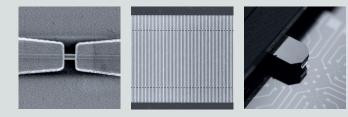


# **NanoFrazor**

# THE VERSATILE AND MODULAR NANOFABRICATION TOOL





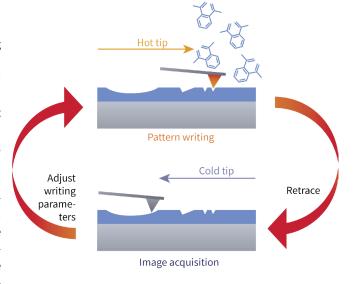
# **NanoFrazor**

# 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 laser direct 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)

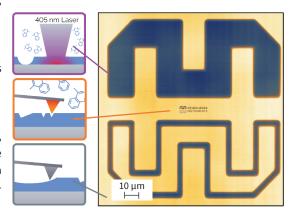
Fast direct resist sublimation for large-area patterning, e.g. contact wires and pads.

# 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 lithography session.



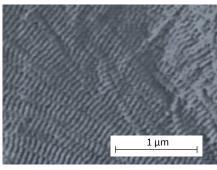
Heidelberg Instruments micro- and nano-logos written 30 nm deep into PPA resist and imaged by NanoFrazor

### 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.

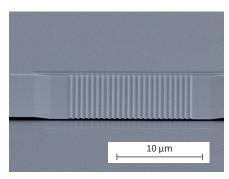
### **GRAYSCALE NANOLITHOGRAPHY**

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

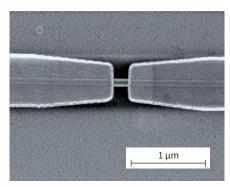
Courtesy of Prof. Elisa Riedo, NYU



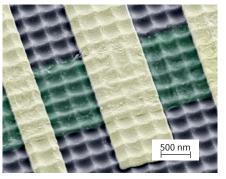
A sinusoidal grating overlaid onto a waveguide structure

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



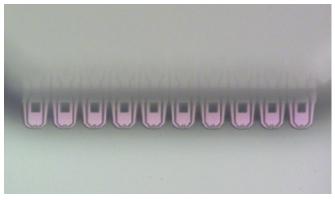
A MoS $_2$  transistor, fabricated by combining grayscale patterning, markerless overlay and damage-free lithography on this sensitive material

Courtesy of Berke Erbas, EPFL

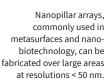
Accurate overlay and stitching are achieved by in-situ topography imaging used to detect structures of interest precisely. Features buried under resist (flakes, wires, etc) can be used as natural markers. Furthermore, automated correlation stitching of write fields can be applied, both for t-SPL and 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.

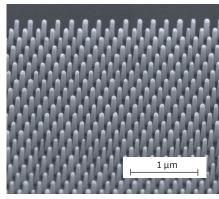
## **RESOLUTION MEETS THROUGHPUT**

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





# NanoFrazor SYSTEM SPECIFICATIONS

Minimum lines and spaces [half pitch, nm] 25 25 25 1000 Grayscale / 3D-resolution (step size in PPA) [nm] 2 2 2	15			Thermal p	robe lithography	Direct laser sublimation	
Minimum structure size [nm] 15 15 15 600 Minimum lines and spaces [half pitch, nm] 25 25 25 1000 Grayscale / 3D-resolution (step size in PPA] [nm] 2 2 2  Maximum writing field size [X µm x Y µm] 60 x 60 60 x 60 60 x 60 60 x 60 Overlay accuracy (markerless, using in-situ imaging) [nm] 25 25 5 5 600 Overlay accuracy (markerless, using in-situ imaging) [nm] 25 25 5 5 600 Overlay accuracy (markerless, using in-situ imaging) [nm] 25 25 5 5 600 Overlay accuracy (markerless, using in-situ imaging) [nm] 25 25 600 Write speed (bypical scan speed) [mm/s] 10 1000 10 000 10 000 10 000  **Topography imaging performance**  **Lateral imaging resolution (feature size) [nm] 1000 10 00	15			Single tip	Decapede		
Minimum structure size [nm]   15	15	Patterning performance					
Grayscale / 3D-resolution (step size in PPA) [nm] 2 2 2	1 (step size in PPA) [nm] 2 2 2 3 - 2 - 2 2 - 2 2 2 2 2 3 2 3 3 2 3 3 2 3 3 3 3	Minimum structure size [nm]		15	15	600	
Maximum writing field size [X µm x Y µm] 60 x 60 60	ze [X μm x Y μm]   60 x 60   60 x 60   60 x 60     (markerless, using in-situ imaging) [nm]   25   25   600     speed) [mm/s]   1   1   5     (pmr/min]   1000   10 000   100 000     speed) [mm/s]   1   1   5     (pmr/min]   1000   10 000   100 000     speed) [mm/s]   1   1   5     (pmr/min]   1000   10 000   100 000     speed) [mm]   10   -     graphy sensitivity) [nm]   <0.5   -     tresolution) [μm²/min]   1000   10 000   -      1x 1 mm² to 100 x 100 mm² (150 x 150 mm² possible with limitations)     Thickness: up to 10 mm   0.6 μm digital resolution, 2 μm diffraction limit, 1.0 mm x 1.0 mm field of view, autofocus     see			25	25	1000	
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 (typical scan speed) [mm/s] 1 1 1 5  Write speed (50 nm pixel) [µm²/min] 1000 10 000 10 000 10 000  Topography imaging performance  Lateral imaging resolution (feature size) [nm] 10 - Vertical resolution (topography sensitivity) [nm] < 0.5 - 1  Imaging speed (@ 50 nm resolution) [µm²/min] 1000 10 000 1  Base system features  Substrate sizes 1x1 mm² to 100 x 100 mm² (150 x 150 mm² 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 m gas-flow regulation   (Dimension 185 cm x 78 cm x 128 cm / weight 650 kg)  Integrated components Tip heater, topography sensor, electrostatic actuation  NanoFrazor cantilever features (both Single Tip and Decapede)  Integrated components Tip heater, topography sensor, electrostatic actuation  Tip peometry 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 - 80 kg	(markerless, using in-situ imaging) [nm] 25 25 600  reless, using in-situ imaging) [nm] 25 25 600  respect [nm] 10 10 000  relession [nm] 20 25 25 600  respective size [nm] 10 25 25 25 25  respective size [nm] 20			2	2	-	
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Write speed (typical scan speed) [mm/s] 1 1 1 5  Write speed (50 nm pixel) [µm²/min] 1000 10 000 10 000 10 000  Topography imaging performance  Lateral imaging resolution (feature size) [nm] 10 -  Vertical resolution (topography sensitivity) [nm] < 0.5 -  Imaging speed (@ 50 nm resolution) [µm²/min] 1000 10 000 -  Base system features  Substrate sizes 1 x 1 mm² to 100 x 100 mm² (150 x 150 mm² 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 subclimation 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 m 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 × 80 kg	In speed) [mm/s] 1 1 1 5  I) [µm²/min] 1000 10 000 10000 100 000  Derformance  In (feature size) [nm] 10 - 10000 10 000 10 00			25	25	600	
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Lateral imaging performance  Lateral imaging resolution (feature size) [nm] 10 -  Vertical resolution (topography sensitivity) [nm] < <0.5 -  Imaging speed (@ 50 nm resolution) [µm²/min] 1000 10 000 -  Base system features  Substrate sizes	or (feature size) [nm] 10 - graphy sensitivity) [nm] < 0.5	Write speed (typical scan speed	d) [mm/s]	1	1	5	
Lateral imaging resolution (feature size) [nm] 10 - Vertical resolution (topography sensitivity) [nm] < 0.5 - Imaging speed (@ 50 nm resolution) [µm²/min] 1000 10 000 -  Base system features  Substrate sizes	graphy sensitivity) [nm]	Write speed (50 nm pixel) [μm²,	/min]	1000	10 000	100 000	
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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 m 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  ~50 kg  ~80 kg	Active vibration isolation stage  Tres / modularity  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  Parallel writing with 10 tips  Three-layer acoustic isolation, superior vibration isolation   PC-controlled temperature and humidity monitorin gas-flow regulation   (Dimension 185 cm x 78 cm x 128 cm / weight 650 kg)  Integration in glovebox available for nanolithography in a controlled environment  r features (both Single Tip and Decapede)  Tip heater, topography sensor, electrostatic actuation  Conical tip with < 10 nm radius and 750 nm length  range  25 °C - 1100 °C (< 1 K setpoint resolution)  ons & installation requirements  Table-top unit: 44 cm x 40 cm x 45 cm  ~50 kg  Controller: 84 cm x 60 cm x 56 cm  ~80 kg  1 x 110 or 230 V AC, 10 A	Optical microscope	0.6 μm digital resolution, 2 μm diffraction limit, 1.0 mm x 1.0 mm field of view, autofocus				
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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  Three-layer acoustic isolation, superior vibration isolation   PC-controlled temperature and humidity m gas-flow regulation   (Dimension 185 cm × 78 cm × 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 × 40 cm × 45 cm  Controller: 84 cm × 60 cm × 56 cm  ~80 kg	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  Parallel writing with 10 tips  Three-layer acoustic isolation, superior vibration isolation   PC-controlled temperature and humidity monitorin gas-flow regulation   (Dimension 185 cm x 78 cm x 128 cm / weight 650 kg)  Integration in glovebox available for nanolithography in a controlled environment  r features (both Single Tip and Decapede)  Tip heater, topography sensor, electrostatic actuation  Conical tip with < 10 nm radius and 750 nm length  range  25 °C - 1100 °C (< 1 K setpoint resolution)  Ons & installation requirements  Table-top unit: 44 cm x 40 cm x 45 cm  ~50 kg  (230 VAC, 10 A)	Vibration isolation	Active vibration isolation stage				
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 m 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  *80 kg	Laser autofocus: Using the distance sensor of the NanoFrazor cantilever  Parallel writing with 10 tips  Three-layer acoustic isolation, superior vibration isolation   PC-controlled temperature and humidity monitorin gas-flow regulation   (Dimension 185 cm x 78 cm x 128 cm / weight 650 kg)  Integration in glovebox available for nanolithography in a controlled environment  r features (both Single Tip and Decapede)  Tip heater, topography sensor, electrostatic actuation  Conical tip with < 10 nm radius and 750 nm length  range 25 °C - 1100 °C (< 1 K setpoint resolution)  Ons & installation requirements  Table-top unit: 44 cm x 40 cm x 45 cm  ~50 kg  Controller: 84 cm x 60 cm x 56 cm  ~80 kg  1 x 110 or 230 V AC, 10 A	Optional system features / r	modularity				
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Weight ~50 kg ~80 kg	~50 kg		· · · · · · · · · · · · · · · · · · ·	F and	Combrellow 04 are v CO are	v 55 am	
	1 x 110 or 230 V AC, 10 A	-	·	o ciii		X 30 CIII	
TX TIO OF 250 V AC, TO A			- Ju Kg		- J		
Software features	256 grayscale levels, topography image analysis and drawing for overlay, mix 8, match between tip and laser writing				1 X 110 01 230 V AC, 10 A		

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.

Visit product website for more information

To contact your local representative, please consult our website heidelberg-instruments.com

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