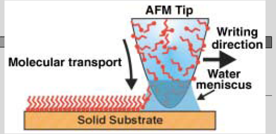
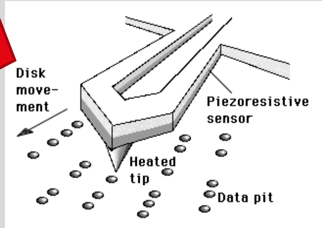
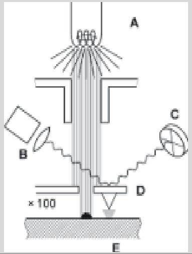
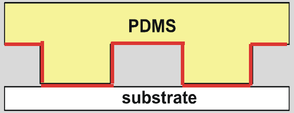
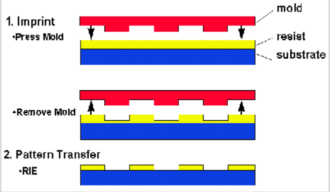
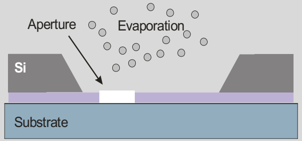
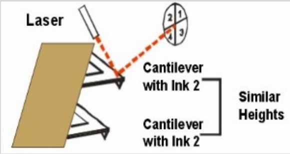
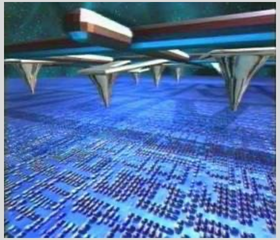
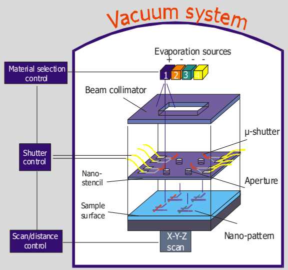
Introduction to alternative patterning

- UV lithography not covered
- Electron beam lithography covered by FPM in his lecture

Alternative techniques include:

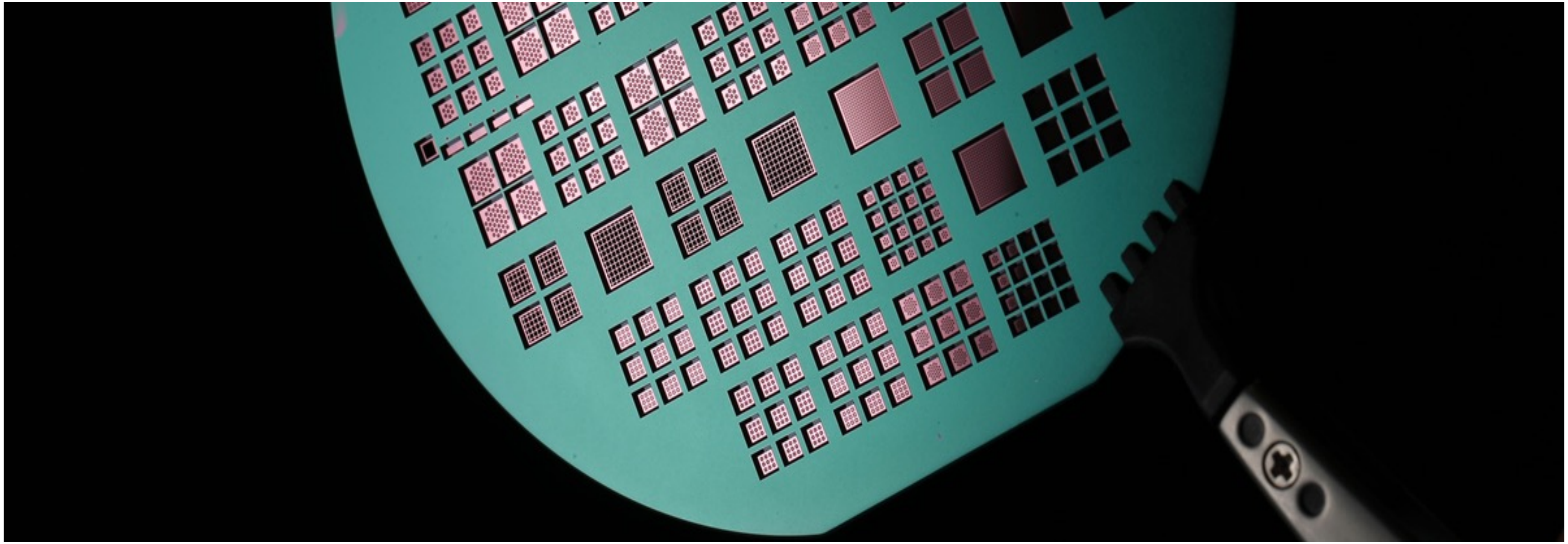
- Wet material transfer (stamping)
- Vacuum techniques (depo, etching, implantation)
- Thermo-mechanical methods (NIL, …)
- Ion beam methods
- Self-assembly (Bottom-up)
- Directed self-assembly (hybrid top-down and bottom-up)

	Molecule Delivery Wet, soft-contact, 100 nm scale		Thermo-mechanical Nano-imprint, embossing, hard contact, 10 nm scale		Local Deposition Stencil, vacuum, no contact 10-100 nm scale	
Single & Scanning *de novo*	**DipPen NADIS**		**Heated AFM**		**AFM Nanostencil**	
Parallel & Static *Replication*	**Soft-litho-graphy**		**NIL**		**Membrane Nano-stencil**	
Parallel & Scanning *Adaptive* *mass-* *production*	**Parallel NADIS**		**Millipede**		**Smart Stencil**	

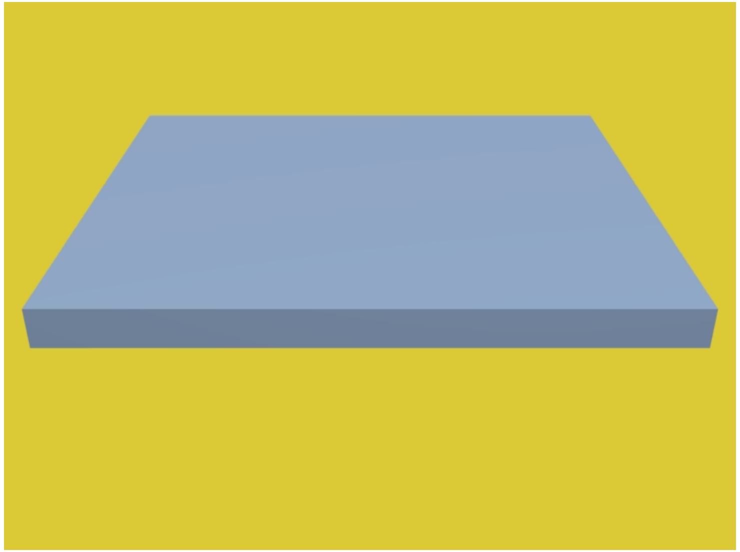
Stencil lithography (basics)

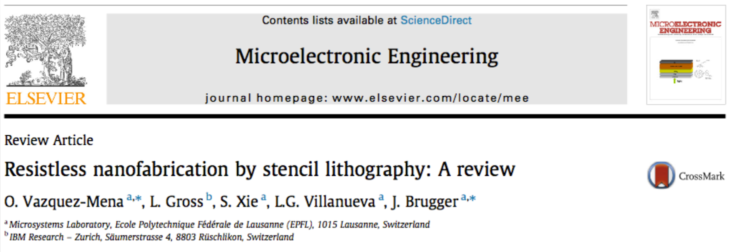
- High resolution shadow masks
- Simple application examples
- Unique configurations where ordinary lithography would fail
- Blurring and diffusion issues
- Dynamic stencil

Nanostencil



EPFL





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Review Article

Resistless nanofabrication by stencil lithography: A review

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Prof. Oscar Vazquez-Mena
UC San Diego

Nanostencil lithography

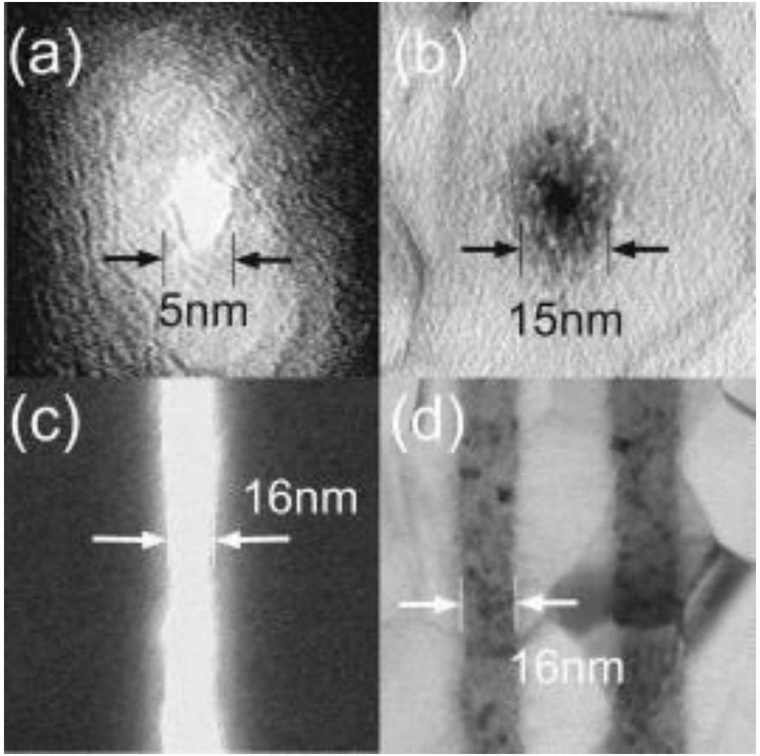
Many challenges:
Gap
Blurring
Membrane stability
Alignment

But also many opportunities:
Vacuum clean
No resist chemistry
Fast and simple, cost efficient nano
Wide choice of material & substrates
Mainly for PVD

Nanostenciling (1999)

Bright-field STEM images. (a) A hole 5 nm in diameter etched through a silicon nitride membrane. (b) A metal dot made by evaporating 10 nm of Er through an orifice 5–10 nm in diameter onto an oxidized aluminum film held at room temperature. (c) Section of a 4 μm-long × 15–20-nm-wide line etched through a silicon nitride membrane. (d) Sections of 10-nm-thick Er lines which are deposited through an orifice similar to the one shown in (c), at room temperature onto an oxidized Al film. The two lines, 19 nm and 16 nm wide, were made by separate depositions of Er, from different angles, through the same linear hole

Early works and probably world record



Deshmukh et al APL 1999

Stencil fabrication

LPCVD 50-500 nm thick SiN

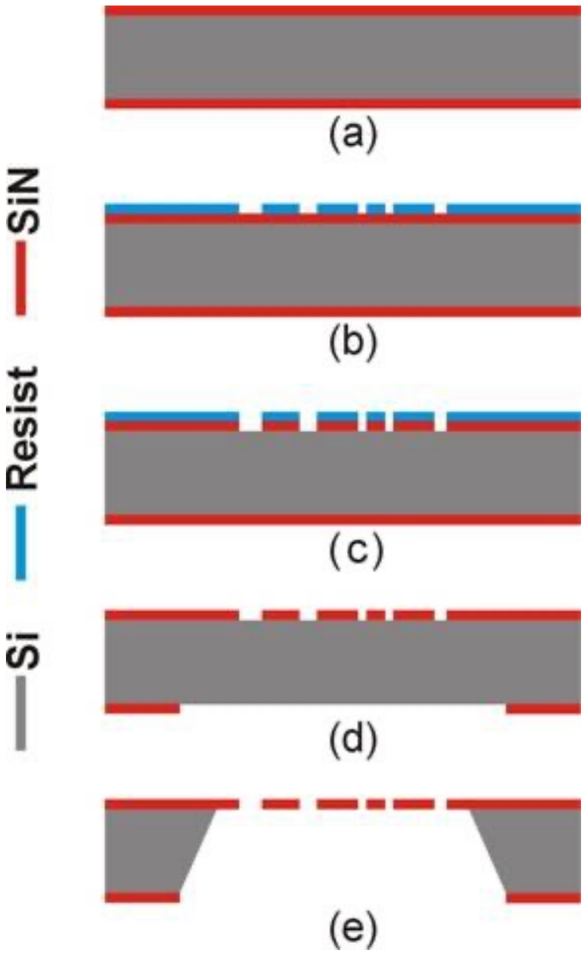
Pattern definition in photoresist

Pattern transfer into SiN

Membrane window definition and KOH etching

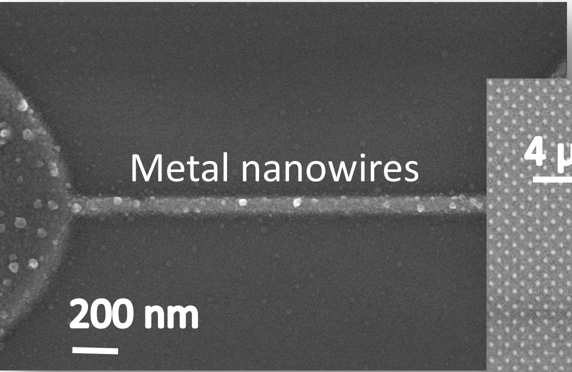
Fabrication of nanoscale apertures in membrane by:

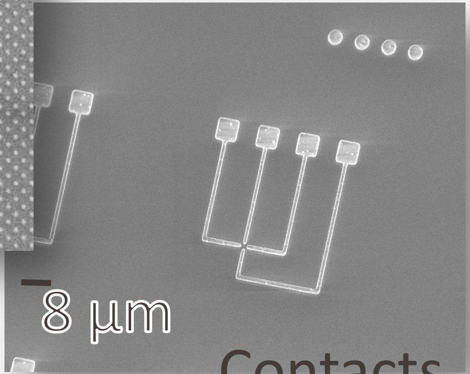
- Focused Ion Beam Milling
- Electron beam lithography
- Laser interference lithography
- Nanoimprint lithography
- Deep UV lithography

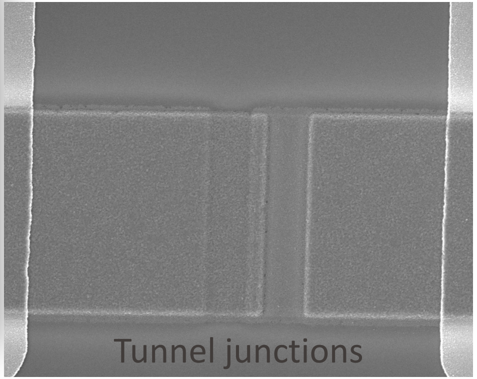


What can been done?

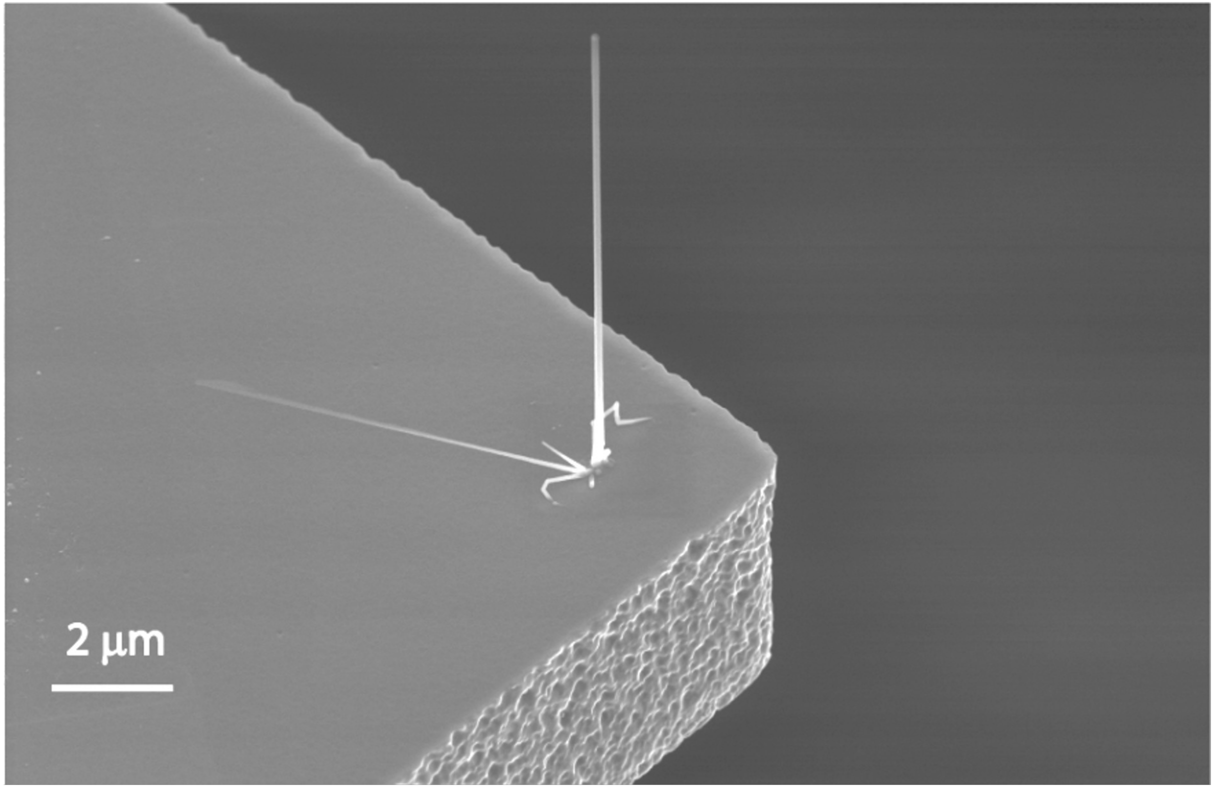
- Deposition of different metals
  - Aluminium, Gold, Chromium, Titanium, Platinum, etc.
- Metallic structures





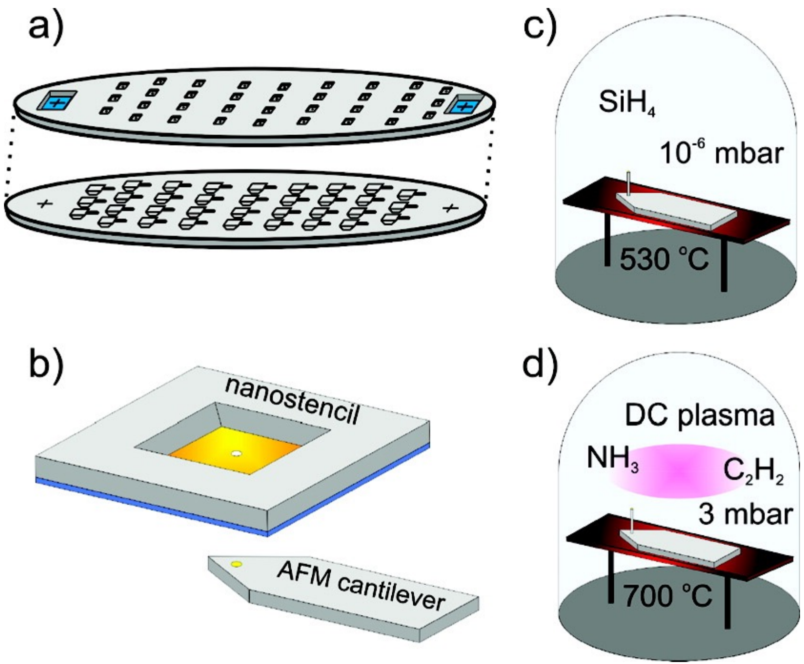


Unique examples



Stenciling on free-standing substrates

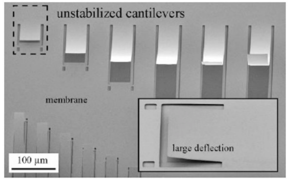
- Stencil fabrication for catalyst deposition
- Stencil alignment to cantilever full-wafer
- Catalyst deposition through aligned stencil
- CNT/Si NW growth
- AFM measurements



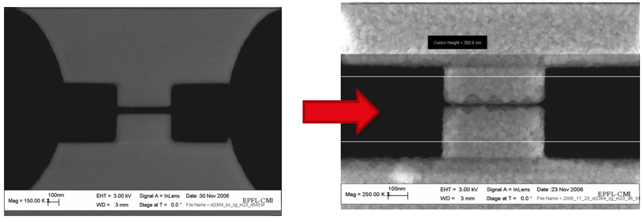
D. S. Engstrom et al., Nano Letters **11 (4), 2011**

Major challenges

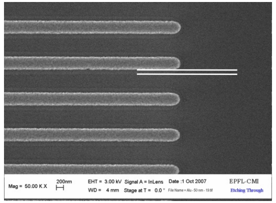
Membrane stability



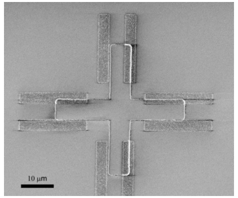
Clogging



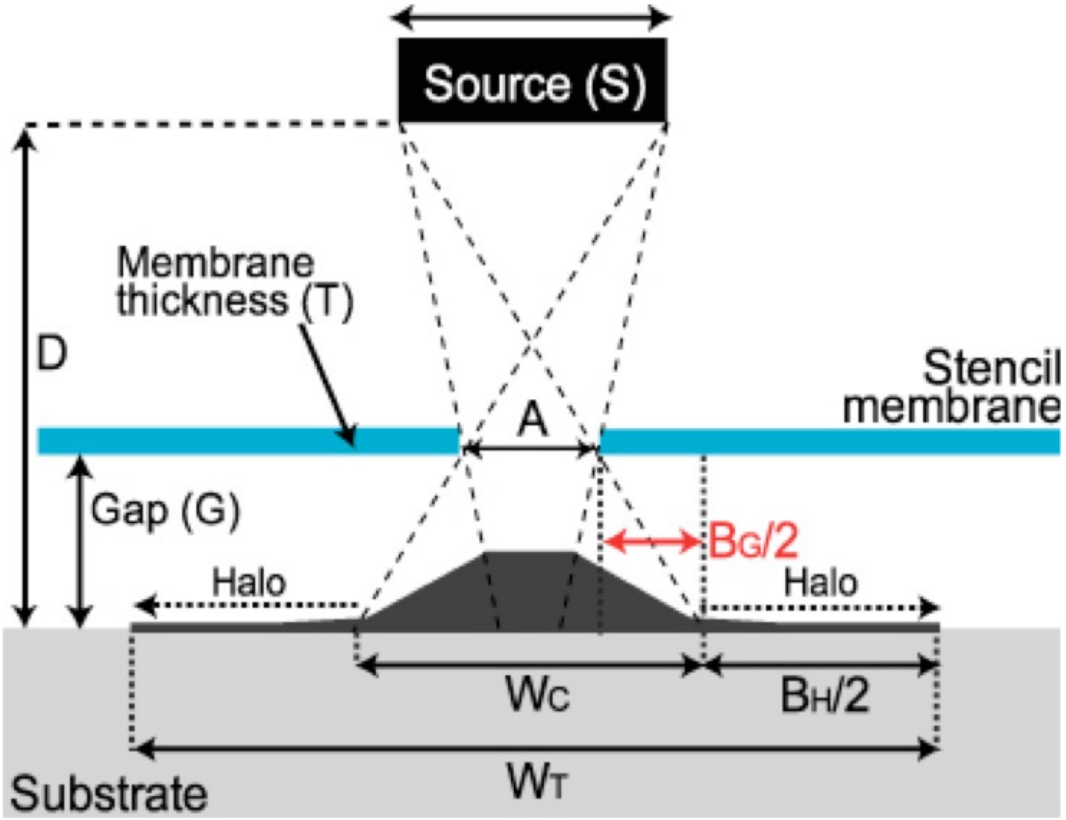
Blurring



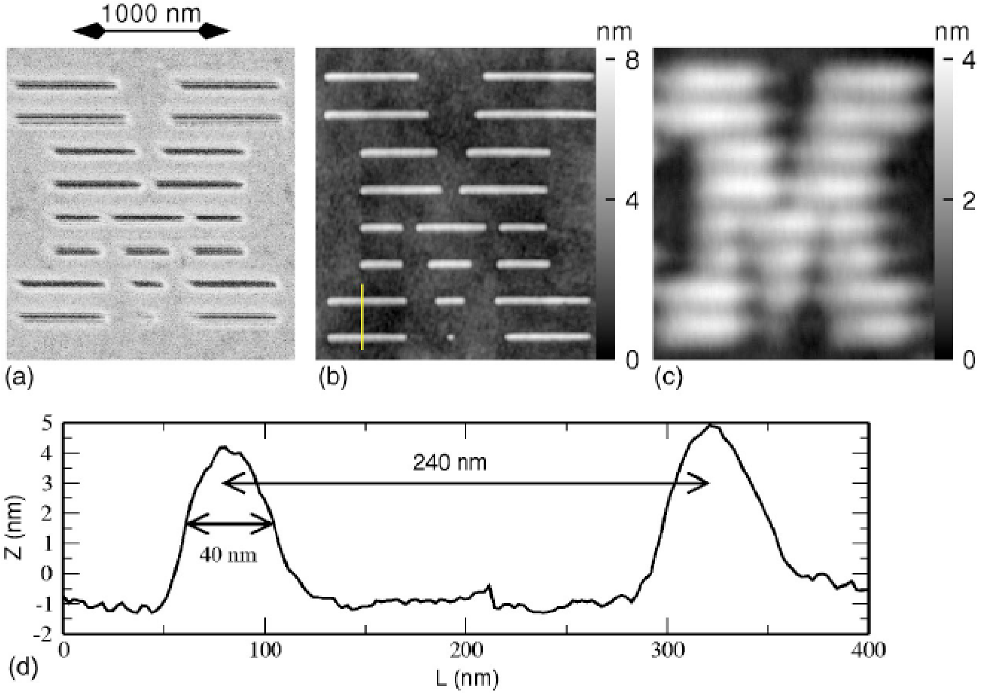
Alignment



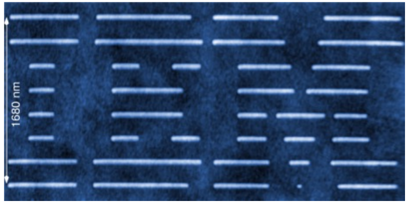
Stencil litho details



Watch out for surface diffusion



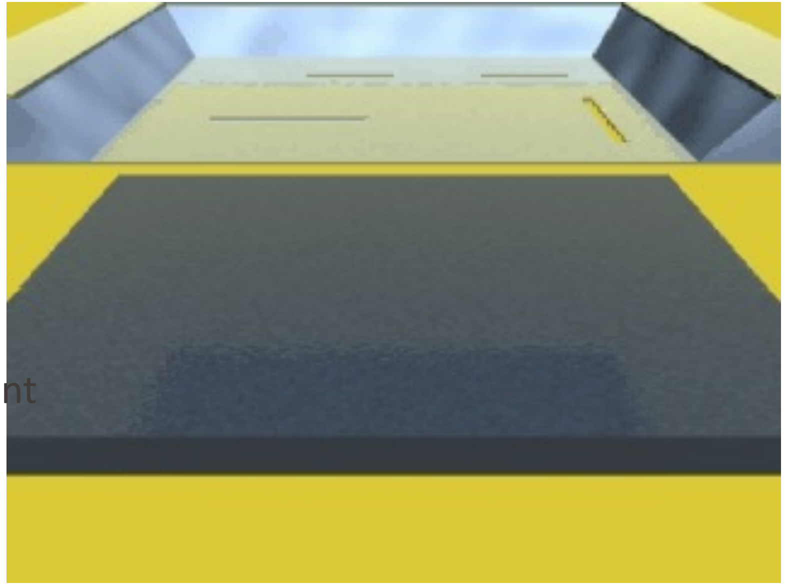
(a) FIB image of the stencil mask used here
(b) DFM image of the 40 nm wide Cu structure on SiO2
(c) DFM image of the C60 structure (diffusion induced halo).
(d) Line profile of the section marked.



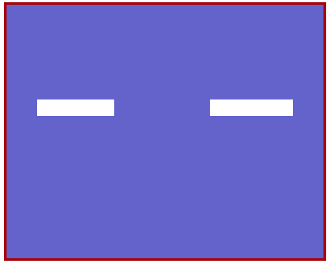
Percy Zahl et al., Rev. Sci. Instrum. 76, (2005)

IBM Research Laboratory Ruschlikon

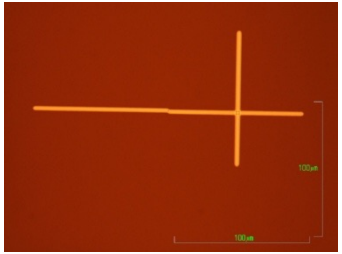
The moving shadow mask



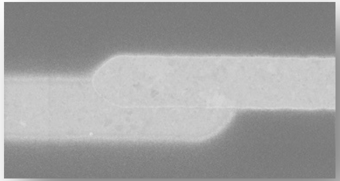
- Step and repeat
- Reposition stencil in vacuum between subsequent deposition steps
- No exposure to atmosphere
- In-situ oxidation
- Clean surface/interface
- Tunnel junctions
- 2 materials (or more)



stencil



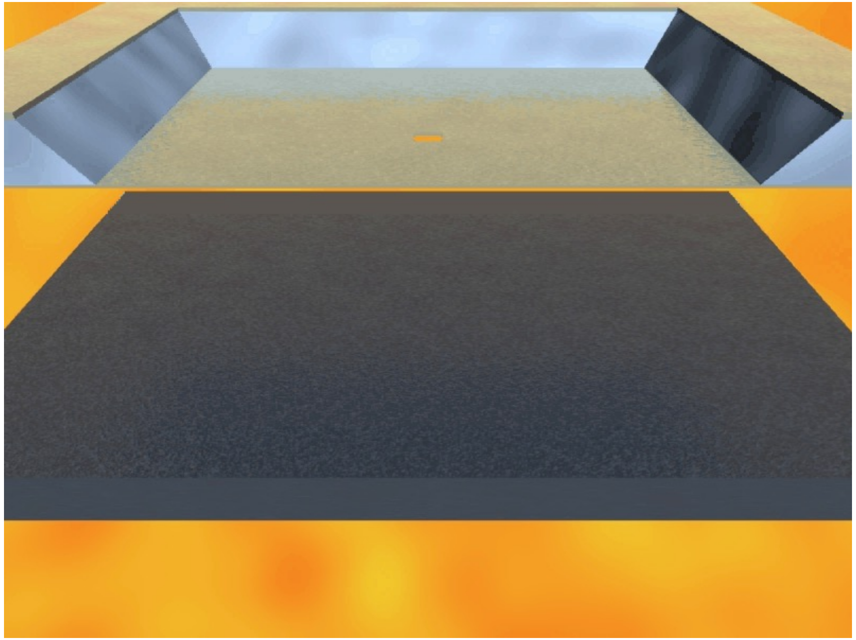
stitched



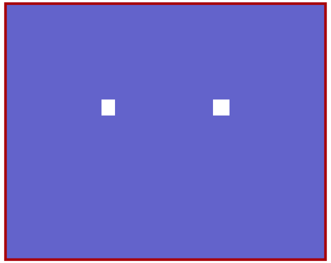
junctions

EPFL

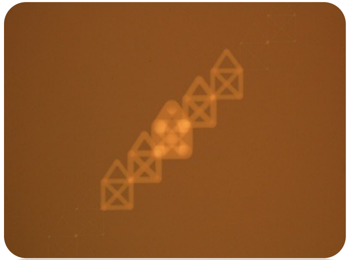
Dynamic stenciling



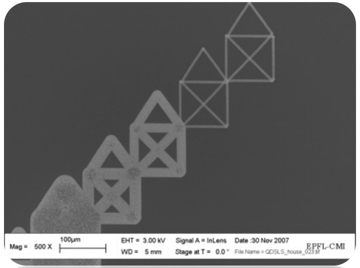
- Dynamic stencil
- Free motion in vacuum
- Rapid prototyping
- Flexible lithography
- PC controlled
- Parallel patterning
- Tapered film thickness



stencil



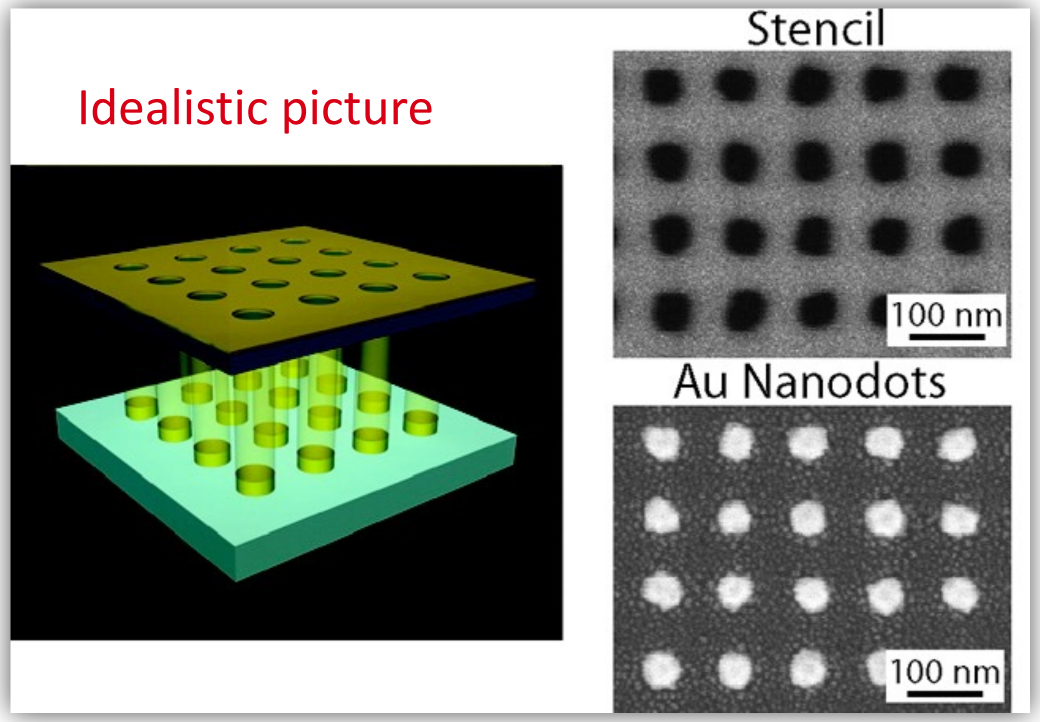
Free motion



SEM image

Metallic nanostructures stenciled

Idealistic picture



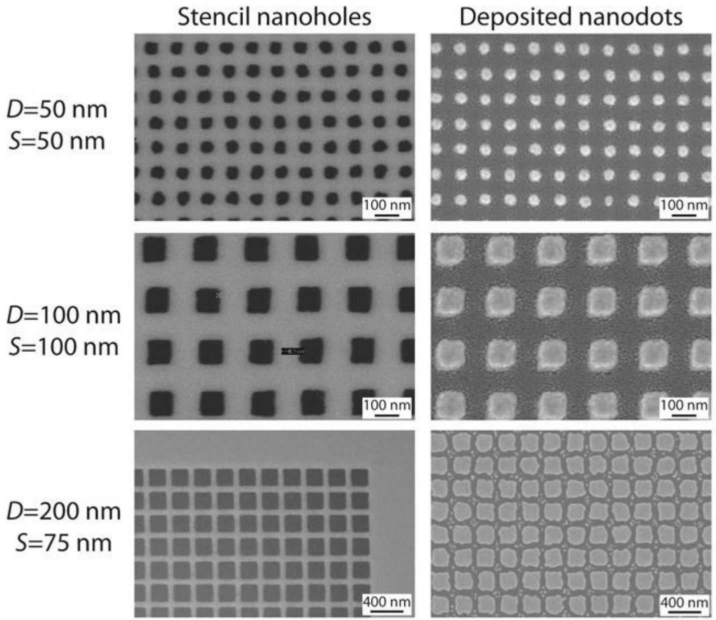
Reality
Blurring
Diffusion

5 nm Ti / 50 nm Au

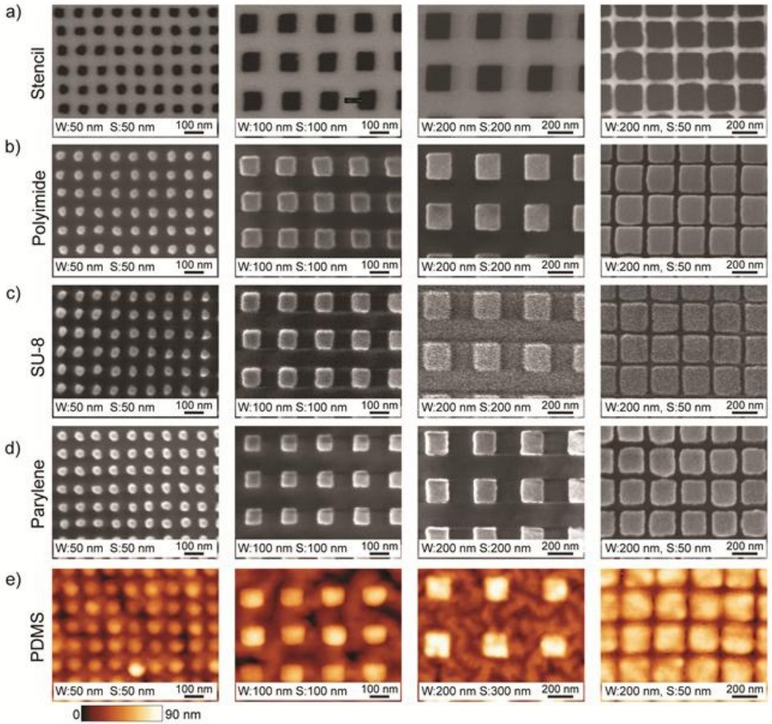
Metallic nanostructures stenciled onto …

5 nm Ti / 50 nm Au

… silicon (Au clusters)



… polymer (no Au clusters)



- Vazquez-Mena et al, ACS Nano (2010); ASC Nano (2012)

Appl. Phys. A 79, 743–745 (2004)
DOI: 10.1007/s00339-004-2749-0

Applied Physics A
Materials Science & Processing

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Exploring microstencils for sub-micron patterning using pulsed laser deposition

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EPFL

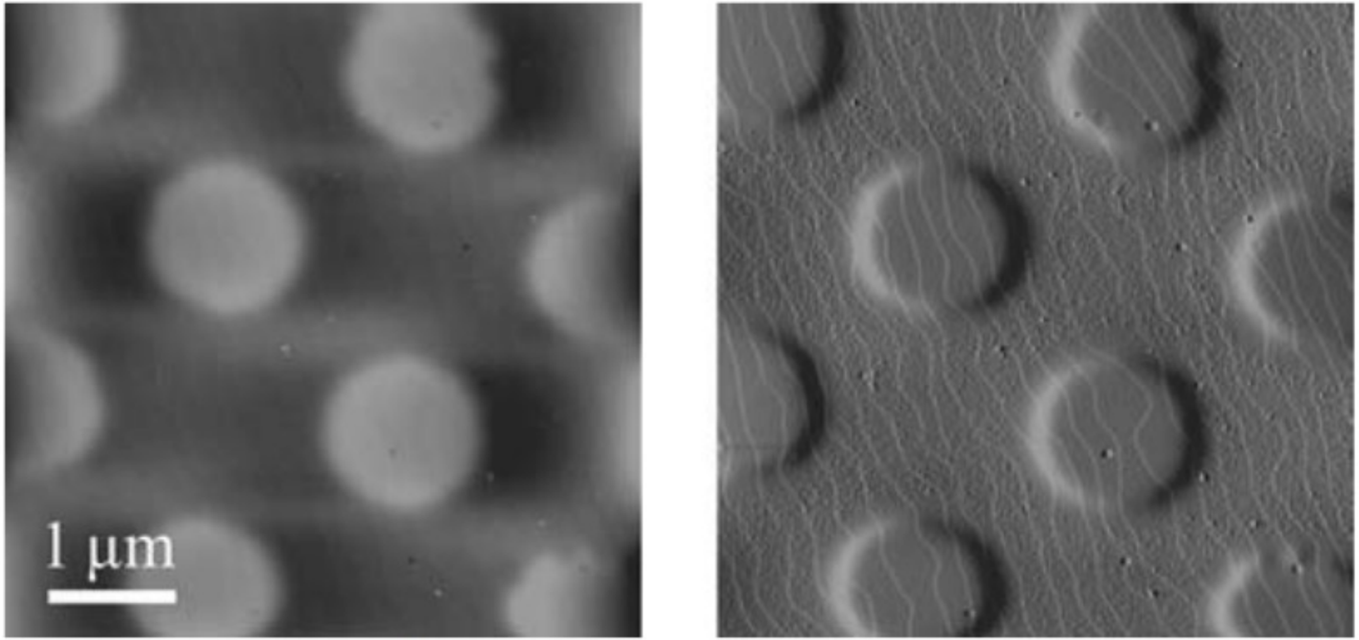

FIGURE 2 $5 \times 5\,\mu m^2$ CM-AFM image of 5.2-nm-high Ni islands on a $SrTiO_3$ substrate. Height (*left*) and deflection (*right*) images. The deposition parameters used are a $5.0\,J\,cm^{-2}$ fluence, 4.0×10^{-4} mbar Ar pressure, $2.5\,ml\,min^{-1}$ Ar flow and a 42.0 mm target–substrate distance

Stencil lithography: Take away message

- Straight forward surface patterning
- No need for photoresist chemistry
- Unique for fragile surfaces

- Stencils are fragile
- Blurring
- Clogging
- Alignment issues
- Closed-loop geometries