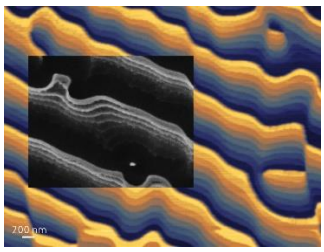
Thermal Resist

Resist for the thermal scanning probe lithography (t-SPL) and direct laser lithography

Thermal Resist AR-P 8100/Phoenix 81 (PPA)

Dedicated thermal resist for 2D and 3D patterning with high resolution and clean sublimation. Can be combined with direct laser writer.

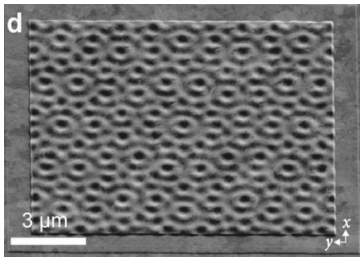


3D hologram patterned and transferred into Si,

cf. Prof. Jianwen Dong, Sun Yat-Sen University, Guangzhou (China)

Thermal Resist AR-P 617 (PMMA-co-MA)

Possible to remove directly by thermal probe heating, also suitable as underlayer for water-free two-layer lift-off together with AR-P 8100.

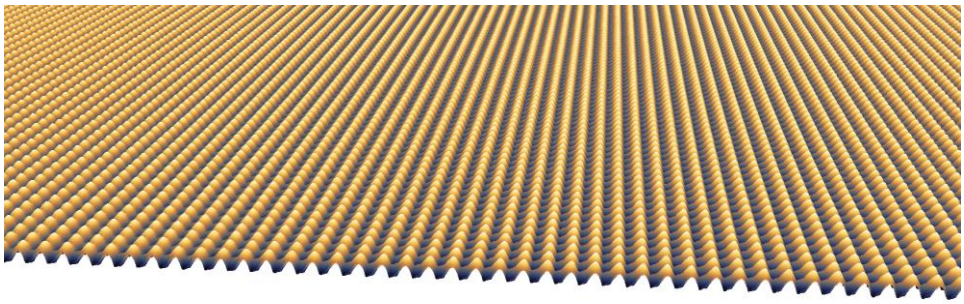


Quasiperiodic optical Fourier surfaces templated in Ag

cf. Lassaline *et al*, **Nature**, 2020

Thermal Resist AR-P 6200 series/CSAR 62

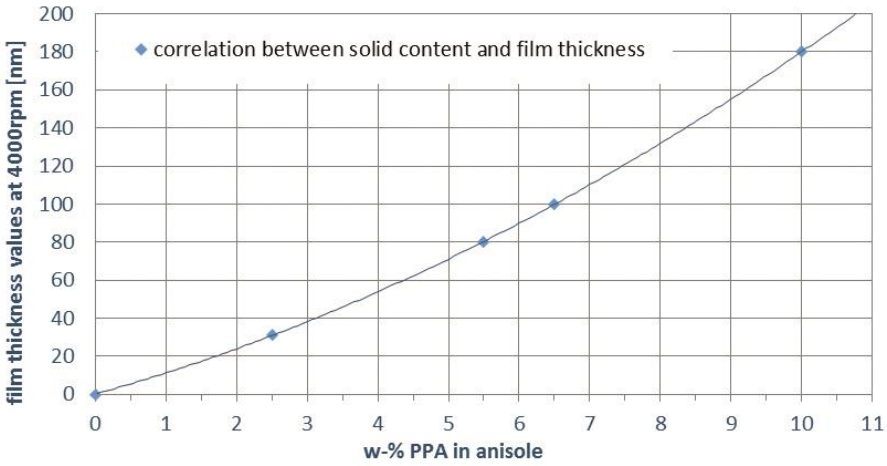
High resolution e-beam resist also works for direct removal by heated probe (limited tip lifetime)



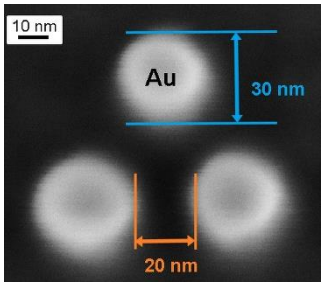
Array of 250 nm wide 3D features written directly into **CSAR 62** resist by t-SPL.

Additional info and images that can be used in the detailed descriptions of the resists:

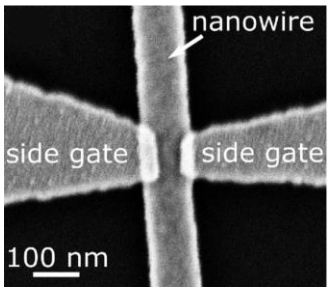
Concentration wt[%]	Film Thickness [nm]																																
	6	8	10	12	14	16	18	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	110	120	130	140	150	160	170	180	190	200
0.85			6k	5k		2k																												
1.3						6k			2k																									
2								6k		2k																								
2.5									6k	5k			2k																					
3											6k				2k																			
5												6k								2k														
6																			6k	5k		4k			3k		2k							
7.5																					6k							2k						
10																											6k							2k



Spin-speeds and concentrations required to achieve various thicknesses of **Phoenix 81**.

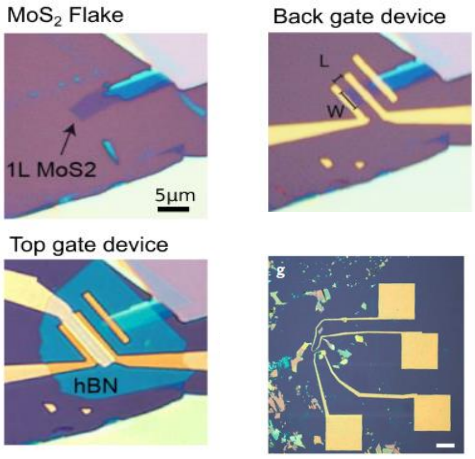


Pillars written into **Phoenix 81** by t-SPL and etched into 20nm Au using a hard mask stack and ion beam etching.



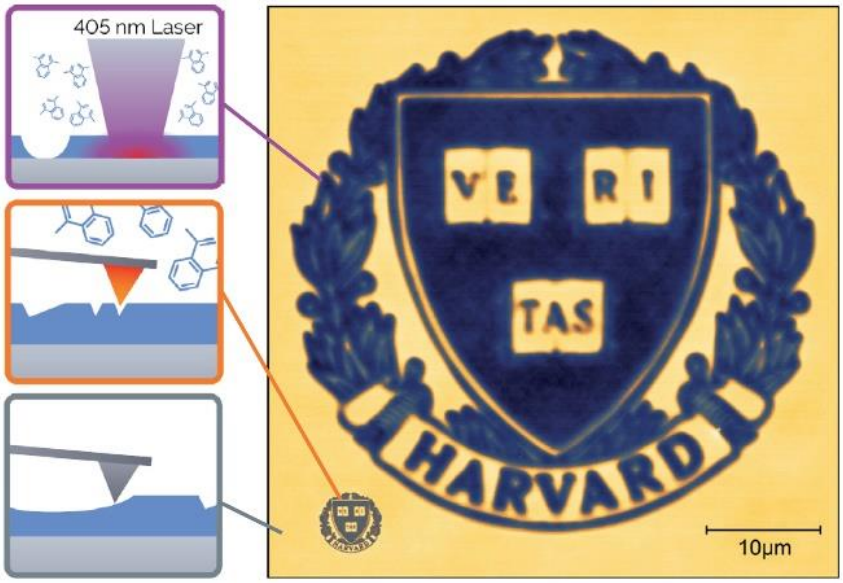
Side electrodes onto a nanowire made markerless overlay using t-SPL in **Phoenix 81**.

cf. Rawlings *et al*., Transducers 2017

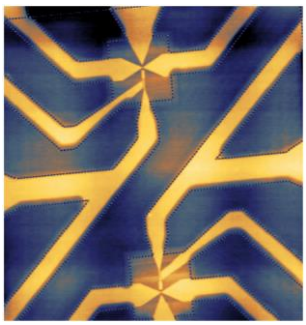


Metal contacts for record MoS2 transistors using two-layer lift-off with **Phoenix 81**

cf. Zheng *et al.,* **Nature Electronics** 2019

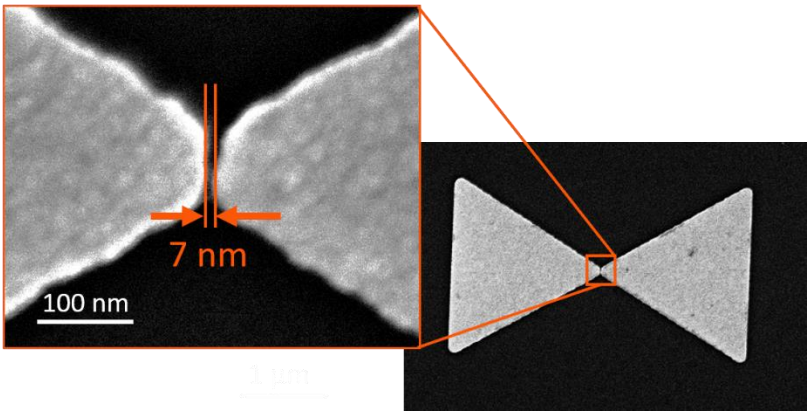


NanoFrazor AFM image of Harvard logo patterned by 405nm laser (large logo) and t-SPL (small logo) into **Phoenix 81** in the same NanoFrazor system.

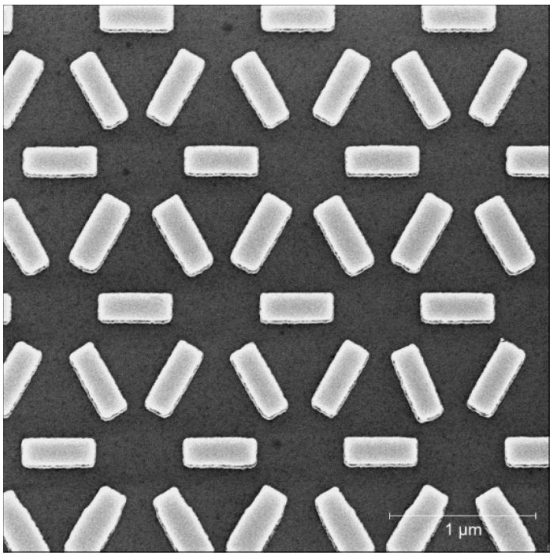


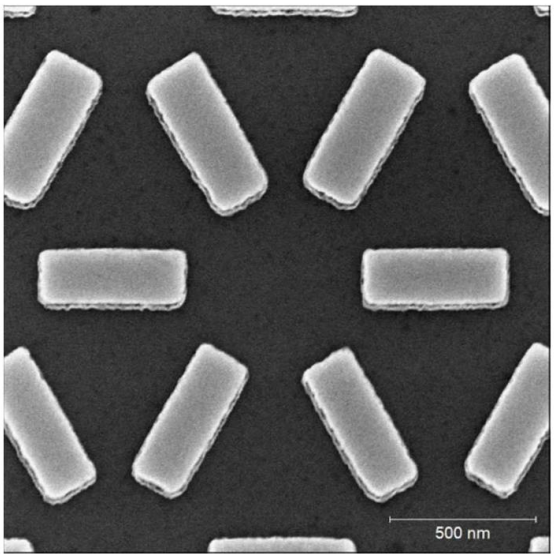
Room-temperature single electron transistors made by t-SPL (nanofeatures) and direct laser sublimation (microfeatures) of **Phoenix 81** and etching into Si.

Electrodes made by t-SPL and a two layer lift-off with **Phoenix 81** and **PMMA-co-MA**.



7nm gap made by t-SPL and a two layer lift-off with **Phoenix 81** and **PMMA-co-MA**.





Two layer lift-off using **CSAR** and **PMMA-co-MA**.

NanoFrazor - Thermal scanning probe lithography (t-SPL)

Polyphthalaldehydes (PPA) are thermally patternable resists developed for thermal scanning probe lithography (t-SPL) applications with NanoFrazor systems (Heidelberg Instruments Nano).

NanoFrazor systems are t-SPL tools that are capable of binary lithography with **sub-10 nm resolution** and **3D patterning** with sub-nm vertical resolution. The heated tip sublimates the PPA and can also perform **in-situ imaging** similarly to AFM, which is used for precise markerless overlay and stitching. Due to the fact that no charged particles are involved in the process, the NanoFrazor lithography is **non-invasive**, i.e. doesn't damage the samples or implant additional charges. NanoFrazor lithography is **compatible with standard pattern transfer processes**: Bilayer lift-off, high-resolution etching, transfer and amplification of 3D patterns into different materials, etc. NanoFrazor does **not require vacuum or cleanroom facility**. A clean room is however recommended for the coating the substrates with resist Phoenix 81.

Alternative applications of Phoenix 81

Thermal laser mix&match lithography

Phoenix 81 can be sublimated directly with a focused 405 nm laser. Phoenix 81 does not absorb light at 405 nm and the sublimation process also depends on the substrate and film thickness of Phoenix 81. The process requires a higher dose than usual photoresists, but no wet development is required. It is used in **mix&match approach** in the NanoFrazor Explore where small structures are written by a **heated tip (t-SPL)** and larger features (~500nm resolution) are written with an **integrated laser**. The AFM capability of the NanoFrazor allows immediate inspection and enables automated and **accurate overlay** between the t-SPL and laser written features.

There is ongoing development effort towards variants of a more sensitive PPA based resist to increase laser write speed.

Thermal laser lithography can achieve resolutions below the focal spot size of a laser beam.

Photolithography with pulsed UV lasers

UV laser light results from IOM Leibniz (to be added by Allresist)

Electron beam lithography

EBL results (to be added by Allresist)