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Maskless Grayscale Lithography for Micro & Nano Optics

EPIC Technology Meeting on Disruptive Optics at Thales

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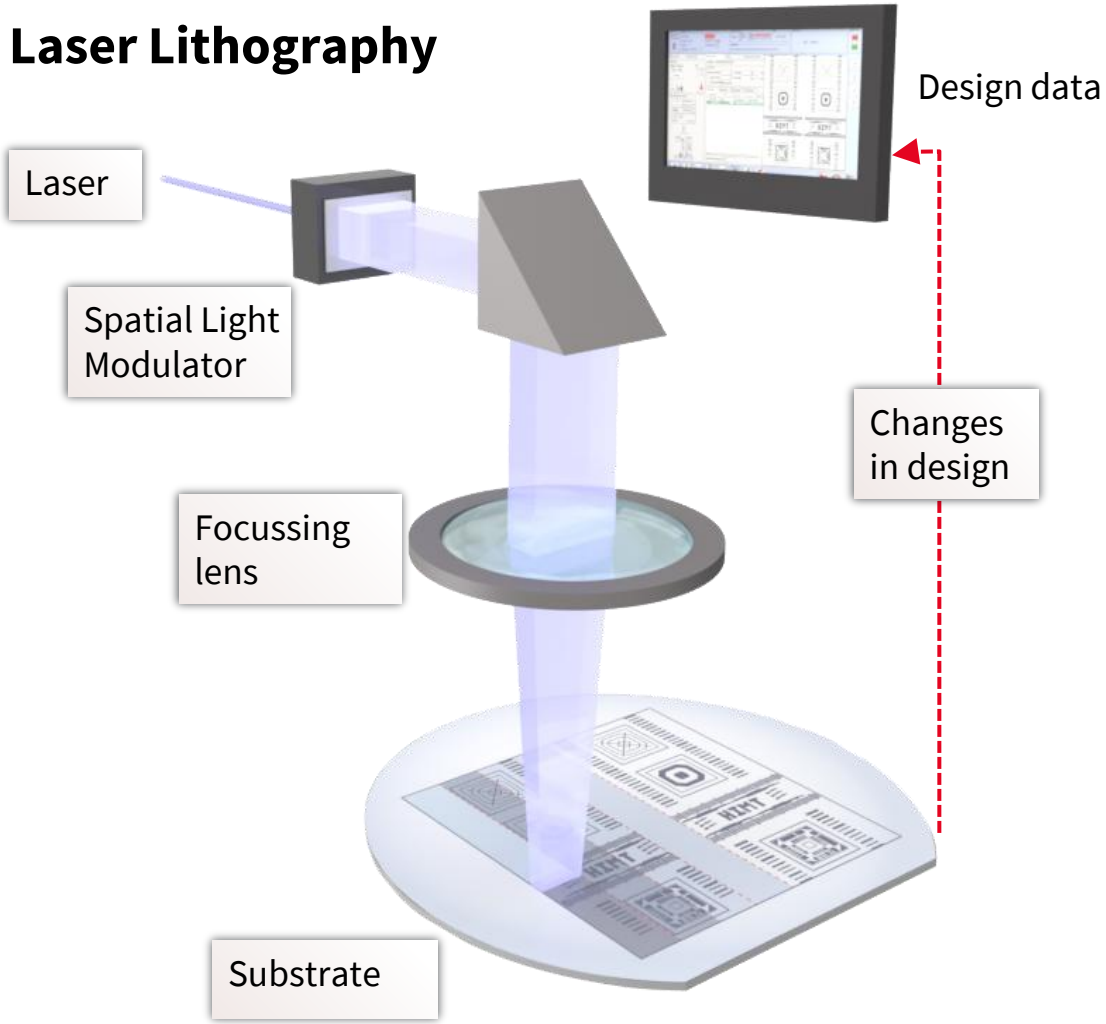
heidelberg-instruments.com

Presentation‘s Content:

- Laser Direct writing introduction
  - Principle
  - 2D Applications
- Maskless Grayscale Lithography
  - Principle
  - Material limits
- From resist to functional material
  - Etching
  - Replication
- T-SPL
  - Principle
  - Grayscale nanolithography
- Pattern transfer
  - Examples with 2D patterns

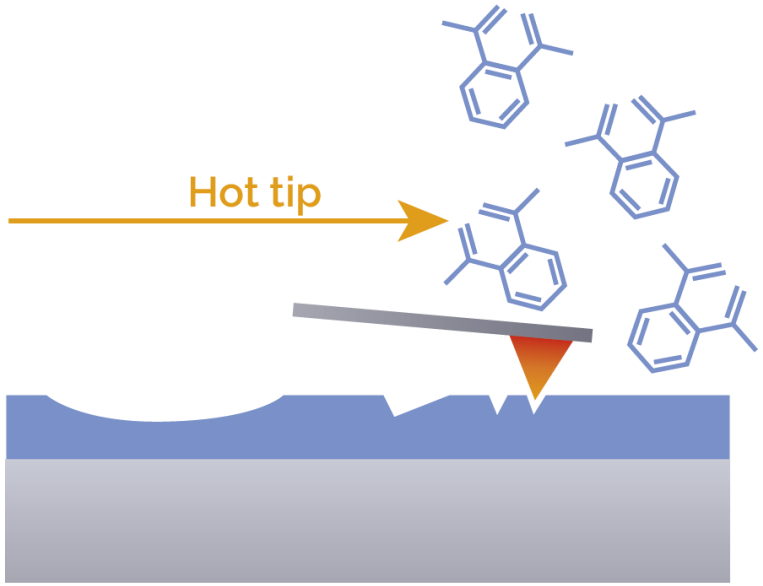
Maskless Lithography in a Nutshell

Laser Lithography



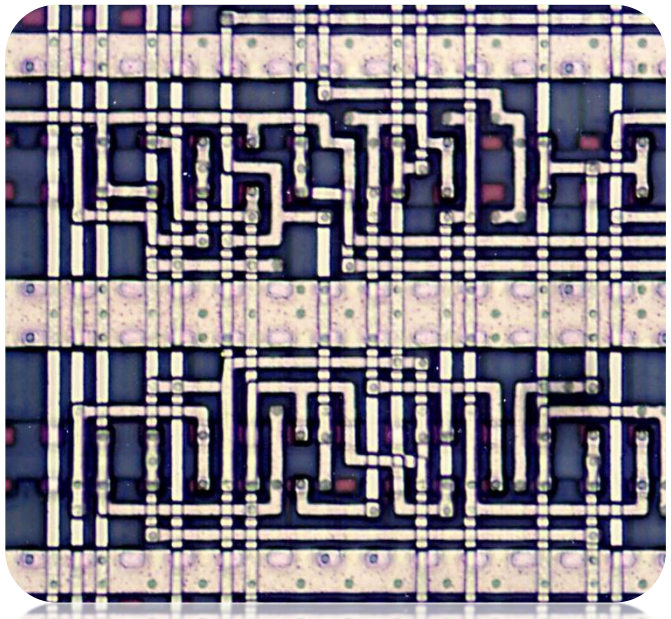
- No mask is needed
- Design directly written onto the resist coated substrate

Thermal Scanning Probe Lithography (t-SPL)

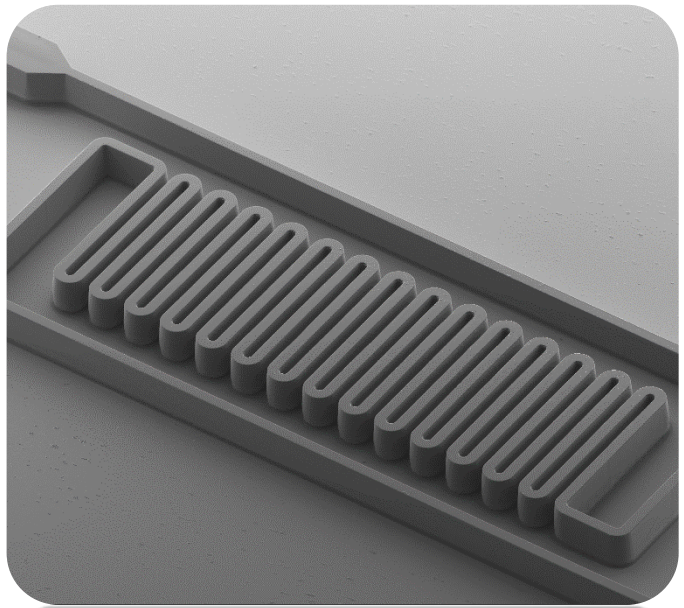


Maskless Lithography is widely used for 2D Applications

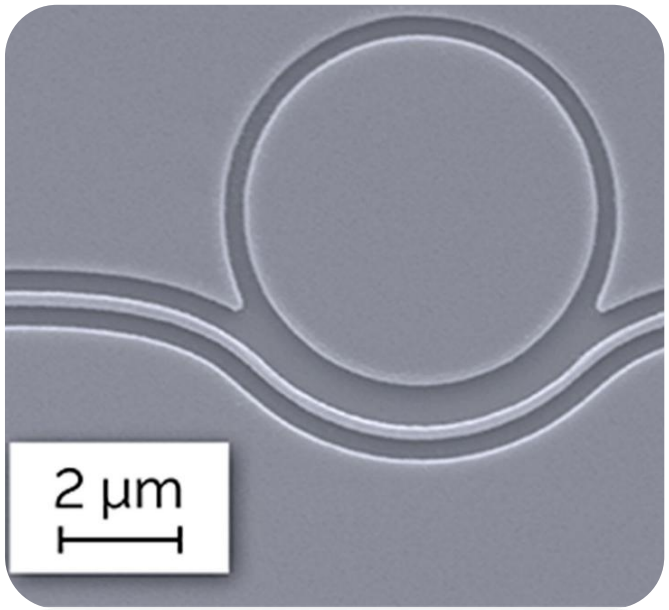
Multi-layer
Electronic device



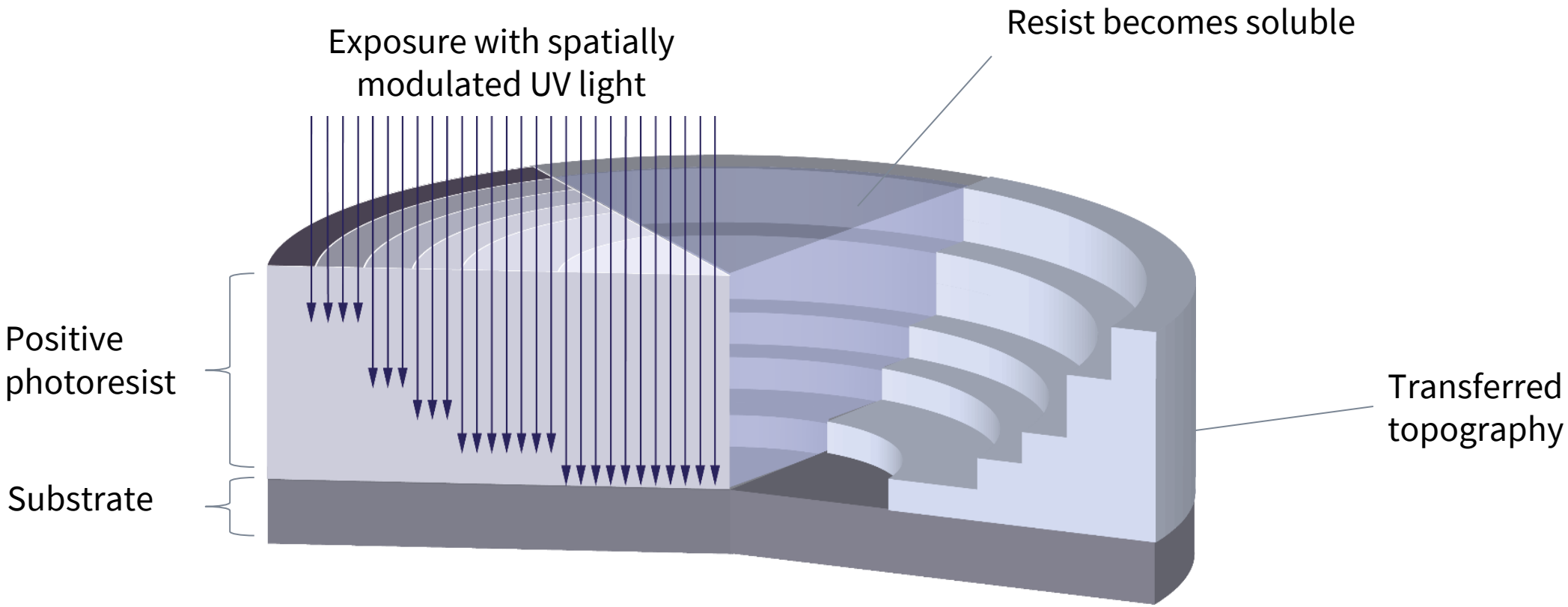
Microfluidic
in 80 µm mr-DWL



Waveguides
High resolution



Grayscale Lithography



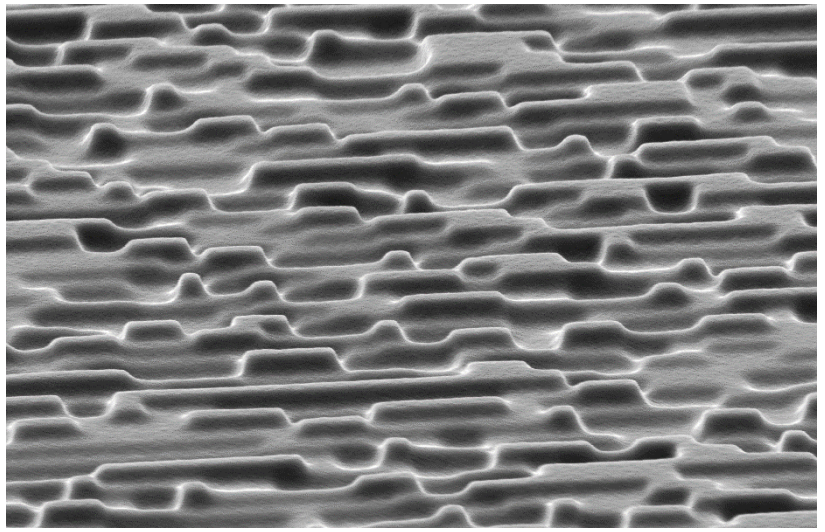
Greatscale, now with over 65000 gray levels !

Grayscale Resists

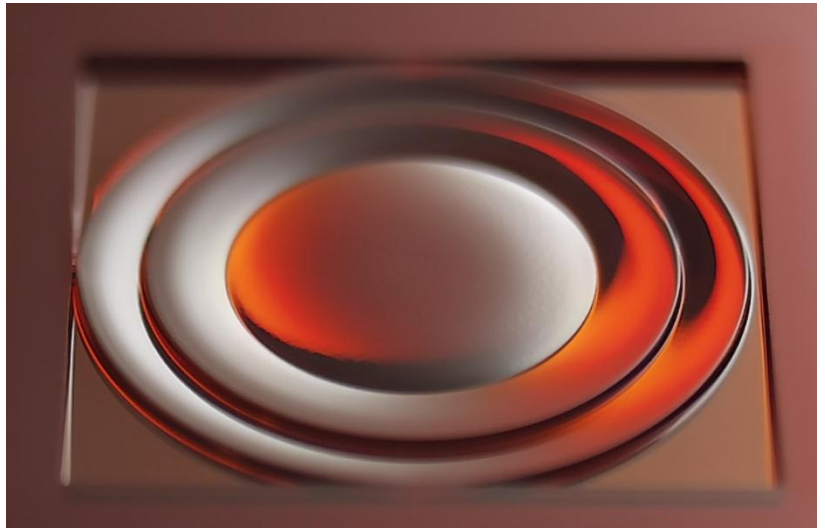
- Positive tone resist
- Low contrast resist facilitates shape tuning
- Process stability is crucial

Resist name	Thickness range (µm)
AZ 4562	6 ~ 80*
ma-P 1275G	8 ~ 60**
AZ 4533	2.7 ~ 4.7
S 1813	1 ~ 1.8
S 1818	1.5 ~ 2.5
AZ P 4620	6 ~ 15
mr-P 22G XP	50 ~ 150 ***
…	

* *with multiple coating*
** *with low spin speed*
*** *experimental resist*



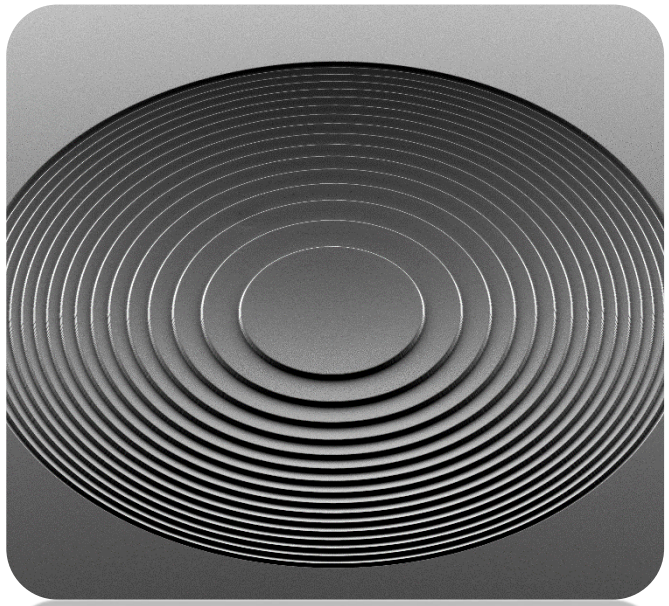
DOE 800 nm high - squares 1µm – 4 steps



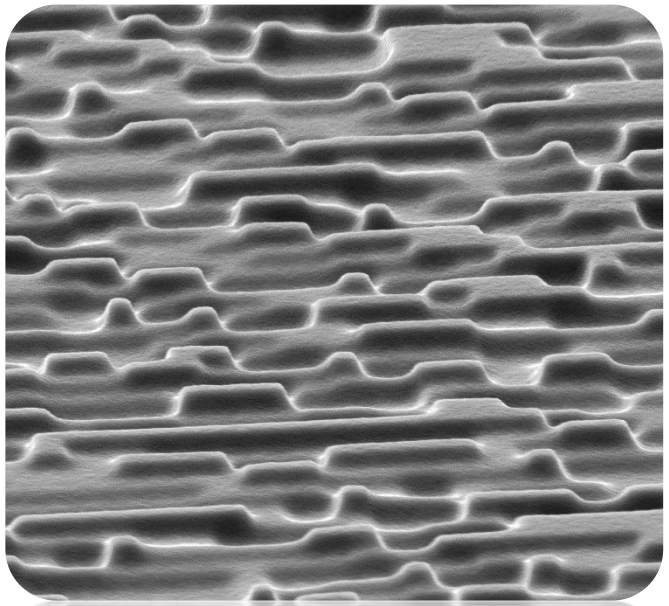
Fresnel Lens 5mm diameter 120 µm high

Laser Grayscale – Applications

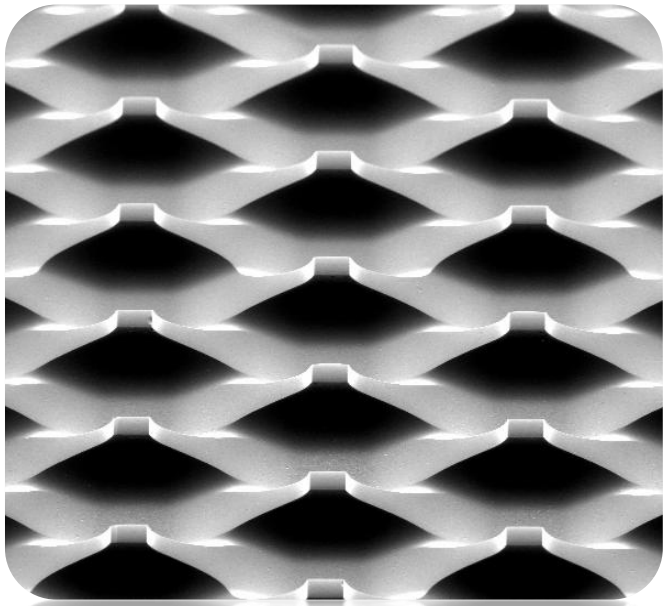
Fresnel lenses



DOE

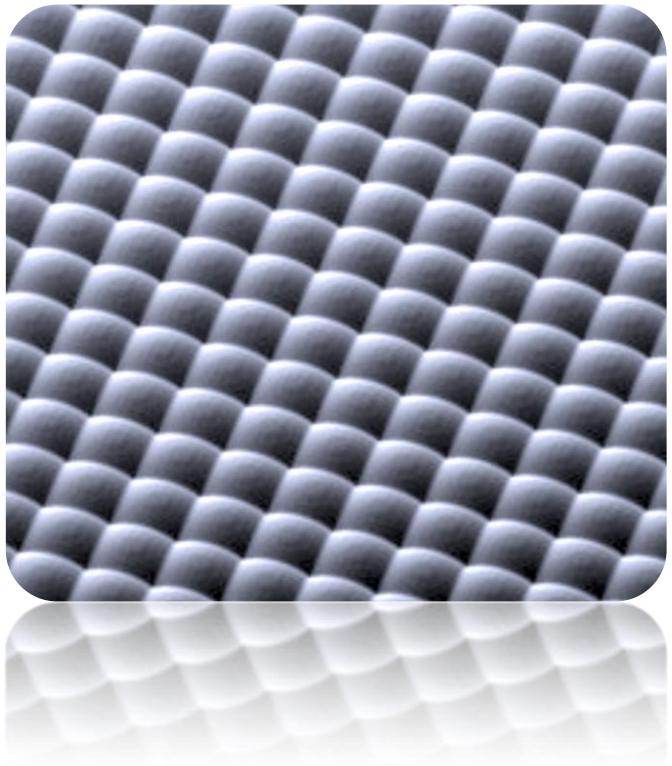


Texturing



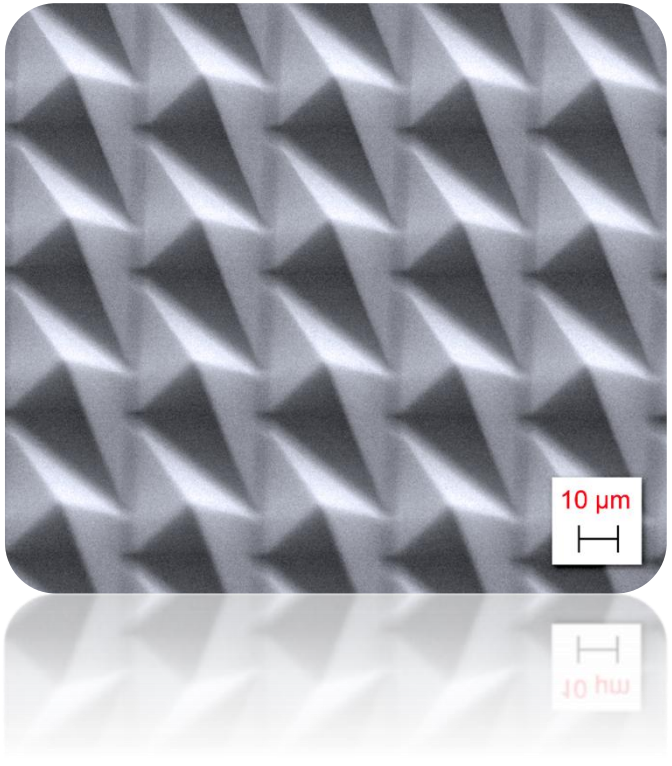
Laser Grayscale – Applications

Micro lens arrays



Blazed gratings

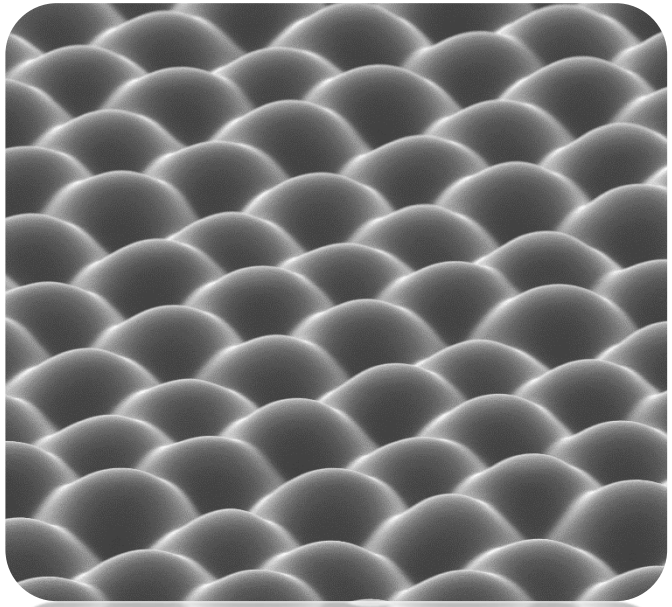
Reflectors



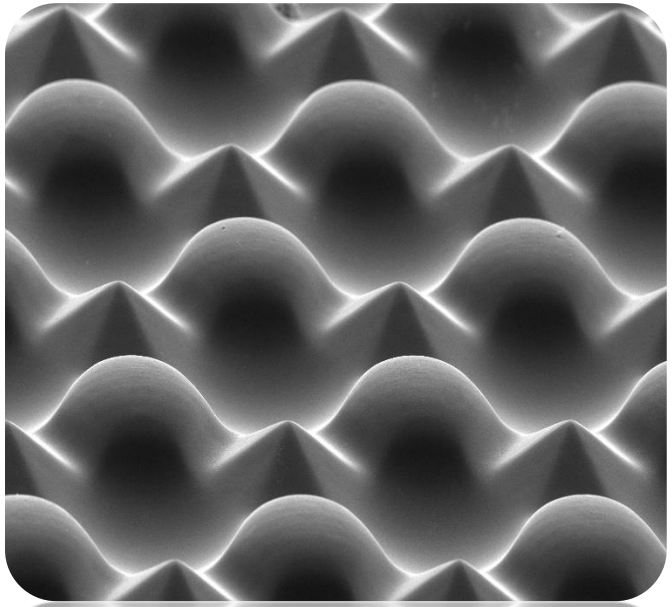
Laser Grayscale – Applications

Decorative printing

Beam shaping - Diffusor



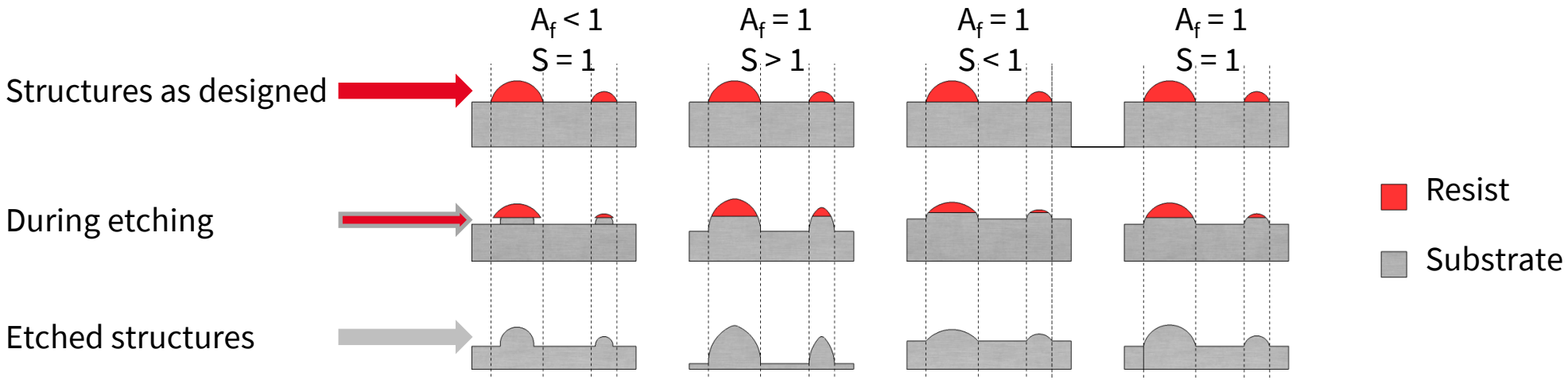
Freeform optics



Shape Transfer into the Substrate via Etching

- **Anisotropy Factor (A_f) ⇔ etching direction**
  - Etching occurs in all direction => $A_f = 0$.
  - Fine tuned reactive ion etching (RIE) => straight vertical side walls => $A_f = 1$.

- **Selectivity**, $S = \frac{etch\ rate\ of\ the\ substrate\ material}{etch\ rate\ of\ the\ resist}$



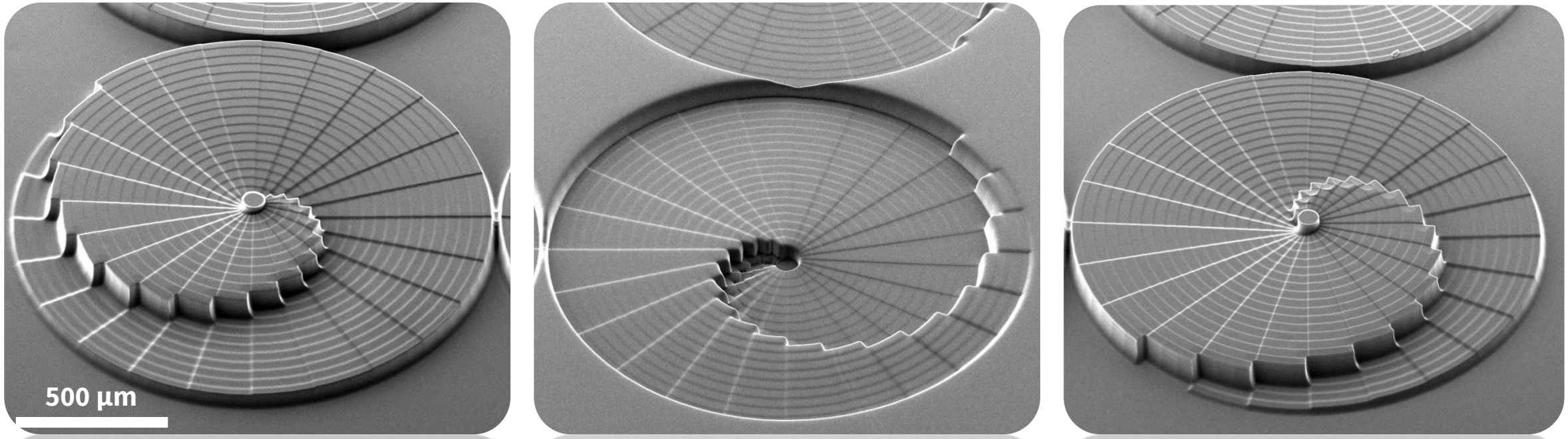
Replication From a Resist Master to a Functional Material

In collaboration with micro resist technology

Master in mr-P 22G_XP
made with a DWL

Mold in PDMS

Replica in OrmoClear® FX

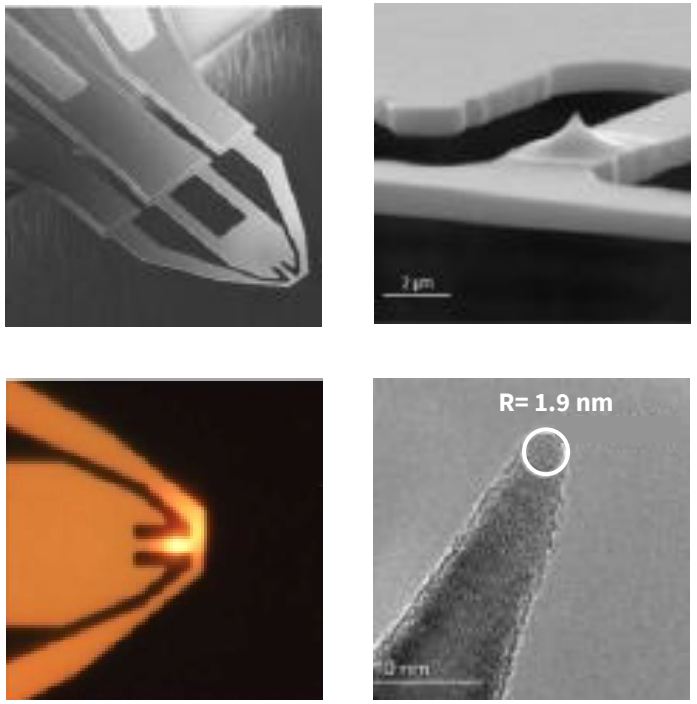


Low temperature curing

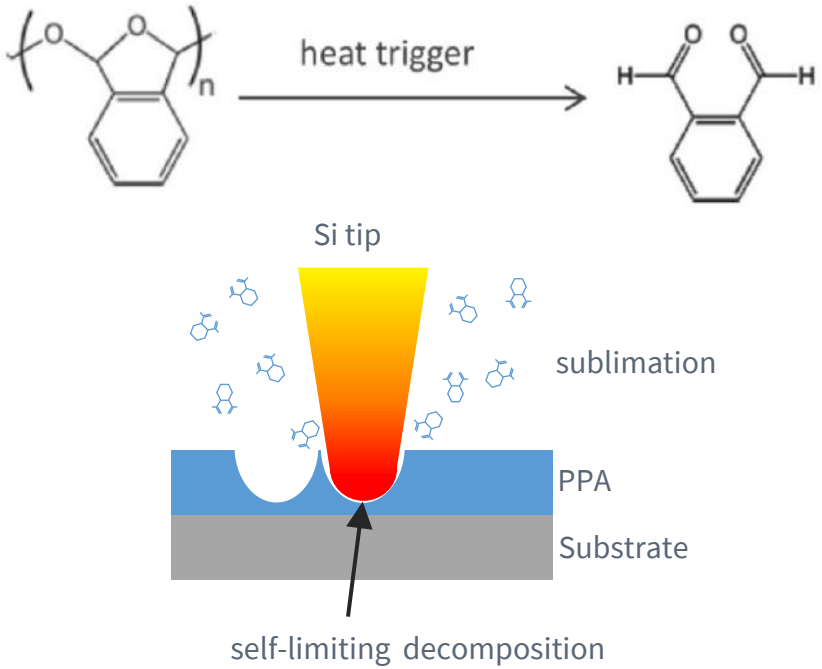
UV curing

NanoFrazor Technology

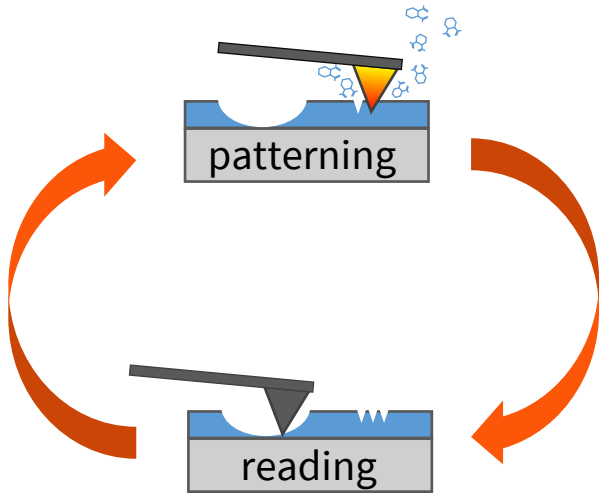
Ultra-sharp heated tip



Thermally-sensitive resist (PPA)

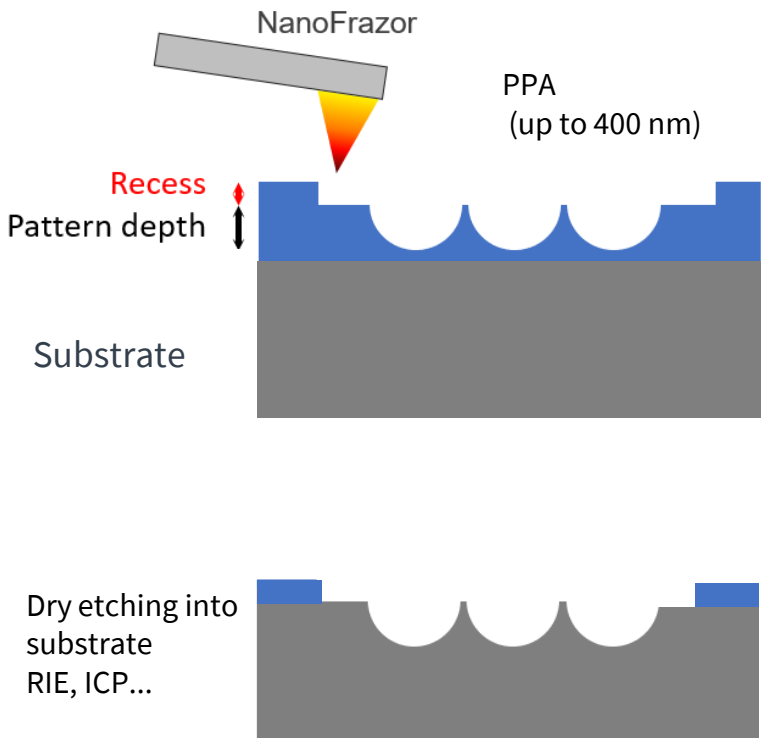


Closed loop operation

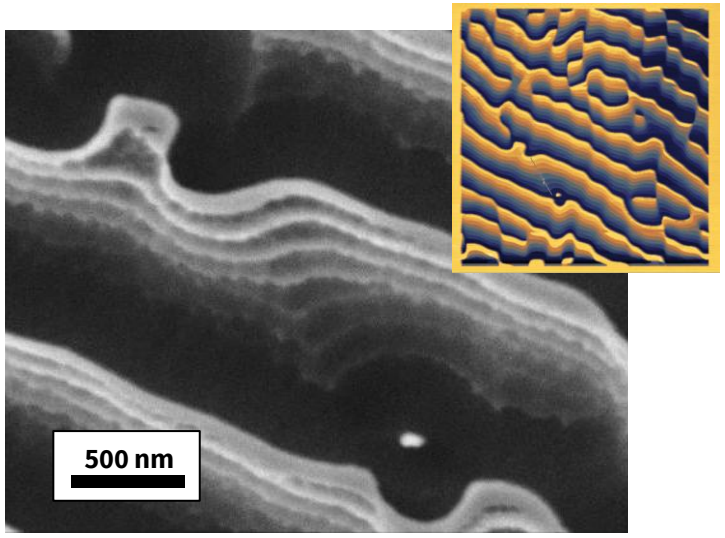


Single nm Grayscale Precision Enables new Possibilities in Photonics

Grayscale patterning process flow

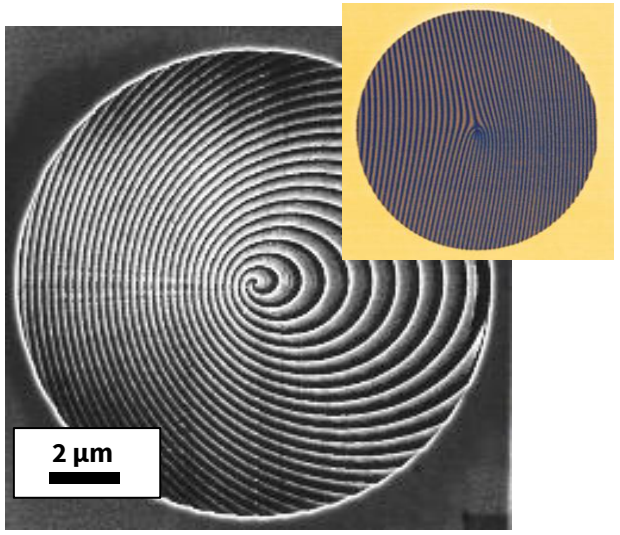


Hologram in Si (700 nm deep)



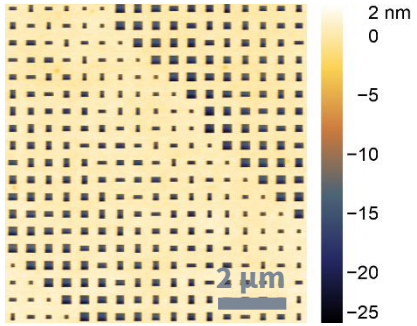
Kulmala *et al.*, SPIE, 2018

Phase Plates in SiN membranes

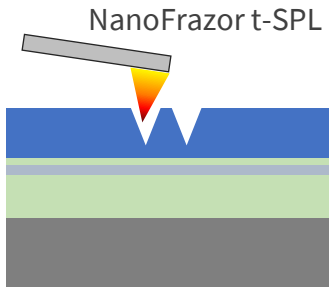


Hettler *et al.*, Micron, 2019

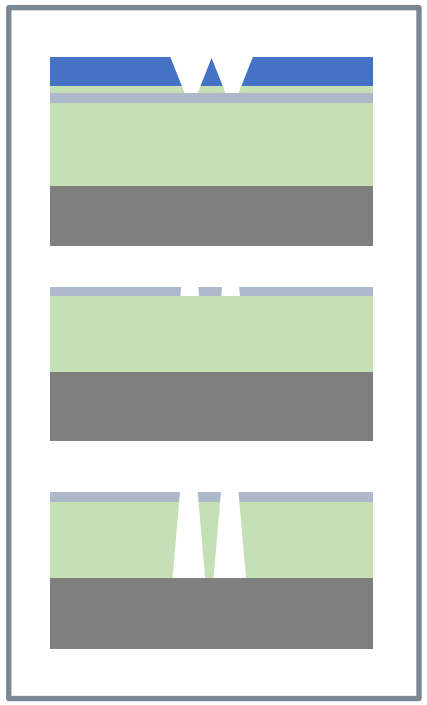
Pattern Transfer Process – Image Reversal



Topography in PPA



High-resolution (HR) resist stack
PPA 22 nm
PMMA buffer 2 nm
SiO2 hardmask 2 nm
PMMA/MA 180 nm
Si substrate

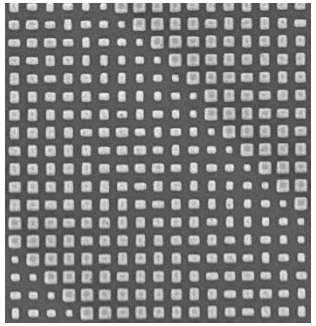


RIE dry etching steps
to open the HR stack

SiO_2 hard mask deposition
with e-beam evaporation

Lift-off in DMSO or acetone

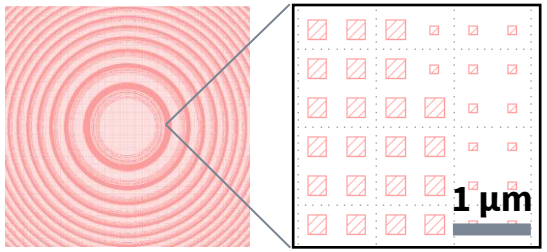
Pattern transfer in Si



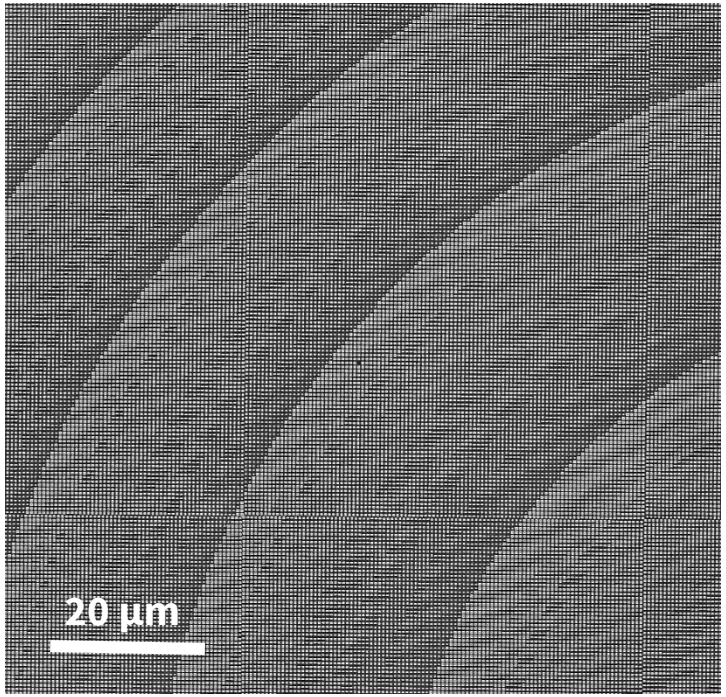
Etching of Si with ICP-RIE
with HBr chemistry

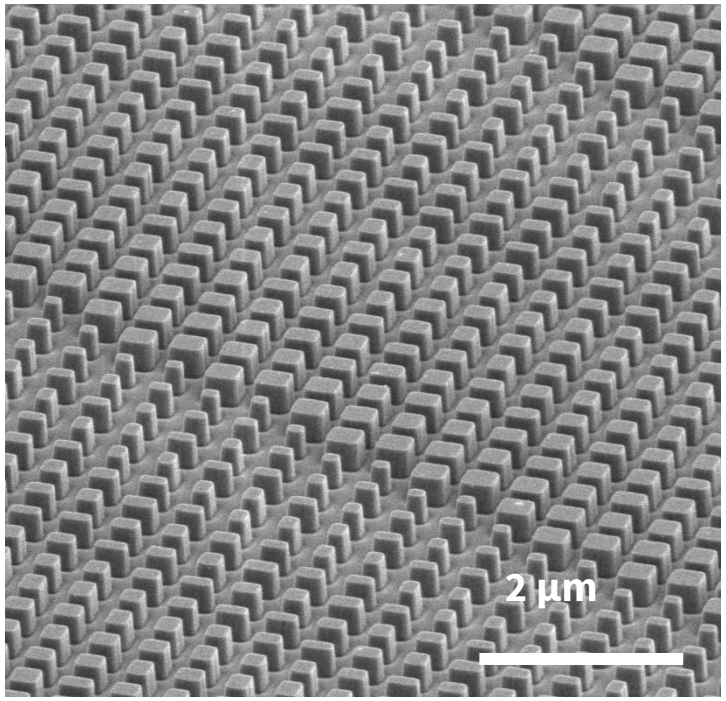
Wet etching with BHF
to remove the SiO_2 hard mask

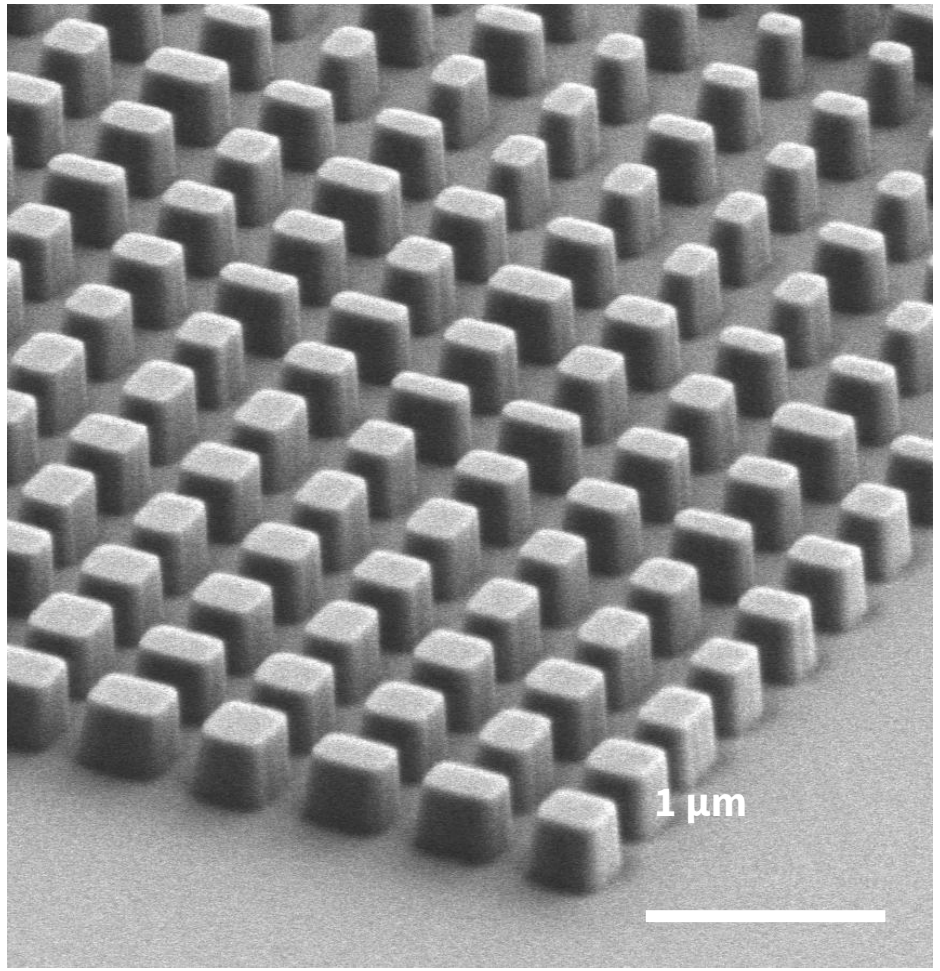
Metalens Fabrication with the NanoFrazor



Area of 690 x 690 µm^2
containing rectangles
of sizes 100 – 250 nm

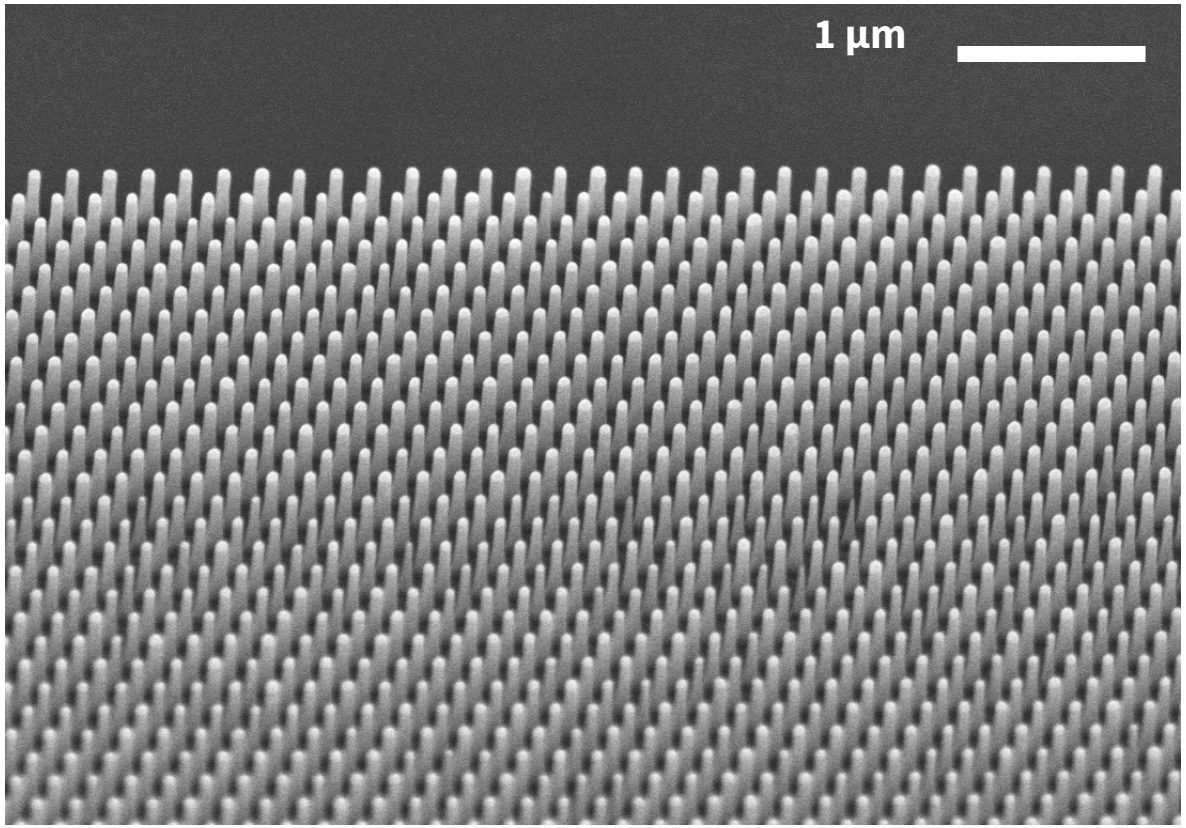


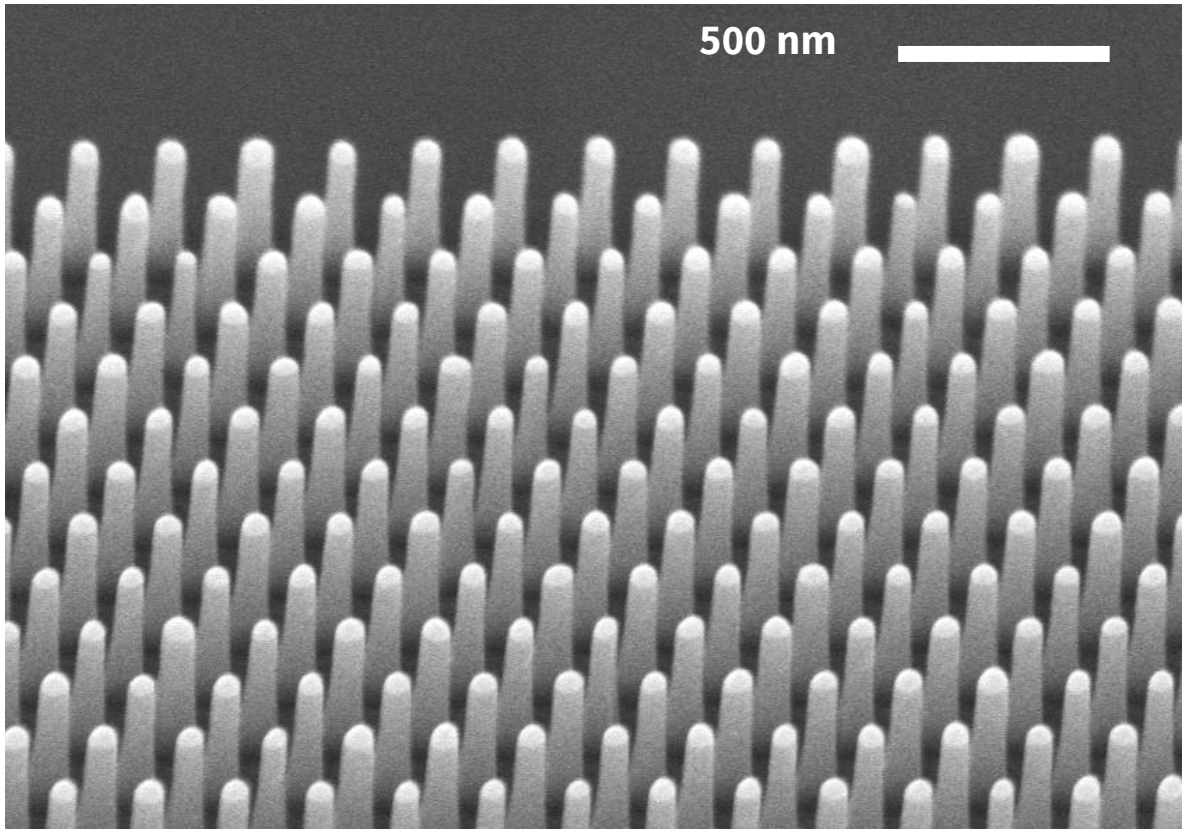




Array of Nanopillars Ø 50 nm

Ø 50 nm, 300 nm high diameter pillars hold immense potential for **flat optics** and **metasurfaces** applications





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- Brochures
- Application Notes
- Whitepapers
- …

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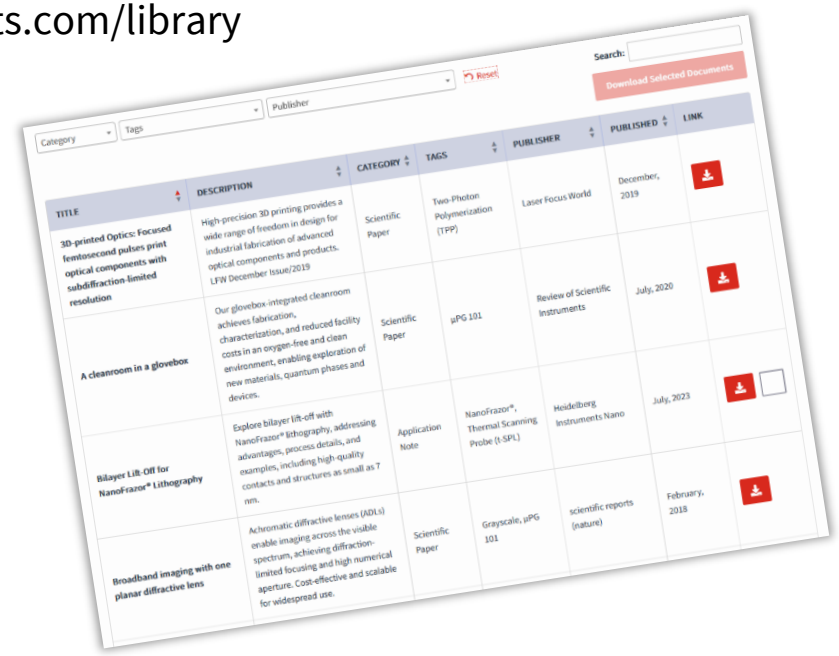

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THANK YOU!

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