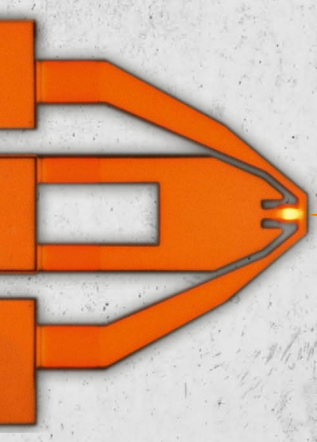
NanoFrazor® Explore

SwissLitho AG
Innovative Nanofabrication Tools

Your tool for rapid prototyping of high quality 3D nanodevices



Go beyond E-Beam Lithography

- More possibilities
- Easy to use
- Low costs
- Swiss quality

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explore more! »

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Advantages

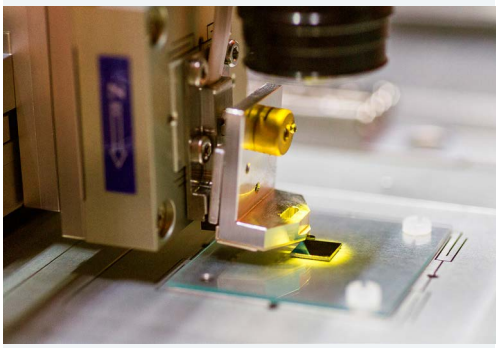
What makes the NanoFrazor special?

- 3D direct write → new devices, sub-10 nm resolution
- In-situ inspection → save time, increase accuracy
- Low costs → compared to E-Beam Lithography

The NanoFrazor Explore has been developed for researchers, who want to have quick and easy access to high-resolution nanometer sized geometries of almost arbitrary kind. Even 3D nanopatterns can be fabricated in a single process step with unmatched precision.

	E-Beam Lithography*	NanoFrazor Explore
Resolution half-pitch demonstrated	**< 10 nm**	**< 10 nm**
Write speed @ 10 nm resolution	**≈ 1 mm/s**	**≈ 1 mm/s**
Unique features		
in-situ inspection with < 1 nm vertical resolution	**no**	**yes**
3D nanolithography with < 2 nm vertical accuracy	**no**	**yes**
Closed-Loop Lithography combined patterning & inspection	**no**	**yes**
Correlation Overlay marker free with < 5 nm accuracy [9]	**no**	**yes**
Correlation Stitching natural surface roughness as marker [6]	**no**	**yes**
Chemical patterning Local heating of various materials	**no**	**yes**
Disadvantages		
Wet development necessary & critical for the pattern	**yes**	**no**
Electron damage possible with graphene, nanowires, etc.	**yes**	**no**
Proximity corrections dose adjustments necessary	**yes**	**no**
Various		
Atmosphere inside the system	**UHV**	**ambient / nitrogen**
Maintenance repeated effort & costs	**service contract** (≈30'000 $ p.a., excl. new parts)	**exchange of cantilever** (1 min, 60 $, every few days)
Energy consumption, Voltage of the whole system	**>10 kW, 100 kV**	**< 1 kW, 10 V**
Footprint & room requirements for good usability and performance	**>10 m², shielded clean rooms**	**<2 m², any room**
Chance to publish high-impact paper on processing of novel nanodevices	**Low** (>50 years old, everything already done)	**Very high** (only available since 2014)

* typical 100 kV E-Beam writer using HSQ or PMMA as resist



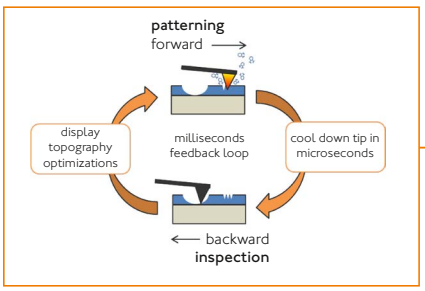
Technology

Patterning Principle

The heart of the NanoFrazor is a silicon cantilever with a heatable sharp tip. The NanoFrazor controls the movement of this cantilever extremely fast and accurately. Whenever the NanoFrazor brings the heated tip in contact with the resist surface, the resist evaporates and leaves a tiny hole with the dimension of the tip. A multitude of such holes constitutes complex 3D patterns [1, 2].

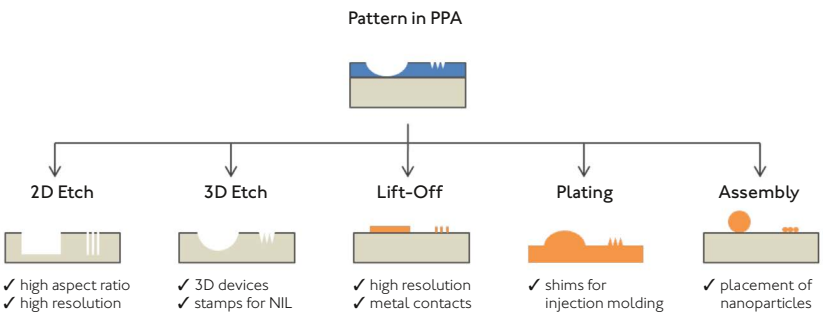
Closed-Loop Lithography

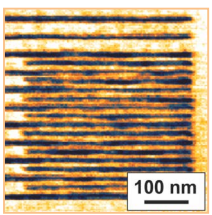
The written nanostructures are imaged by the cold tip at each line during the patterning. Sub-nm deviations from the target pattern are detected immediately and used as feedback for the patterning process. This enables accurate control of the patterning depth and hence 3D patterning with unmatched precision. Furthermore, the in-situ inspection capability of the NanoFrazor facilitates novel and unique ways for stitching [6] and overlay [9].



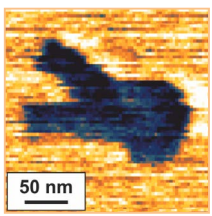
Resists and Pattern Transfer

The recommended resists for the NanoFrazor are PPA and molecular glass. They allow high resolution and 3D patterning. In addition, the resists are compatible with pattern transfer methods like etching [4, 7], lift-off [10], plating, or self-assembly. This enables patterning of semiconductors, glasses, metals, polymers or patterns out of nanoparticles [5] or proteins [8].
SwissLitho supports its customers with the pattern transfer processes.

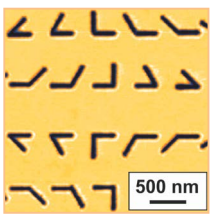




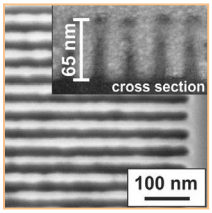
10 nm lines and spaces



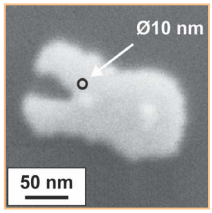
circle with two handles



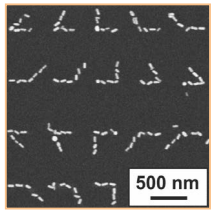
shape matching traps



etched 65 nm deep in Si [10]



Lift-off with 30 nm Ni [10]



Self-assembled Au nanorods [5]

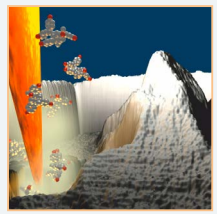
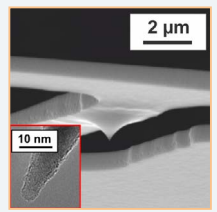
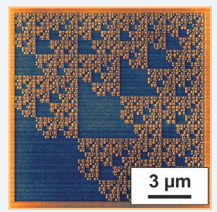


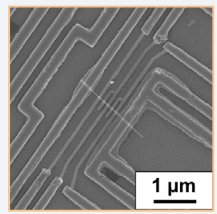
Illustration of the NanoFrazor creating a nanoscale Matterhorn [1]



Silicon tip with 3 nm radius on micro-heater (up to 1000°C)



Fractal pattern with ≈1 million pixels (10 nm) written within 12 seconds [3]



Markerless overlay of top gates for nanowire device without electron damage

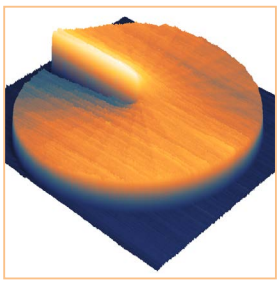
Publications

[1] Pires *et al.*, **Science**, 238, 732-735, (2010)
[2] Knoll *et al.*, **Advanced Materials**, 22, 31, (2010)
[3] Paul *et al.*, **Nanotechnology**, 22, 275-306, (2011)
[4] Holzner, **Appl. Phys. Lett.**, 99, 023110, (2011)
[5] Holzner *et al.*, **Nano Lett.**, 11, 3957–3962, (2011)
[6] Paul *et al.* **Nanotechnology**, 23, 385307, (2012)
[7] Cheong *et al.*, **Nano Lett.**, 13, 4485-4491, (2013)
[8] Carrol *et al.*, **Langmuir**, 29, 8675-8682, (2013)
[9] Rawling *et al.*, **IEEE Nano**, 6, 1204-1212, (2014)
[10] Wolf *et al.*, **JVSTB**, 33, 02B102, (2015)

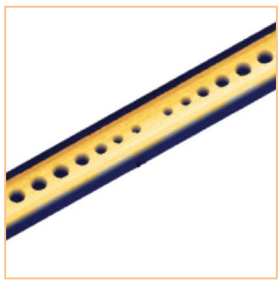
Applications

The NanoFrazor Explore covers a wide range of applications. Like E-Beam Lithography it is suitable for the fabrication of templates and prototypes of a variety of devices and components at resolutions well below 100 nm.

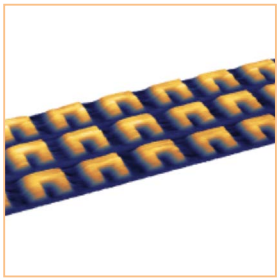
The NanoFrazor extends the application range of E-Beam significantly. The unique 3D capability with extreme accuracy enables novel devices and components. Furthermore, sensitive materials and devices are not damaged by high energy beam during the NanoFrazor patterning process. This is crucial for the development and improvement of future nanodevices.



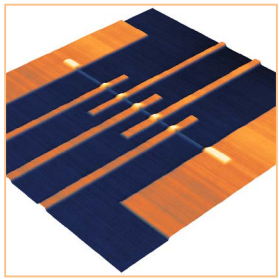
Nanooptics
3D optical elements
like spiral phase plates,
microlenses or holograms



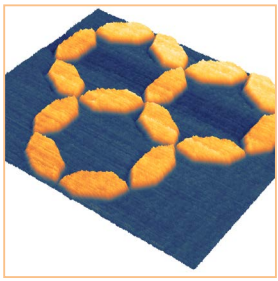
Nanophotonics
Photonic crystals, cavities
or waveguides with low
roughness



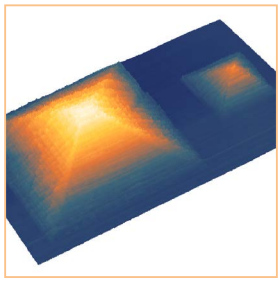
Plasmonics
High resolution metal
structures for metamaterials
or optical antennas



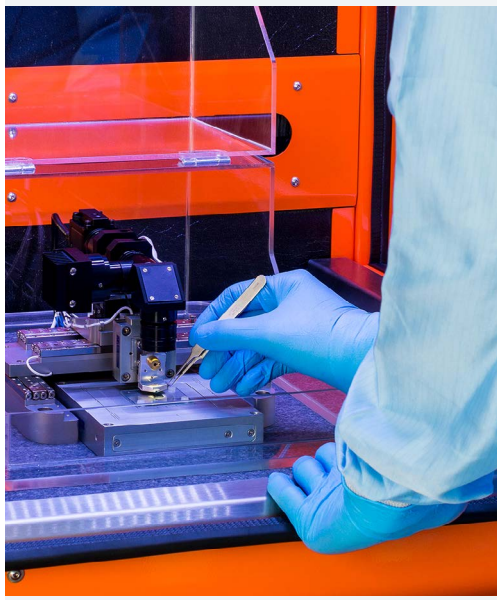
Nanoelectronics
Novel nanowire and quantum
devices using precise overlay

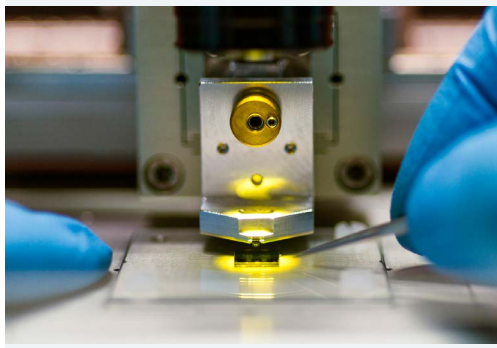


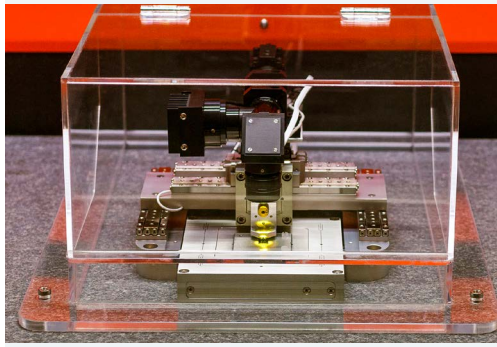
Nanomagnetism
Smallest magnetic structures
for studies on spintronics
or artificial spin ice



Stamps & Molds
Unique precision with 3D
templates for NIL or injection
molding







NanoFrazor® Explore

The NanoFrazor Explore is a standalone nanolithography system fitting into any laboratory or cleanroom. The open and flexible design leaves plenty of possibilities for the integration of extensions or the exploration of beyond lithography applications.

» Software

- intuitive user interface based on IGOR Pro
- powerful scripting library for advanced users
- import and modification of various layout file formats
- free & regular updates

» Housing

- **Dimensions & Weight**
  - footprint: 128 cm x 78 cm
  - height: 185 cm
  - weight: 650 kg
- **Integrated compartments**
  - electronic controllers (19" rack)
  - gas supply and regulation
- **Connections**
  - standard power plug
  - USB connection to PC

» Workspace

- superior acoustic & vibration isolation
- monitored & controlled atmosphere
- easy access from three sides
- integrated high resolution optical microscope to monitor sample and cantilever

» Thermal cantilevers

- ultra-sharp Si tips
- integrated micro-heater (up to 1000°C)
- integrated sensor with sub-nm sensitivity
- integrated Z actuation with µs response time and sub-nm accuracy

» Mechanics

- **Positioning system**
  - 100 mm XY, 10 mm Z
  - 1 nm sensor resolution
- **High speed piezo scanners**
  - 75 µm XY, 20 µm Z
  - advanced control for single nm accuracy at several mm/s scan speed

About us

SwissLitho is a young high-tech company with the vision to change the way nanostructures are made and explored. SwissLitho offers innovative nanofabrication tools mainly based on its unique Nano-Frazor technology. The privately owned company is proud of its international and interdisciplinary character with employees from 10 different countries.

History

1995 Start of the «Millipede» project at IBM Research Zurich
2010 Proof-of-principle of the NanoFrazor technology
2012 Foundation of SwissLitho by Dr. Philip Paul and Dr. Felix Holzner
2014 First installation of a NanoFrazor Explore
2015 Build-up of an international sales and distribution network

Awards

SwissLitho has received some of the most prestigious startup and technology awards, along with prize money in excess of CHF 500'000.

- Venture Kick Awards (2011 & 2012)
- McKinsey Venture Award (2012)
- ZKB Pionierpreis Technopark (2013)
- Heuberger Winterthur Jungunternehmerpreis (2013)
- Micro Nano Engineering (MNE) Award (2014)
- R&D 100 (2015)

Research Collaborations

EU Project «Single Nanometer Manufacturing»

Eurostars «PPA-Litho»

Customer collaborations

Technology Details

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