

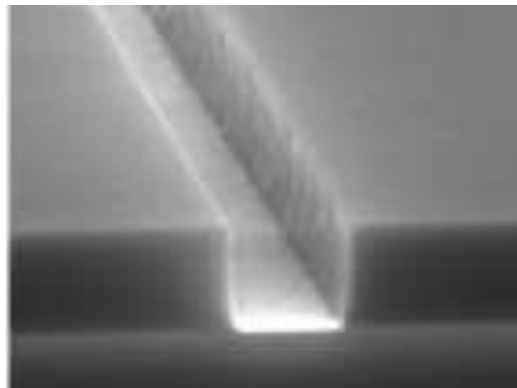
Introduction into Electron Beam Lithography

What is electron beam lithography?

Method that uses a focused beam of electrons to draw patterns on a surface covered with an electron-sensitive film called resist.

Type of resist

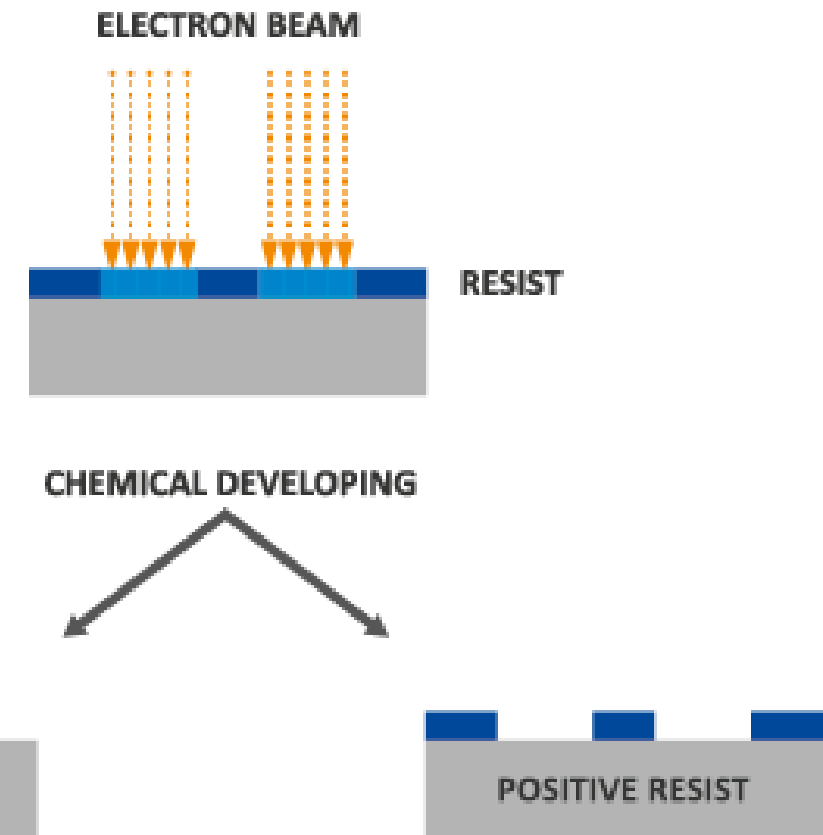
- Positive resist – PMMA, ma-P, CSAR, ZEP, ...
- Negative resist – HSQ, ma-N, NANOTM SU-8 series, ...



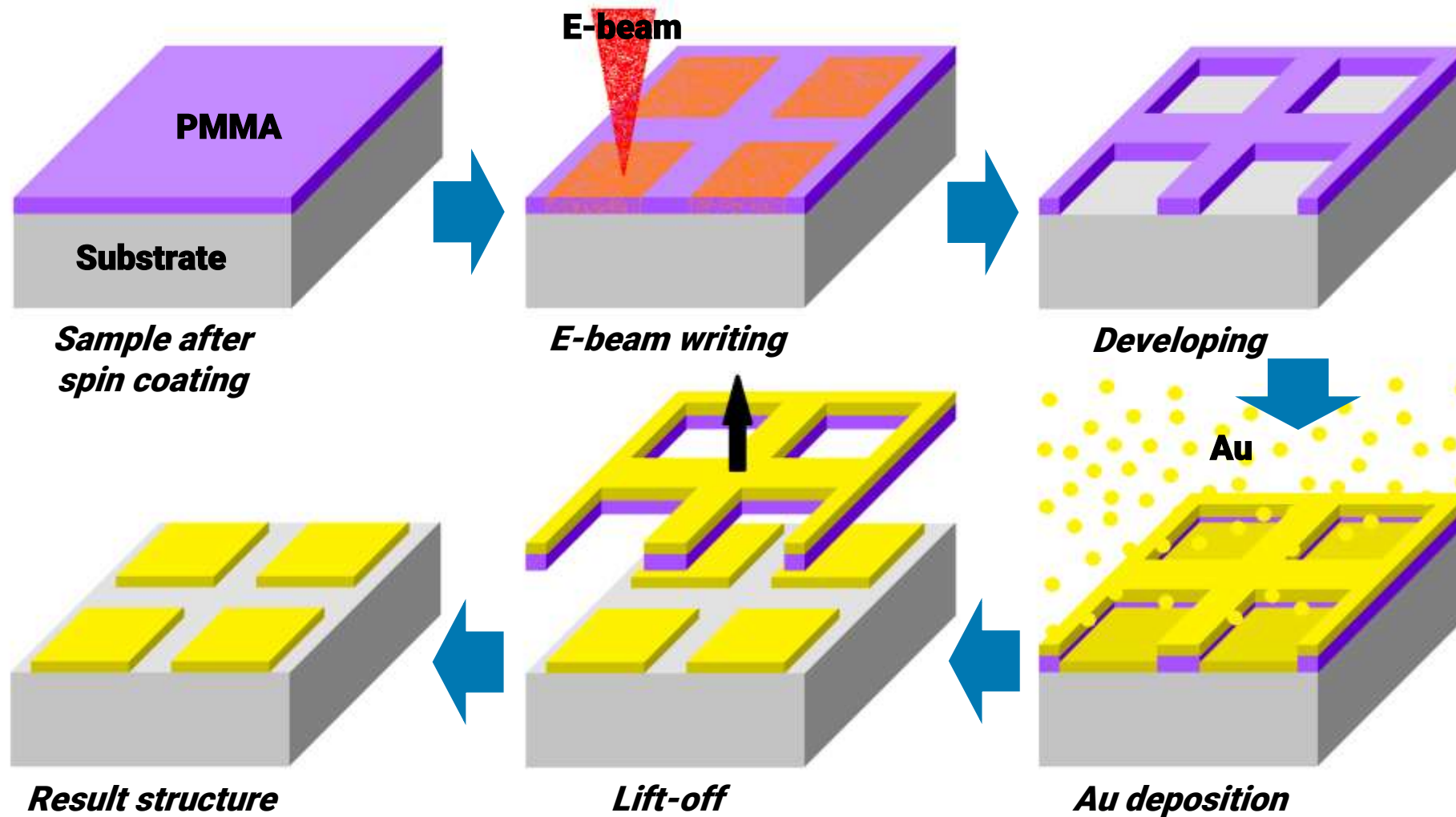
Positive resist



Negative resist



Typical EBL process sequence



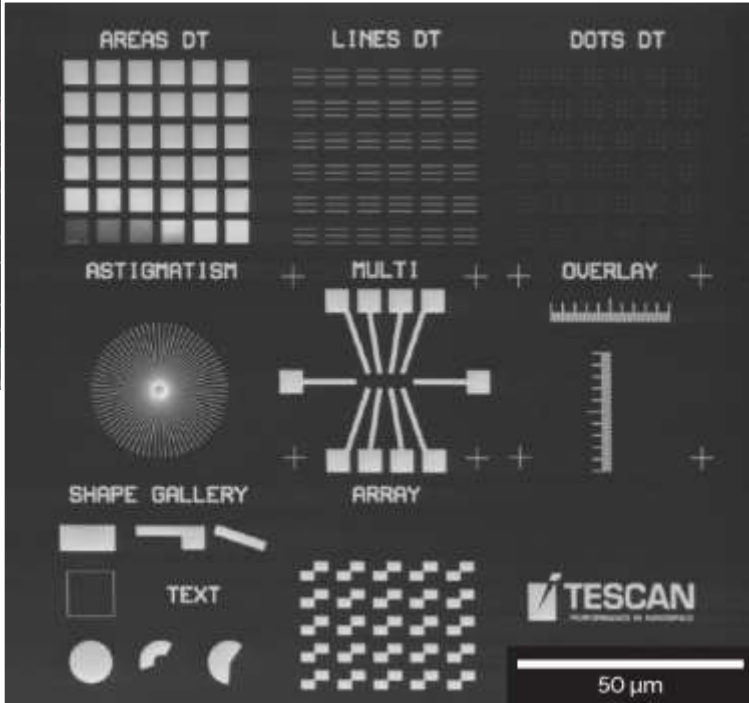
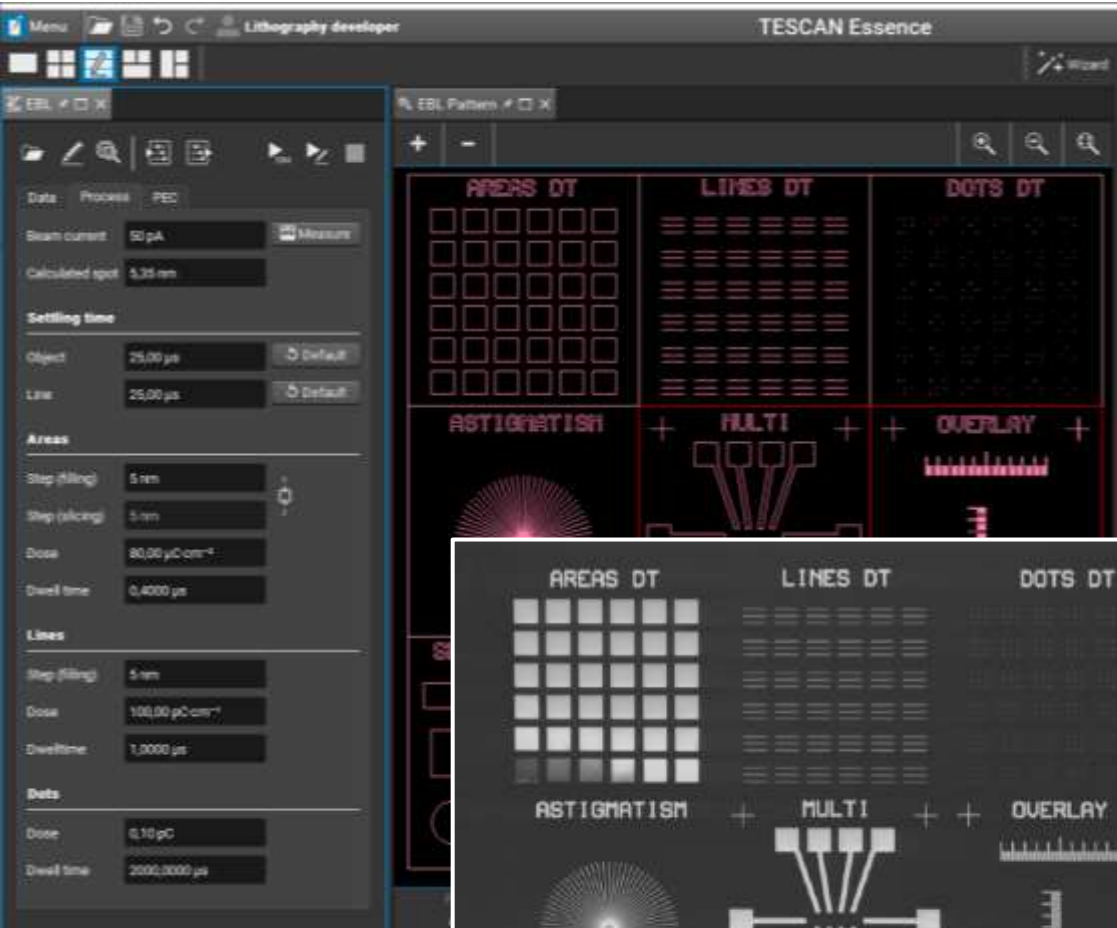
TESCAN Essence™ EBL Kit

Value Proposition

Considerations for EBL: university labs and research centers

- **Necessity to prepare micro- and nanostructures with specific shapes, dimensions and material composition on various substrates needed to support prototyping applications for basic and applied research**
- **Possibility to use standard microscopy system not only for routine imaging and analysis, but also for nanofabrication**
- **Possible combination of focused electron and direct-writing ion beam-based lithography techniques on one FIB-SEM system for fast prototyping of micro- and nanodevices**

TESCAN Essence™ EBL Kit
for Electron
Beam Lithography



TESCAN Essence™ EBL Kit on TESCAN's SEM or FIB-SEM platforms



- **TESCAN MIRA** as turnkey EBL solution because of its beneficial resolution–current performance
- **TESCAN SOLARIS** system with FIB and EBL capabilities as powerful nanoprototyping workstation

TESCAN Essence™ EBL Kit

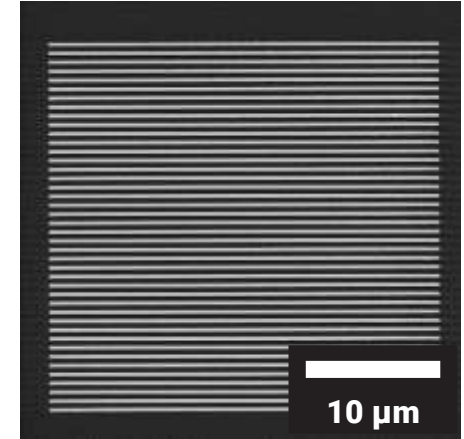
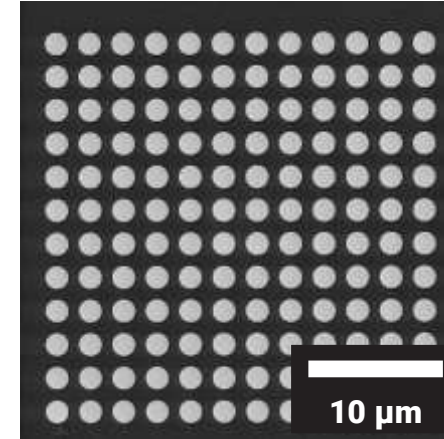
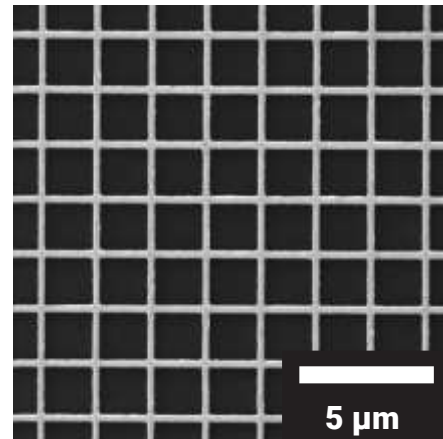
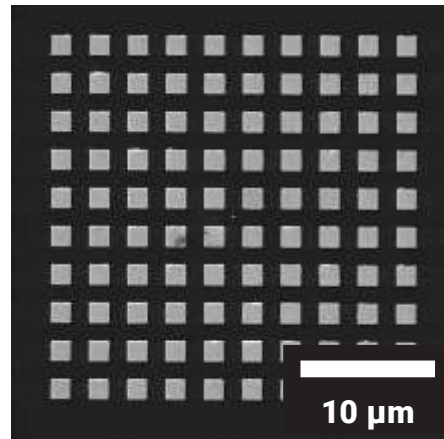
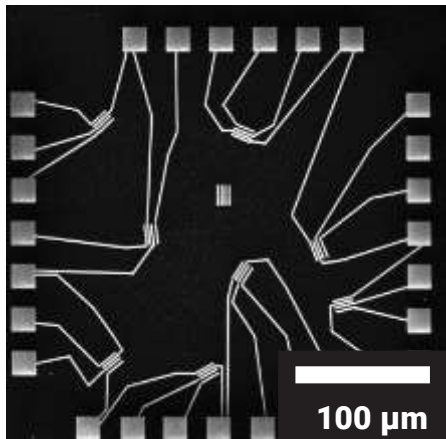
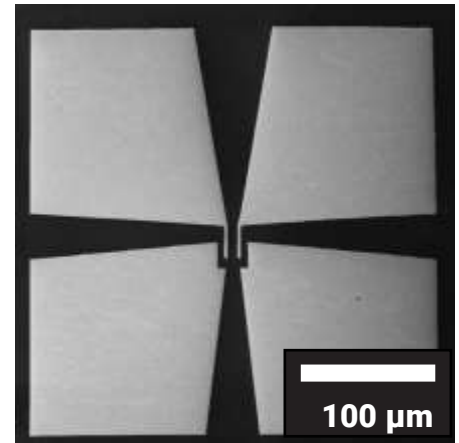
Applications

TESCAN's EBL solution applications

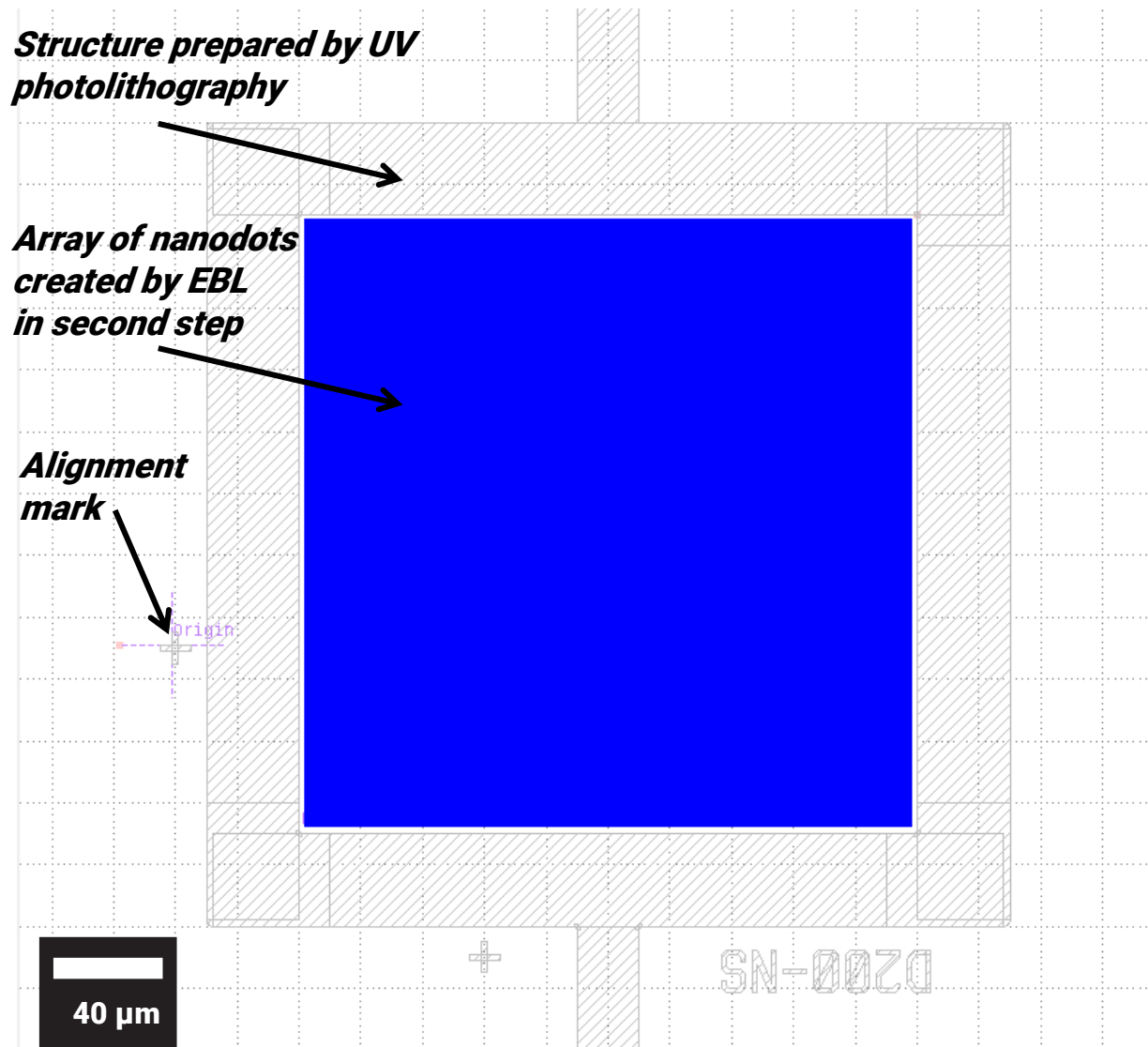
- EBL as common technique in the field of basic and applied research – laboratory micro- and nanoprototyping:

sensors, optics, photonics, plasmonics, spintronics, MEMS, microfluidics

and surfaces for cell growth
- Extended nanoprototyping capabilities if EBL is combined with separately controlled direct-writing focused ion beam-based lithography (EBL integrated on a TESCAN's FIB-SEM system)



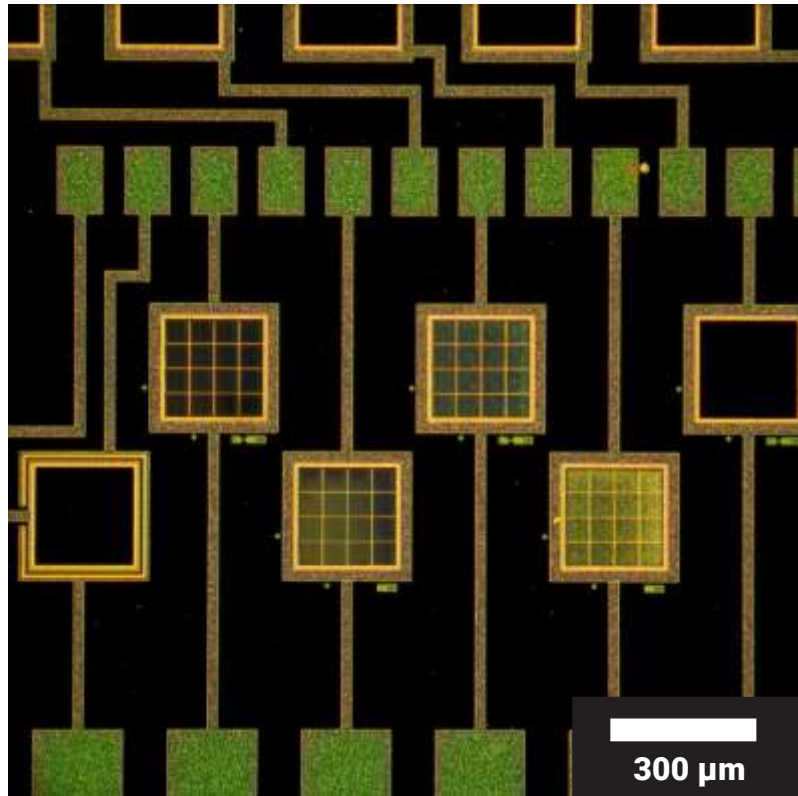
Preparation of photodiodes for NIR/IR region



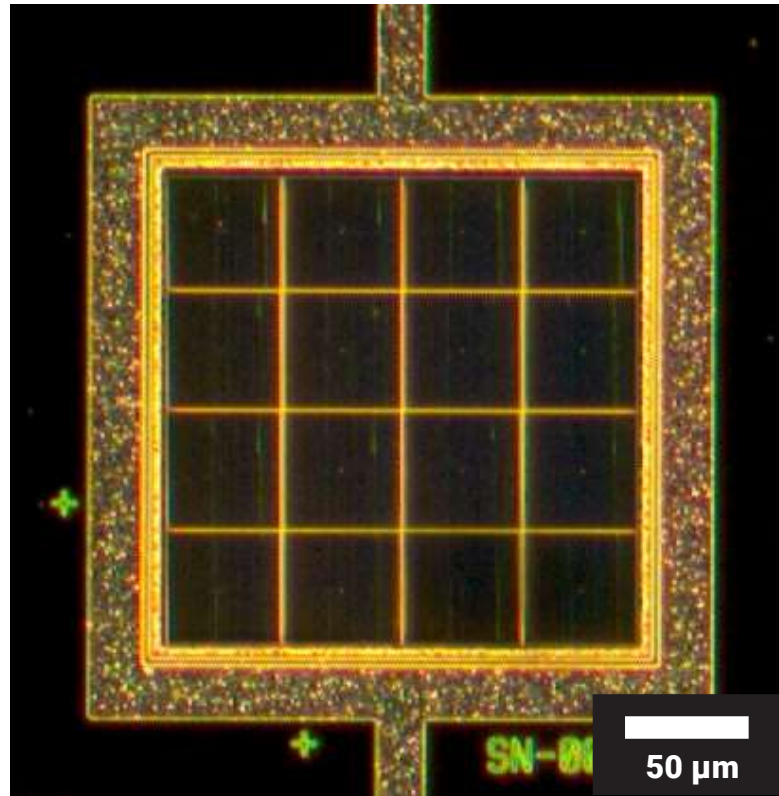
- Preparation of nanodots by EBL into windows created by UV photolithography in first step
- Overlay accuracy ensured by alignment mark (created by UV photolithography)
- Navigation between alignment mark and exposed areas was controlled by EBL software

*Sample courtesy of Fondazione Bruno Kessler (FBK)
Institute, Trento, Italy*

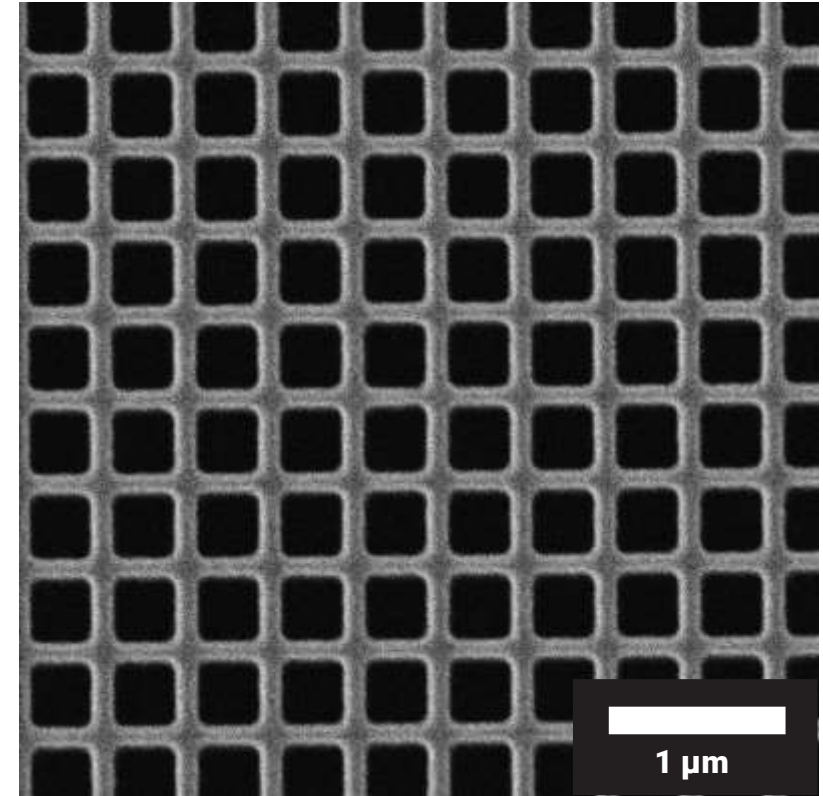
Preparation of photodiodes for NIR/IR region



Overview light microscopy image of the photodiode



Detailed light microscopy image with window-shape structure and nanodot arrays inside



Detailed SEM image of nanodots after sample developing and before metal deposition

Plasmonic metasurfaces for light focusing

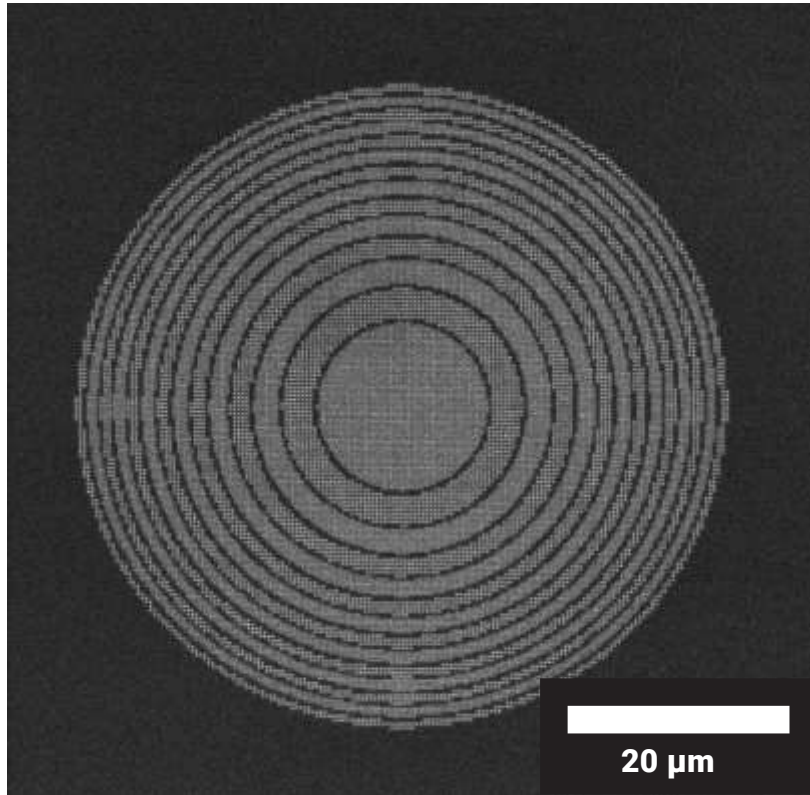
- Fabrication of zone plate (lens) composed of silver plasmonic nanoantennas utilizing phase effect for focusing transmitted visible light
- These plasmonics effects can also be observed via light microscope in reflection mode as different colors which depend on diameter of silver nanodiscs

Sample courtesy of Institute of Physical Engineering, Brno University of Technology, Brno

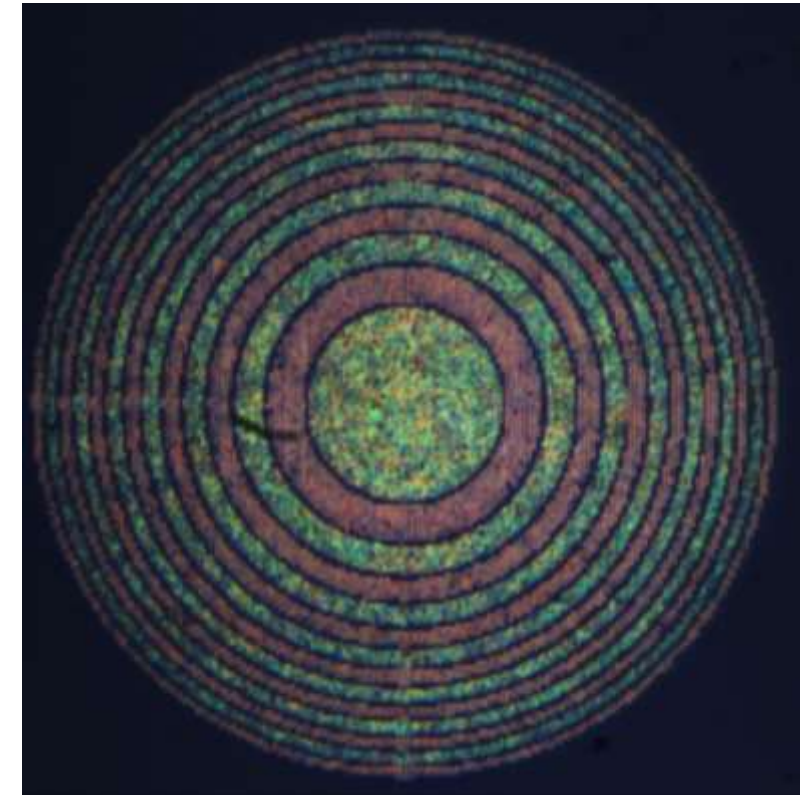
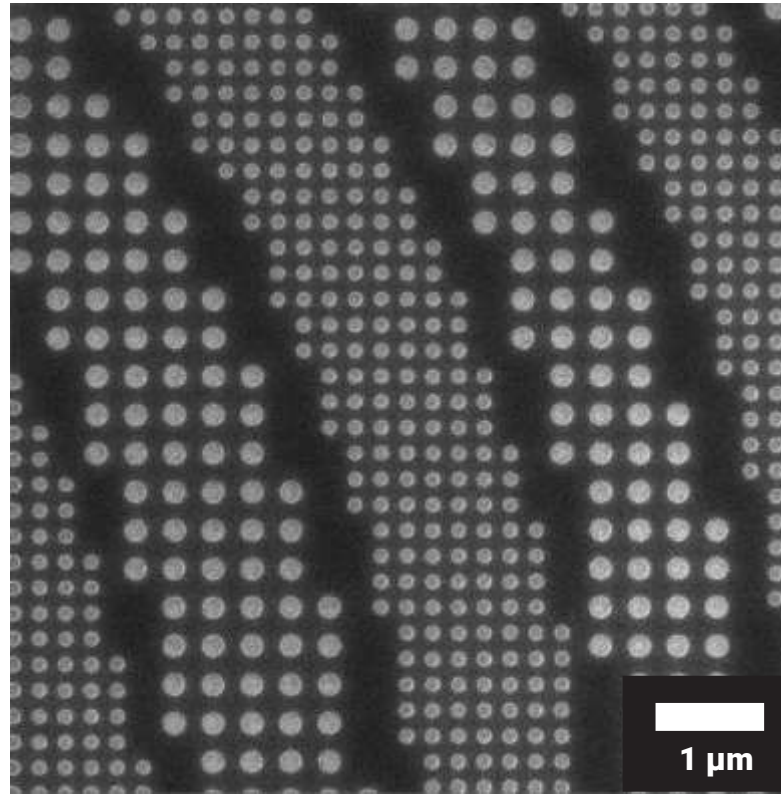


10 μm

Plasmonic metasurfaces for light focusing

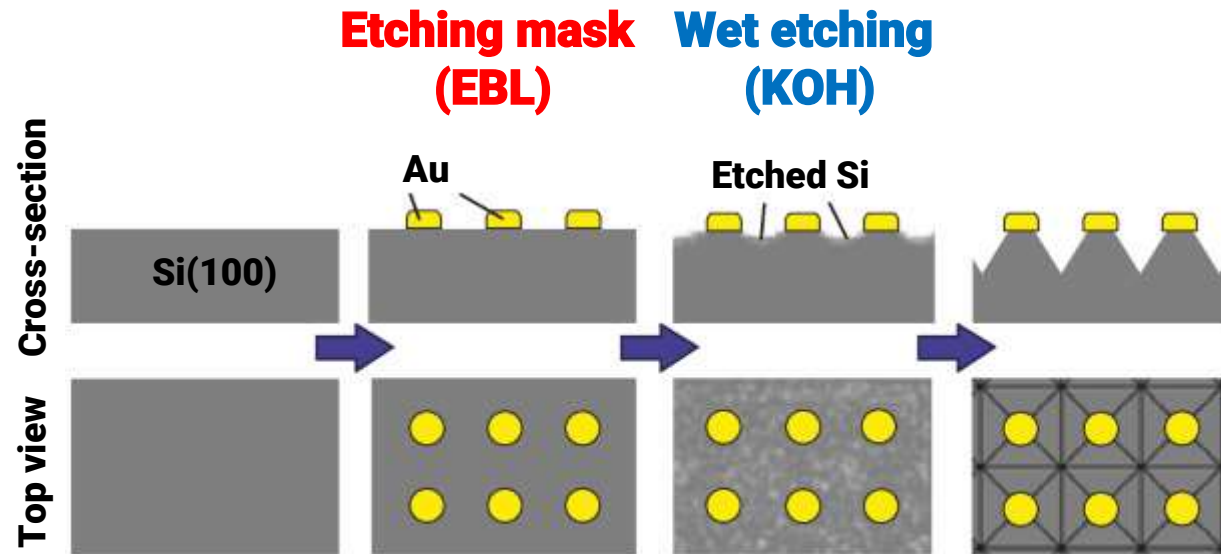


Overview and detailed SEM image of holes array after sample developing and before silver deposition



Overview light microscopy image of the structure with visible local differences in the optical response

Selective wet etching of silicon

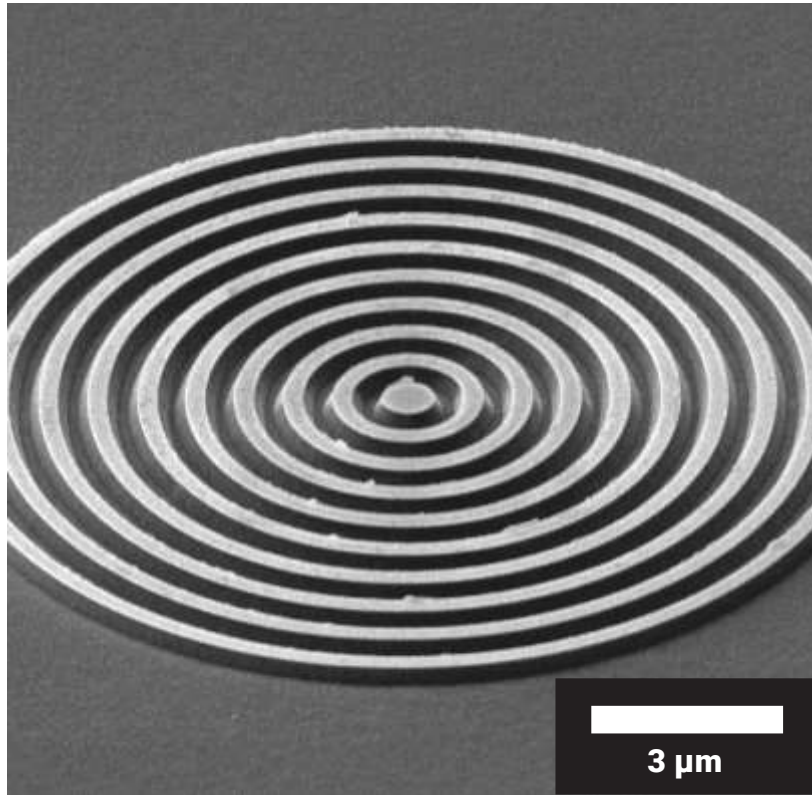


Schematic of anisotropic selective wet etching of Si with metallic mask prepared by EBL

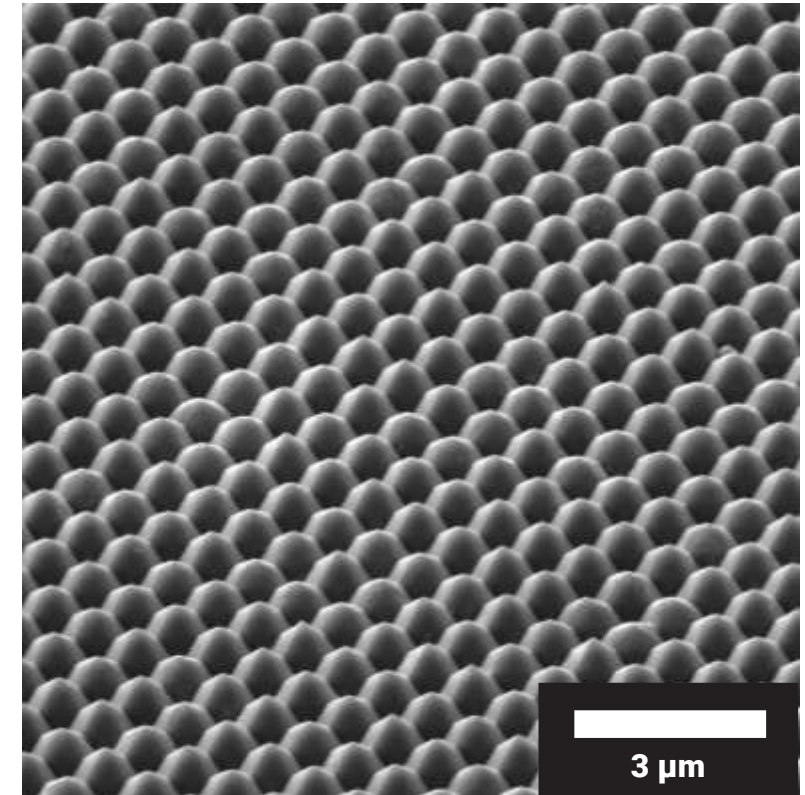
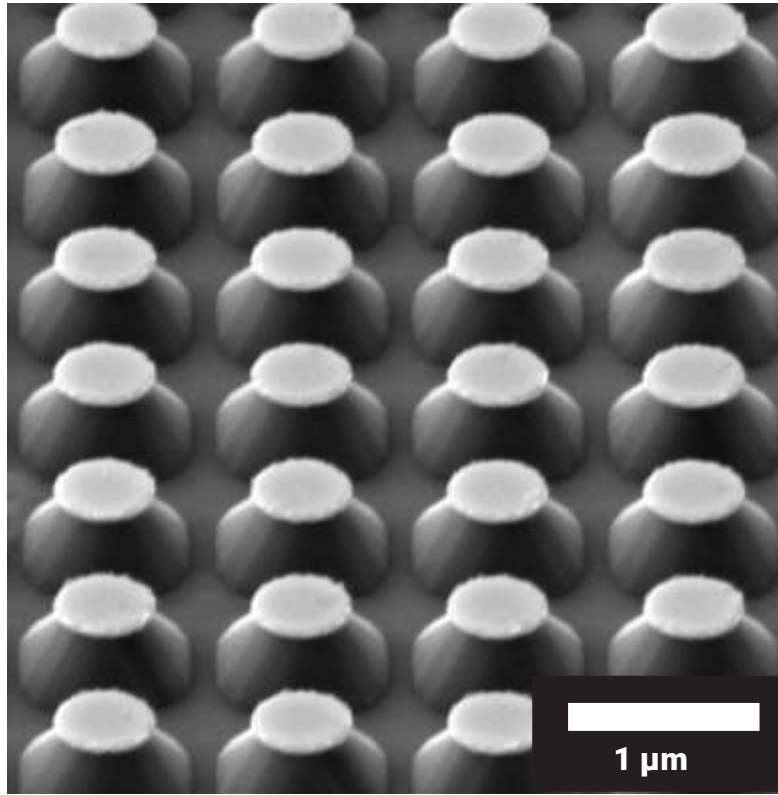
- Prepare etching mask from exposed and developed resist only using EBL
- Deposition of another suitable material and lift-off process is needed if resist is not resistant to an applied chemical during selective etch
- Study of selective anisotropic wet etching of silicon in KOH

Sample courtesy of Central European Institute of Technology (CEITEC), Brno

Selective wet etching of silicon



SEM image of silicon surface after wet etching in KOH with etching mask composed from gold and with the shape of concentric circles (left image) or an array of discs



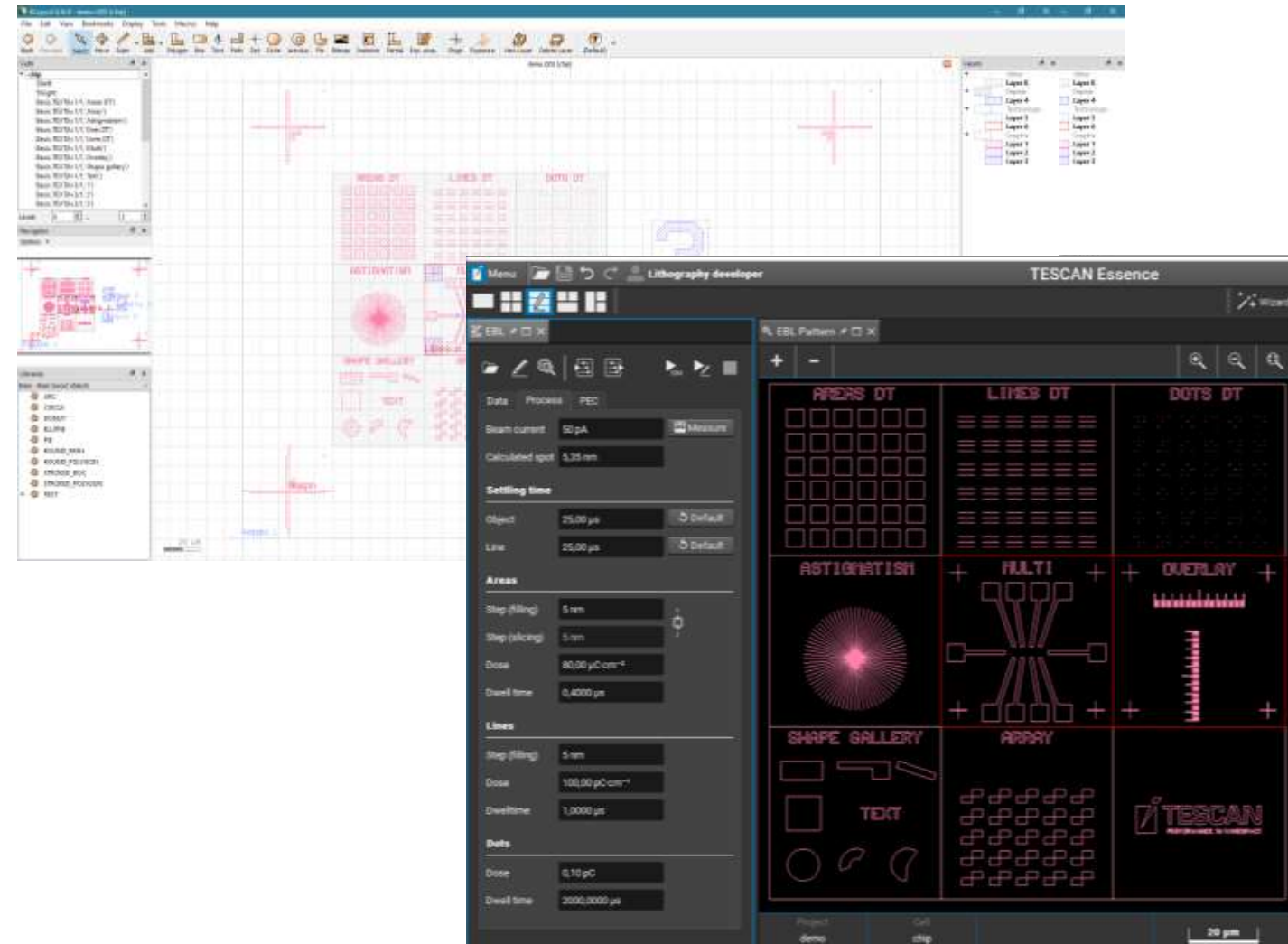
SEM image of modified silicon surface by wet etching and after etching mask removal

Technology behind TESCAN EssenceTM EBL Kit

TESCAN's EBL solution

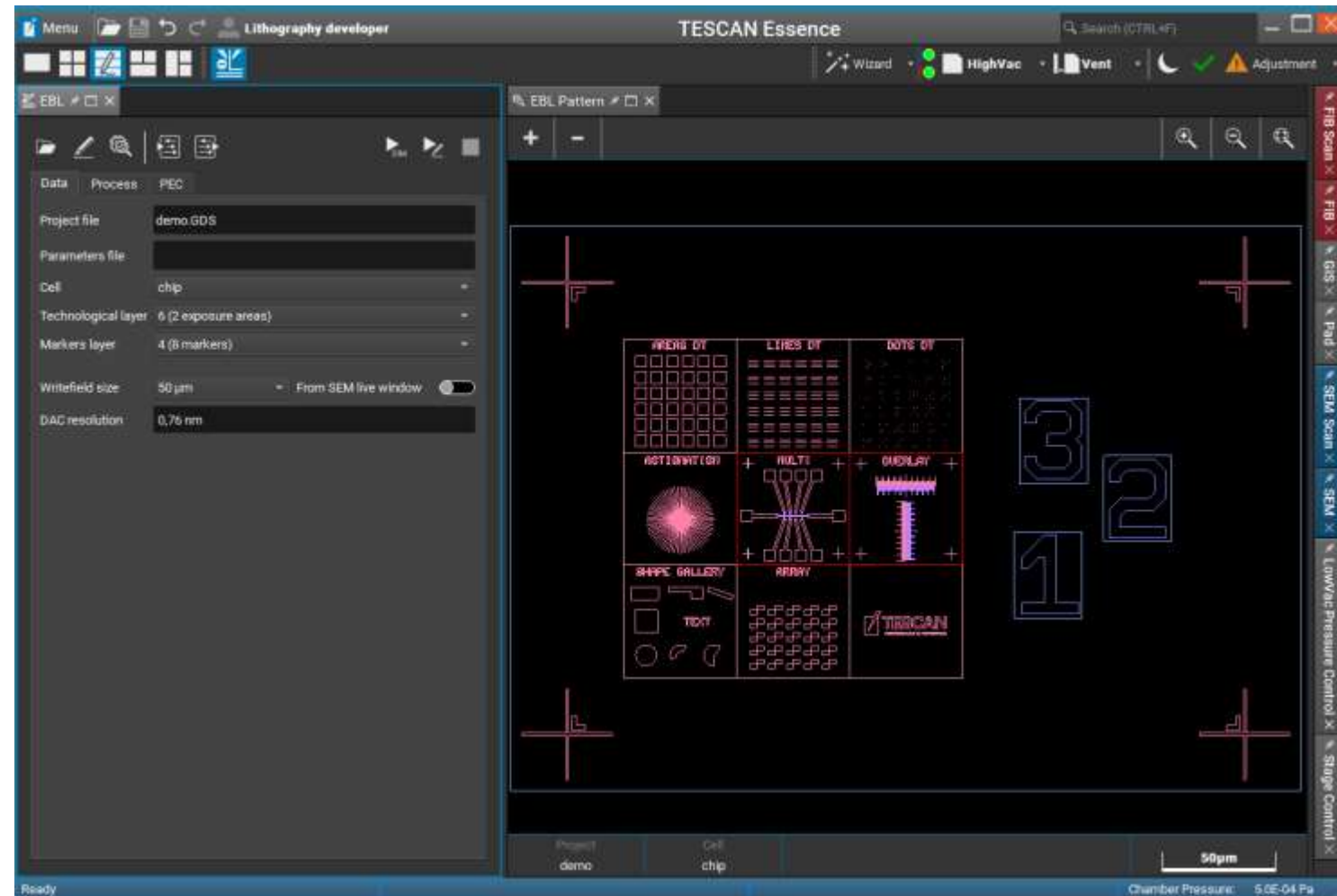
Contents of TESCAN's EBL solution

- TESCAN's electrostatic beam blanker for SEM column
- TESCAN Essence™ EBL Kit
 - Essence™ EBL software module
 - External pattern editor KLayout
 - Digital nanopatterning engine
 - Accessories for EBL
- High performance PC
- TESCAN Flow™ EBL Offline (*optional*)



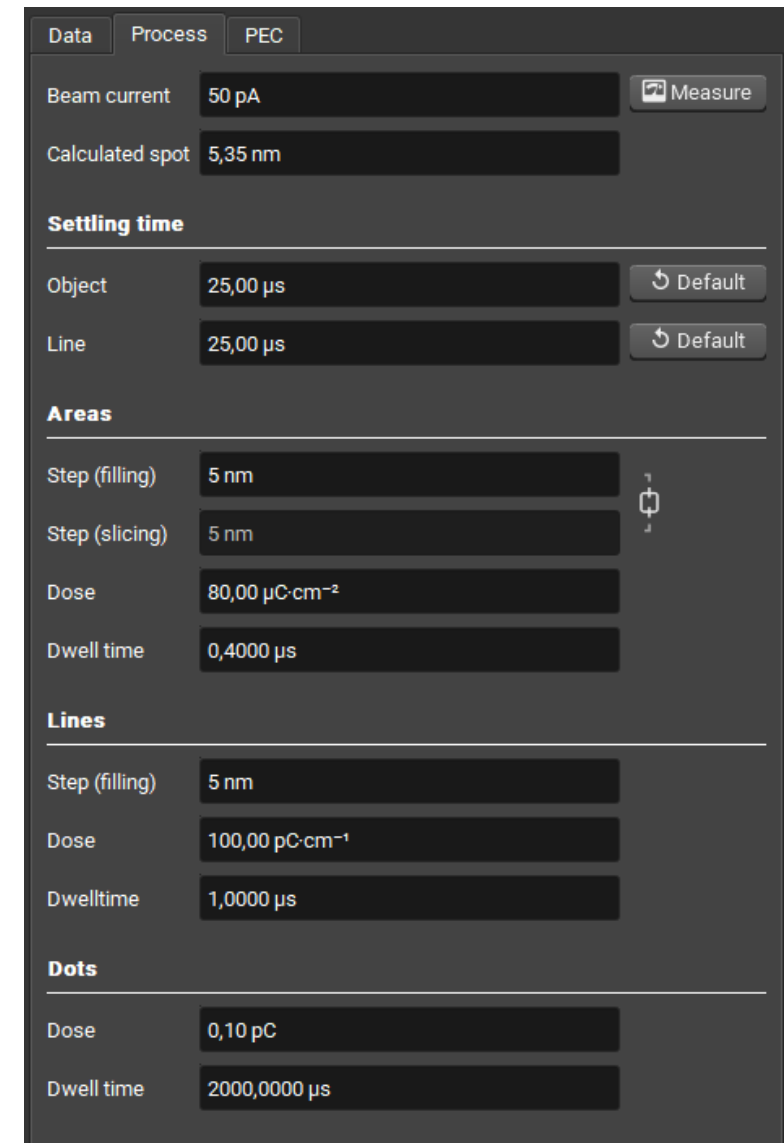
TESCAN Essence™ EBL Kit - Essence™ EBL software module

- Fully integrated software module for EBL process control
- Full support of the GDSII hierarchical data format
- Check objects to be exposed in pattern viewer
- Define write field size



TESCAN Essence™ EBL Kit - Essence™ EBL software module

- Optimize exposure conditions with continual beam current control and theoretical beam spot size estimate functionality
- Set different values of settling time and electron dose for various structures (dot-, line-, area-based)



The screenshot displays the TESCAN Essence EBL software interface, showing various parameters for Data, Process, and PEC tabs. The interface is dark-themed with white text and input fields.

Data | **Process** | **PEC**

Beam current: 50 pA [Measure]

Calculated spot: 5,35 nm

Settling time

Object: 25,00 μ s [Default]

Line: 25,00 μ s [Default]

Areas

Step (filling): 5 nm []

Step (slicing): 5 nm []

Dose: 80,00 μ C·cm⁻²

Dwell time: 0,4000 μ s

Lines

Step (filling): 5 nm

Dose: 100,00 pC·cm⁻¹

Dwelltime: 1,0000 μ s

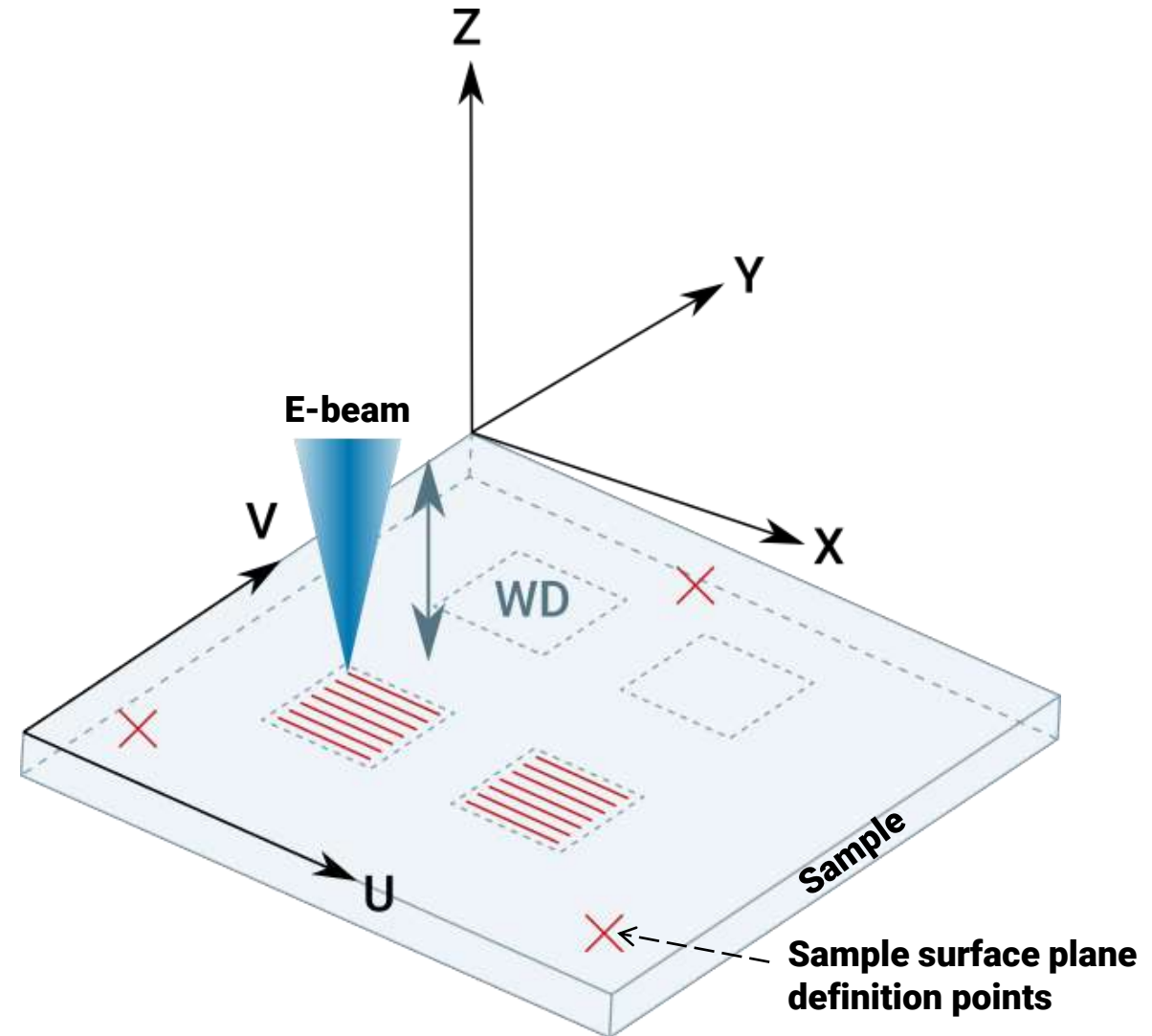
Dots

Dose: 0,10 pC

Dwell time: 2000,0000 μ s

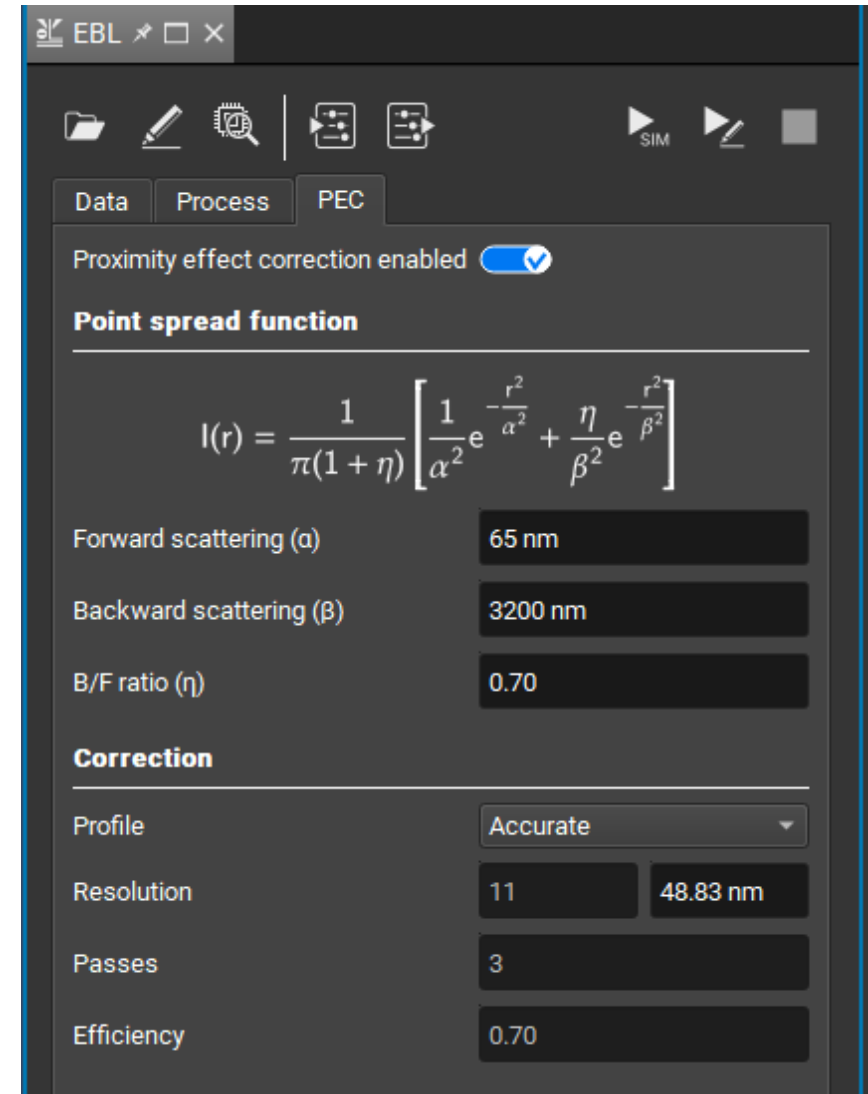
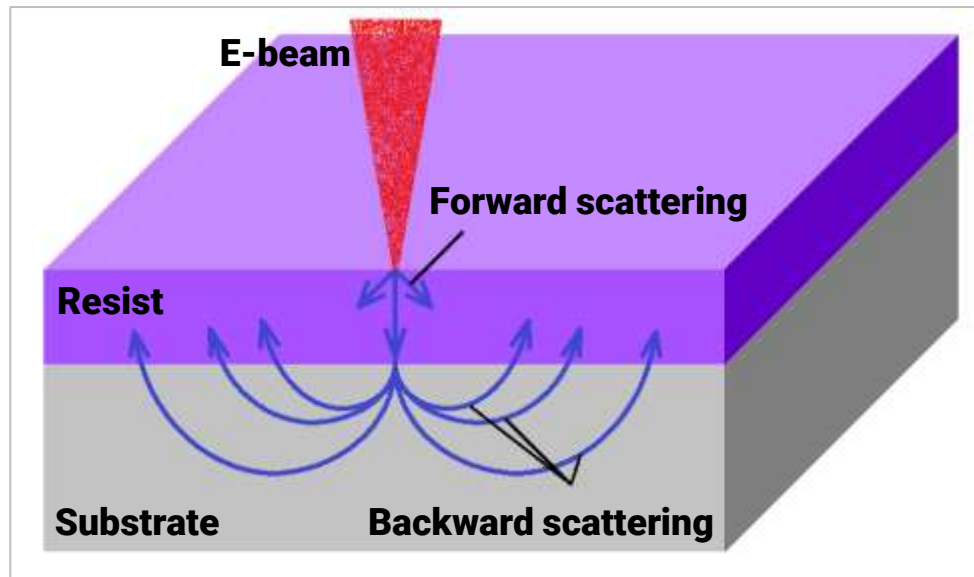
TESCAN Essence™ EBL Kit - Essence™ EBL software module

- Sample navigation within UV coordinate system
- Z-leveling by beam refocusing between exposed fields



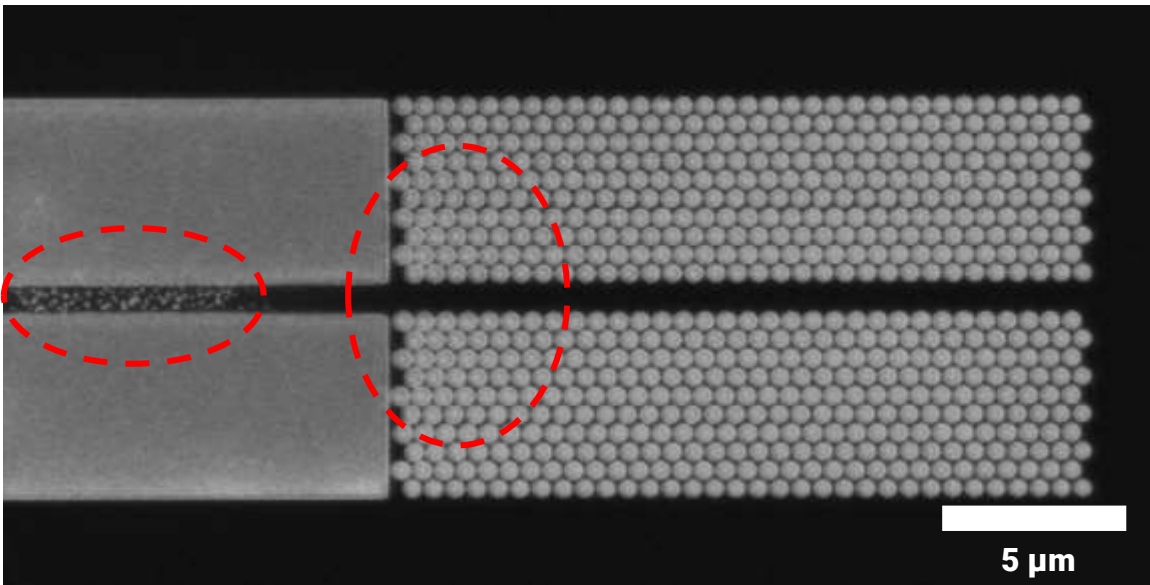
TESCAN Essence™ EBL Kit - Essence™ EBL software module

- Proximity effect correction (PEC) to optimize exposure homogeneity in patterns with uneven density



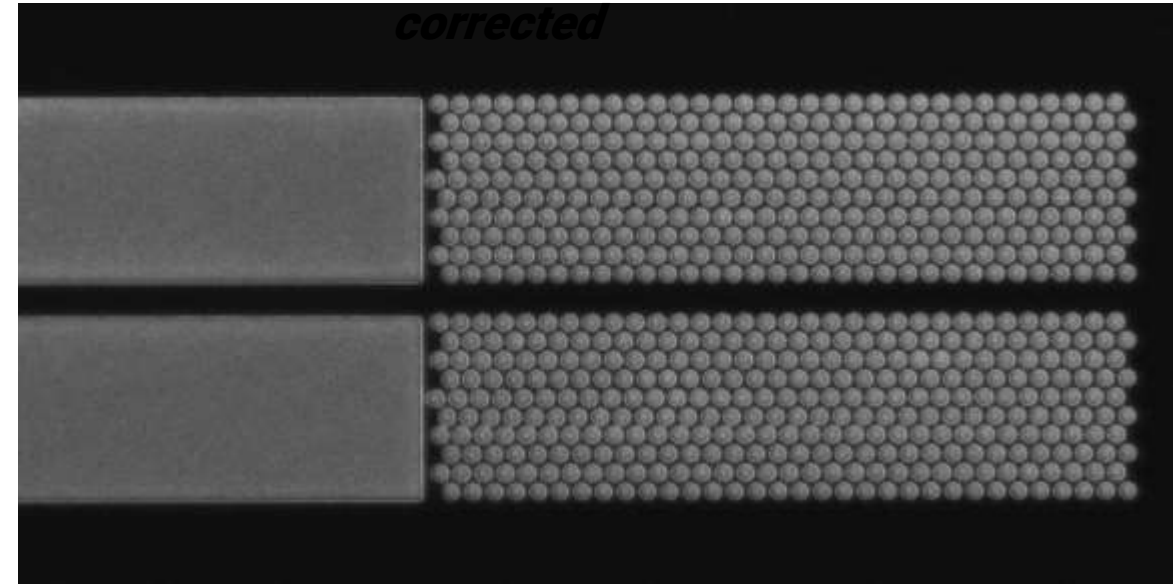
TESCAN Essence™ EBL Kit - Essence™ EBL software module

Not proximity corrected



*SEM
images*

*Proximity
corrected*



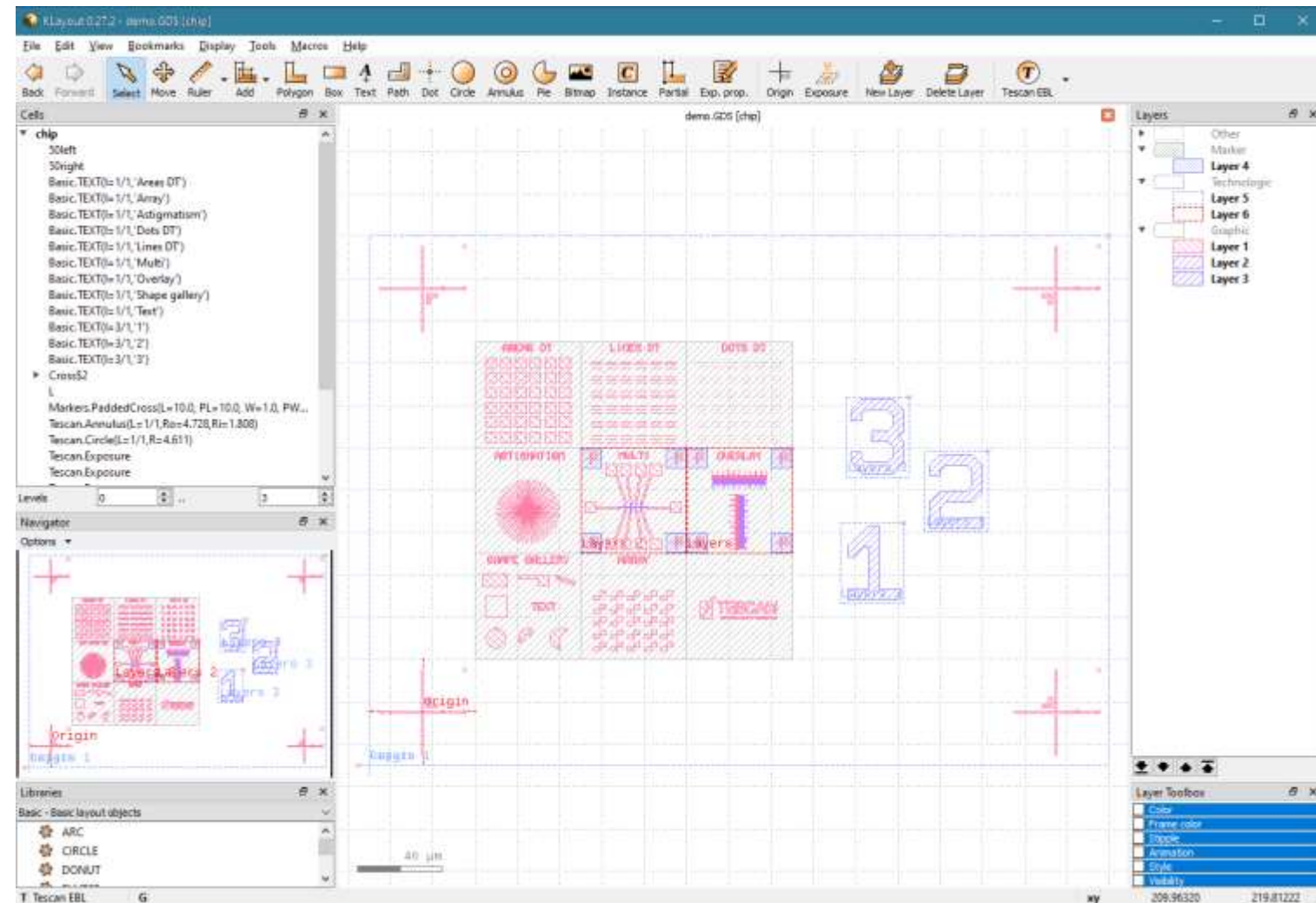
*Light
microscopy
images*



TESCAN Essence™ EBL Kit – External pattern editor KLayout

3rd party GNU GPL licensed GDSII editor

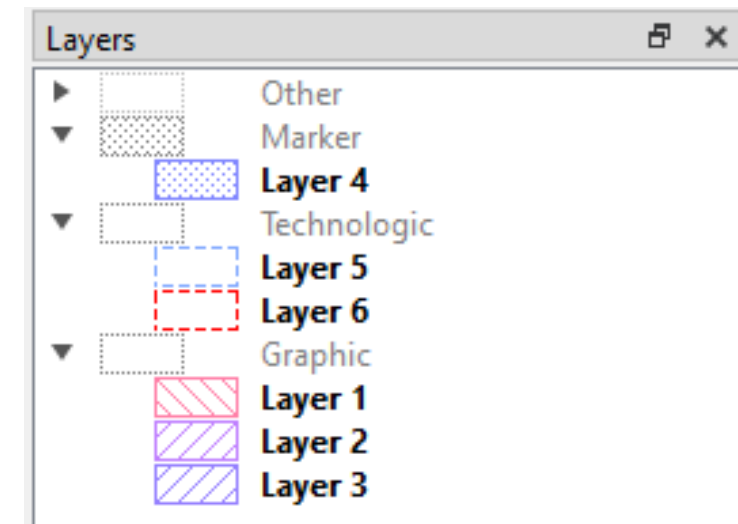
- Highly scriptable and customizable editor, known to and commonly used by EBL users
- TESCAN add-on enabling full EBL integration
- License allows user to install it to unlimited number of PCs free of charge



TESCAN Essence™ EBL Kit – Technological layers

TESCAN's technological layers concept connects the design in KLayout editor with EBL exposure process allowing you to:

- filter relevant geometry to be patterned in multi-step fabrication processes,
- align pattern with markers on the substrate,
- visually design write field placement to avoid field stitches in critical structures



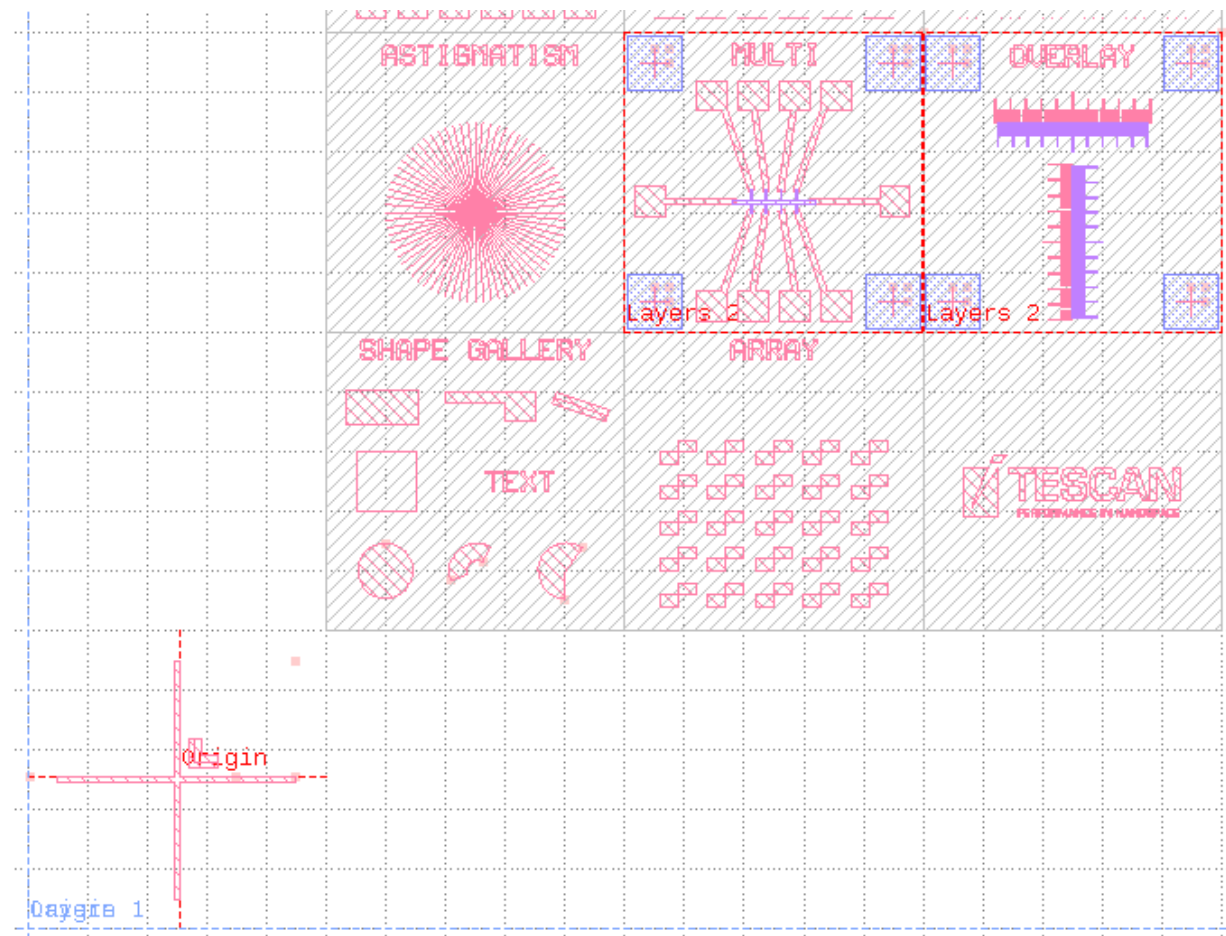
TESCAN Essence™ EBL Kit – Technological layers

Challenge

- Align 2nd exposure (violet structures in multi- and overlay fields) with pattern already fabricated on the sample (red)

Solution

- Perform sample alignment using UV system and then navigate to point marked by origin object placed at large cross in lower left corner
- Mark fields to be patterned using exposure area set to expose objects from graphical layer 2 only (violet)
- Perform fine alignment (manually) using overlay markers (blue squares)



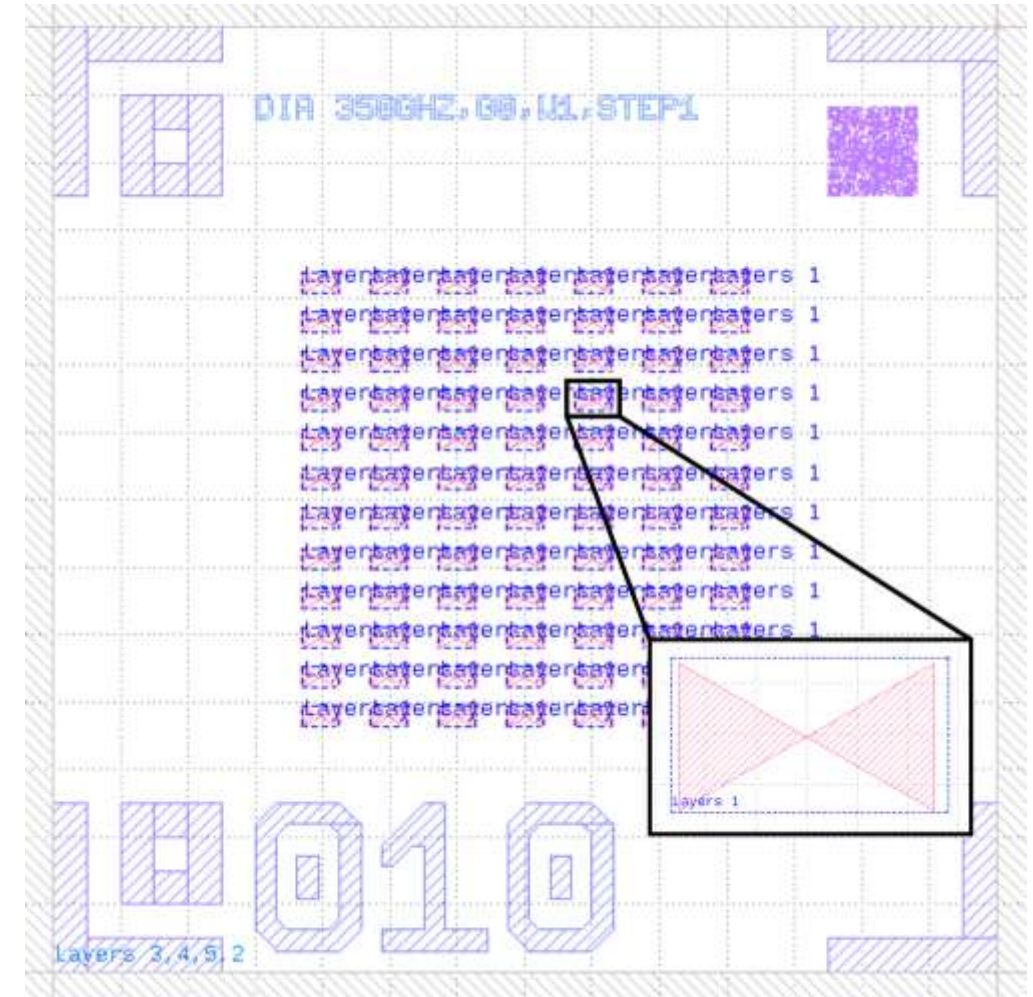
TESCAN Essence™ EBL Kit – Technological layers

Challenge

- Multi-field exposure of an array of structures (plasmonic antennas) to prevent their local partitioning

Solution

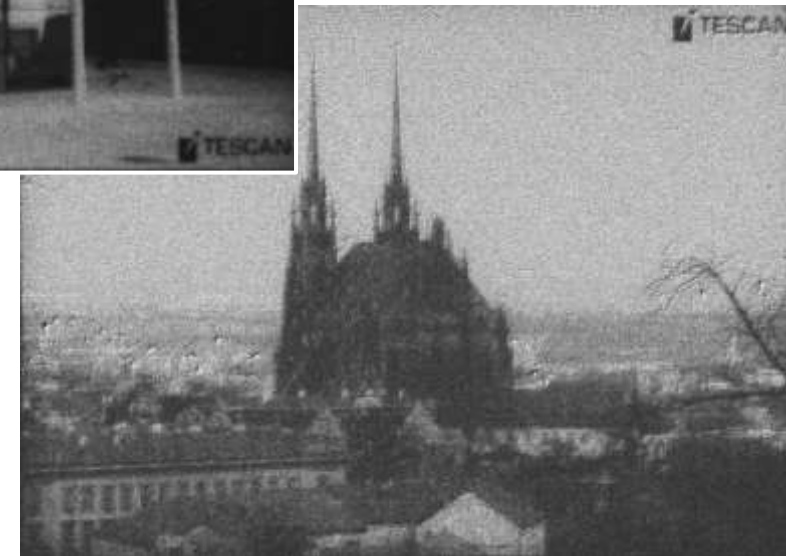
- Insert each antenna in its own exposure area defining the write field, and setting the area for patterning antennas only (red layer 1)
- As the antennas are inserted into the design as an instance array, the exposure area can be defined directly in cell description area. The exposure area is automatically copied with each antenna
- Insert labels into another exposure area for patterning only to the corresponding layers (3, 4, 5 and 2)



*Sample courtesy of Institute of Physical
Engineering, Brno University of Technology, Brno
Project Horizon 2020 - FET OPEN - GA#767227*

TESCAN Essence™ EBL Kit – Bitmap exposure

- Ability to expose a bitmap-based pattern in binary (black and white) or grayscale level



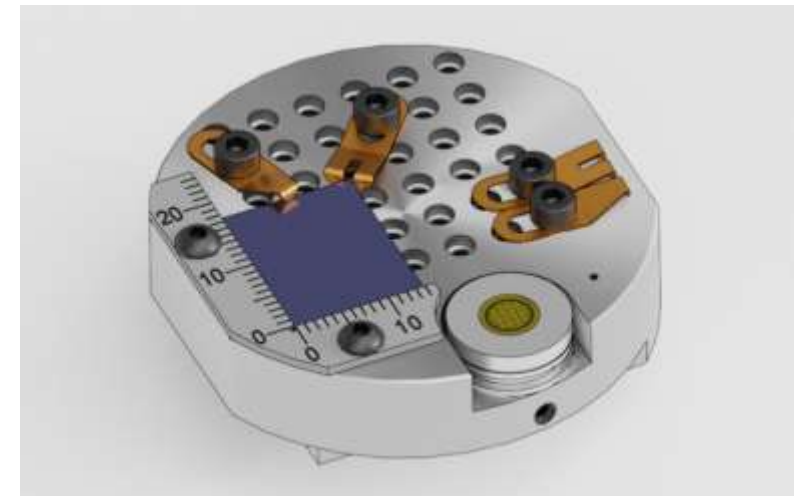
Original bitmap binary images (photographs of TESCAN building and Petrov in Brno)

SEM images of the structures after sample developing (structure width 100 μm)

TESCAN Essence™ EBL Kit - Accessories for EBL

Box with the accessories for initial work with EBL

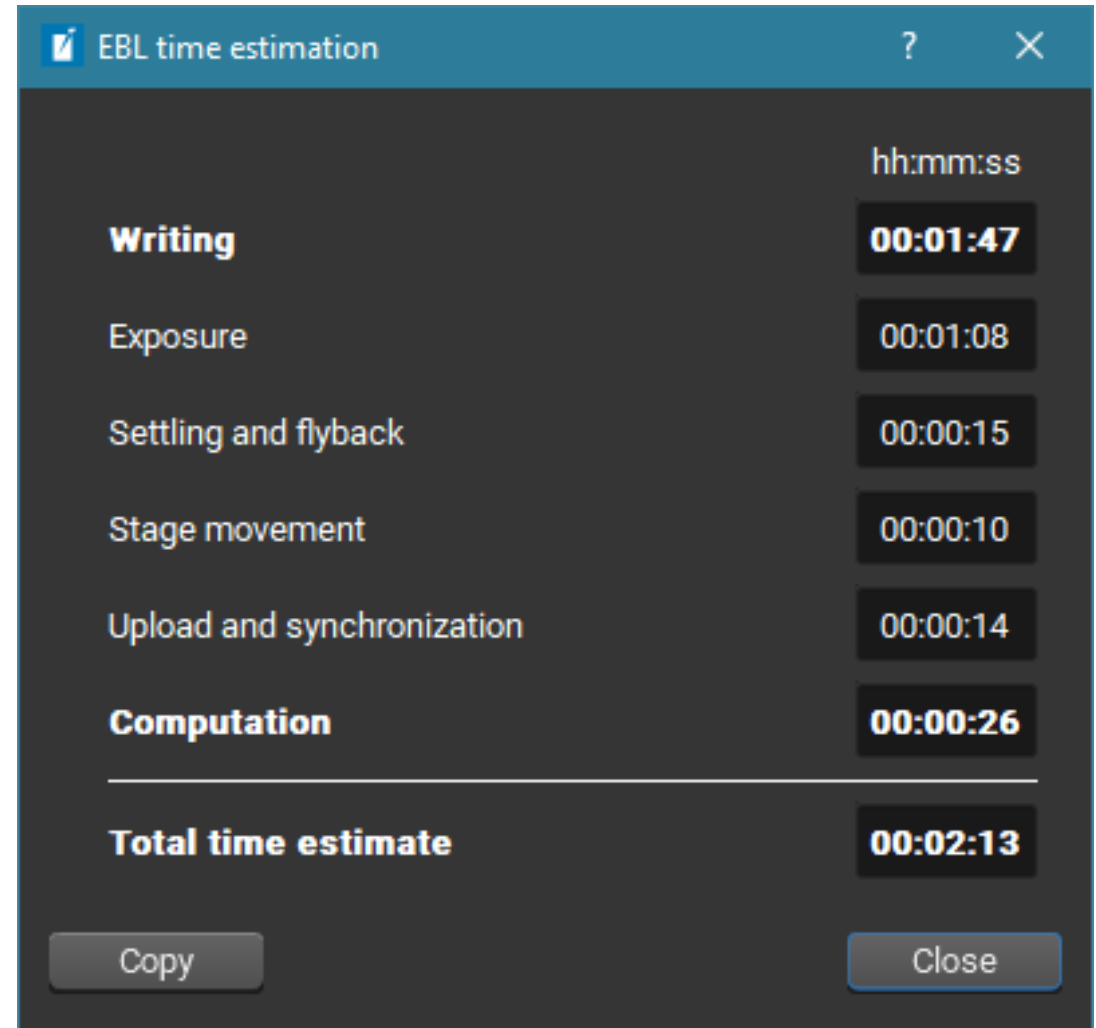
- **Silicon substrates covered with PMMA or CSAR resist layer**
- **Chemicals for resist development**
- **EBL-specific sample handling tools (tweezers, forceps scissors)**
- **AuC resolution sample**
- **Non-magnetic EBL holder fully compatible with SEM hardware and control software**



TESCAN Flow™ EBL Offline

EBL offline software module installed within
TESCAN Flow™ interface

- Set needed exposure condition in advance
- Check objects to be exposed in pattern viewer
- Plan your time requirement for instrument use with the exposure time estimate functionality



	hh:mm:ss
Writing	00:01:47
Exposure	00:01:08
Settling and flyback	00:00:15
Stage movement	00:00:10
Upload and synchronization	00:00:14
Computation	00:00:26
Total time estimate	00:02:13

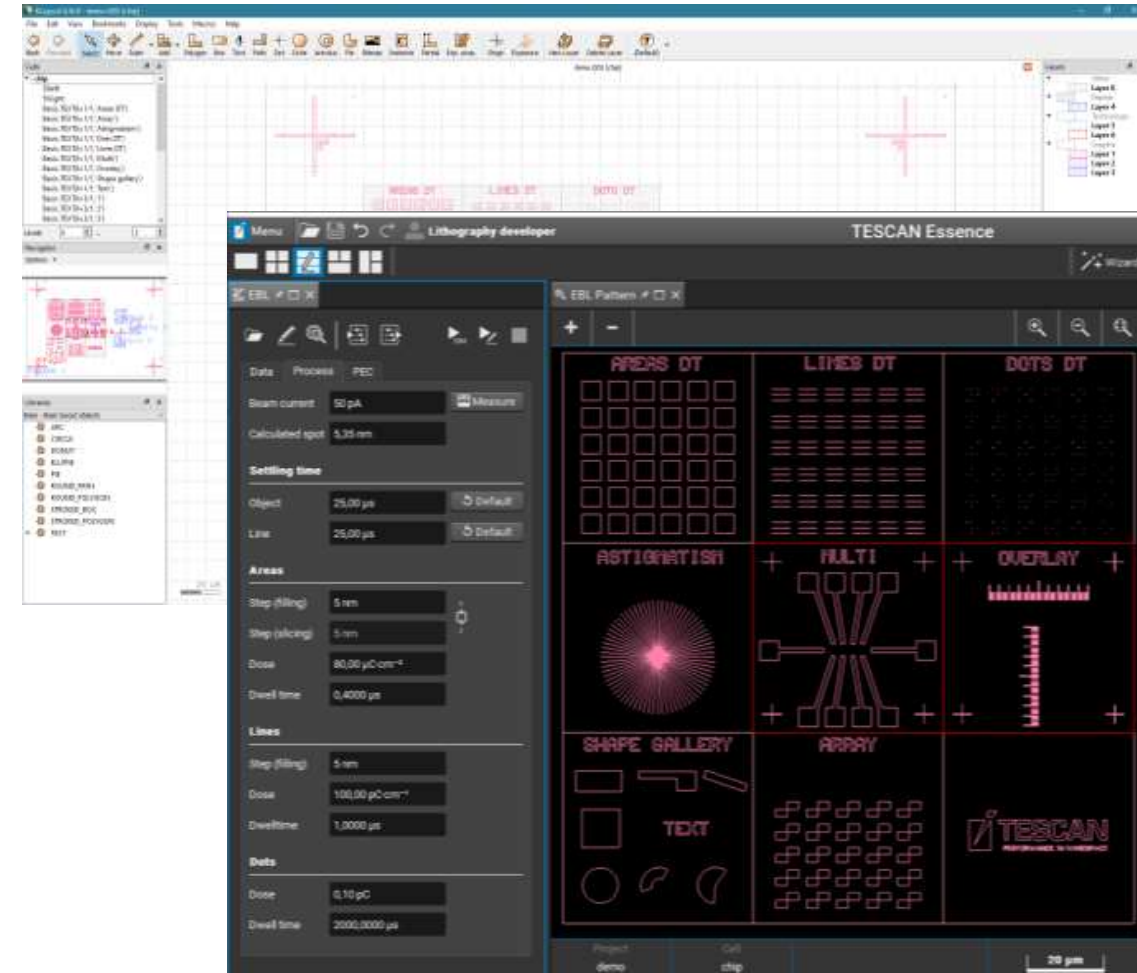
Copy Close

Summary

TESCAN Essence™ EBL Kit

for Electron Beam Lithography

- Utilize TESCANA's complete and cost-effective EBL solution with our Essence™ EBL Kit for performing electron beam lithography on a standard microscopy system
- TESCANA's EBL solution provides flexibility for nano fabrication and also for routine imaging and analysis, to provide a solution tailored for scientific research groups within the universities or research centers
- Create a powerful nanoprototyping workstation with both electron and ion beam-based lithography techniques available to users by adding EBL capability to your TESCANA FIB-SEM system
- Apply advanced EBL software and hardware capabilities to optimize strategy, precision, quality and duration of the exposure process



Thank you for your attention