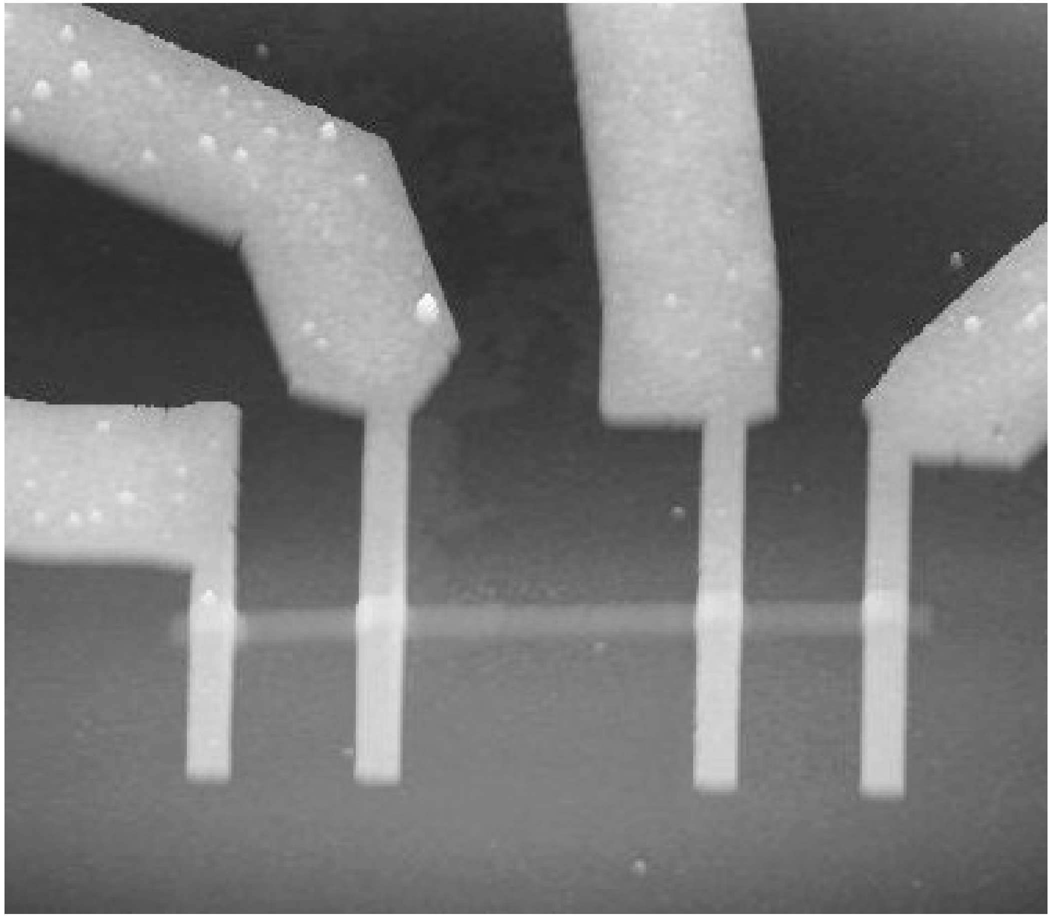
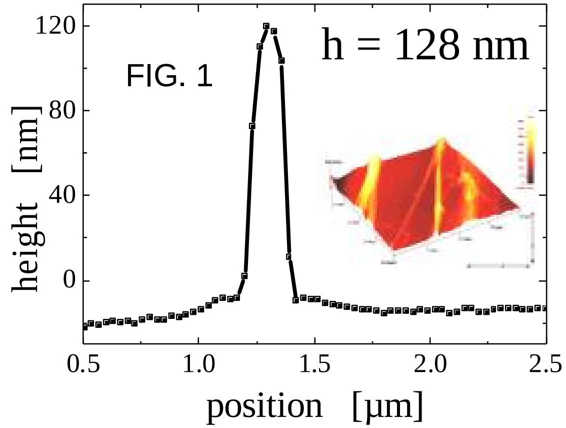
Latest applications – EBID

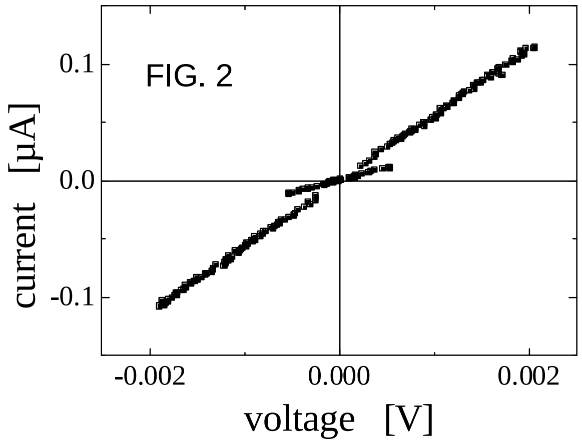
Exposure results



Latest applications – EBID







4 point measurement array for conductivity measurement of deposited material by EBID

FIG. 1. AFM measurements of EBID rectangles used for conductivity tests => **down to 4.5·10^{-3} Ω·cm !**
FIG. 2. Electrical 4 point measurement of a 70 nm wide EBID rectangle exposed using a dwell time of 300 ms. From the 4 point results a barrier like characteristics due to the gold – EBID interface becomes apparent.

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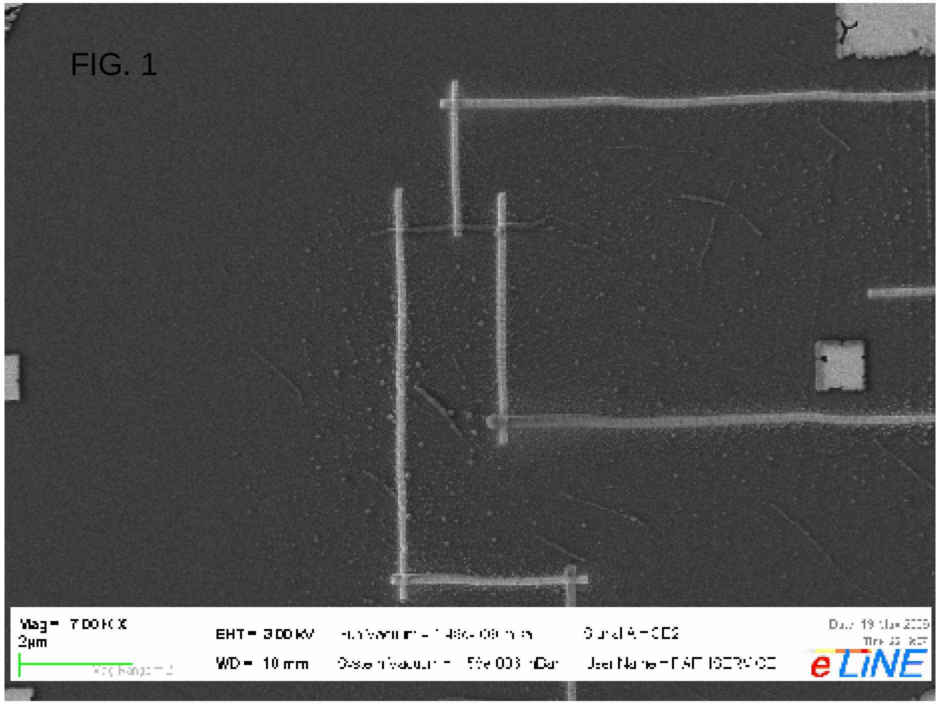
Latest applications – EBID



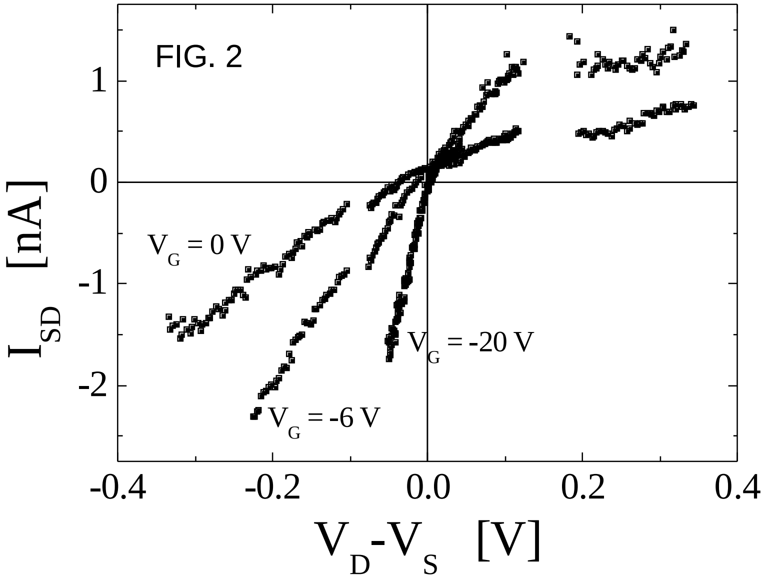


FIG. 1. SEM micrographs showing a 3 point wiring of CNTs fabricated by EBID.
FIG. 2. Transistor characteristics of the CNT shown in Fig. 1 using EBID wiring, 3 point measurement and a back gate (200 nm SiO_2), source-drain current vs. voltage for various gate voltages

To be published in JVST B, S. Bauerdick et al.

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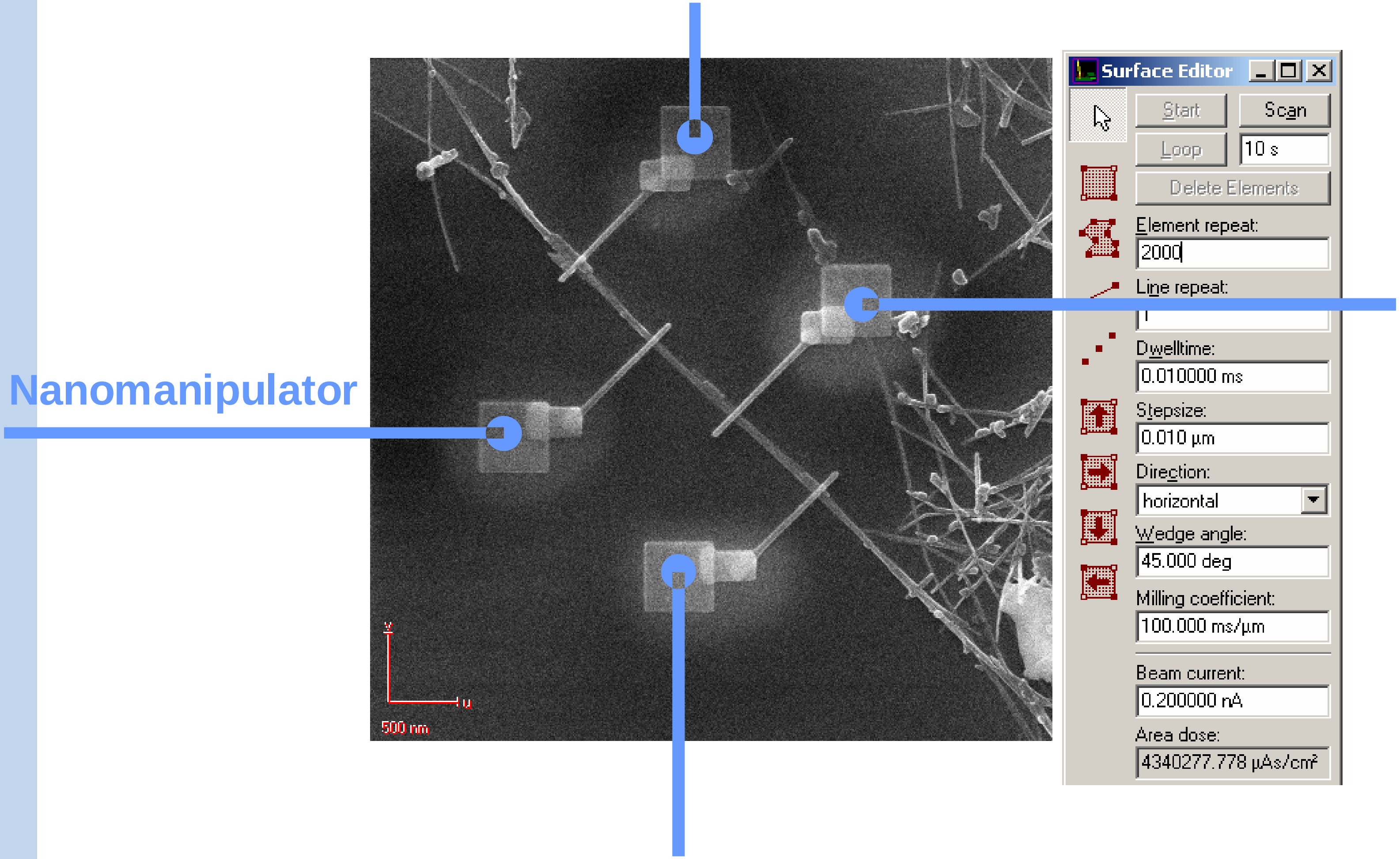
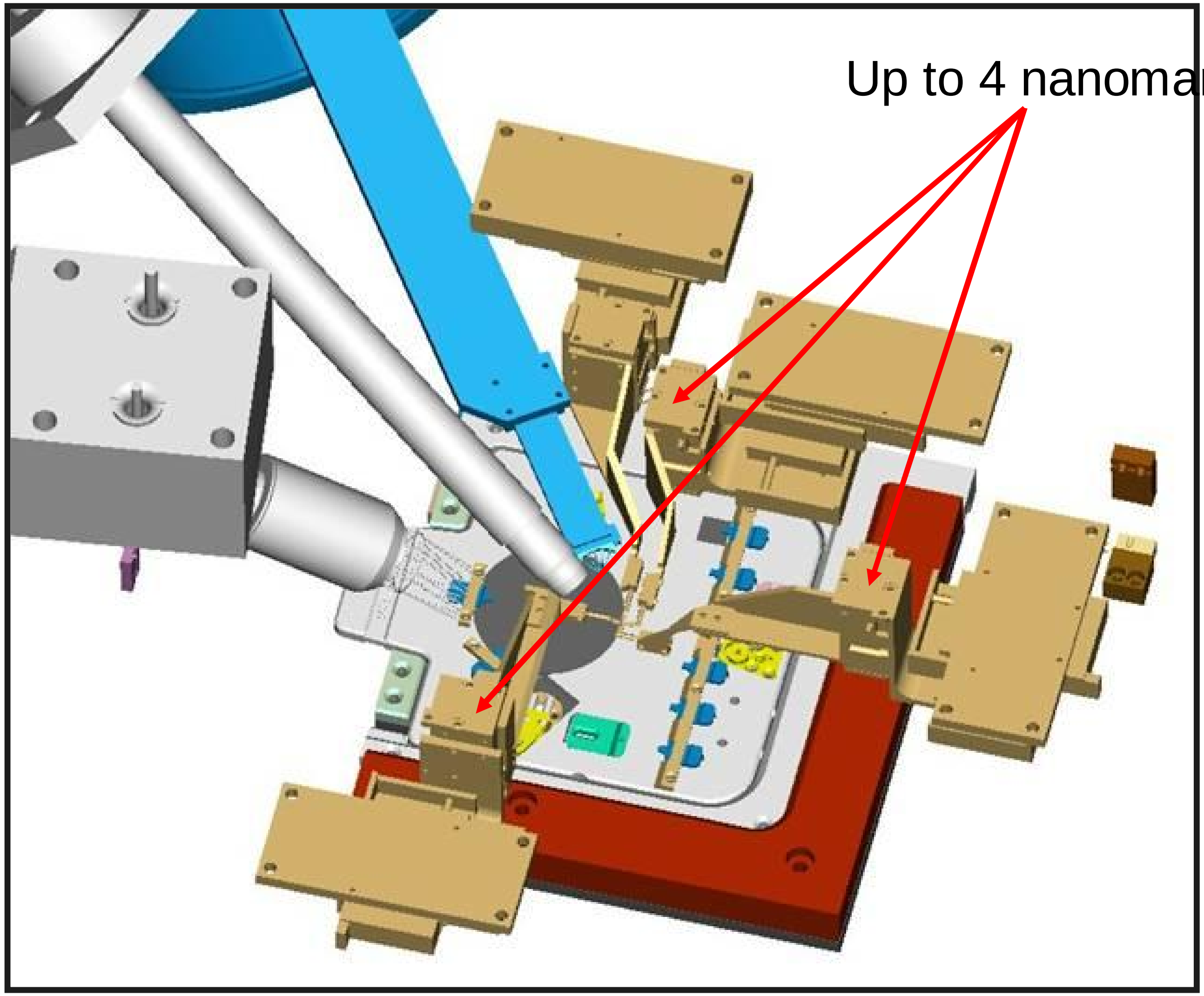
Latest applications - EBID



„Wiring“ of CNTs on SiO_2-sample (by metalorganic precursor deposition)
S. Bauerdick, Raith inhouse

Nano-Manipulators (CAD top view)



Up to 4 nanomanipulators !

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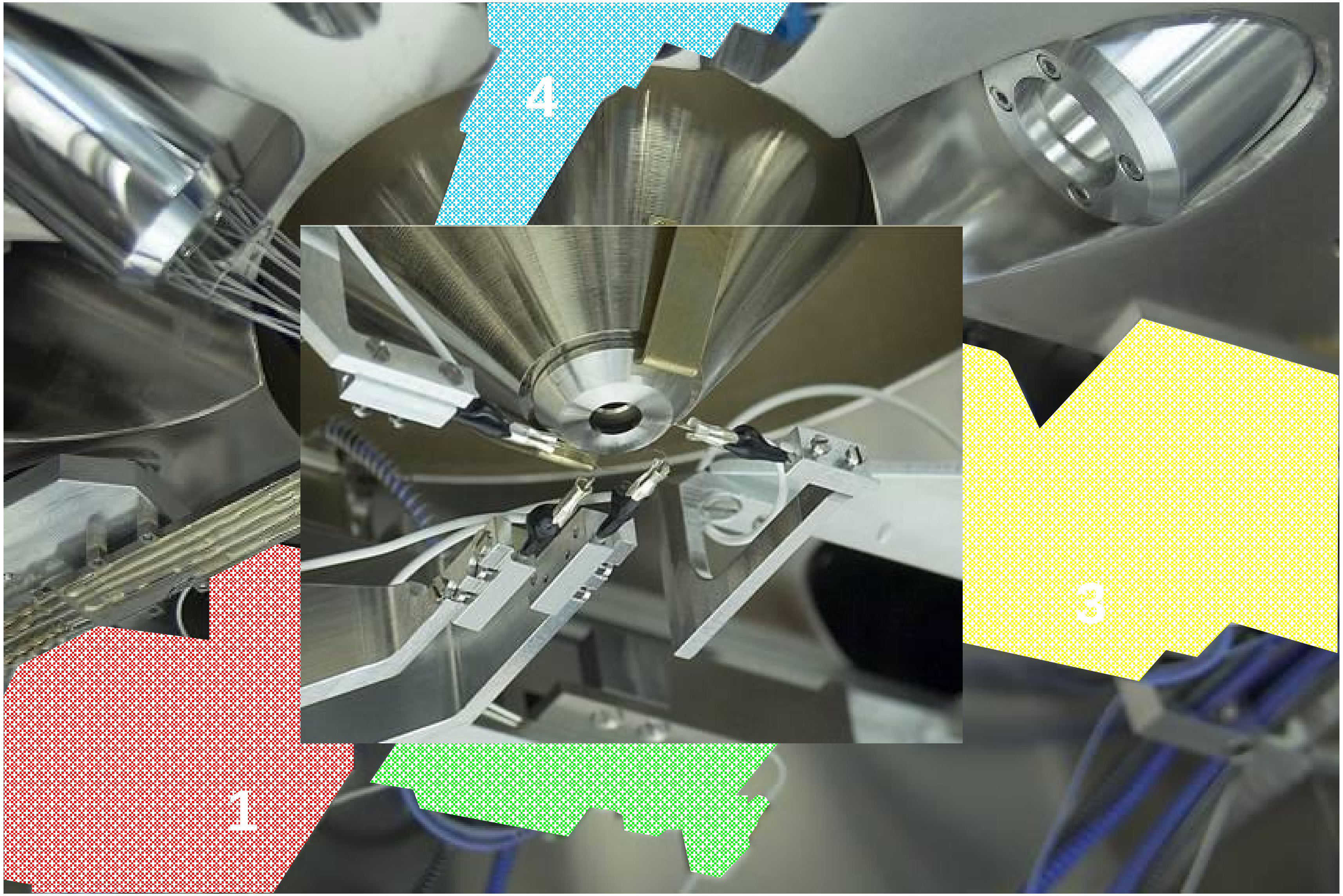
4 Nanomanipulators arranged



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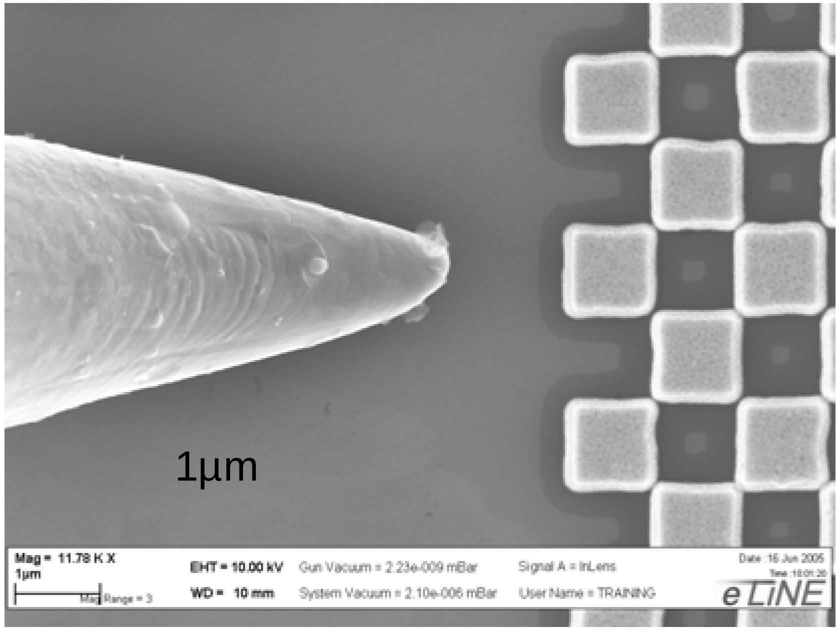
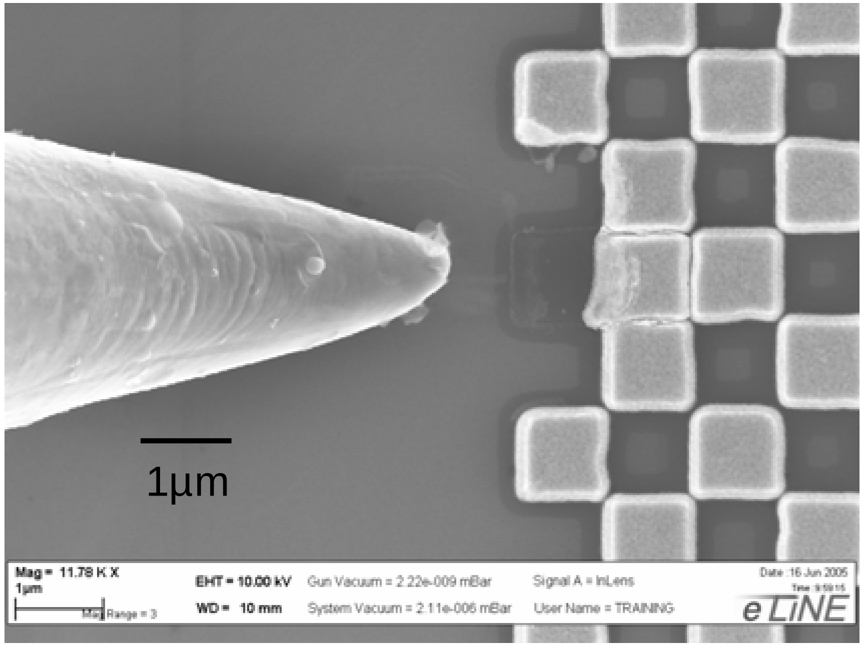
Nanomanipulator applications



„Nano-Sokoban“

A.Linden, S. Bauerdick, Raith inhouse



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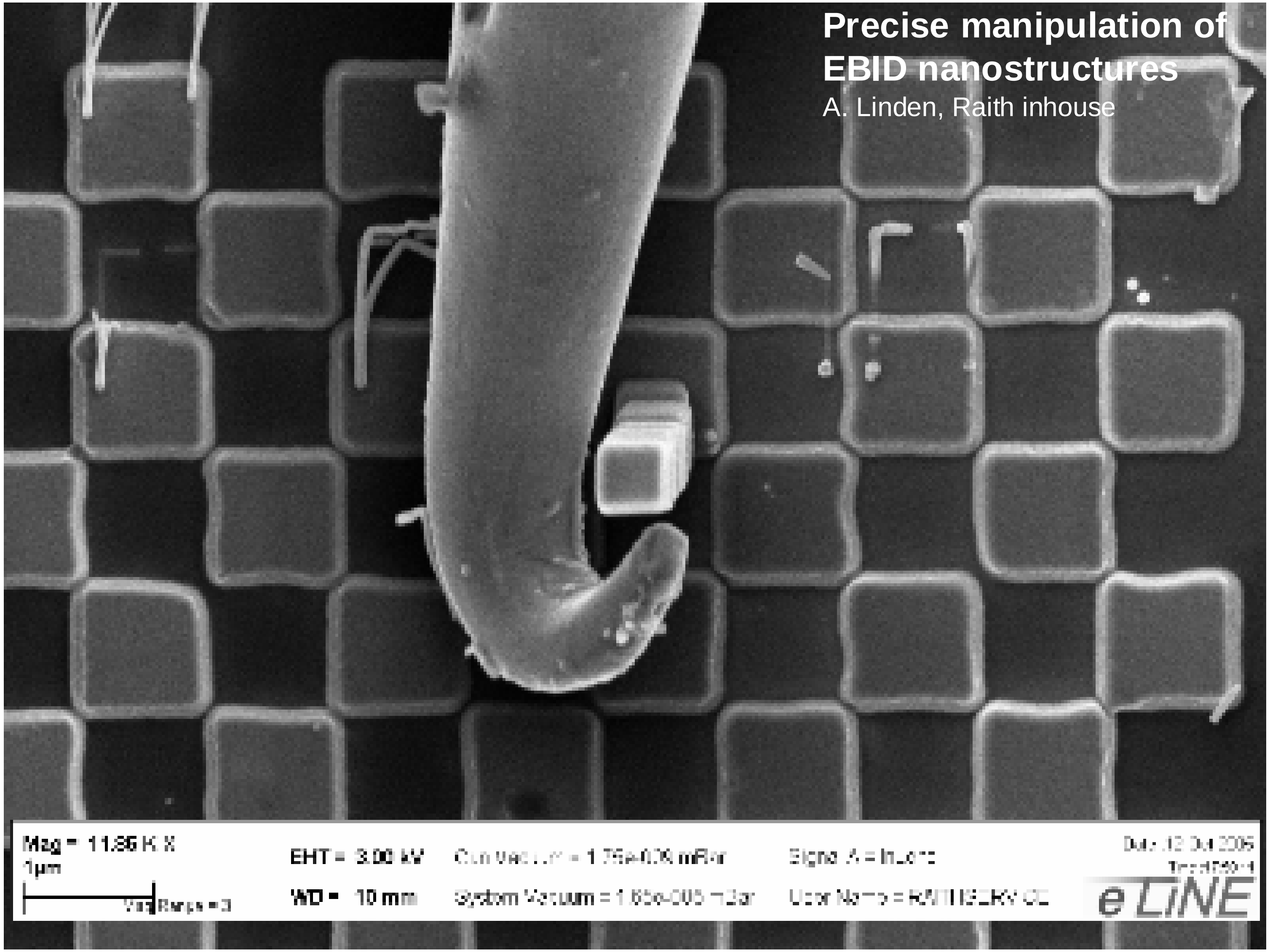
EBID *and* Nanomanipulation



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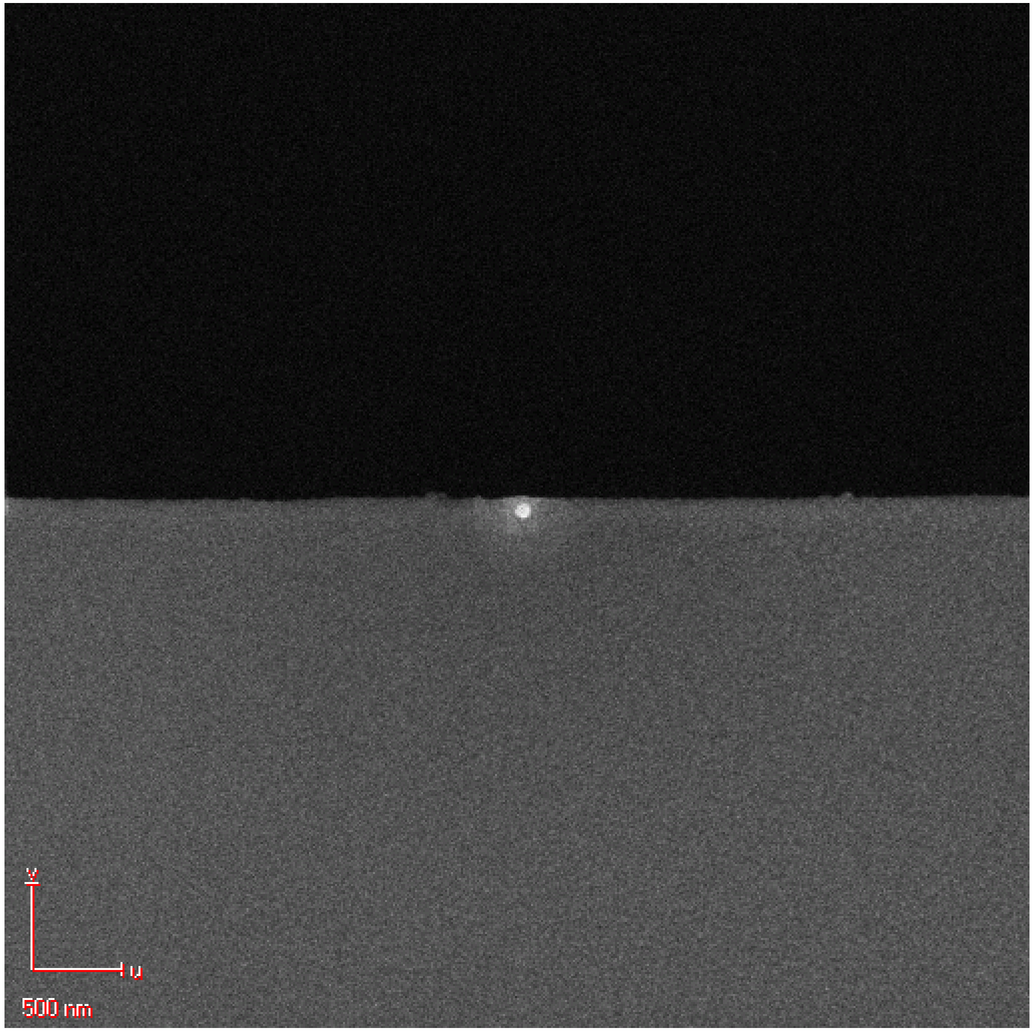
EBID *and* Nanomanipulation



EBID and manipulation of small nanostructures
A. Linden, Raith inhouse

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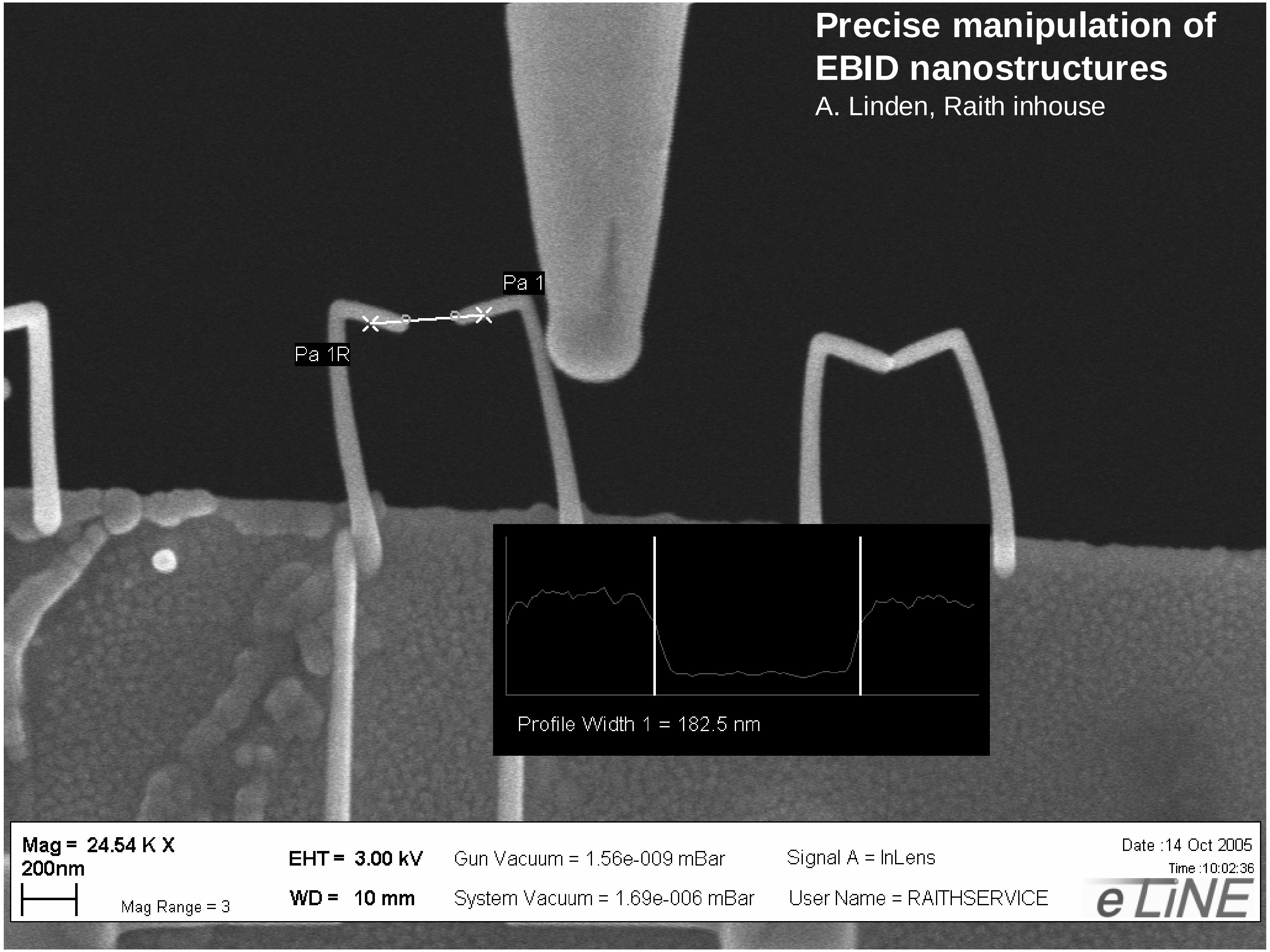
EBID *and* Nanomanipulation



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EBID / Nanomanipulator applications

EBID / NMT Movie

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INNOVATION FROM A WORLD LEADER IN ELECTRON BEAM LITHOGRAPHY
AND SEMICONDUCTOR NAVIGATION SOLUTIONS

Further new EBL Functionality …

Fixed Beam Moving Stage (FBMS) Mode

Fixed Beam Moving Stage Applications

Typical FBMS applications are extended (curved) paths

- with a length several mm or cm
- with a fixed width in the range of 20 nm to 20 µm
- where stitching errors are crucial for the performance of the device
- where a large number of stitching borders would result in long exposure times

FBMS Mode: Principles of Operation

Stage travels at constant speed along (curved) paths of any length and shape - with stationary beam

à Avoids stitchfield boundaries

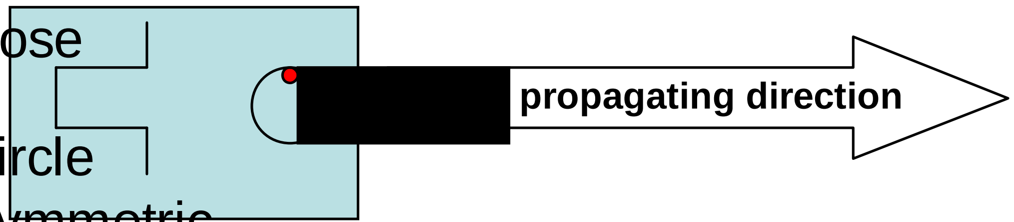
à Effective for extended paths

A. Spot Mode

B. Area Mode

constant dose

circle symmetric



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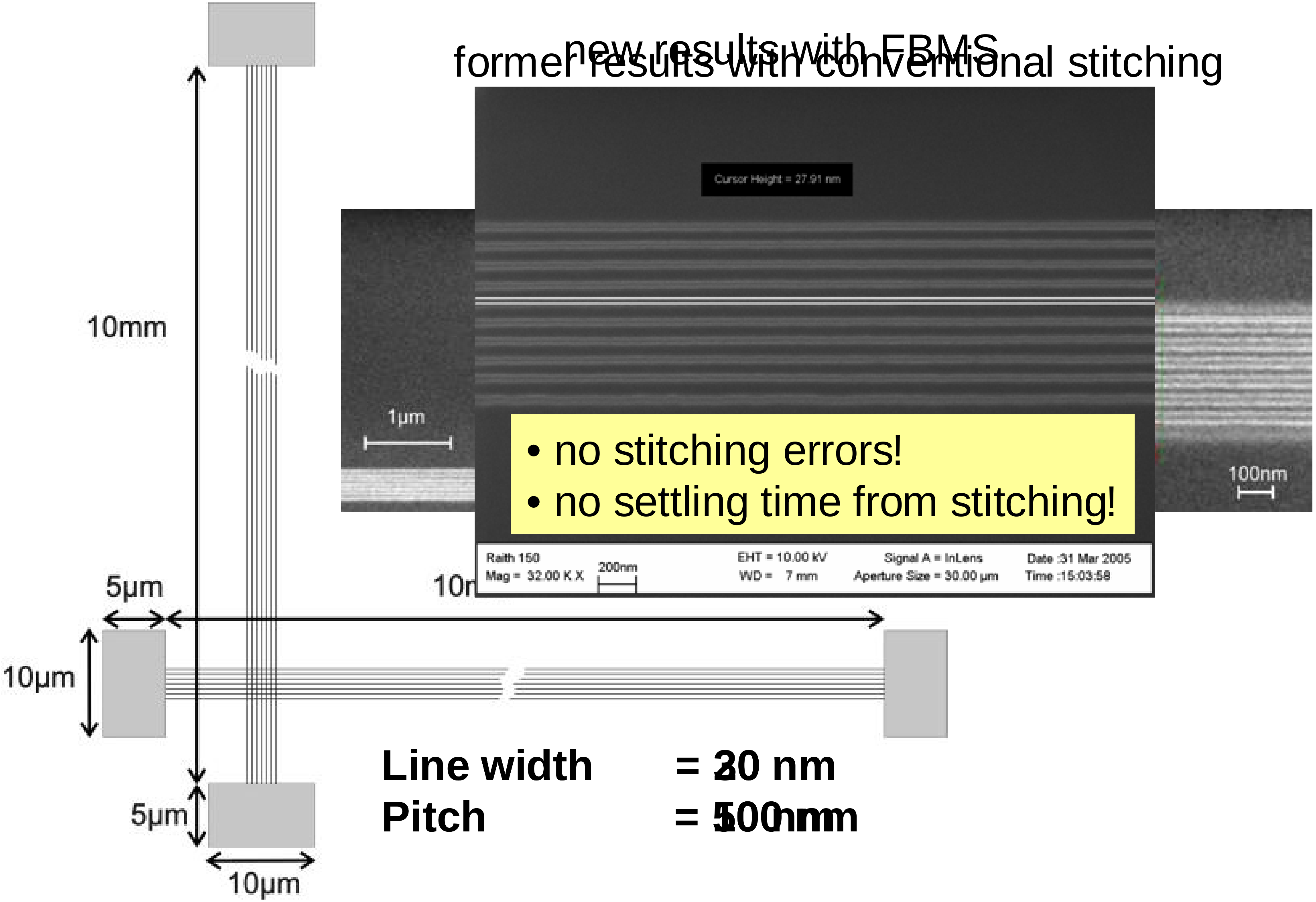
Application Example

former results with conventional stitching

new results with EBMS



- no stitching errors!
- no settling time from stitching!

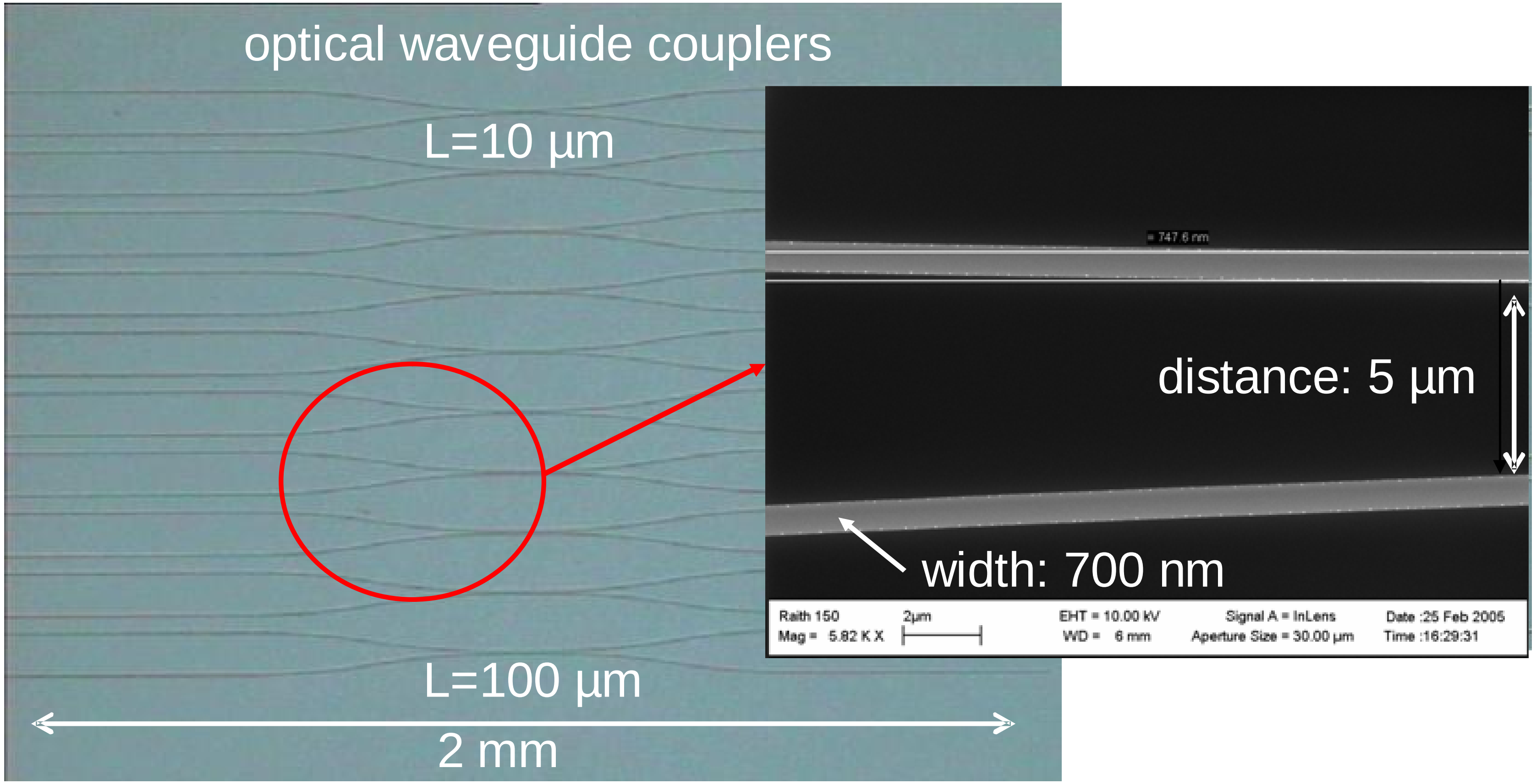
Line width = 20 nm

Line width = 30 nm

Pitch = 100 nm

Pitch = 500 nm

FBMS Application: Optical Waveguides



Minimum waveguide losses due to stitching-free FBMS writing!

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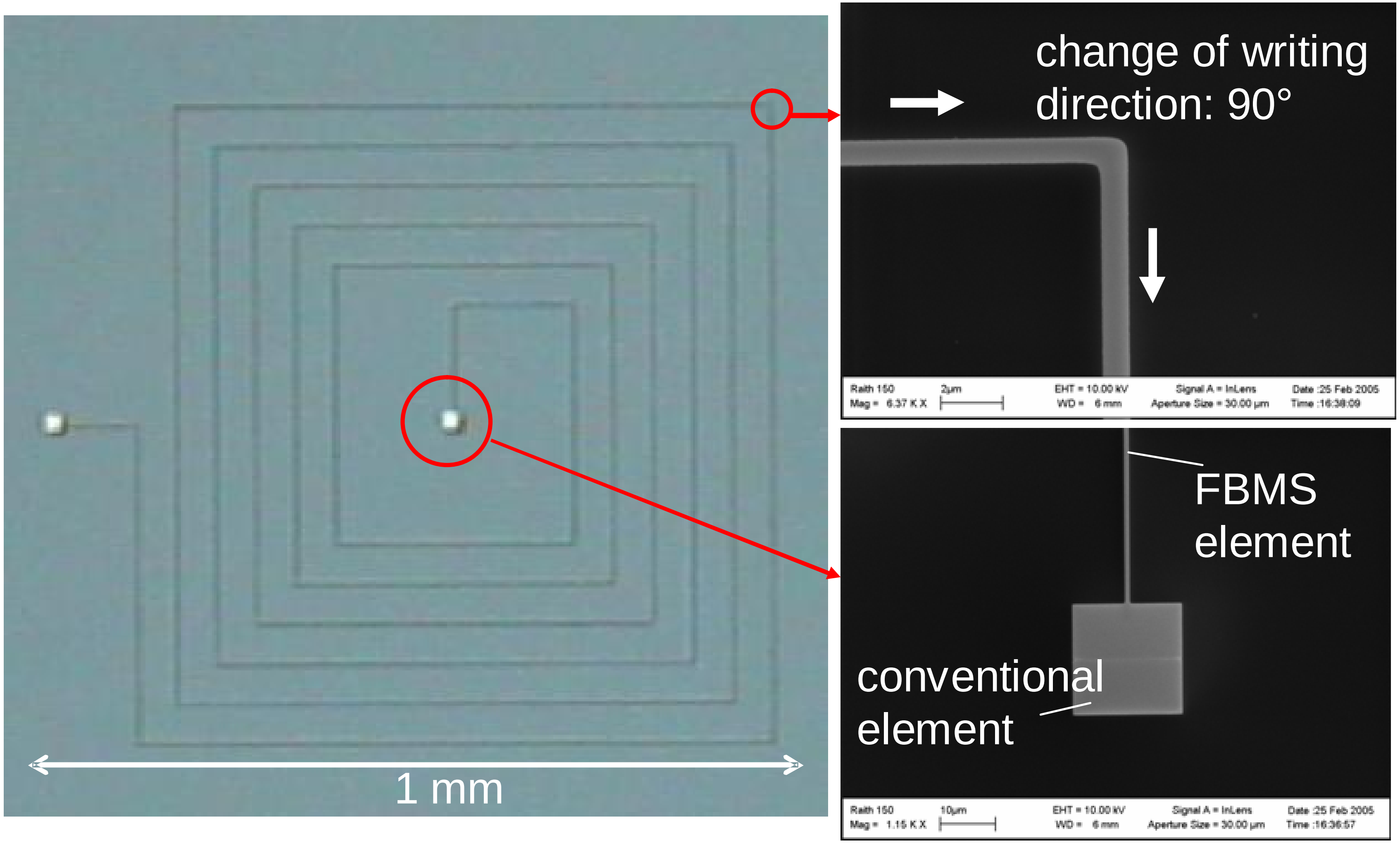
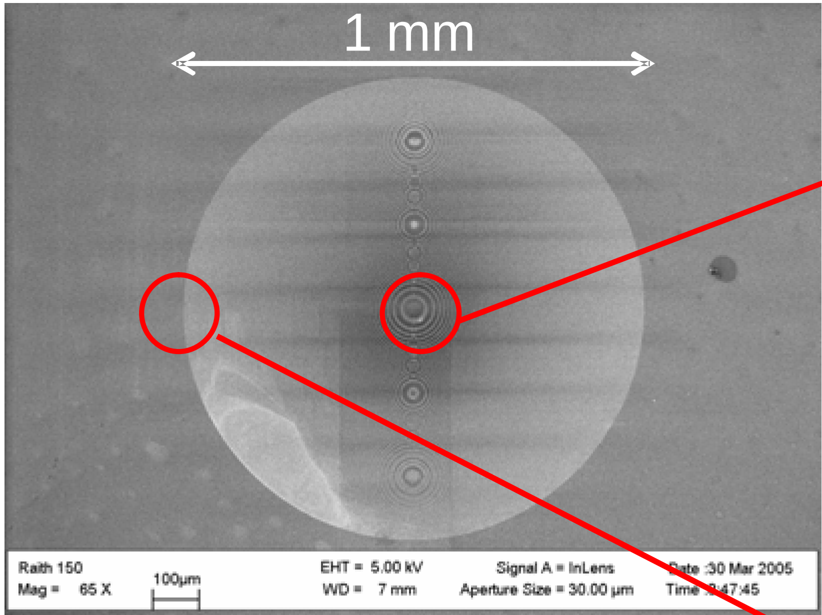
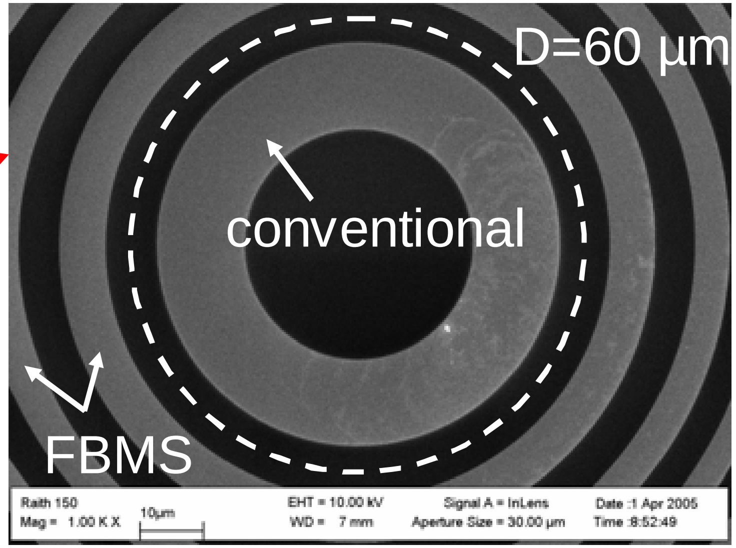
FBMS Application: Electrical leads

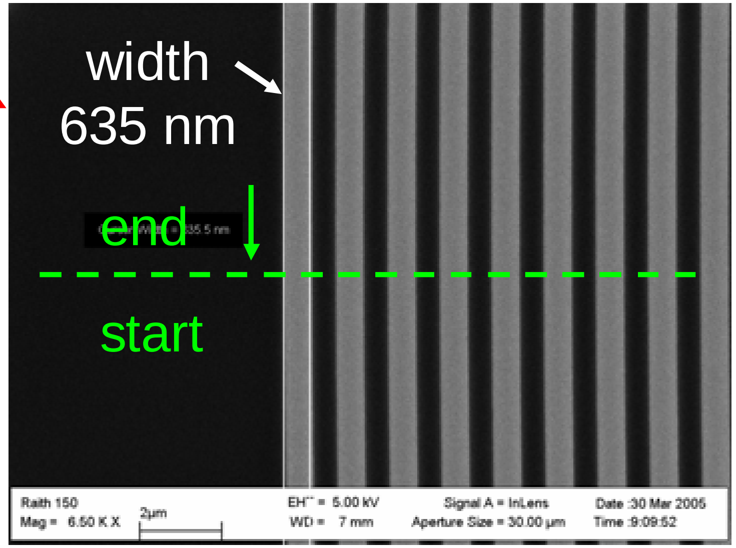


Elongated electrical connections without points of interruption

FBMS Applications: Zone plates







195 different FBMS path widths in a single exposure.

required dwell time: 43.6 min
FBMS exposure time: 45 min

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Raith new *ion*LiNE

- ***ion*** **beam *Li*thography, *N*anofabrication and *E*ngineering workstation**

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Introduction

ionLiNE:

ion **beam** ***Li*** **thography,** ***N*** **anofabrication and**
E **ngineering workstation**

New class of instrument, no competition against well established Dual/Cross/Double beam systems !

Raith new ionLiNE - concept

- **Same platform as e_LiNE, all options possible …**

- Nano lithography tool architecture basis
- Advanced ion beam patterning capabilities
- Simple operation
- High level of system integration

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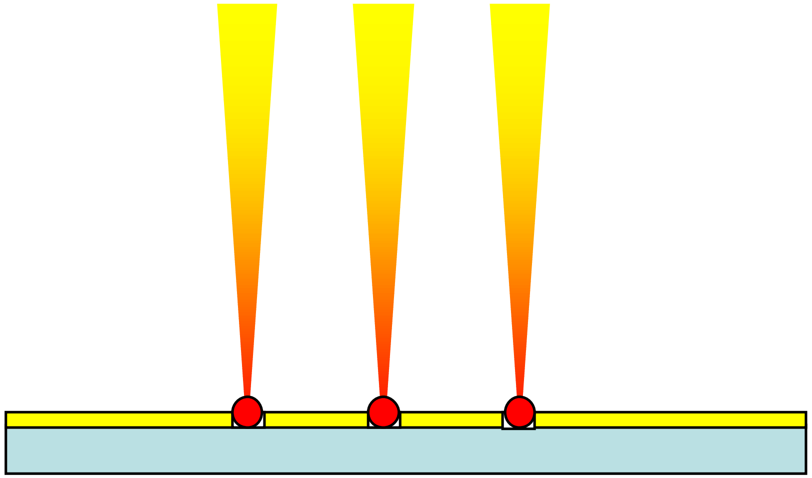
Raith new ionLiNE - main applications

- **Large area, UHR & low dose processes for …**
  (J. Gierak, talk last monday afternoon)

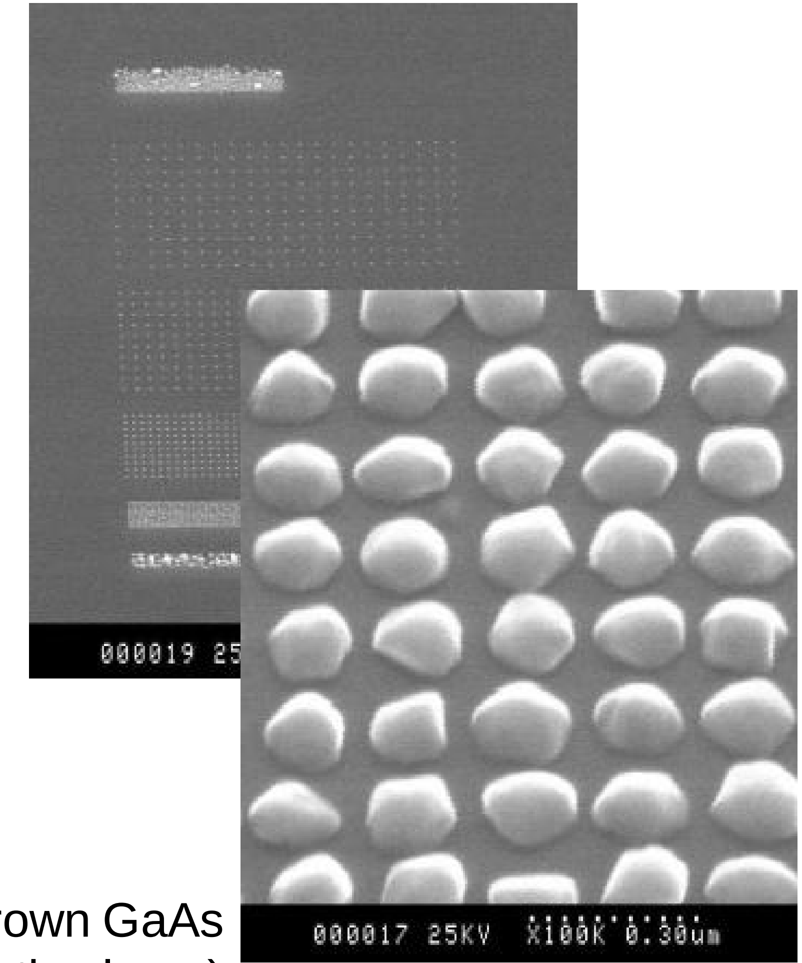
- Selective epitaxy / self-assembly
- (Magn.) Thin film nano-patterning/-engineering
- Conductive material nanopatterning
- Surface functionalizaton
- Defect injection / implantation
- Nanopores
- 3D nanoengineering
- ion beam lithography

Selective epitaxial growth by surface "functionalization"

Expose low dose FIB in order to erase protective layer thus opening / „functionalizing" substrate surface for selective epitaxy



Apply MOCVD for GaAs growth



SEM images of MOCVD grown GaAs
(SiNx protective layer)

MNE2005 Vienna, Kitslaar et. al.

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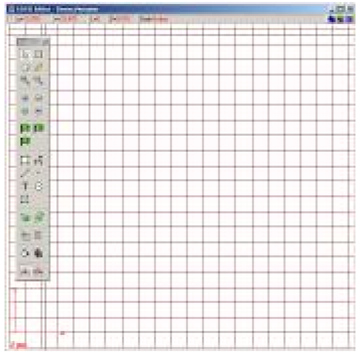
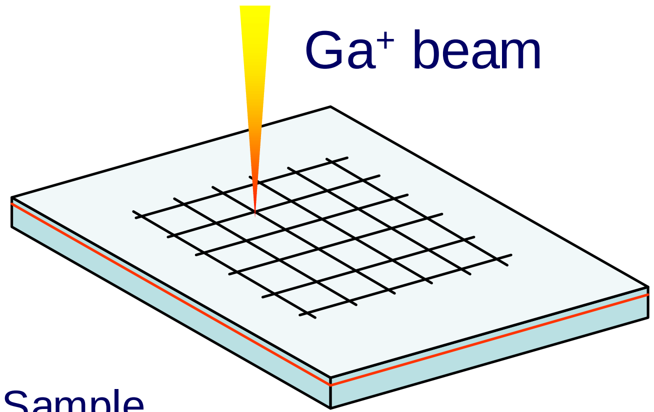
Creating small magnetic domains

Taylor / create borders between physical active (here: magnetic) areas with low dose and UHR FIB

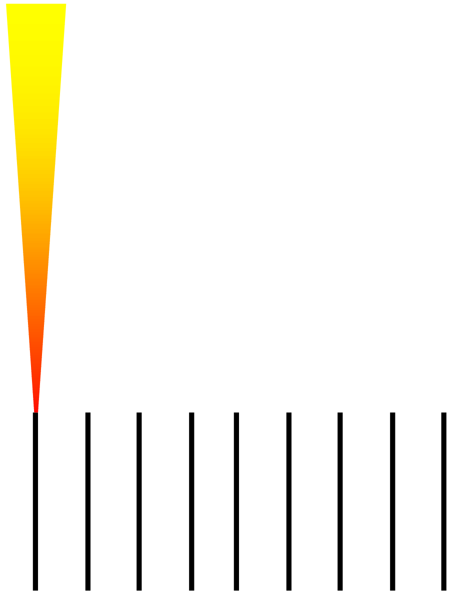


GDSII Design



Ga^{+} beam

Sample
Pt(3.4nm)/Co(1.4nm)/Pt(4.5nm)



=> **Thin film** engineering

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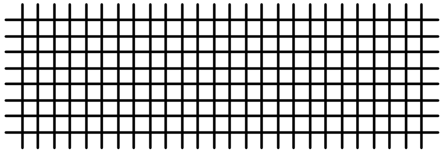
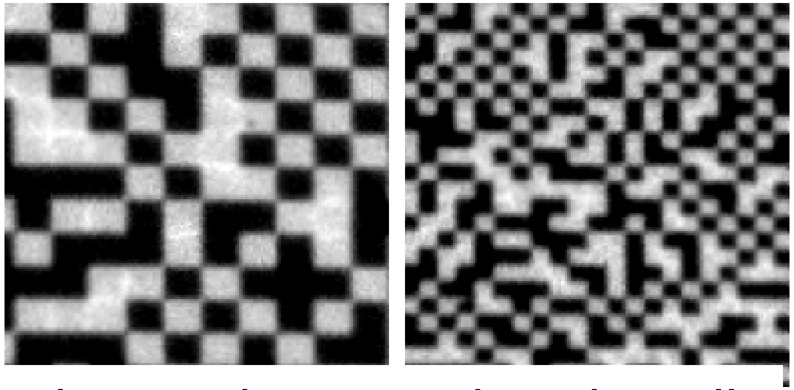
Creating small magnetic domains

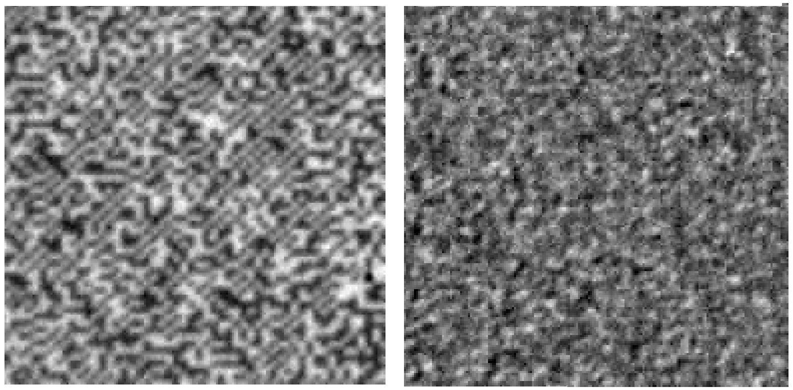


Taylor / create borders between physical active (magnetic) areas with low dose UHR FIB



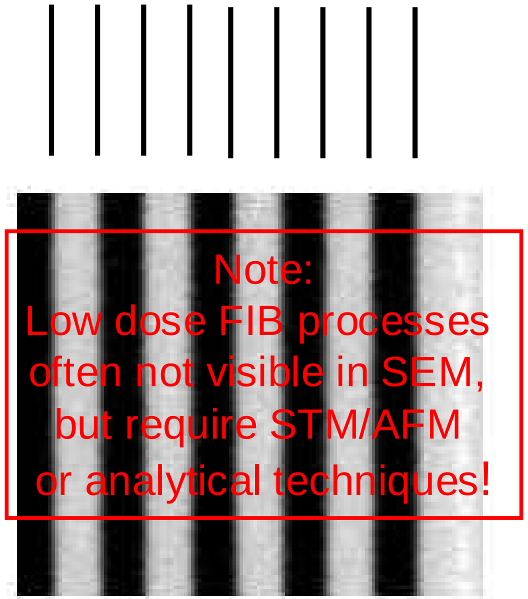
Distance between domain walls

1500 nm 750 nm



300 nm 50 nm

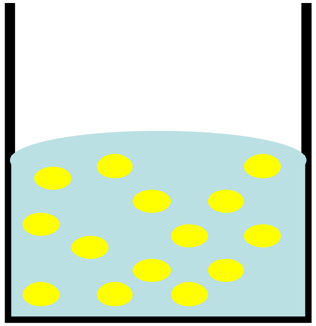
Faraday microscope image of pre-structured Pt/Co/Pt thin film



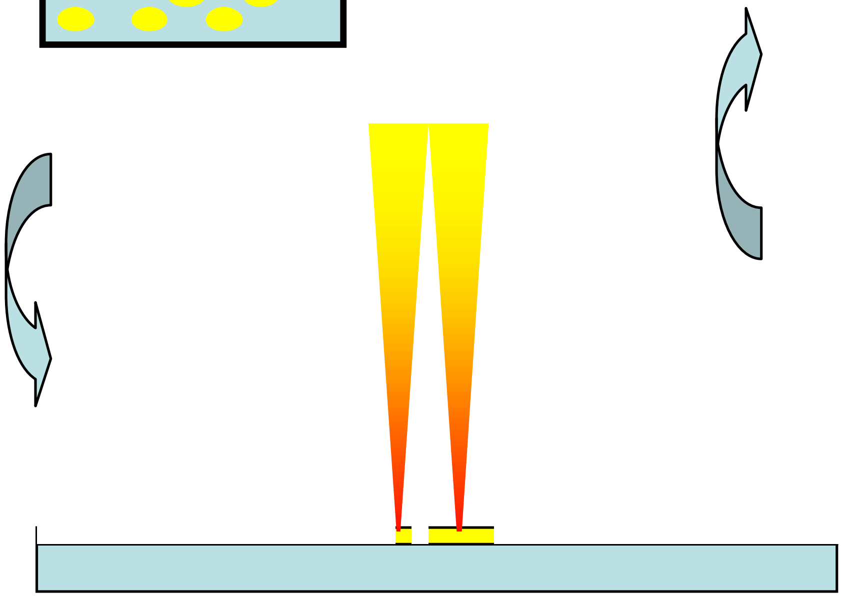
J. Appl. Phys. 95, 2614 (2004), V. Repain et al.

Nanopatterning of conducting material

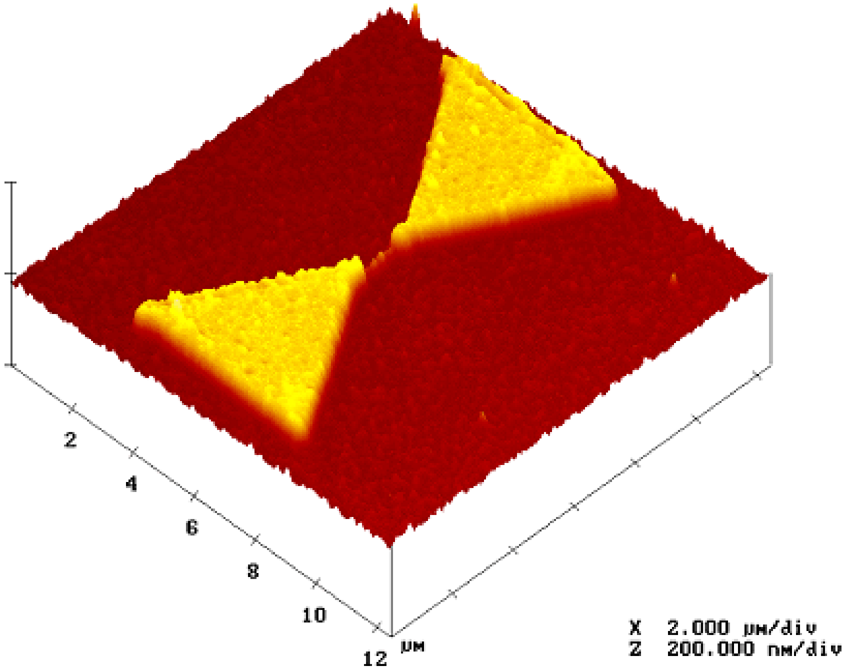
“Exposure” of cluster film “resist”



Spincoat solution containing Au_{55} nanoparticles with organic ligand shell



Apply FIB to destroy „protective“ ligand shell in order to „weld“ Au_{55} nanoparticles, dissolve unexposed areas

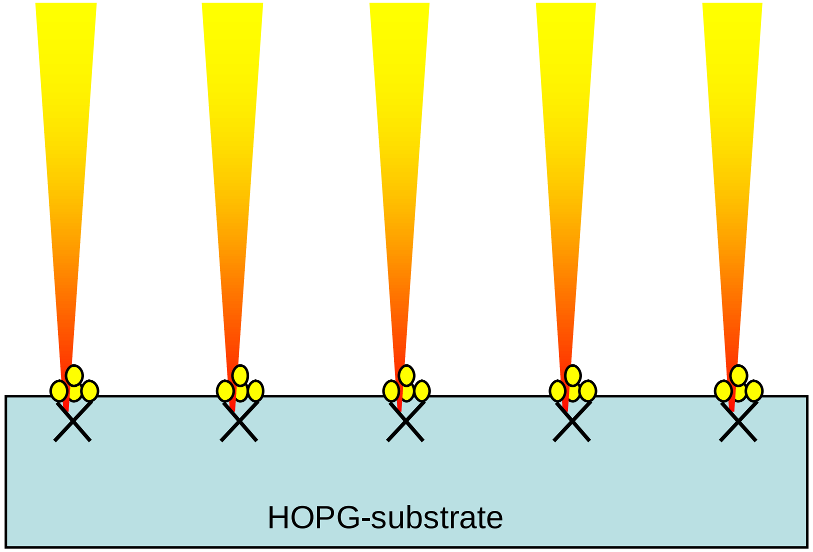


Au_{55} down to 30nm line width

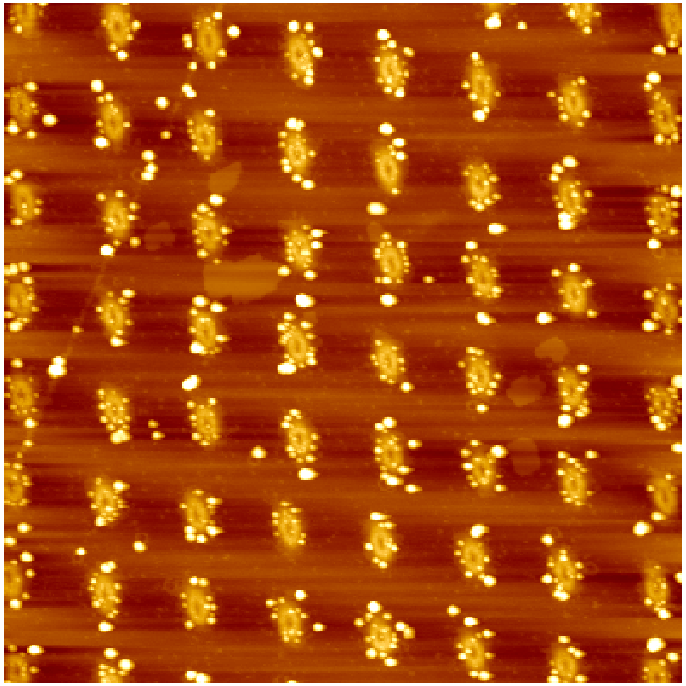
JVST B, Vol. 17, No. 6, Nov/Dec 1999

Crystal defect injection and Au deposition

Expose HOPG with low dose FIB and induce surface defects serving as nucleation sites



Deposit Gold cluster which will preferentially nucleate at surface defects („functionalization“)



Deposited Au cluster on HOPG substrate

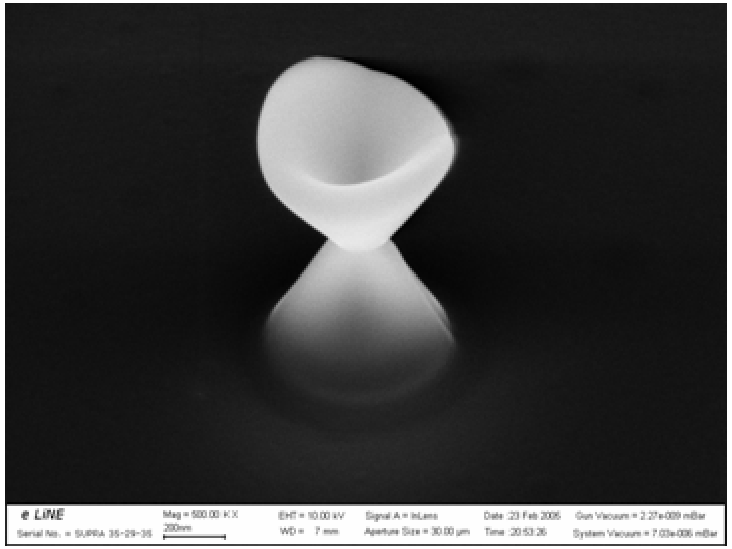
Appl. Surf. Sc., Vol. 226, 1-3, 2004

Raith

Thank you for your attention !

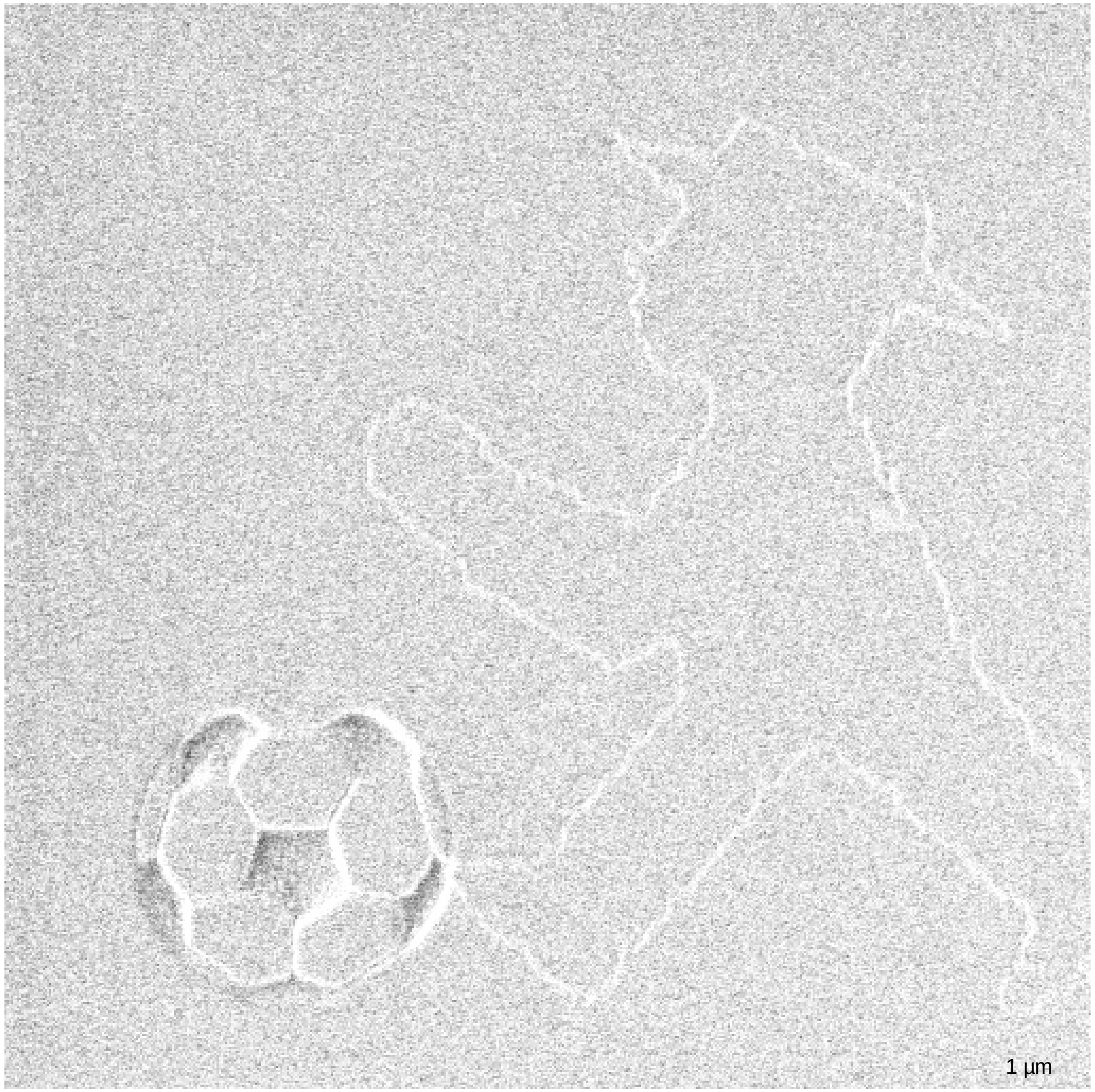
QUESTIONS, PLEASE !!!

… or like a cup of tea?



Raith

Raith new ionLiNE

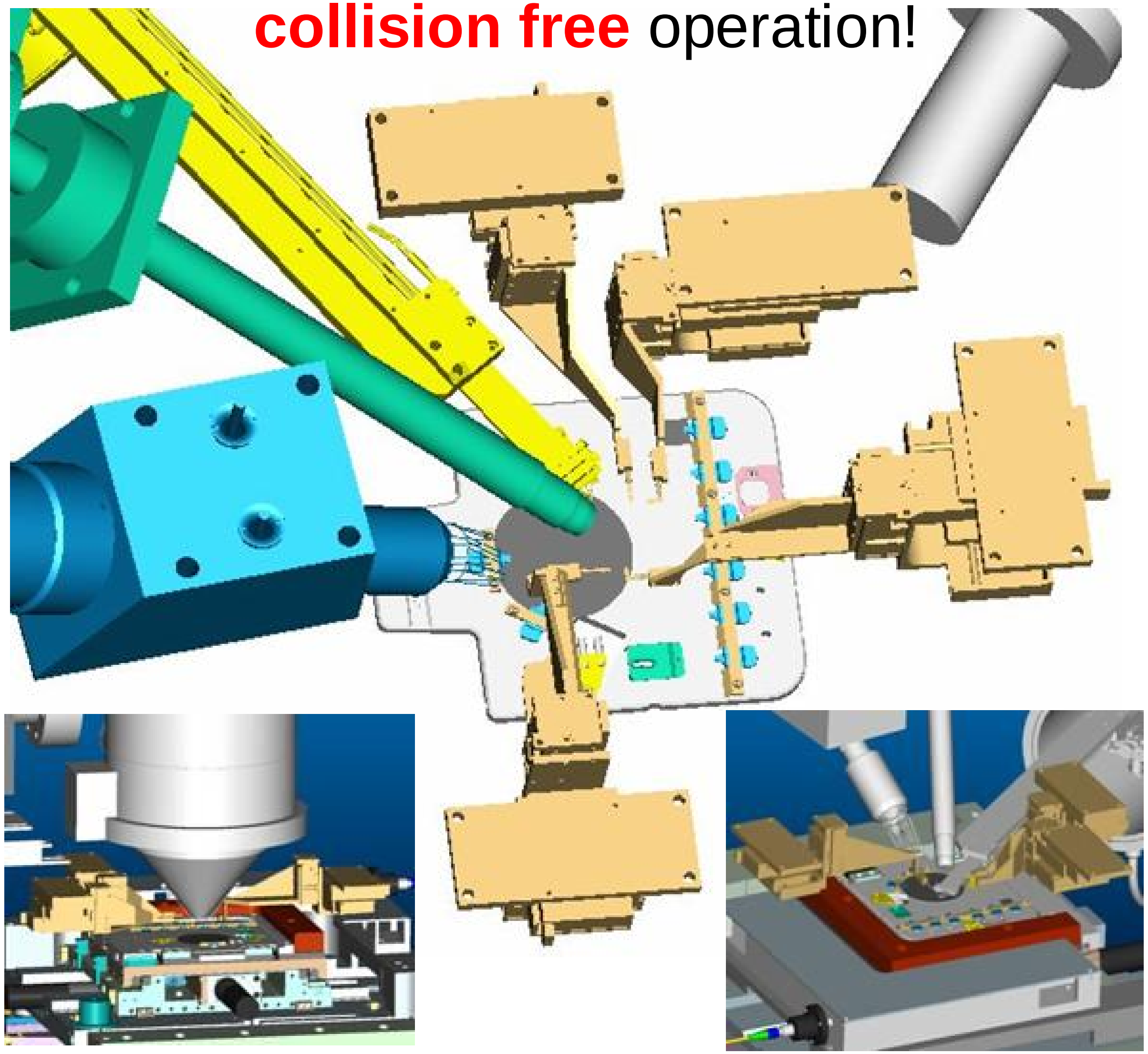


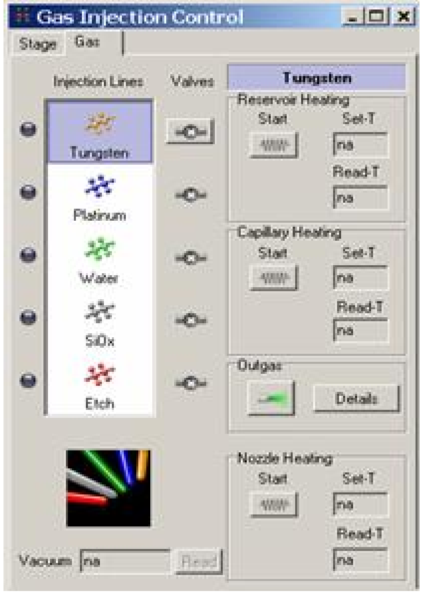
… et bonne chance pour „les Bleus“ contre les brésiliens !

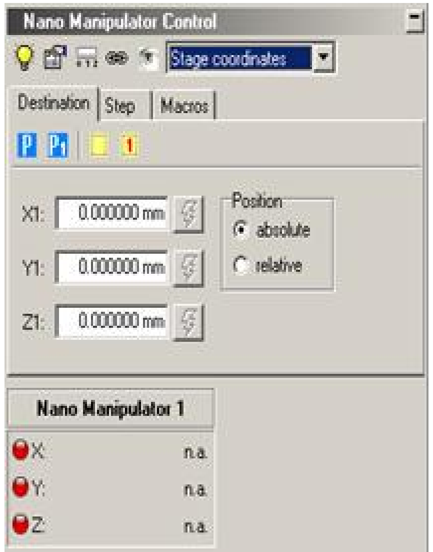
FIB 3D demo pattern,
S. Bauerdick, Raith inhouse

High level of system integration and control

collision free operation!







EBID summary

ENABLING Advanced Nanotechnology

Ion Beam induced deposition (IBID) is widely used for semiconductor application.

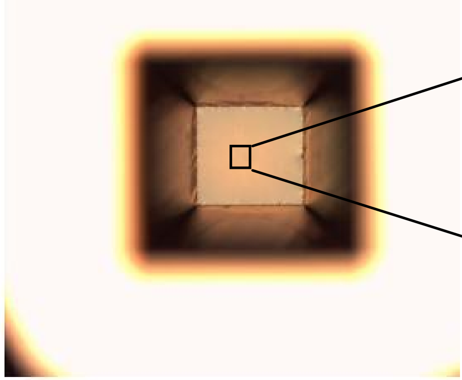
However, Electron Beam induced deposition (EBID) is at the edge to get extremely popular due to following significant advantages:

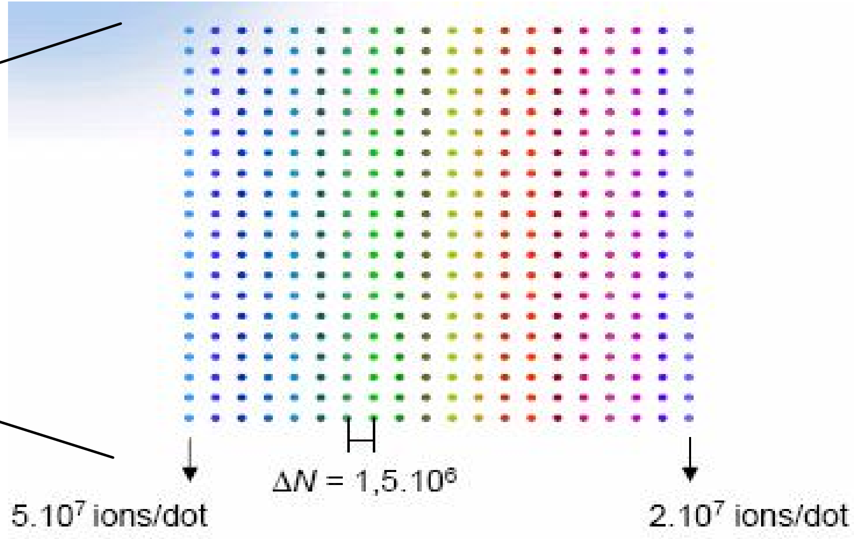
- higher resolution by smaller probe size
- no gallium implantation / contamination
- no unwanted etching, damage of sensitive samples (Carbon Nanotubes, thin films)
- less contamination around the incident point (IBID requires intensive healing processes - Takai et al.)
- higher imaging resolution capability for Nano Engineering

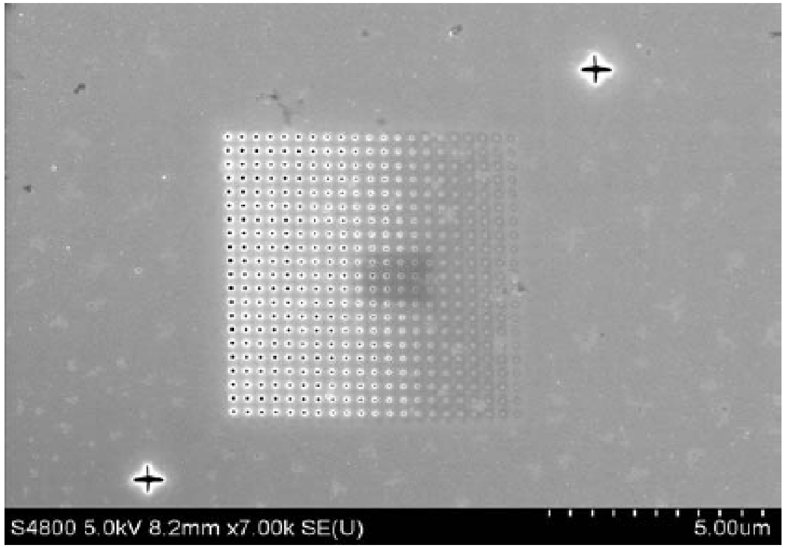
Raith

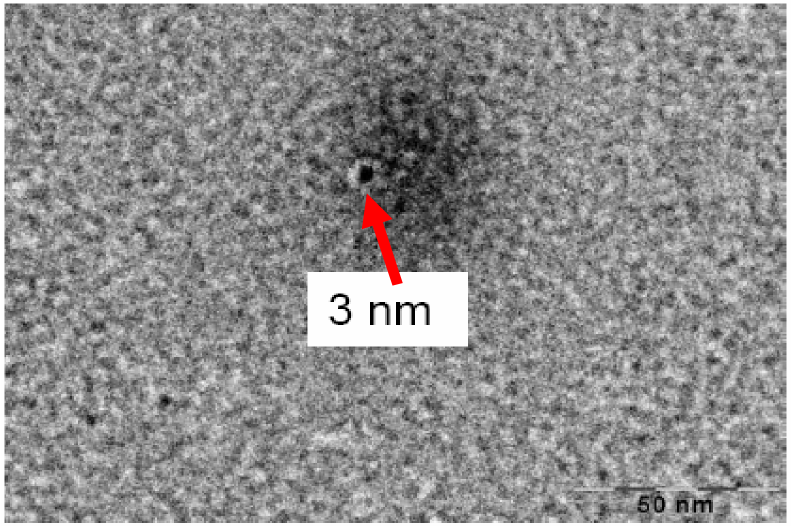
Nanopores – Drilling

Membrane 85 nm SiC









Raith