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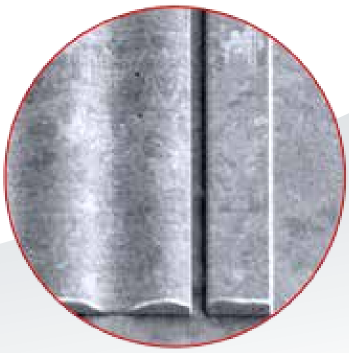
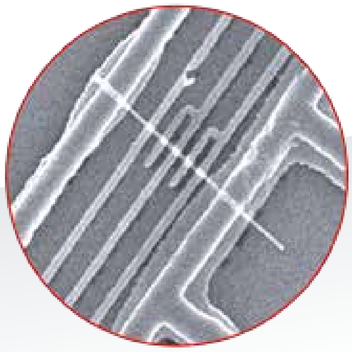
INSTRUMENTS

NanoFrazor Explore

Revolutionizing Nanofabrication





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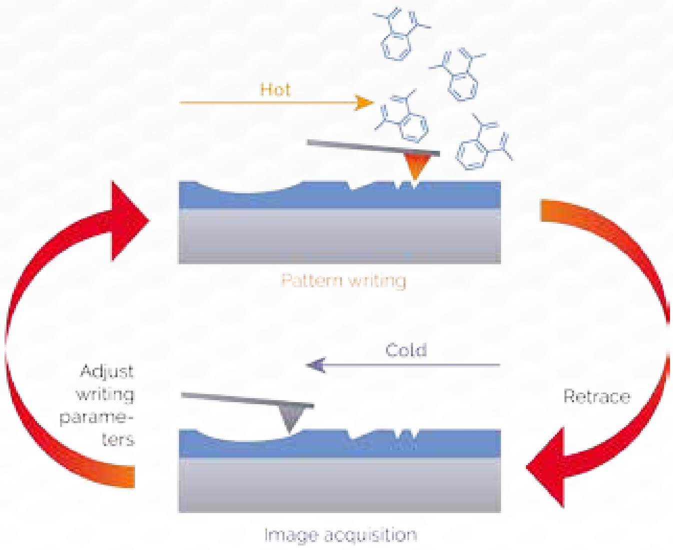
HEIDELBERG INSTRUMENTS

NanoFrazor Explore
THE FIRST HYBRID MIX&MATCH NANO- AND MICROLITHOGRAPHY TOOL

The NanoFrazor Explore takes nanofabrication to a new level. The NanoFrazor technology is commercially available only since 2014, but its unique capabilities have already enabled many revolutionary nanotechnology devices and discoveries.

NanoFrazor lithography systems are based on thermal scanning probe lithography. Core of the NanoFrazor technology is an ultra-sharp heatable probe tip which is used for writing and simultaneous inspection of complex nanostructures. The heated tip creates arbitrary, high-resolution nanostructures by local sublimation of resists. Standard pattern transfer methods like lift-off or etching can be applied.



Patented "Closed-Loop Lithography" ensures high patterning accuracy

PPA - the main resist for NanoFrazor technology

- Polyphthalaldehyde (PPA) decomposes and sublimates without redeposition upon heating by tip or laser
- PPA is suitable for many pattern transfer processes (lift-off, etching, molding, ...). We provide support and an extensive recipe book.
- PPA is commercially available worldwide (Allresist GmbH, Germany)
- Contact us for info on other resists and transfer processes

HYBRID MIX & MATCH DIRECT WRITE LITHOGRAPHY

Since 2019, the NanoFrazor Explore is also equipped with a laser writer module. The increased write speed at micrometer resolution makes the Explore the first real alternative to expensive and complex direct-write nanolithography methods like electron beam lithography.

Laser writing

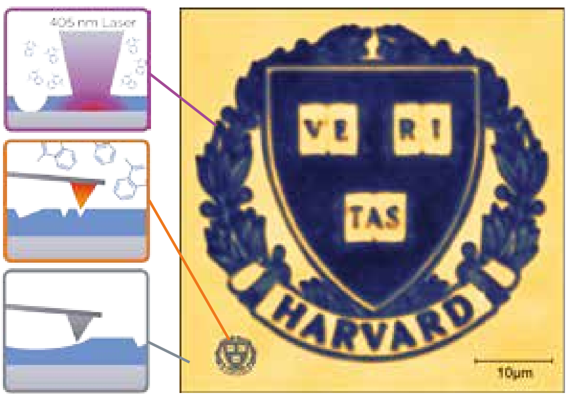
Fast direct resist sublimation for large-area patterning, e.g. contact wires and pads

Thermal probe writing

High precision and high resolution for the critical parts of the nanodevice

Metrology, inspection and alignment

In-situ high-speed AFM with the same tip before, during or after patterning. No wet development required as the resist is removed directly

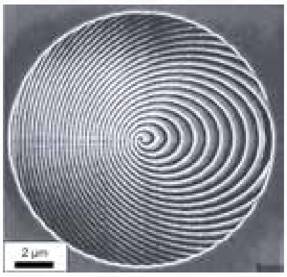


Harvard micro- and nano-logos written 30 nm deep into PPA resist and imaged by NanoFrazor AFM

Courtesy of Harvard CNS

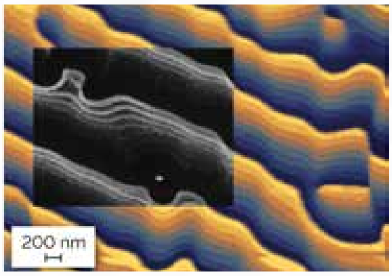
3D GRAYSCALE NANOLITHOGRAPHY

- Patterning depth can be set for each position of the tip (grayscale value of each pixel)
- Closed-Loop Lithography enables unprecedented accuracy (< 1 nm error demonstrated for more than 16 individual depth levels)



3D phase plate etched from PPA into SiN membranes for TEM optics

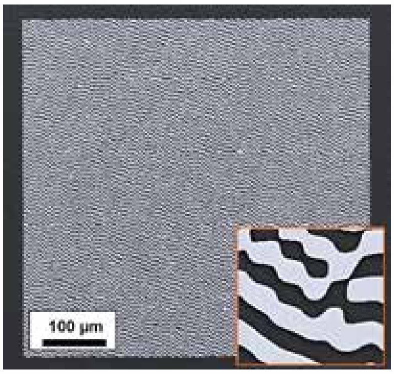
Courtesy of EPFL and KIT



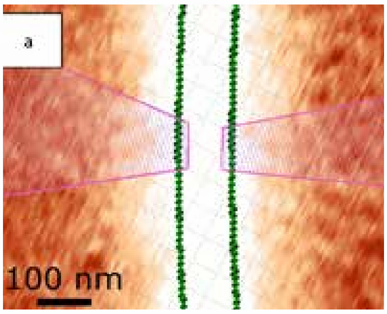
Multilevel hologram written into PPA and simultaneously imaged. Inset is an SEM image after 10x-amplification etch transfer in Si

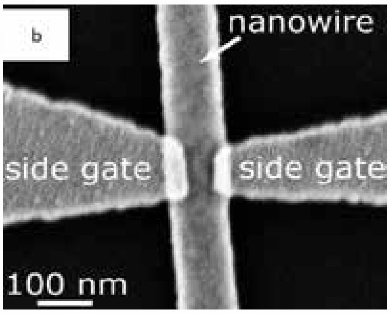
Courtesy of Sun Yat-Sen University

MARKERLESS OVERLAY & STITCHING



Reflective hologram (made with Au lift-off) consisting of 100 000 000 pixels and stitched from 50 µm write fields using an AFM correlation technique.

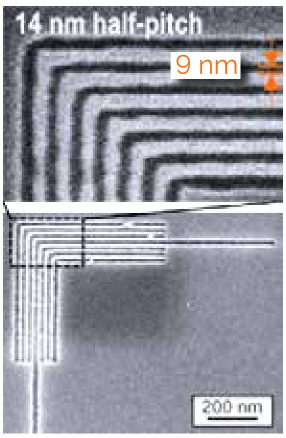


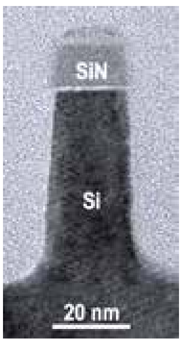


Markerless overlay of metal electrodes on top of a nanowire buried under resist stack. a) Detect nanowire location (green) and draw layout on AFM image (pink). b) SEM after lift-off.

- Accurate overlay and stitching achieved by in-situ AFM (sub-10 nm accuracy demonstrated)
- Features buried under resist (flakes, wires, etc) are used as natural markers
- Automated correlation stitching of write fields

ULTRA-HIGH RESOLUTION





Silicon fins and trenches etched from PPA resist.

Courtesy of IBM Research and imec

- Ultra-sharp tips enable ultra-high resolution (< 10 nm half-pitch demonstrated in resist)
- No proximity effect corrections required

OTHER UNIQUE CAPABILITIES

- **Low damage**: No charged particles beam, hence better device performance with sensitive materials
- **Material conversion** at the nanoscale: direct heat-induced modifications (phase change, chemical reaction, ...) of various materials

NanoFrazor Explore
SYSTEM SPECIFICATIONS

	Thermal Probe Writing	Direct Laser Sublimation
Writing performance		
Minimum structure size [nm]	15	600
Minimum lines and spaces [half pitch, nm]	25	1000
Grayscale / 3D-resolution (step size in PPA) [nm]	2	-
Writing field size [X µm x Y µm]	60 x 60	60 x 60
Field stitching accuracy (markerless, using in-situ AFM imaging) [nm]	25	300
Overlay accuracy (markerless, using in-situ AFM imaging) [nm]	25	100
Write speed (typical scan speed) [mm/s]	1	5
Write speed (thermal Probe: 50 nm pixel, incl. imaging) [µm^2/min]	1000	100 000
AFM imaging performance		
Lateral imaging resolution (feature size) [nm]	10	
Vertical resolution (topography sensitivity) [nm]	0.2	
Imaging speed (50 nm pixel) [µm^2/min]	1000	

System features	
Substrate sizes	1 x 1 mm^2 to 100 x 100 mm^2, 0 – 20 mm thickness (150 x 150 mm^2 possible with limitations)
Optical microscope	0.6 µm optical resolution, 1.0 mm x 1.0 mm field of view, autofocus
Laser source and optics	405 nm wavelength CW fiber laser, up to 150 mW output power on sample, 1.2 µm minimum focal spot size
Real-time laser autofocus	Using the distance sensor of the NanoFrazor cantilever
Magnetic cantilever holder	Fast (< 1 min) and accurate tip exchange
Housing	Three-layer acoustic isolation, superior vibration isolation (> 98% @ 10 Hz) PC-controlled temperature and humidity monitoring, gas-flow regulation
Software features	GDS and bitmap import, 0.1 nm address grid, 256 grayscale levels, AFM image analysis and drawing for overlay, mix & match between tip and laser writing, fully automated calibration routines, Python scripting
NanoFrazor cantilever features	
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)
System dimensions & installation requirements	
Height × width × depth	185 cm x 78 cm x 128 cm
Weight	650 kg
Power input	1 x 110 or 220 V AC, 10 A
Gas input	Compressed air and/or nitrogen with > 4 bar

Other considerations
Recipe book with detailed descriptions of various processes is included (regularly updated with software).
Cantilever tips degrade over time (> 50 h patterning possible). Exchange is fast and low cost for tool owners.
A clean room or special laboratory is not required. No vacuum needed.
Multi-tip extension (optional add-on for Explore system) is scheduled for beta site testing in mid-2020.

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

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