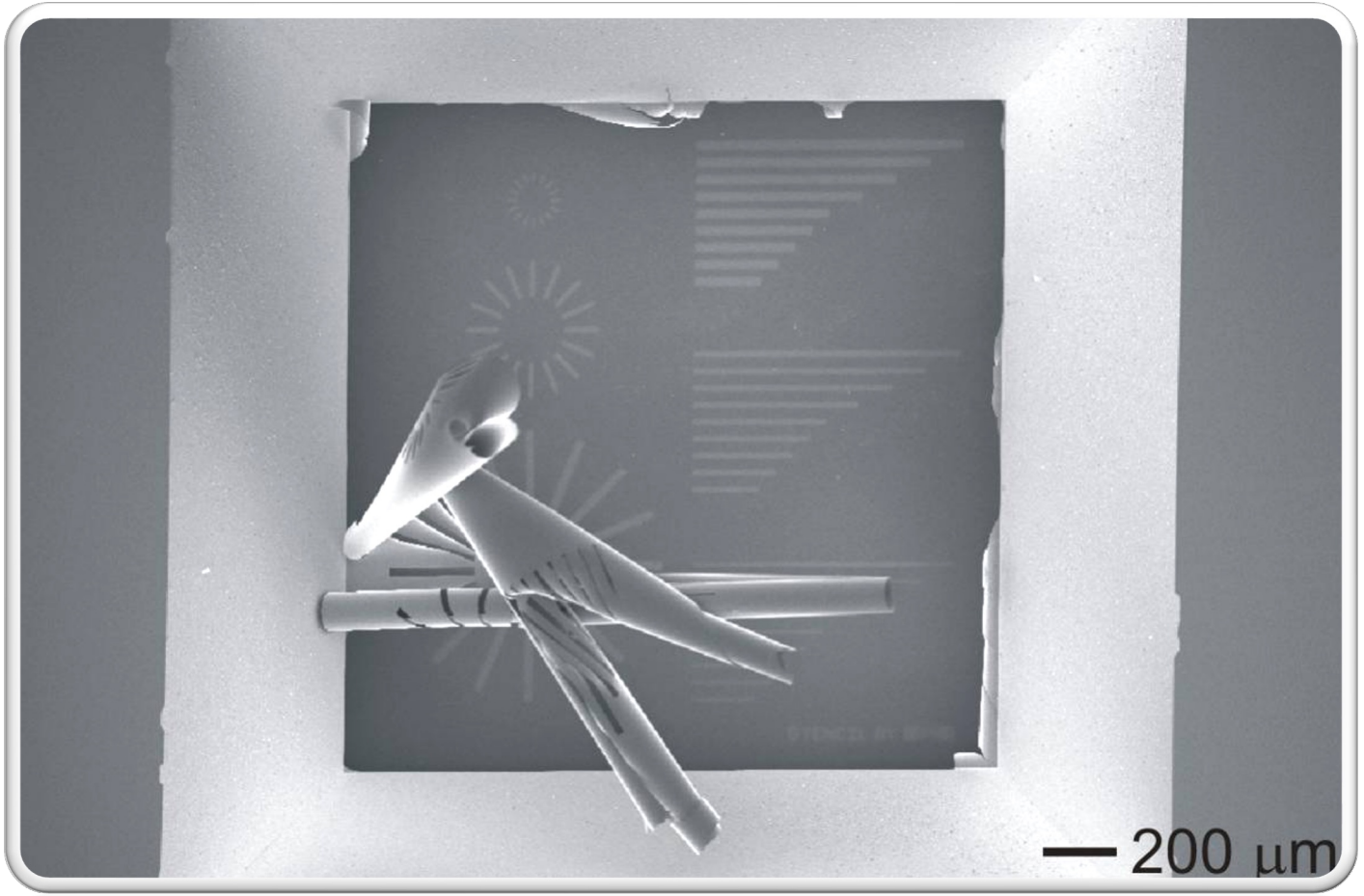
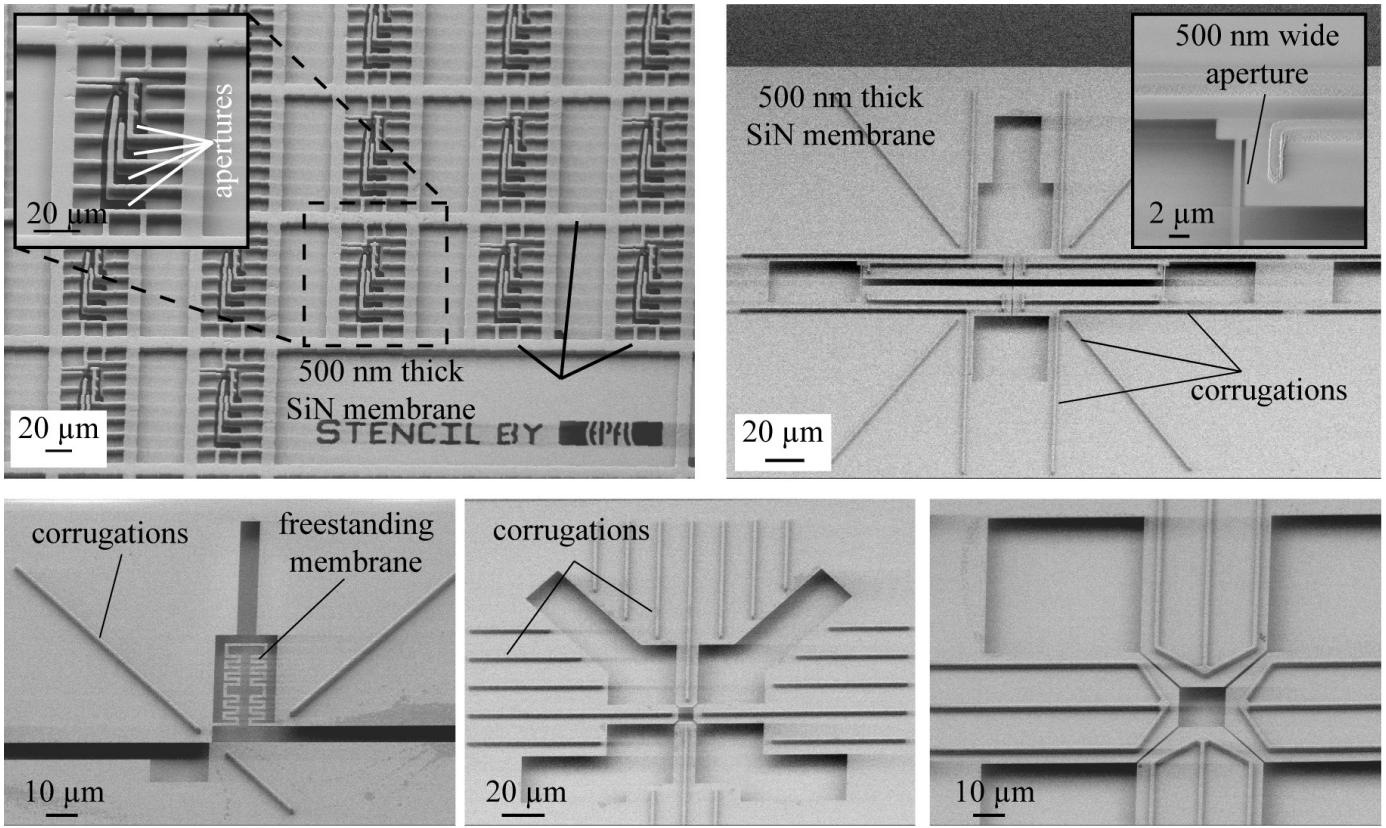
Stencil lithography (advanced)

- Key features of stencil litho
- More on film growth properties
- More on dynamic mode
- Some on ‘3D’ surface nanostructures


200 µm



- Hammer (‘70s)
- Van den Boogaart et al. 2008

Flux tuning using stencils, local control of film growth

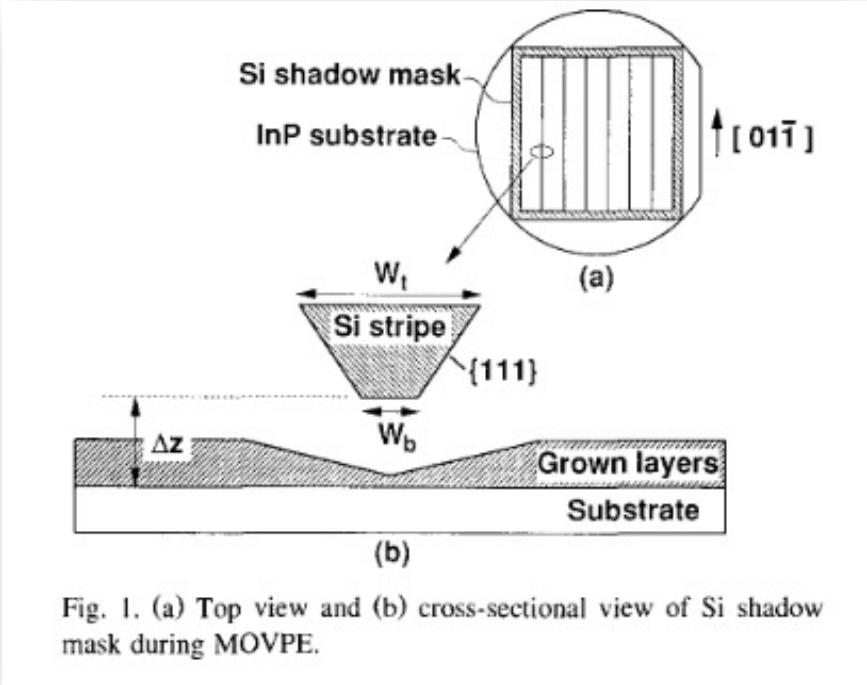
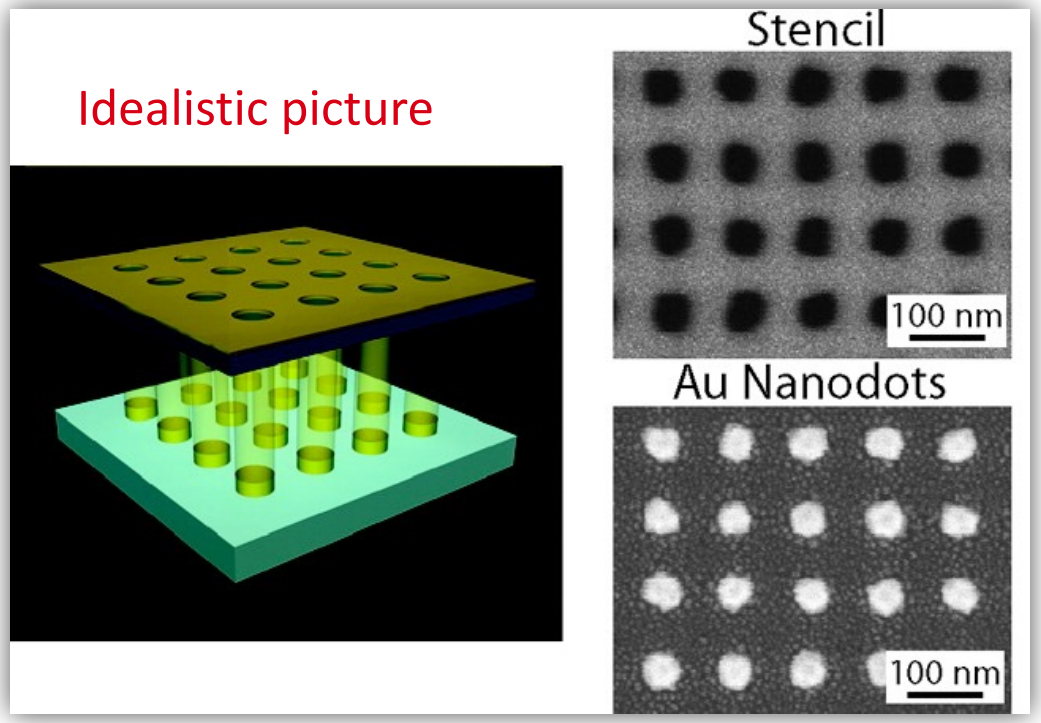


Fig. 1. (a) Top view and (b) cross-sectional view of Si shadow mask during MOVPE.

M. Suzuki et al. Journal Of Crystal Growth (1997)

Metalorganic vapour-phase epitaxy (MOVPE)

Blurring & diffusion: useful?



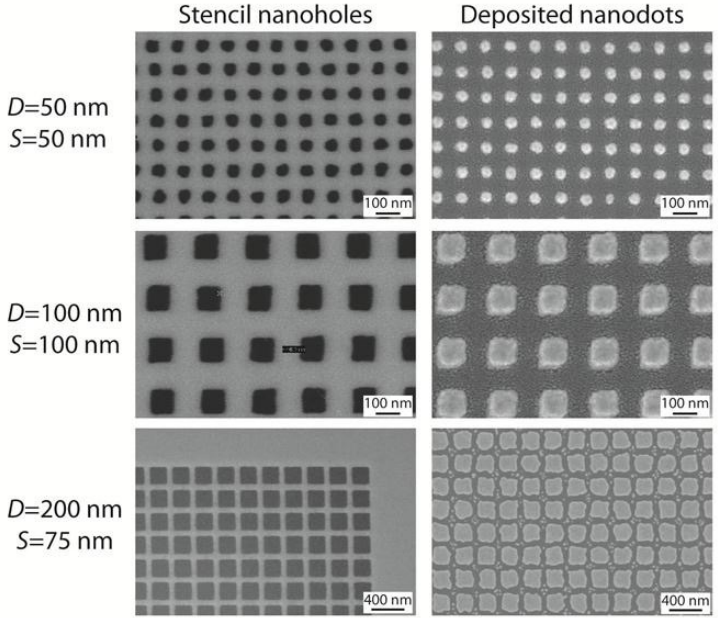
Reality
Blurring
Diffusion

5 nm Ti / 50 nm Au

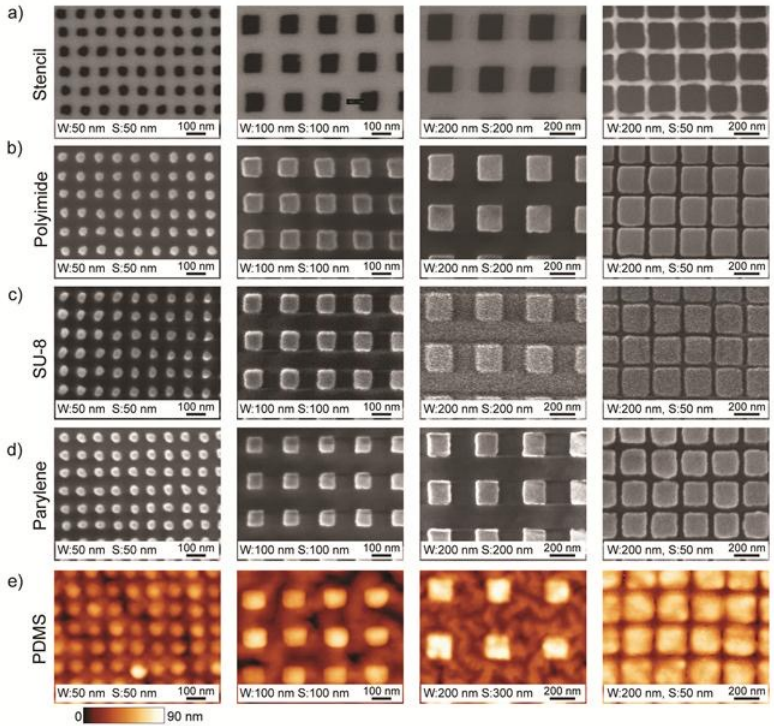
Metallic nanostructures stenciled onto …

5 nm Ti / 50 nm Au

… silicon (Au clusters)

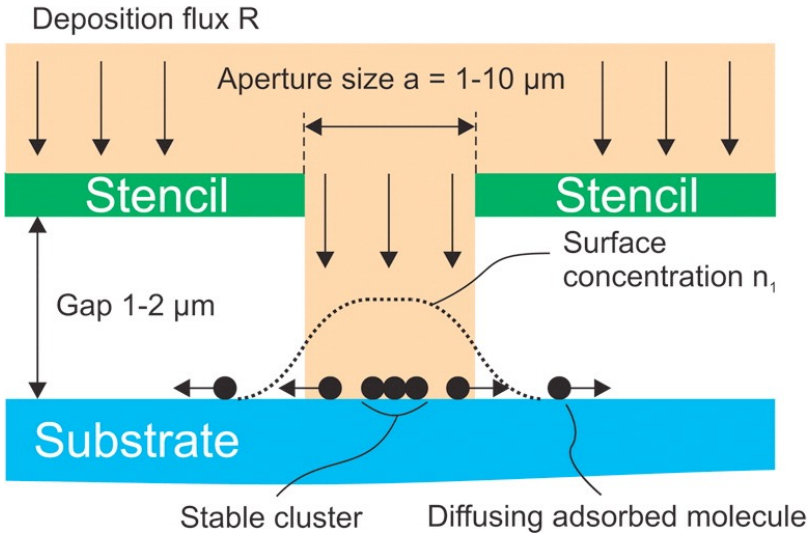


… polymer (no Au clusters)



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

Arrays of Pentacene Large Single Crystals by Stencil Evaporation

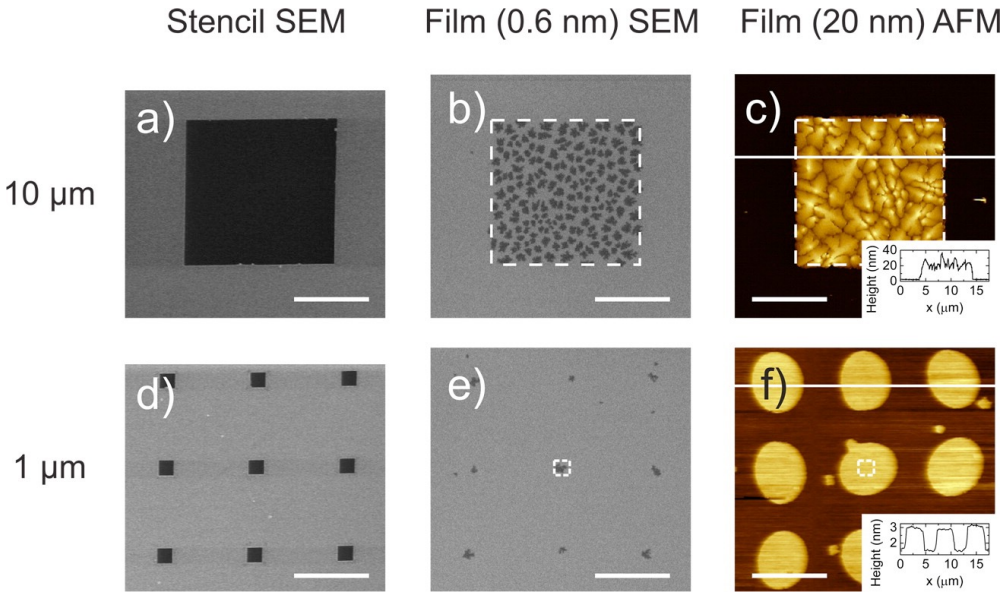


Arrays of pentacene single crystals Patterned on SiO_2 substrates through stencil evaporation
Micron-scale apertures enables a control over nucleation and subsequent diffusive growth

P. Fesenko et al. Cryst. Growth Des. (2016)

Imec/KU Leuven

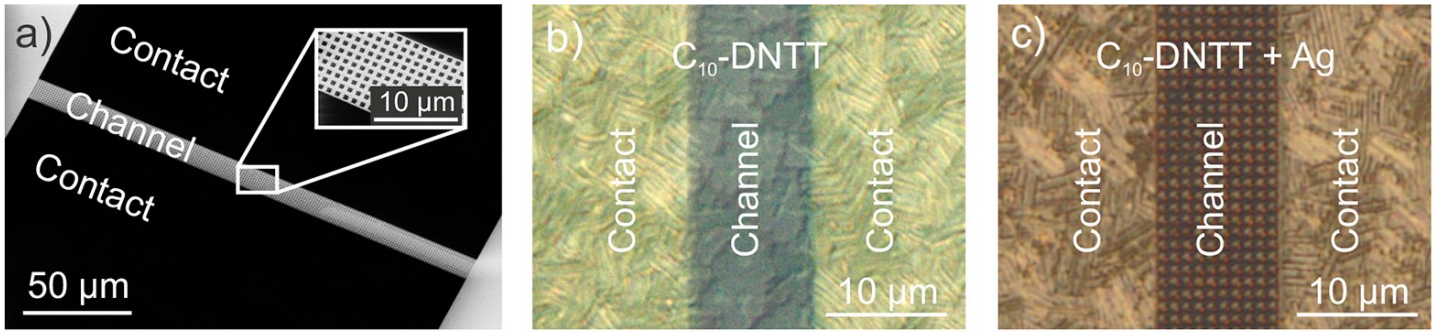
Arrays of Pentacene Large Single Crystals by Stencil Evaporation

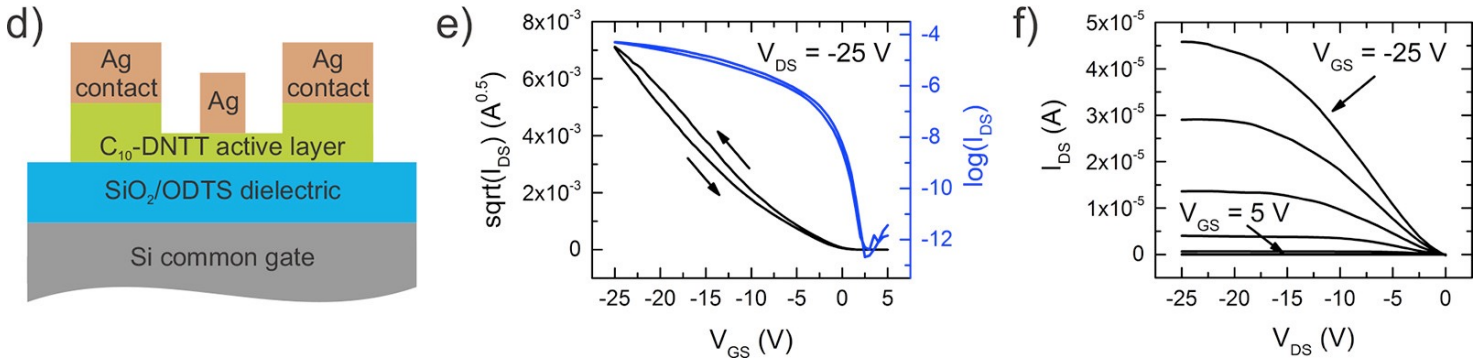


P. Fesenko et al. Cryst. Growth Des. (2016)

Imec/KU Leuven

Depositing both, organic molecules and metal electrodes

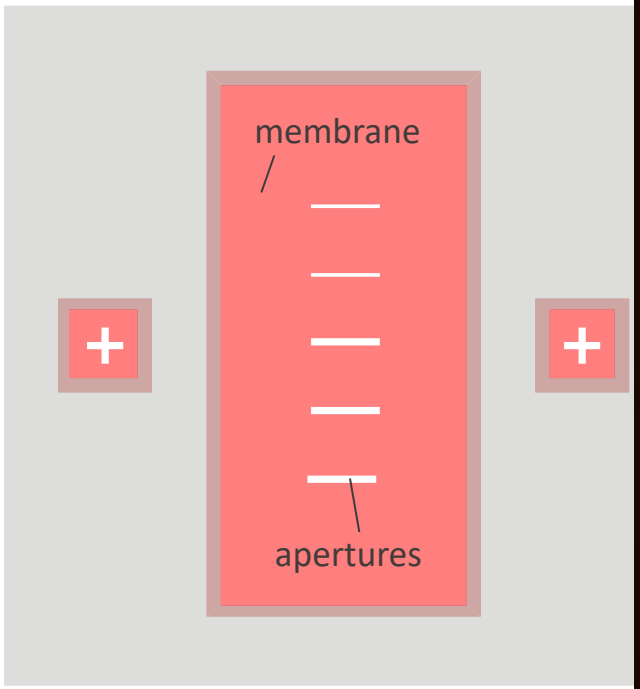


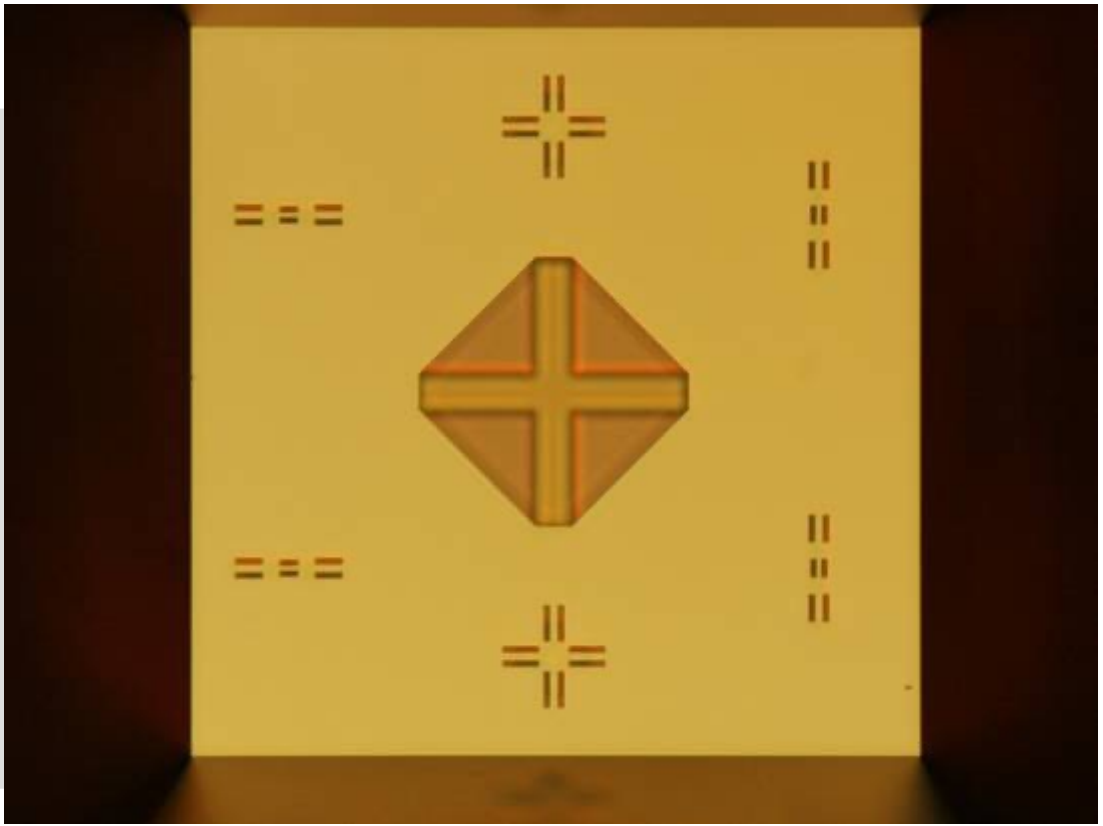


P. Fesenko et al. ACS Appl. Mater. Interfaces, 2017

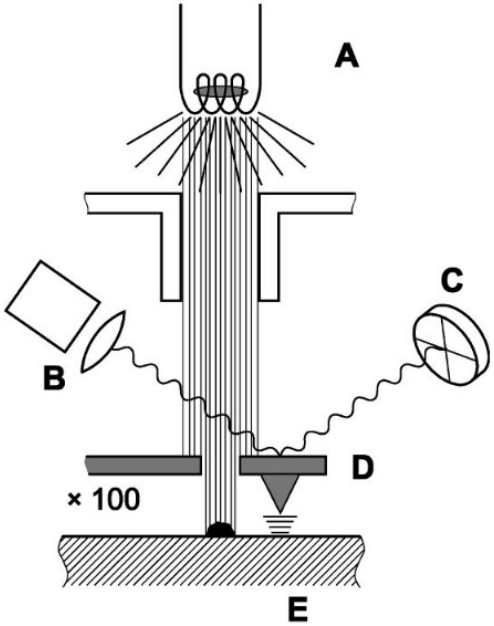
Stencil alignment

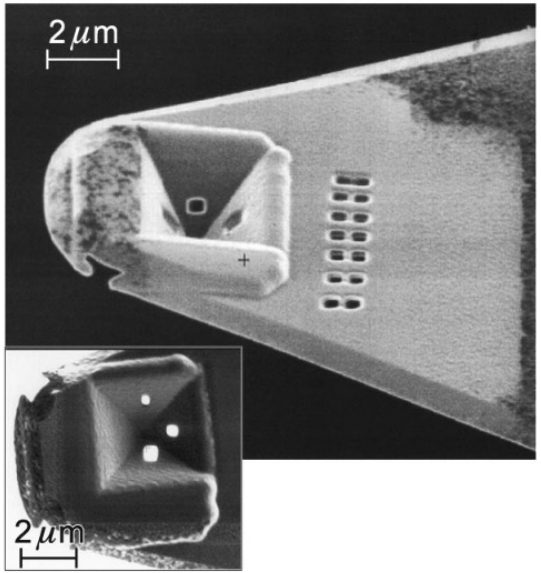
Nanostencil

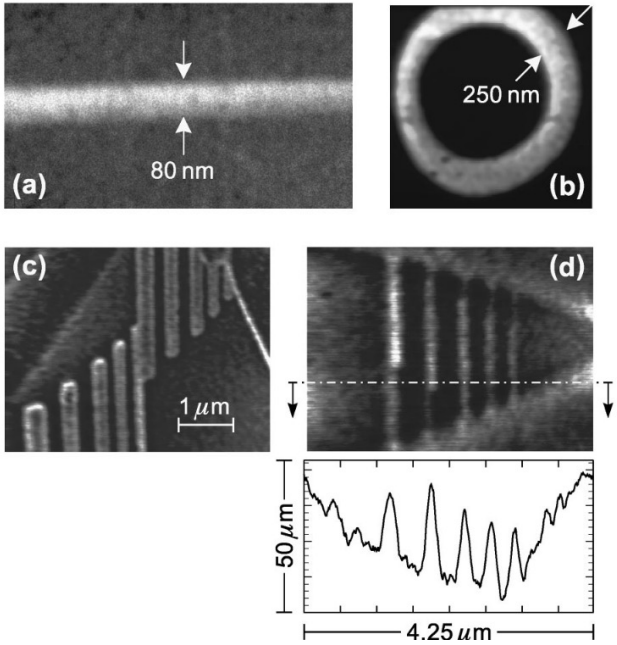


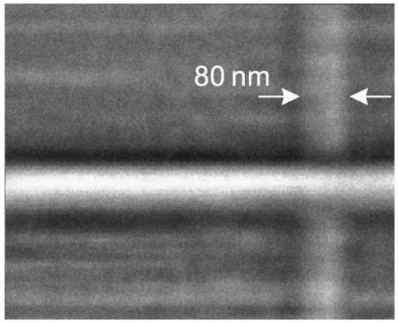


Dynamic nanostencil



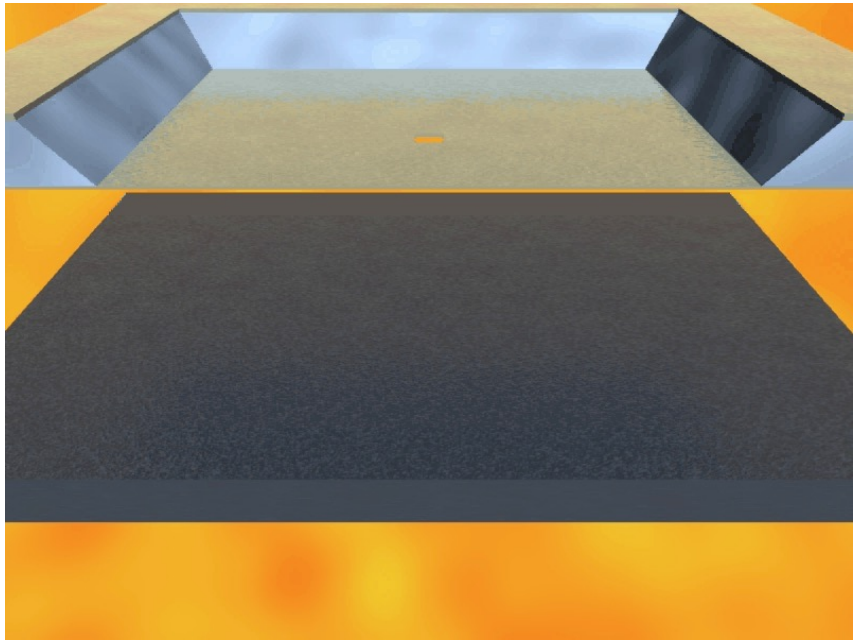




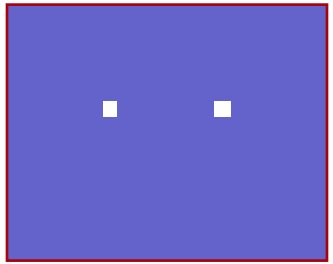


APL 1999

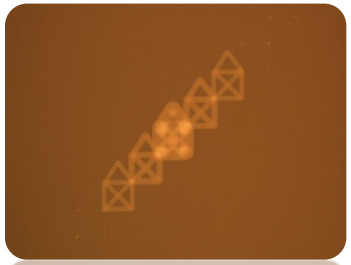
Dynamic stenciling



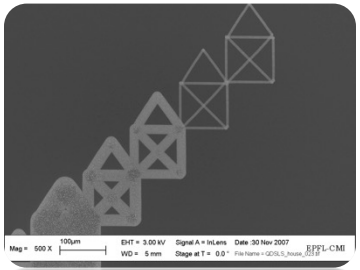
- Dynamic stencil
- Free motion in vacuum
- Rapid prototyping
- Flexible lithography
- PC controlled
- Parallel patterning
- Tapered film thickness



stencil

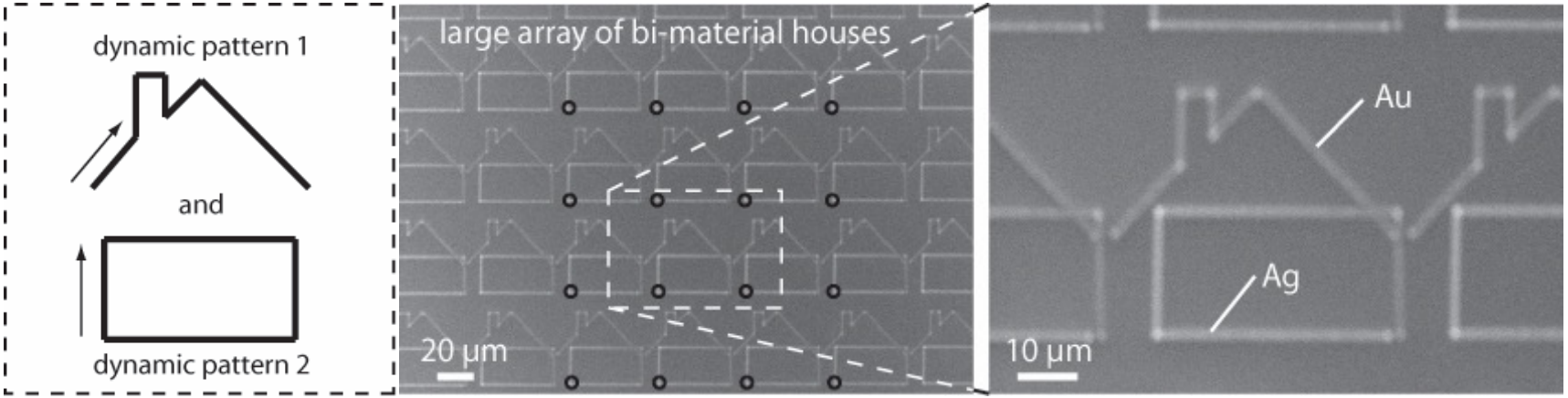


Free motion



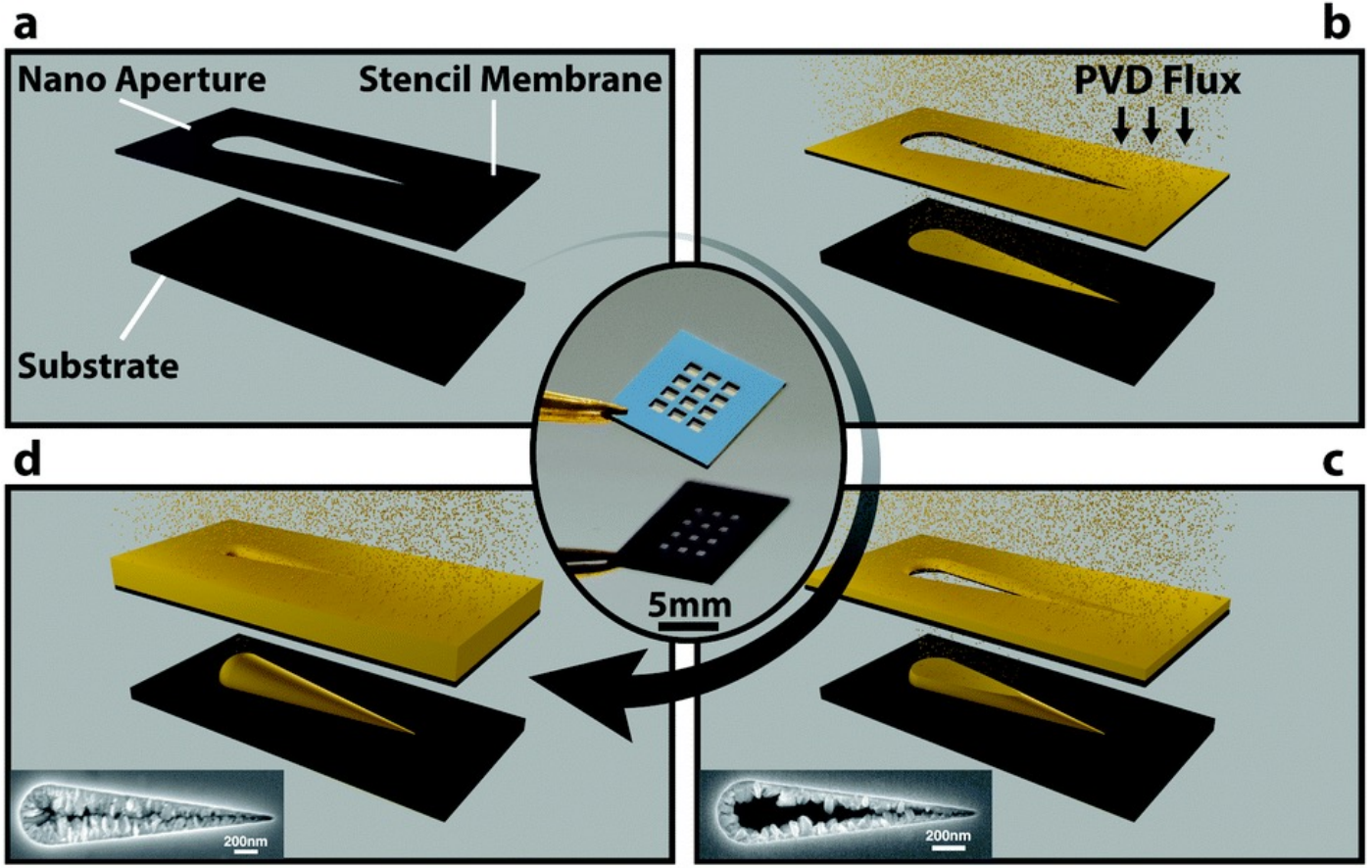
SEM image

Dynamic stenciling

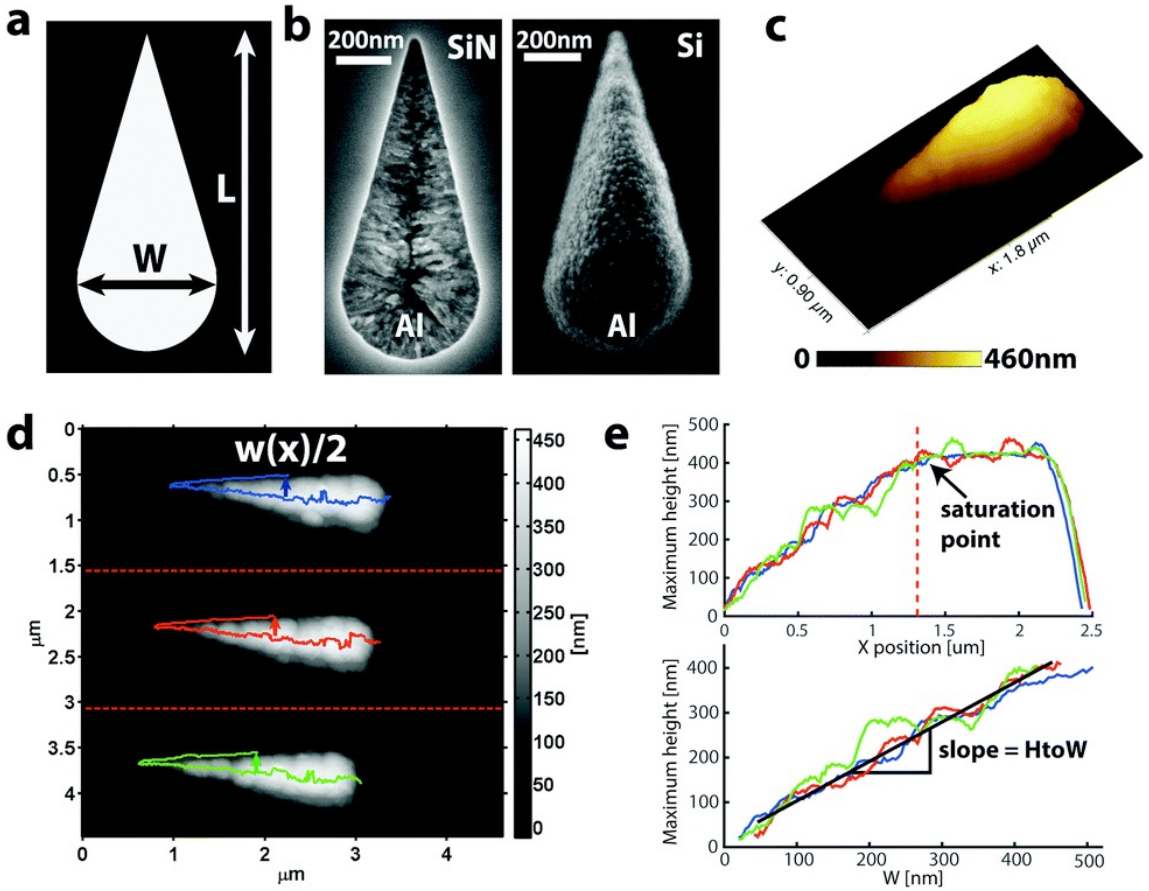


V. Savu, et al.,
J. Vac. Sci.Technol., 2008

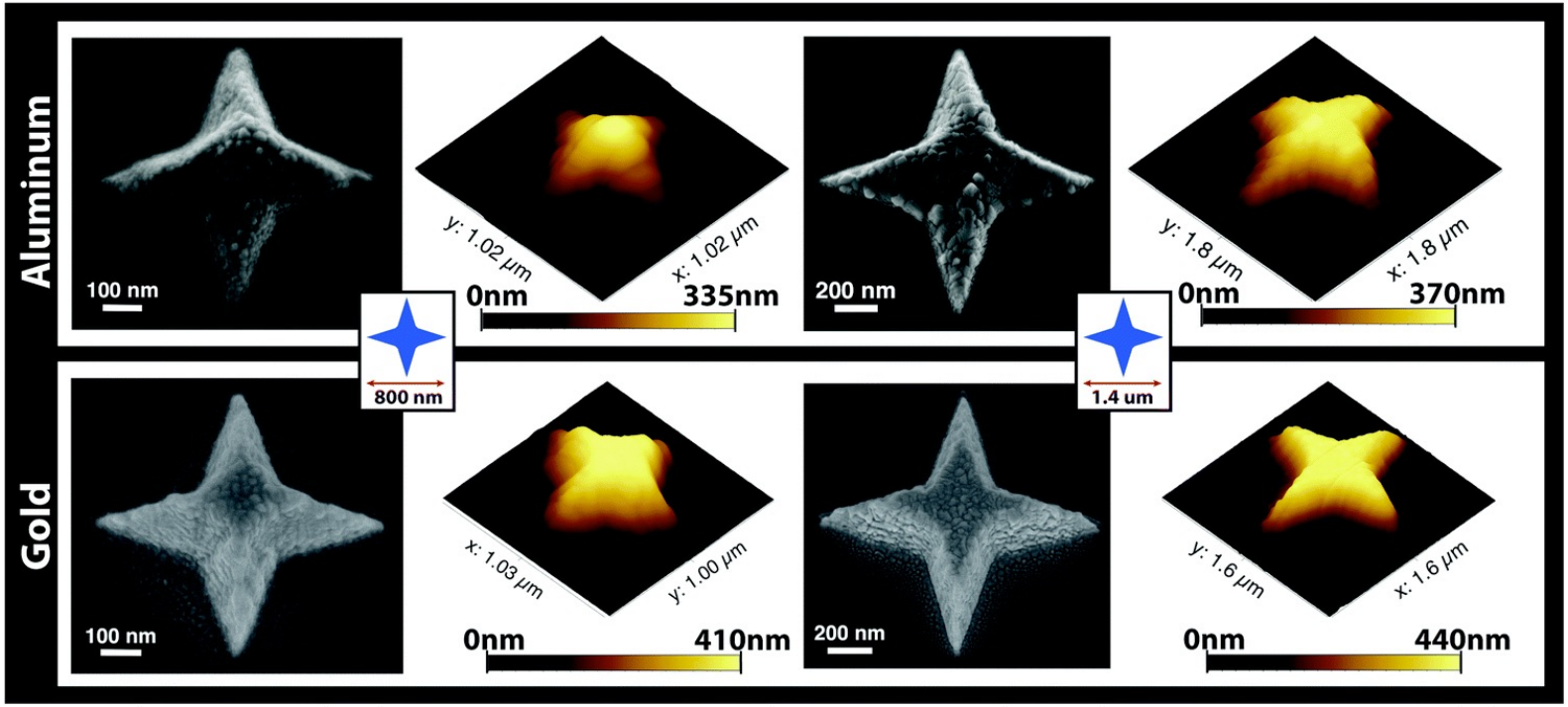
3D in stencil lithography?



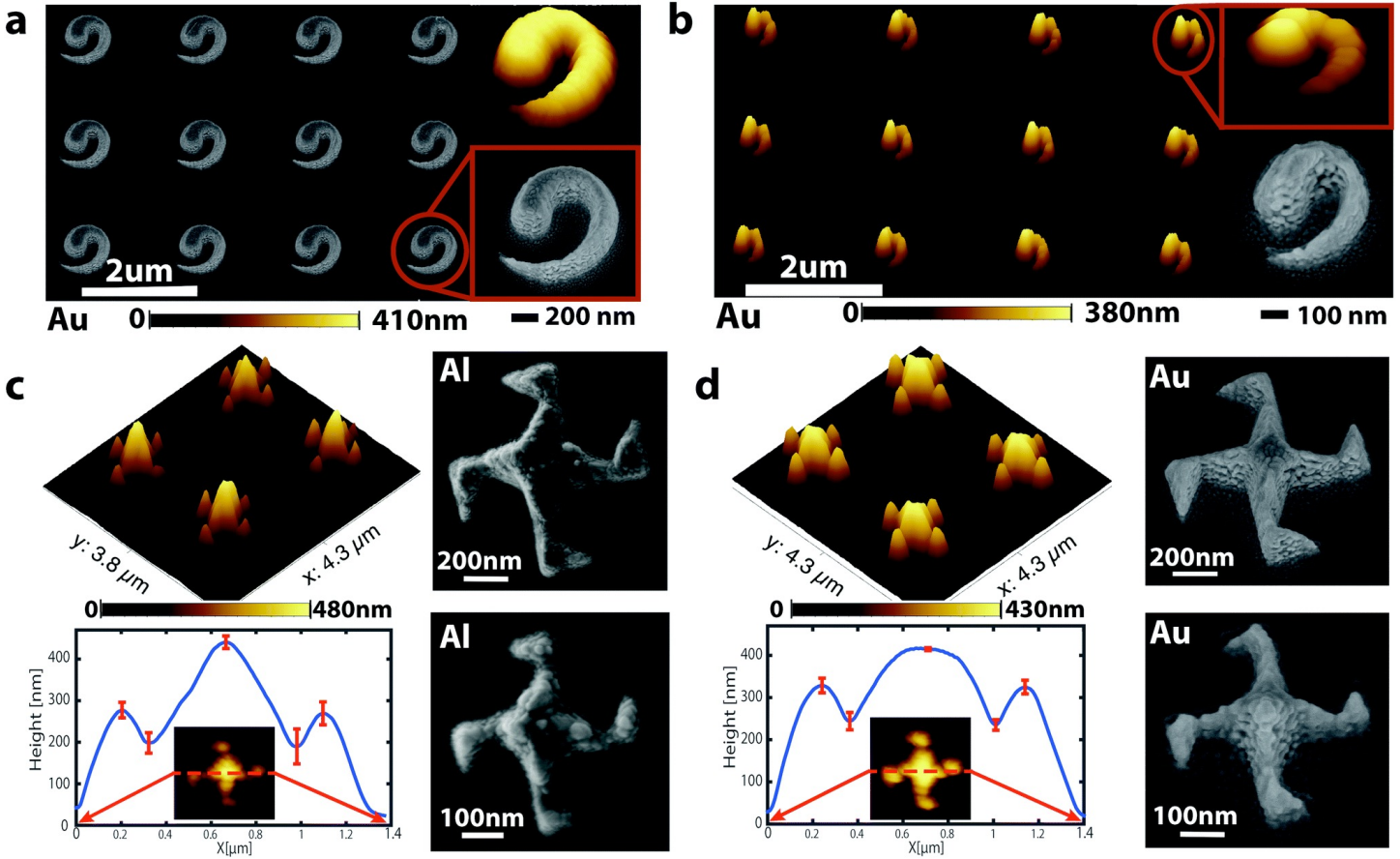
Nanoscale, 2016, 8, 4945-4950



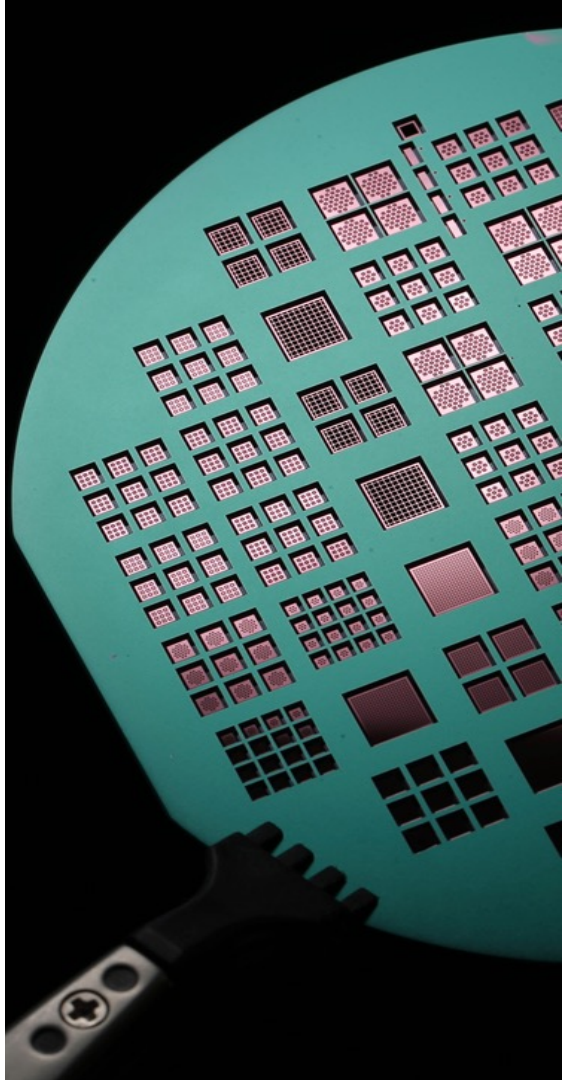
Nanoscale, 2016, 8, 4945-4950



Nanoscale, 2016, 8, 4945-4950



Nanoscale, 2016, 8, 4945-4950

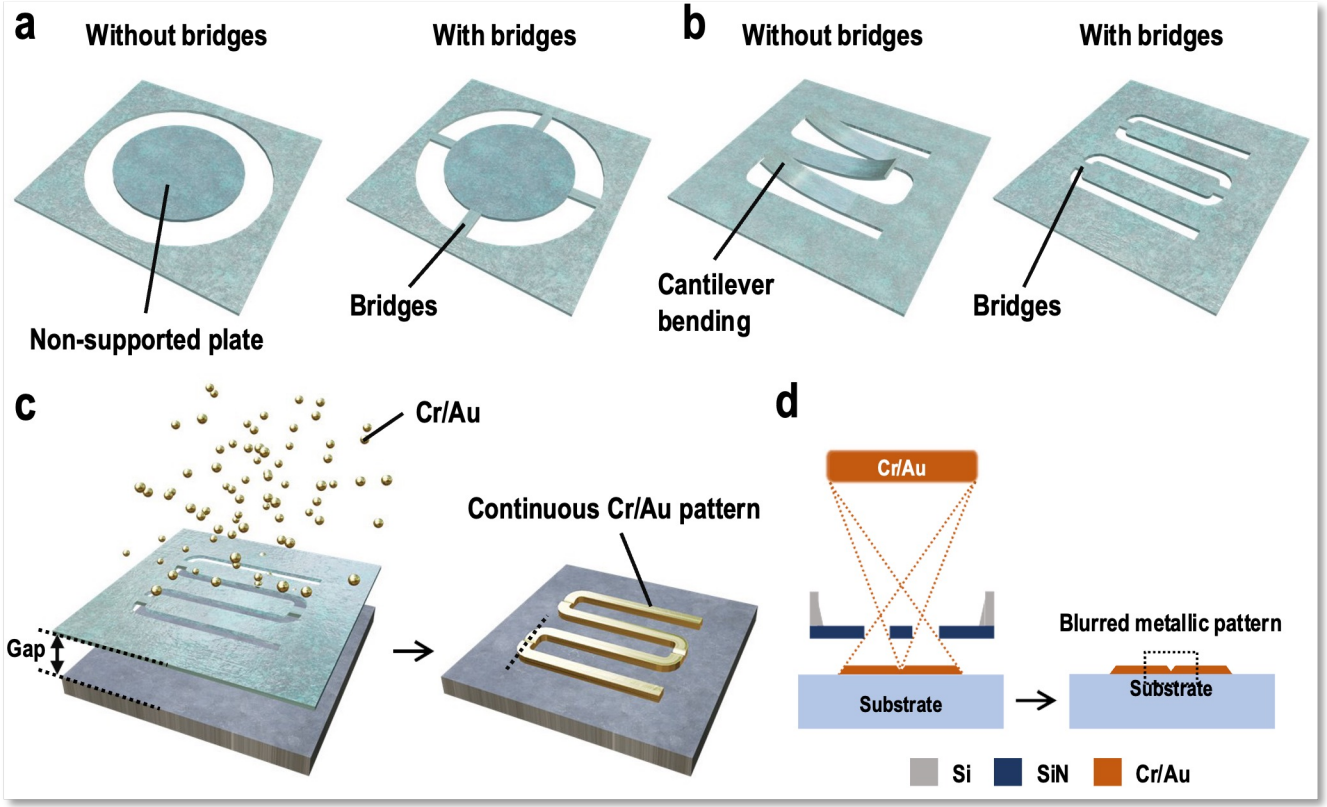


Take away message Nanostencil

- Scalable to < 50 nm resolution
- Full wafer
- Vacuum clean
- No contamination of fragile materials
- Metal and organic materials, dielectrics

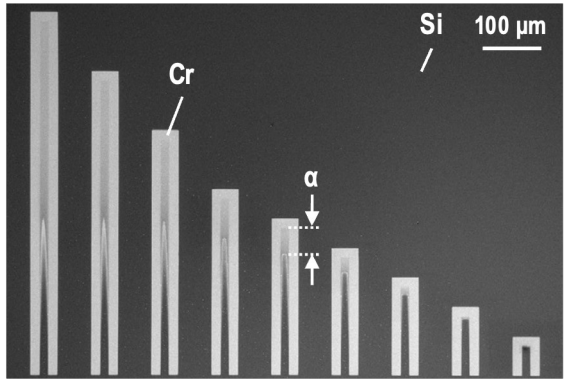
- Fine tuning of material flux
- Control crystal growth
- Micro-manufacturing of OE, flexible wearables, etc.

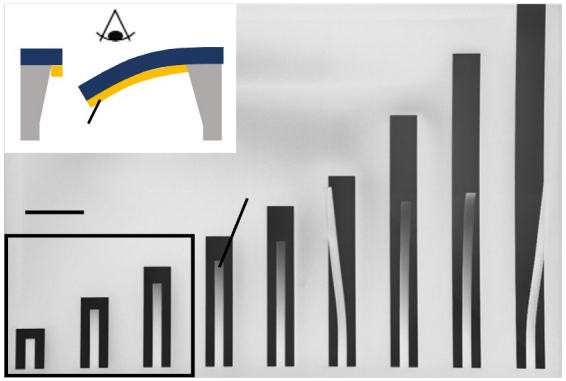
Bridge stencils (micro)



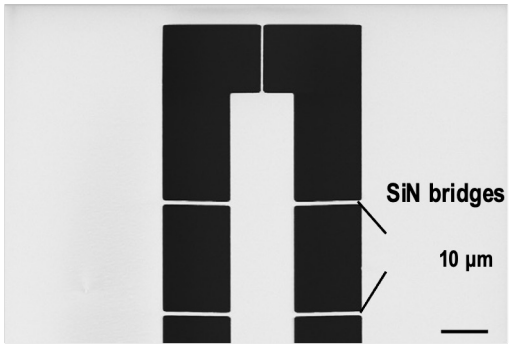
Y.C.Sun et al. *Advanced Materials Technologies (2022) in revision*

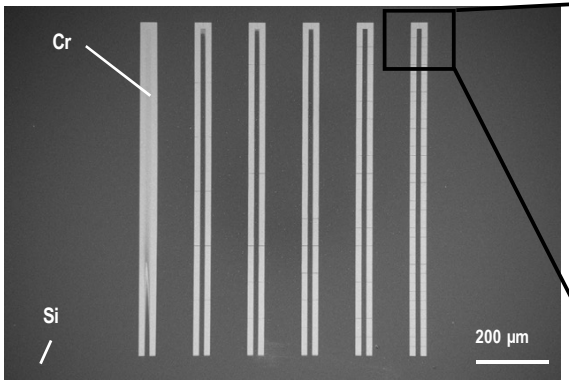
Bridge stencils (micro)

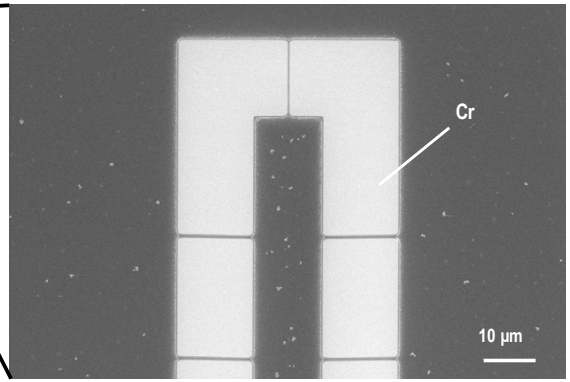




Without bridges







With bridges

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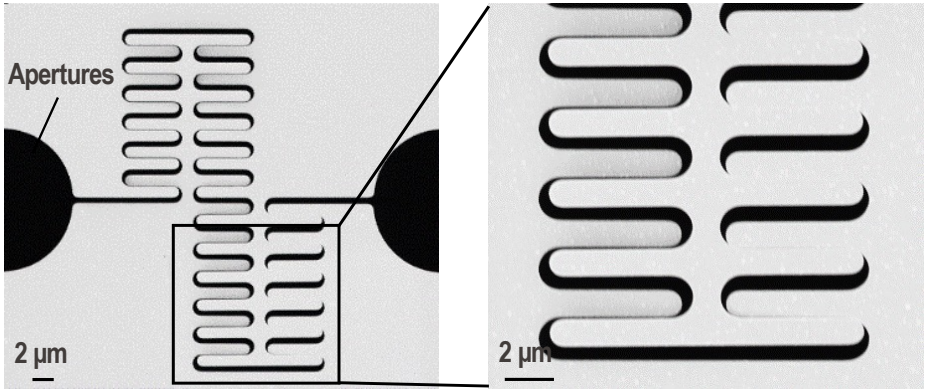
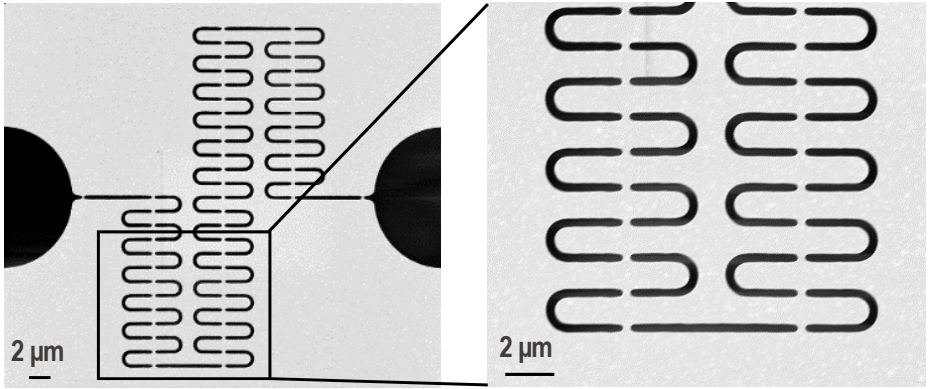
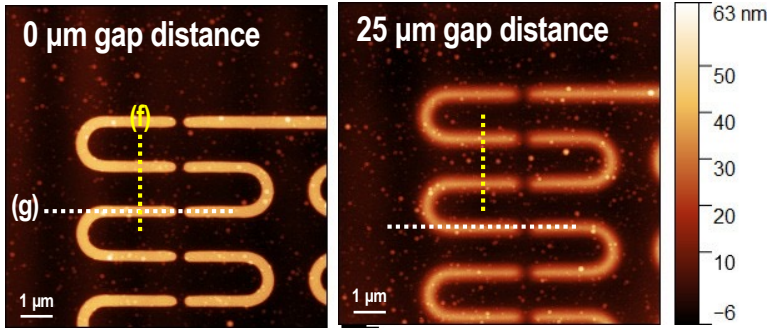
Bridge stencils (nano) … made by DUV

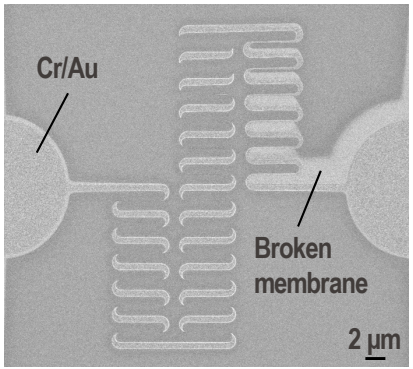
Without bridges

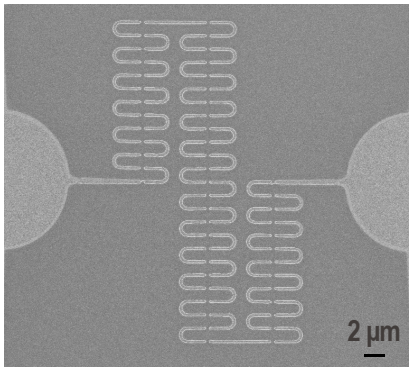
With bridges











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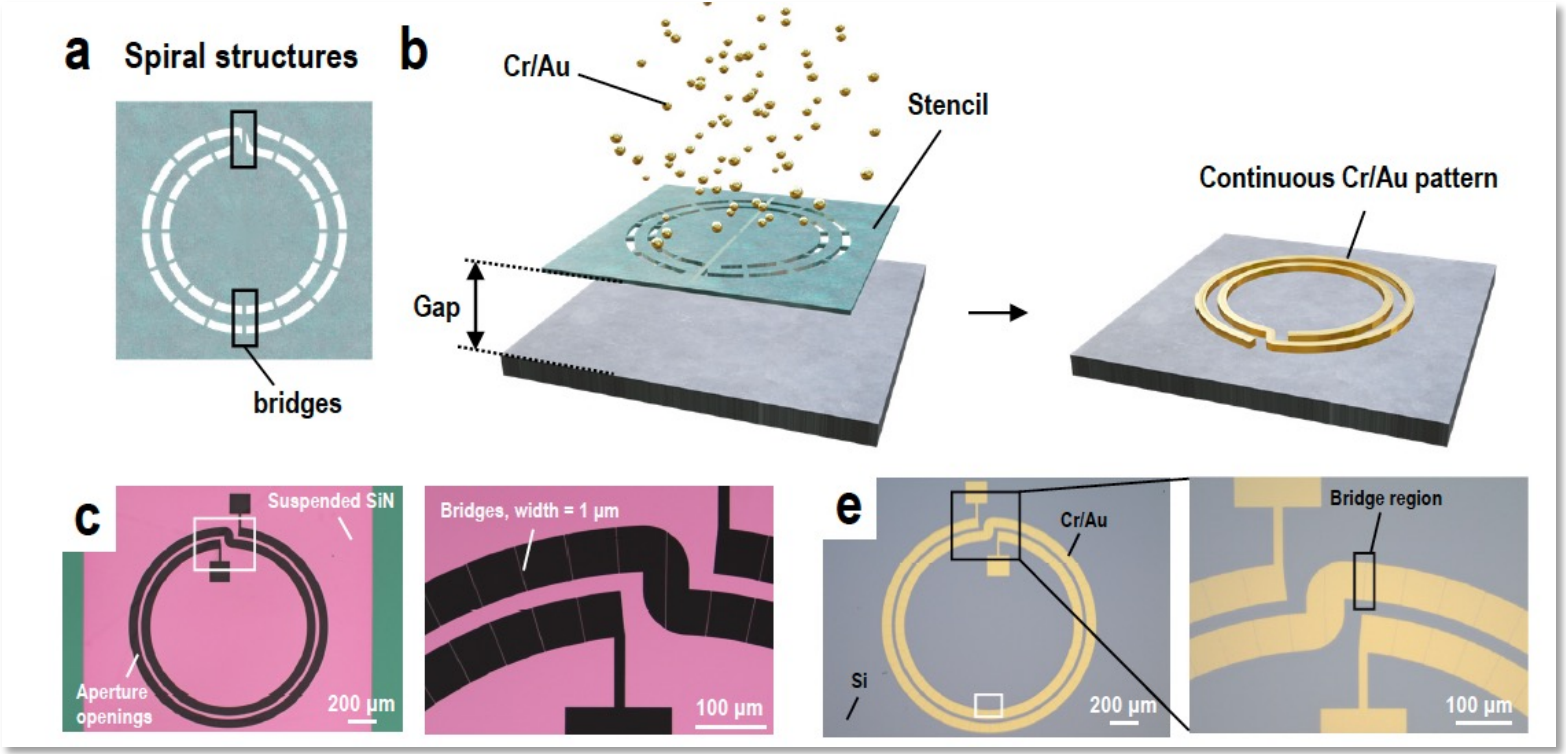
Split ring resonator on flexible substrate



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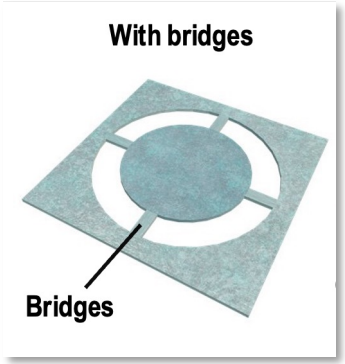
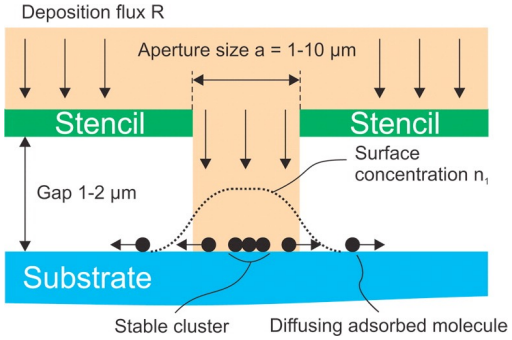




Nano stencil lithography Take home message

Fast, parallel, scalable patterning without any wet stuff

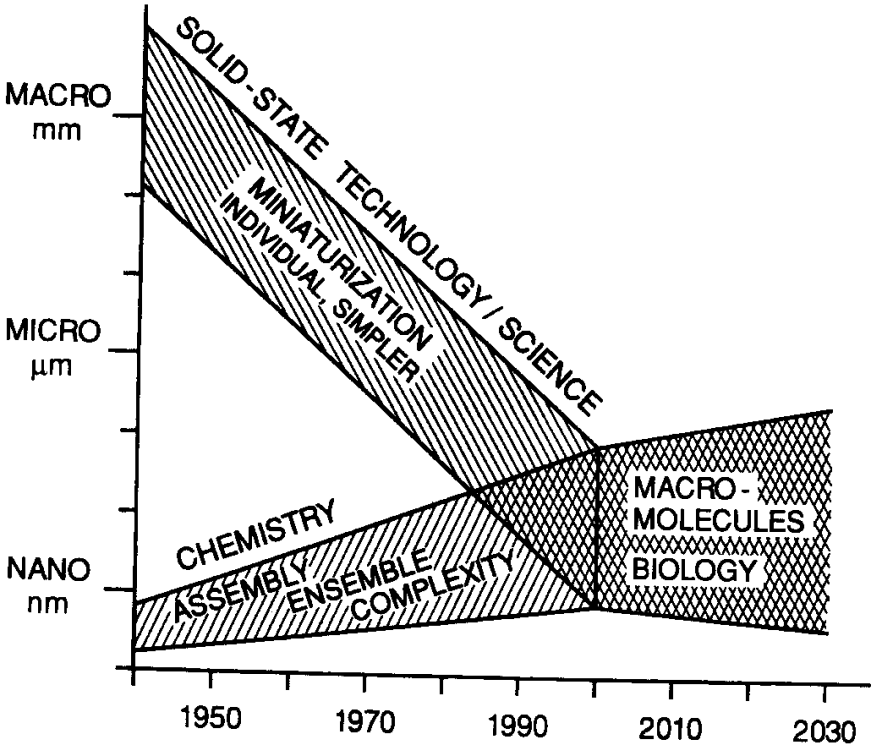
Vacuum clean interfaces

Limits and remedies

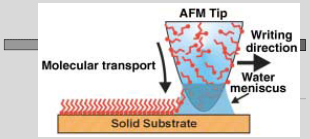
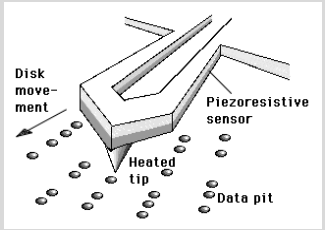
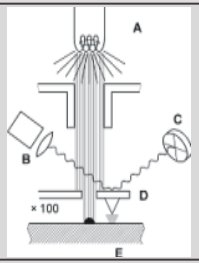
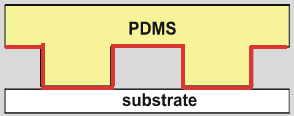
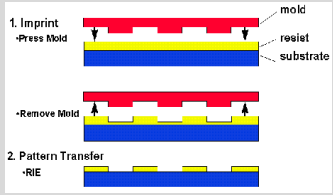
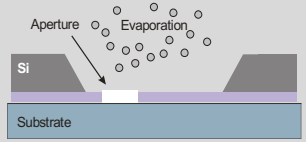
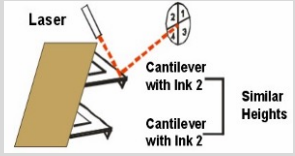
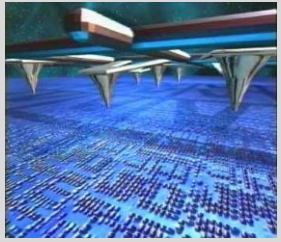
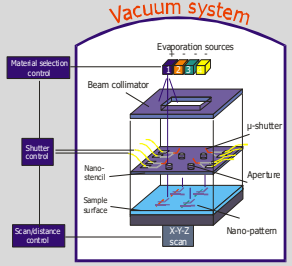
Opportunities

Wrap up

Top-down meet bottom-up



H. Rohrer

	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** 

Advanced T-SPL

by Samuel Zimmermann