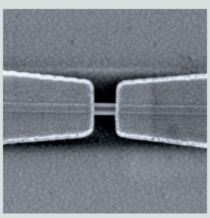
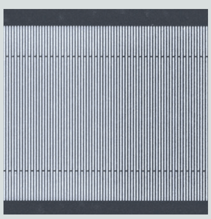
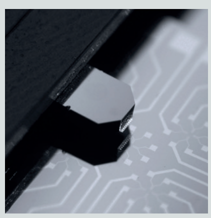
NanoFrazor

THE VERSATILE AND MODULAR NANOFABRICATION TOOL







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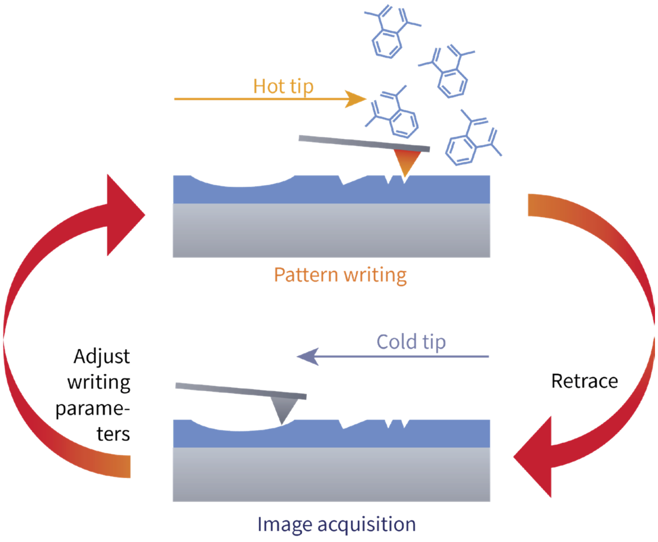
NanoFrazor

THE VERSATILE AND MODULAR NANOLITHOGRAPHY TOOL

The NanoFrazor takes nanofabrication to the next level. Building on decades of research and development, the NanoFrazor brings thermal scanning probe lithography (t-SPL) into your laboratory. Its unique capabilities continue to enable many nanotechnology devices and discoveries.

NanoFrazor lithography systems are based on thermal scanning probe lithography. Core of the NanoFrazor technology is an ultrasharp heatable probe tip, which is used for writing and simultaneous inspection of complex nanostructures. The in-situ inspection data are used in a closed feedback loop to adjust patterning parameters for optimal writing. This approach ensures that the desired depth profiles are created in the resist material, including grayscale patterns with unprecedented accuracy.

The heated tip creates high-resolution nanostructures by local sublimation of resists, allowing for a large variety of designs. Standard pattern transfer methods like lift-off or etching can be applied subsequently. The NanoFrazor Recipe Book, which includes recommended process flows and material data, is available to users for direct integration of thermal scanning probe lithography into device fabrication.



Patented “Closed-Loop Lithography” ensures high patterning accuracy.

MODULARITY

The NanoFrazor is built on a new modular platform that can be configured to best fit each application and laboratory environment. Patterning modes, housing options, and software modules can be combined to give the optimal combination of capabilities, footprint, and flexibility. Upgrades and additional modules can be installed as required, allowing the NanoFrazor to grow with advancing research ideas and requirements.

From left to right: The NanoFrazor as a tabletop version, the standalone version, and in conjunction with a glovebox

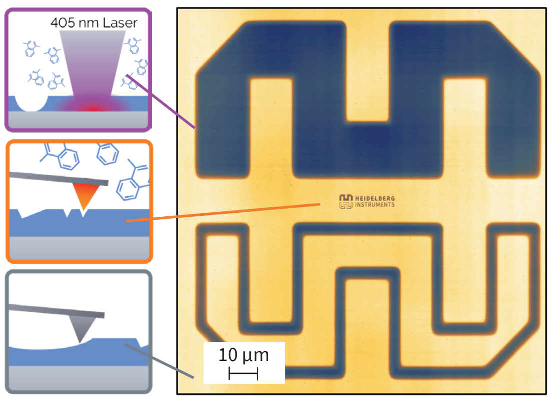
HYBRID MIX & MATCH DIRECT WRITE LITHOGRAPHY

The NanoFrazor can be equipped with a direct laser sublimation (DLS) module for increased write speed at micrometer resolution. The hybrid mix & match lithography approach, combining t-SPL and DLS, makes the NanoFrazor an excellent tool for complete device fabrication.

Direct laser sublimation (DLS)
Fast direct resist sublimation for large-area patterning, e.g. contact wires and pads.

Thermal scanning probe lithography (t-SPL)
High precision and high resolution for the critical parts of the nanodevice.

Metrology, inspection, and alignment
In-situ high-speed imaging with the same tip before, during or after patterning. Immediate validation of the pattern, as the thermal resist is removed directly, and a topography image is produced in-situ during the litho-graphy session.



Heidelberg Instruments micro- and nano-logos written 30 nm deep into PPA resist and imaged by NanoFrazor

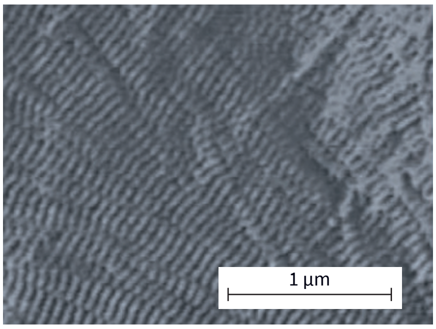
THERMAL RESIST MATERIALS FOR T-SPL

High-purity thermal resist materials, especially poly(phthalaldehyde) (PPA), decompose at modest temperatures and sublimate without redeposition. PPA is suitable for standard pattern transfer processes such as lift-off, etching, and molding. Resist materials are commercially available worldwide.

Bilayer and multi-layer stacks with PPA as the patterning resist can be spin-coated with simple laboratory setups. Common resists such as PMMA, PMMA/MA, and PMGI can be selected as underlayers, keeping the pattern transfer steps after NanoFrazor lithography compatible and safe with a research environment.

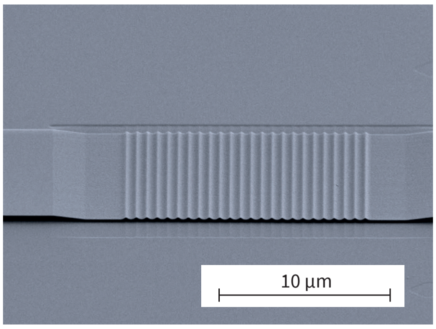
GRAYSCALE NANOLITHOGRAPHY

Closed loop lithography allows the patterning depth to be set for each position on the substrate. With the grayscale value of each pixel set independently, structures for optics, nano-biotechnology, and nanophotonics can be created in a straightforward fashion. The very high vertical accuracy, with < 1 nm error demonstrated, is made possible by dedicated software, ultralow-noise electronics, and noise insulating housing.



A tissue template for bone cell growth, created by grayscale patterning

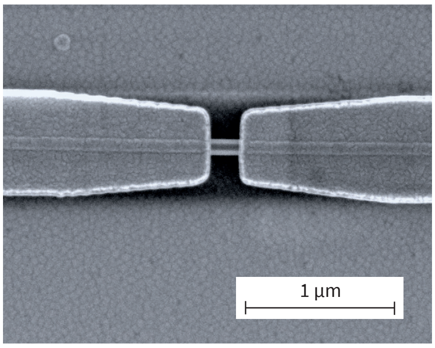
Courtesy of Prof. Elisa Riedo, NYU



A sinusoidal grating overlaid onto a waveguide structure

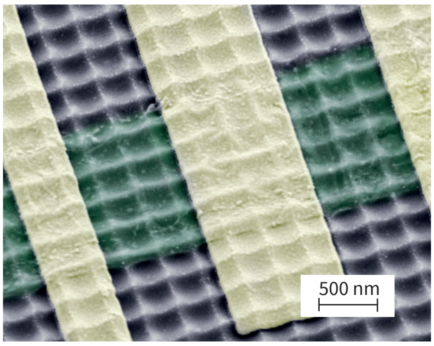
Courtesy of the OMEL Group, ETH Zürich

MARKERLESS OVERLAY COMBINED WITH DAMAGE FREE LITHOGRAPHY



An InSb nanowire, overlaid with electrodes using the markerless overlay capability of the NanoFrazor

Image in collaboration with Dr. Lior Shani, University of Minnesota



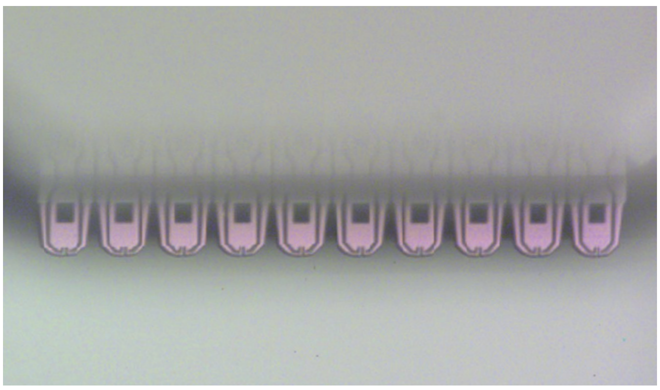
A MoS_2 transistor, fabricated by combining grayscale-patterning, markerless overlay and damage-free lithography on this sensitive material

Courtesy of Dr. Xia Liu and Berke Erbas, EPFL

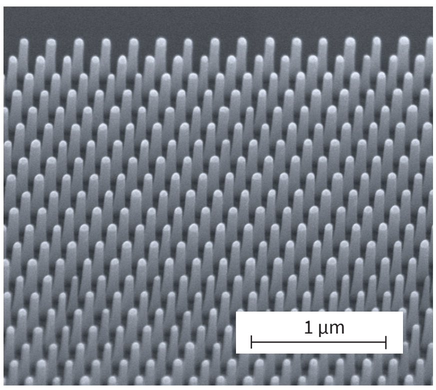
Accurate overlay and stitching are achieved by in-situ topography imaging used to detect structures of interest precisely. Features buried under resist (flakes, wires, etc) can be used as natural markers. Furthermore, automated correlation stitching of write fields can be applied, both for t-SPL and DLS fields, as well as to stitch the two patterning modes with each other. These capabilities can be leveraged with damage-free lithography possible with the NanoFrazor, make the tool a perfect fit for studying and developing sensitive materials such as nanowires and 2-dimensional semiconductors.

RESOLUTION MEETS THROUGHPUT

Ultra-sharp tips enable high resolution, free from proximity effects. Throughput can be increased up to 10 times by using the new Decapede module. With the Decapede, 10 thermal cantilevers pattern simultaneously, independently of each other, thereby increasing throughput without compromising resolution.



Array of 10 thermal cantilevers, as seen through the integrated optical inspection in the NanoFrazor software



Nanopillar arrays, commonly used in metasurfaces and nanobiotechnology, can be fabricated over large areas at resolutions < 50 nm.

NanoFrazor
SYSTEM SPECIFICATIONS

	Thermal probe lithography		Direct laser sublimation
	Single tip	Decapede	
Patterning performance			
Minimum structure size [nm]	15	15	600
Minimum lines and spaces [half pitch, nm]	25	25	1000
Grayscale / 3D-resolution (step size in PPA) [nm]	2	2	-
Maximum writing field size [X µm x Y µm]	60 x 60	60 x 60	60 x 60
Field stitching accuracy (markerless, using in-situ imaging) [nm]	25	25	600
Overlay accuracy (markerless, using in-situ imaging) [nm]	25	25	600
Write speed (scan speed) [mm/s]	1	1	5
Write speed (50 nm pixel) [μm^2/min]	1000	10 000	100 000
Topography imaging performance			
Lateral imaging resolution (feature size) [nm]	10		-
Vertical resolution (topography sensitivity) [nm]	<0.5		-
Imaging speed (@ 50 nm resolution) [μm^2/min]	1000	10 000	-

Base system features	
Substrate sizes	1 x 1 mm^2 to 100 x 100 mm^2 (150 x 150 mm^2 possible with limitations) Thickness: up to 10 mm
Optical microscope	0.6 µm digital resolution, 2 µm diffraction limit, 1.0 mm x 1.0 mm field of view, autofocus
Magnetic cantilever holder	Fast (< 1 min) and accurate tip exchange
Vibration isolation	Active vibration isolation stage

Optional system features / modularity	
Direct laser sublimation	Laser source and optics: 405 nm wavelength CW fiber laser, 300 mW, 1.2 µm minimum focal spot size Laser autofocus: Using the distance sensor of the NanoFrazor cantilever
Decapede	Parallel writing with 10 tips
Standalone housing	Three-layer acoustic isolation, superior vibration isolation | PC-controlled temperature and humidity monitoring, gas-flow regulation | (Dimension 185 cm x 78 cm x 128 cm / weight 650 kg)
Full glovebox integration	Integration in glovebox available for nanolithography in a controlled environment

NanoFrazor cantilever features (both Single Tip and Decapede)	
Integrated components	Tip heater, topography sensor, electrostatic actuation
Tip geometry	Conical tip with < 10 nm radius and 750 nm length
Tip heater temperature range	25 °C – 1100 °C (< 1 K setpoint resolution)

Base system dimensions & installation requirements		
Height × width × depth	Table-top unit: 44 cm x 40 cm x 45 cm	Controller: 84 cm x 60 cm x 56 cm
Weight	~50 kg	~80 kg
Power input		1 x 110 or 230 V AC, 10 A

Software features

GDS and bitmap import, 256 grayscale levels, topography image analysis and drawing for overlay, mix & match between tip and laser writing, fully automated calibration routines, Python scripting

Please note: Specifications depend on individual process conditions and may vary according to equipment configuration. Write speed depends on exposure area. Design and specifications are subject to change without prior notice.

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STI 08/24-H07/24|V1.8.2