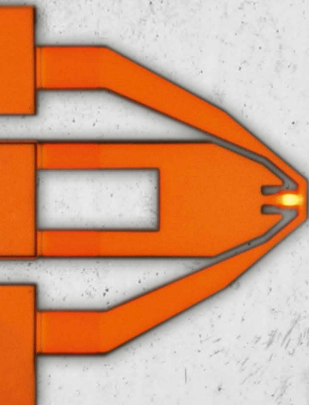



Your tool for rapid prototyping  
of high quality 3D nanodevices



Go beyond  
E-Beam Lithography

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

» [www.nanofrazor.com](http://www.nanofrazor.com)

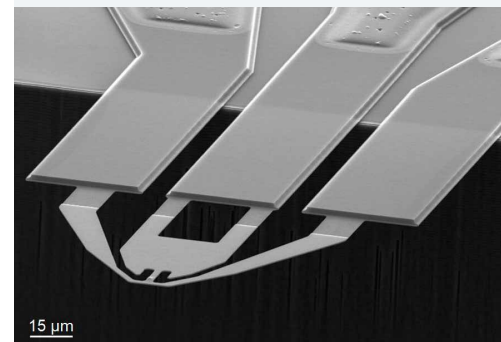
explore more! »»

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



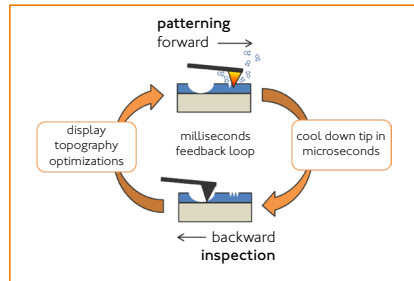
# Technology

## 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.

**Pattern in PPA**

<p><b>2D Etch</b></p> <ul style="list-style-type: none"> <li>✓ high aspect ratio</li> <li>✓ high resolution</li> </ul>	<p><b>3D Etch</b></p> <ul style="list-style-type: none"> <li>✓ 3D devices</li> <li>✓ stamps for NIL</li> </ul>	<p><b>Lift-Off</b></p> <ul style="list-style-type: none"> <li>✓ high resolution</li> <li>✓ metal contacts</li> </ul>	<p><b>Plating</b></p> <ul style="list-style-type: none"> <li>✓ shims for injection molding</li> </ul>	<p><b>Assembly</b></p> <ul style="list-style-type: none"> <li>✓ placement of nanoparticles</li> </ul>
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<p>10 nm lines and spaces</p>	<p>circle with two handles</p>	<p>shape matching traps</p>
<p>etched 65 nm deep in Si [10]</p>	<p>Lift-off with 30 nm Ni [10]</p>	<p>Self-assembled Au nanorods [5]</p>

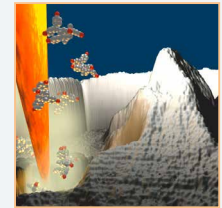
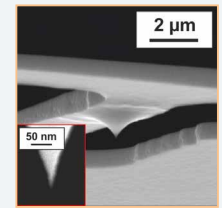
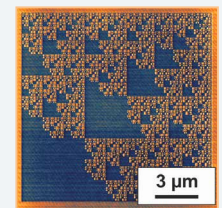


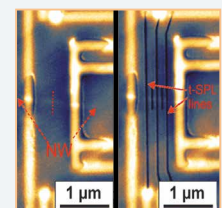
Illustration of the NanoFrazor creating a nanoscale Matterhorn [1]



Silicon tip with 5 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 gate for InAs nanowire (NW) device [10]

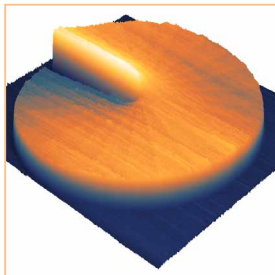
## Publications

- [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)

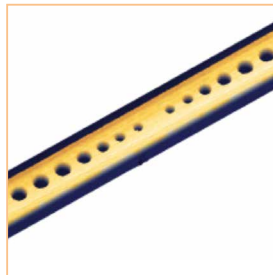
# Applications

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.

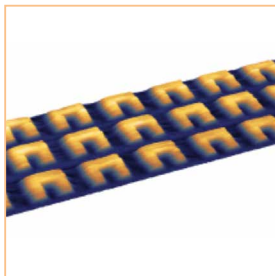
The NanoFrazor extends the application range of E-Beam significantly. The unique 3D capability with extreme accuracy enables novel devices and components. Furthermore, sensitive materials and devices are not damaged by high energy beam during the NanoFrazor patterning process. This is crucial for the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



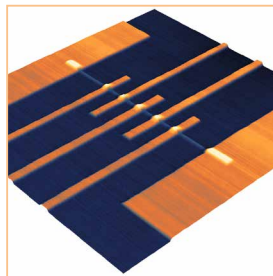
**Nanooptics**  
3D optical elements like spiral phase plates, microlenses or holograms



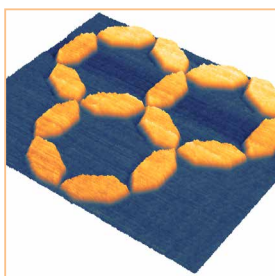
**Nanophotonics**  
Photonic crystals, cavities or waveguides with low roughness



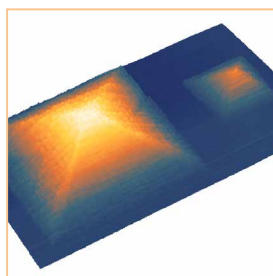
**Plasmonics**  
High resolution metal structures for metamaterials or optical antennas



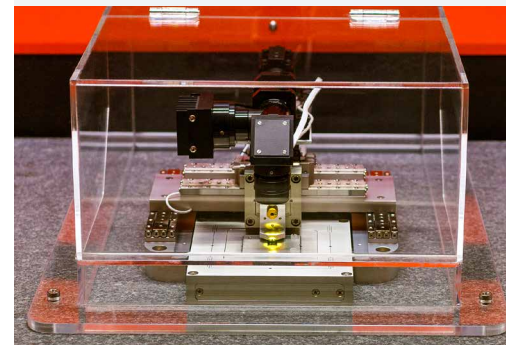
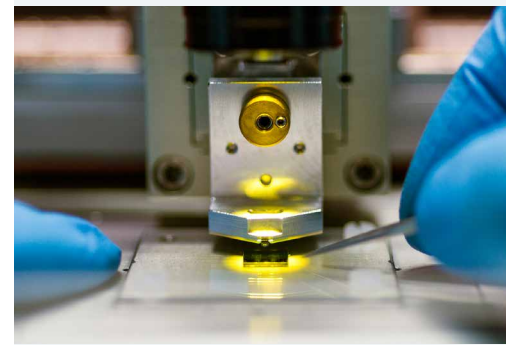
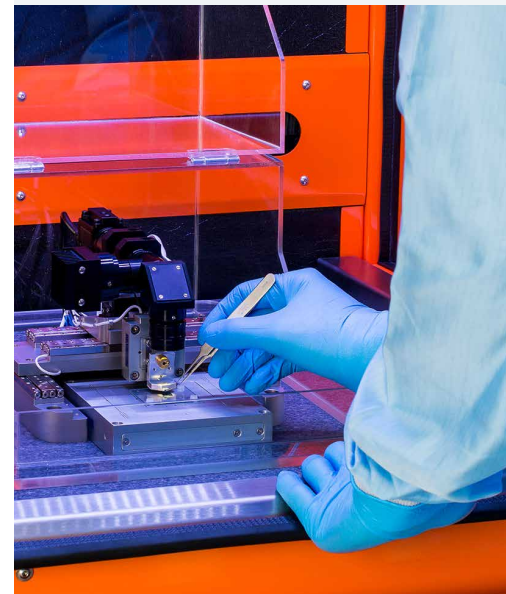
**Nanoelectronics**  
Novel nanowire and quantum devices using precise overlay



**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.

## » 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 the PC

## » 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

## » 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  $\mu$ s response time and sub-nm accuracy

## » Mechanics

- › Positioning system
  - 100 mm XY, 10 mm Z
  - 1 nm sensor resolution
- › High speed piezo scanners
  - 75  $\mu$ m XY, 20  $\mu$ m 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 NanoFrazor technology. The privately owned company is proud of its international and interdisciplinary character with employees from 10 different countries.

## Background

- 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

## 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)

## Research Collaborations

EU Project «Single Nanometer Manufacturing»



Eurostars «PPA-Litho»



Customer collaborations



## Technology White Paper

Read here detailed information about the NanoFrazor Explore!

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