



Micro and Nano Systems at LAAS-CNRS: Which Technologies for Today and Tomorrow ?

Anne-Marie Gué, 9 Novembre 2007

Why developing new and innovative technologies ?

Micro and nanotechnologies are a key point for:

- **Health and safety:** early diagnosis, drug discovery, artificial

Biology and health:

monitoring and detection of bio and chemical species
from micro-volumes to single species (molecule, cell, ...)

... (as, ...) and climatic changes

Power management:

Autonomous and energy saving systems,
energy harvesting, energy storage

Communication:

Tele communications, Communicating systems

Technological needs and challenges

The Chinese puzzle !



Complex systems:

- multi functionalities
- multi disciplinary
- heterogeneous (materials)

new structural and functional materials



Nano in Micro:

- Size reduction
- new and revolutionary principles

3D and heterogeneous integration



Various and numerous fields of application:

- large variety of working
- size specification
- cost requirements
- diversification of support or substrate
- ...

nanopatterning:
structural and chemical
patterning

(very) low cost devices: low cost
materials and simplified processes

large area systems, flexible systems

Outline

- **From s.c. to multimaterials**
- **From planar technology to 3D and heterogeneous structures**
- ~~**From physics to multidisciplinary**~~

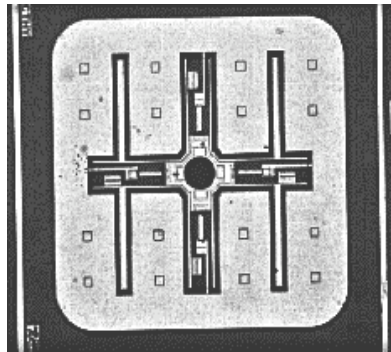


From Planar technology to 3D and heterogeneous structures

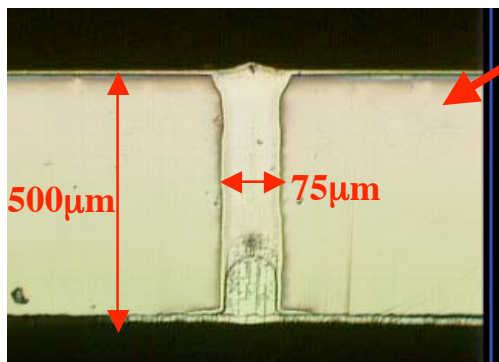
Doubleside process

Double-side processes

At the beginning ...

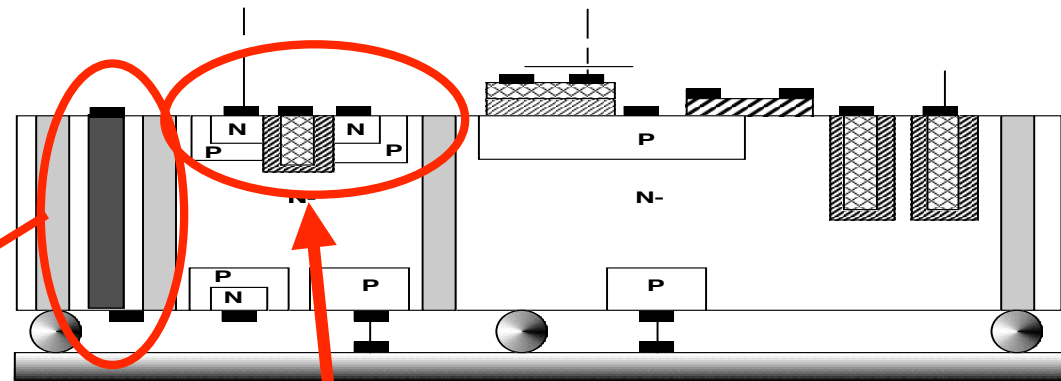


Optically driven thyristor 1980

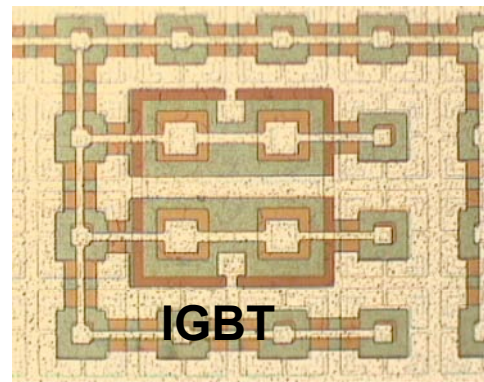


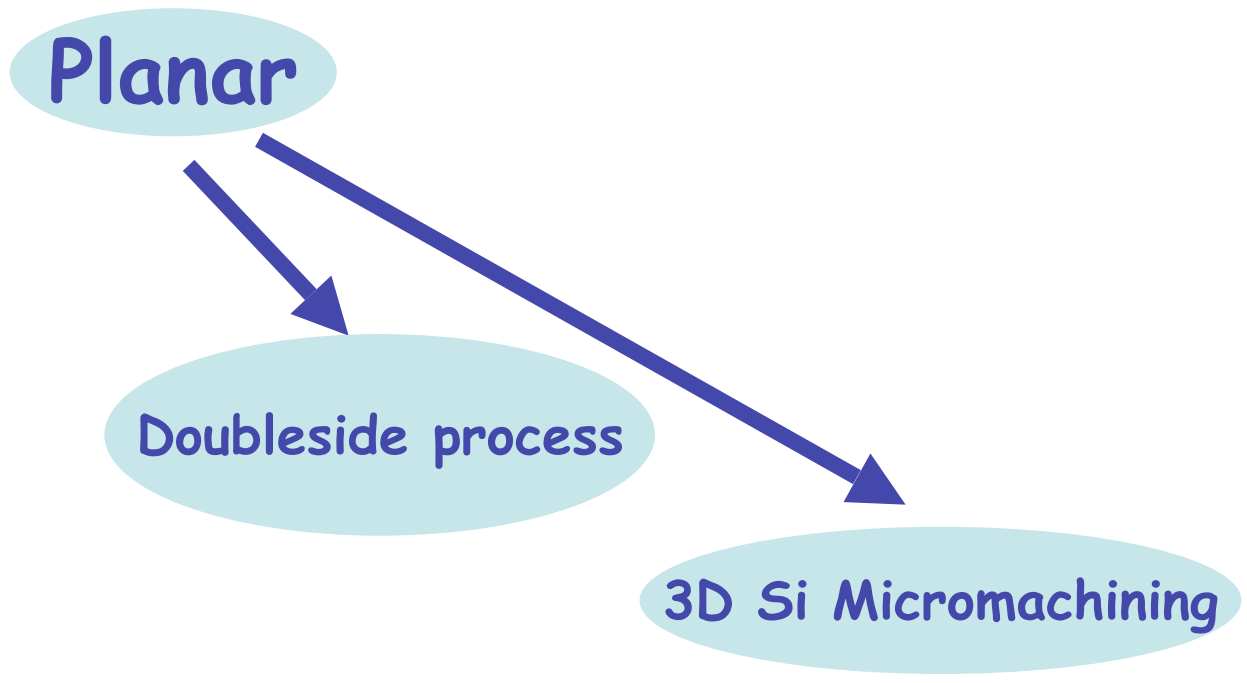
Thru-wafer vias :

- thru-wafer DRIE
- Al thermomigration
- Specific vertical LPCVD furnace



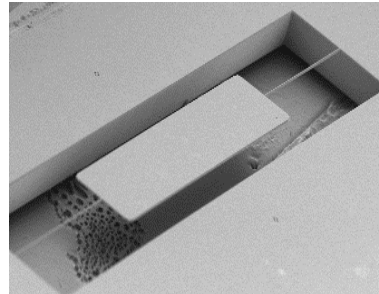
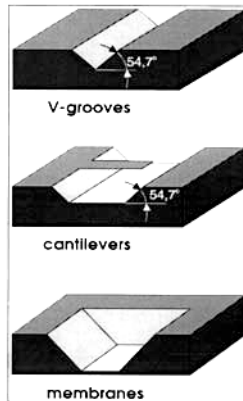
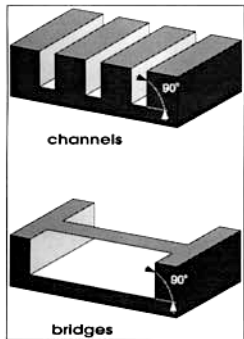
2004



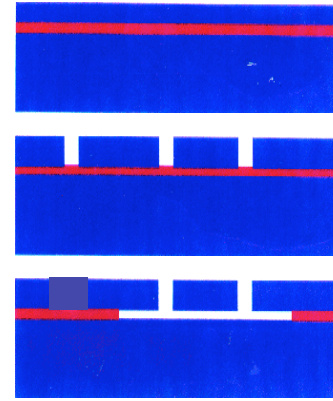


Si Bulk and surface micromachining

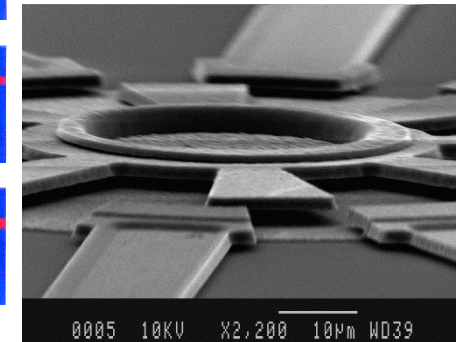
Si wet etching KOH



Si surface micromachining

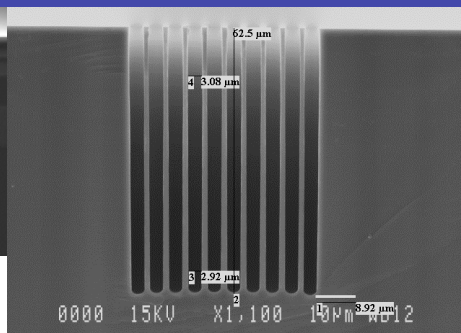
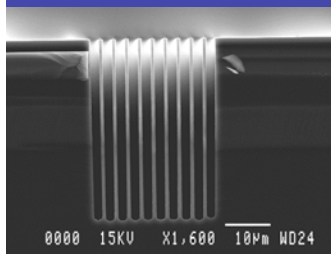


Sacrificial layers:
SOG, SOD, oxidized polySi

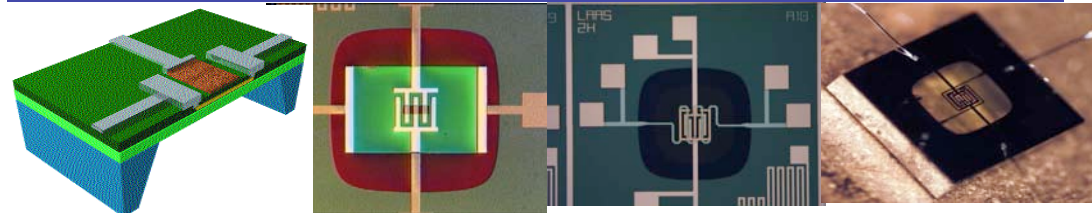


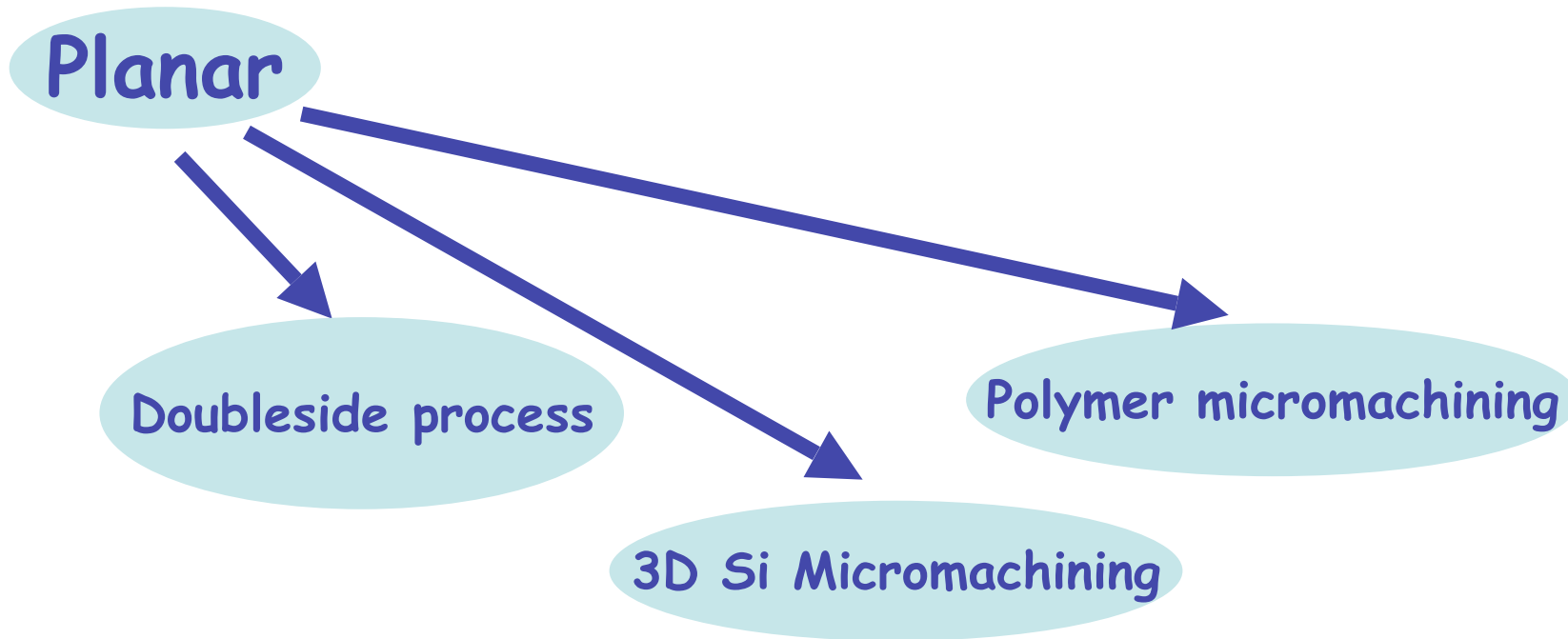
Si ■ SiO₂ ■

Si DRIE for non linear capacitance



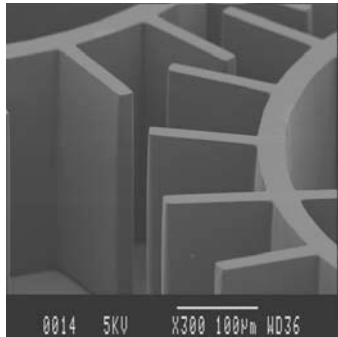
Thin dielectric suspended membranes (hot plates)



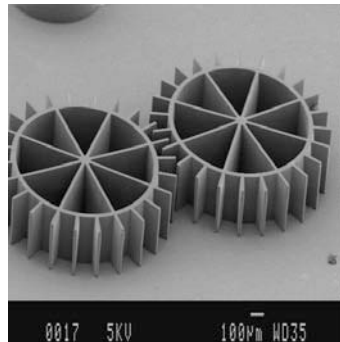


Polymer micromachining: direct lithography

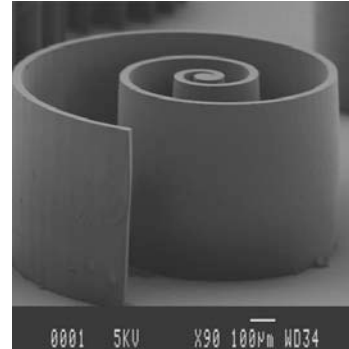
Negative Photoresist (SU 8)



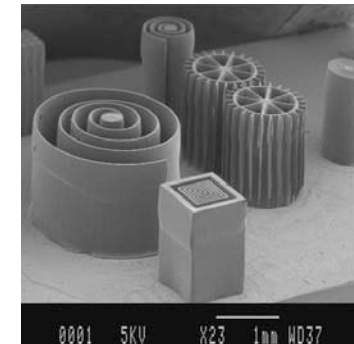
E=200µm



E=300µm

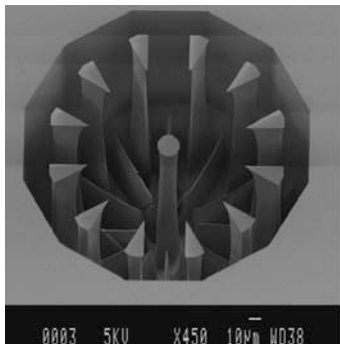


E=500µm

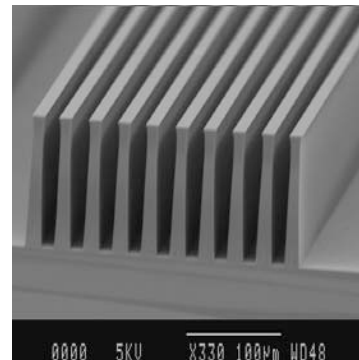


E=1,2mm

Positive Photoresist (AZ 9260)



e=100µm

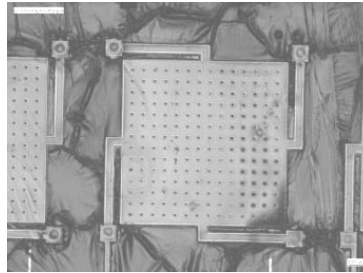
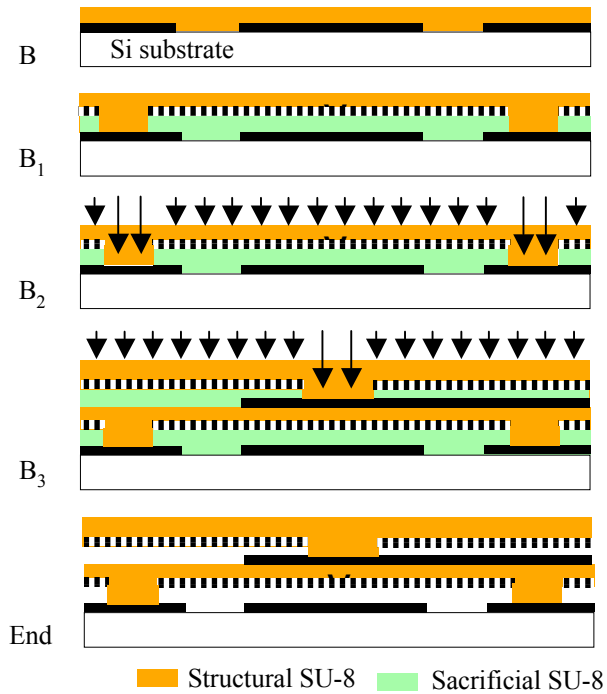


e=100µm

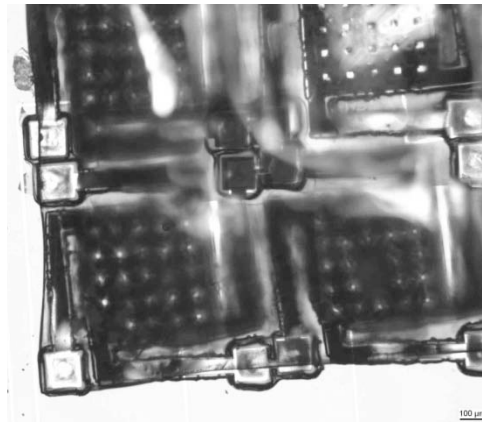
Polymer micromachining: sacrificial layer technology

Adaptative optics

[SU8/SU8]



First level (B₂)



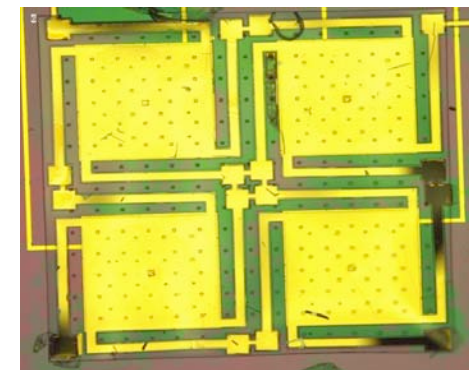
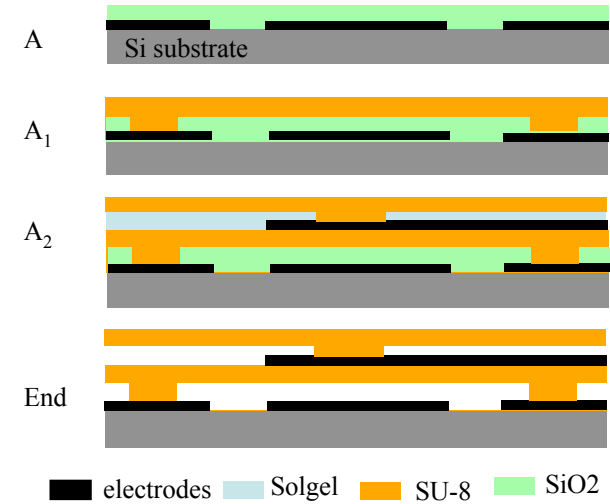
Two levels (end)

Key features

- mirror: roughness < $\lambda/10$
- vertical actuation: up to 10 μm
- pitch: 500 μm to 1 mm

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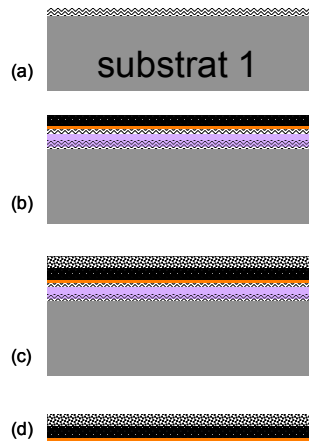
[SiO₂/SU8] + [Solgel/SU8]



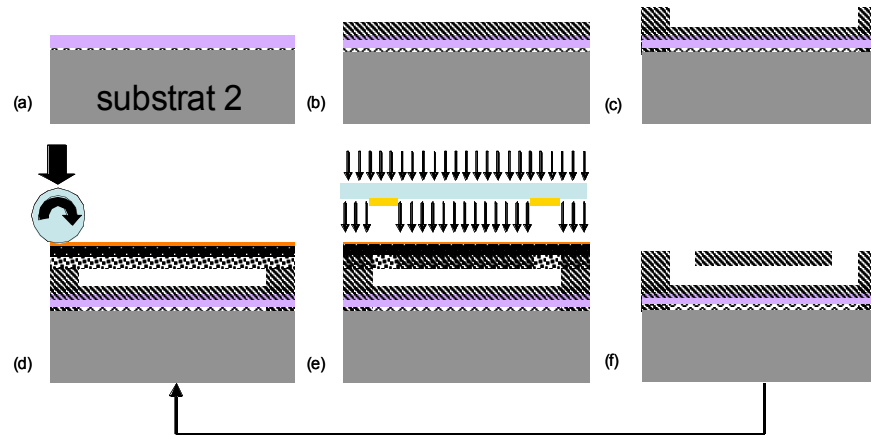
Pitch: 500 μm to 1mm

Polymer micromachining: SU 8 dry films lamination

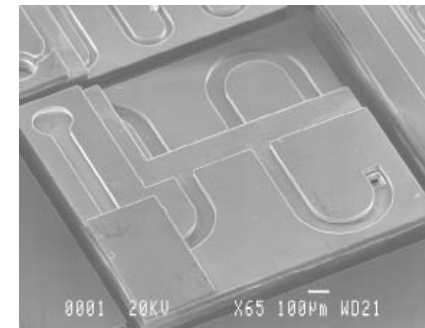
Realization of a non crosslinked SU8 flexible film



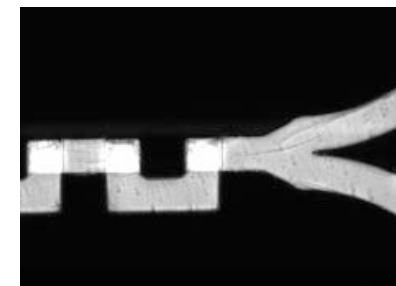
Stacking and patterning of SU8 films



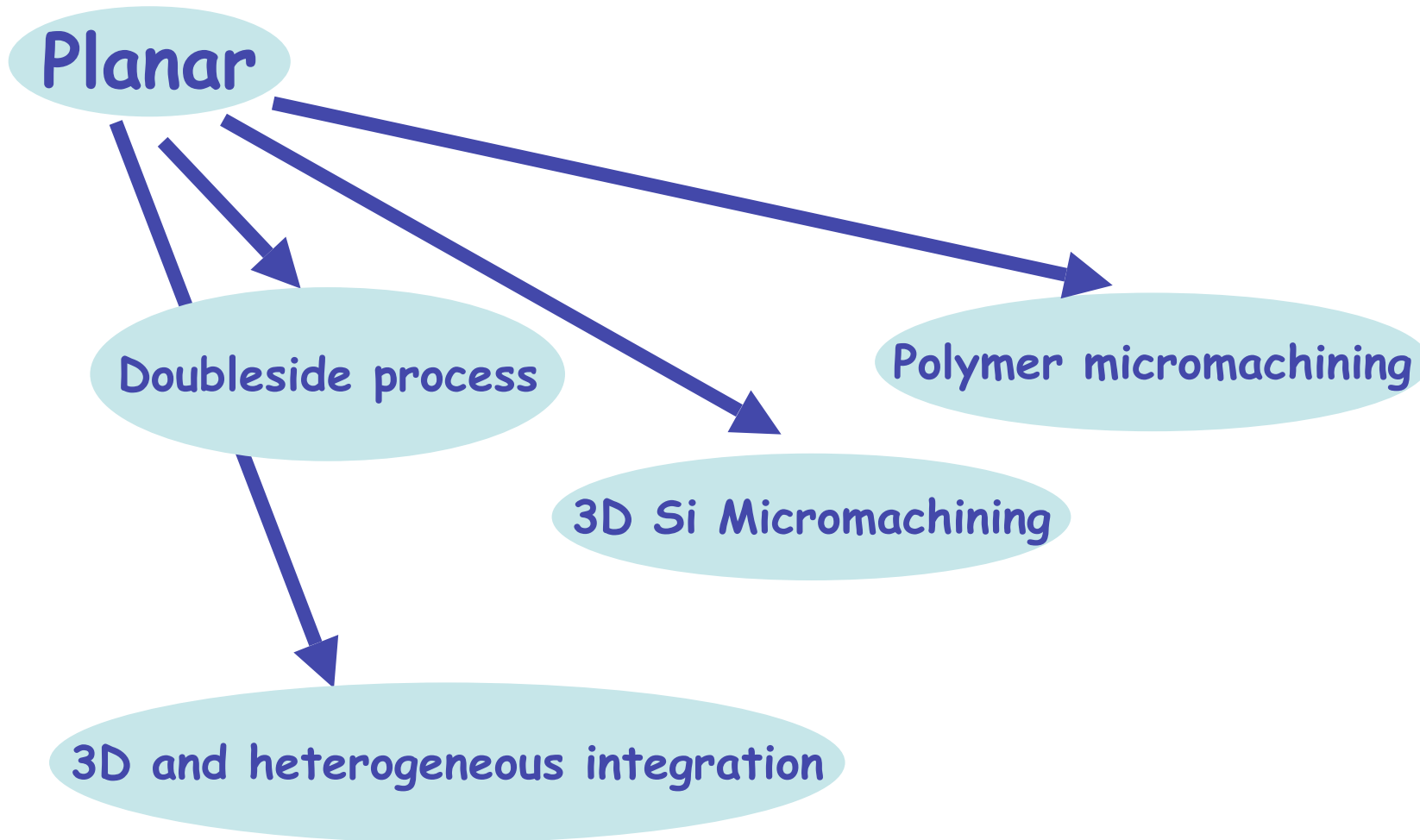
flexible SU-8 chip



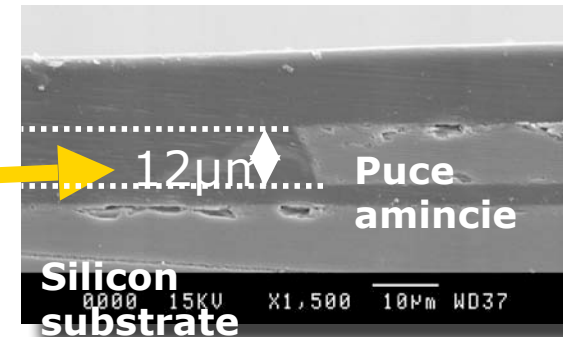
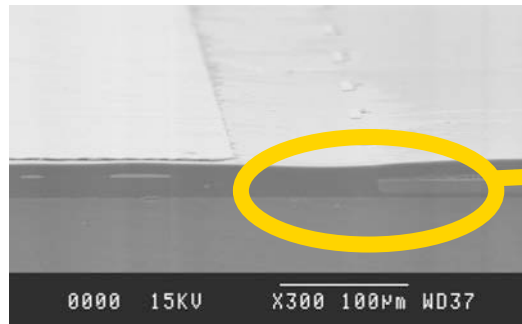
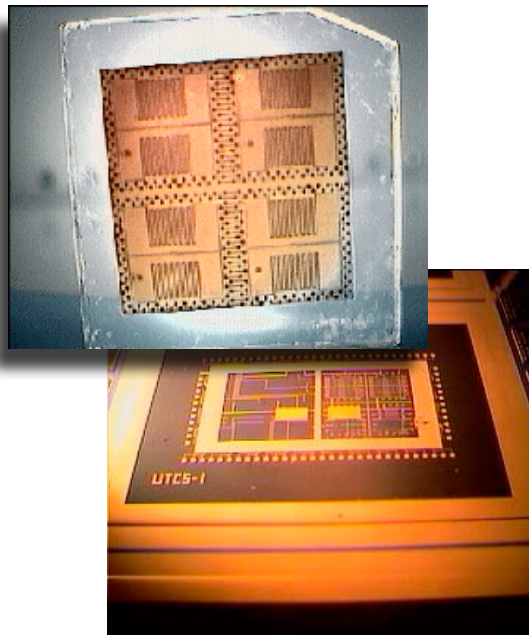
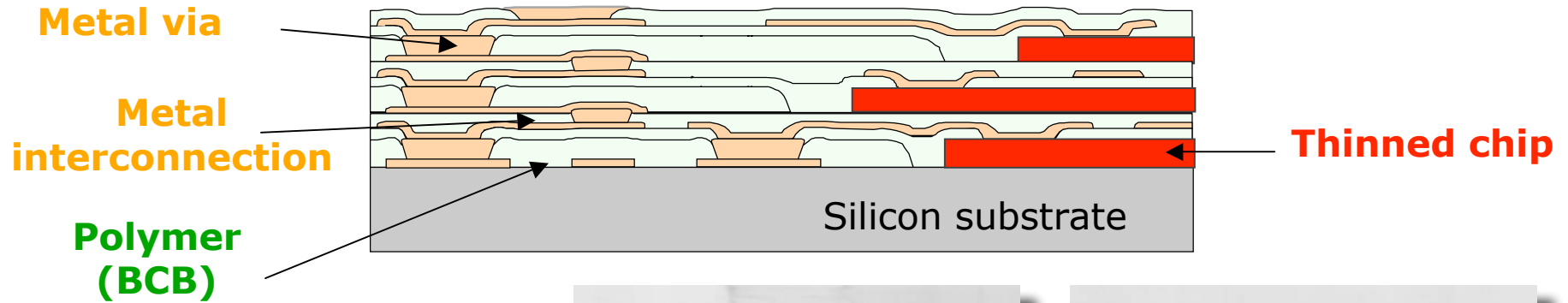
multilevel network



3D micromixer

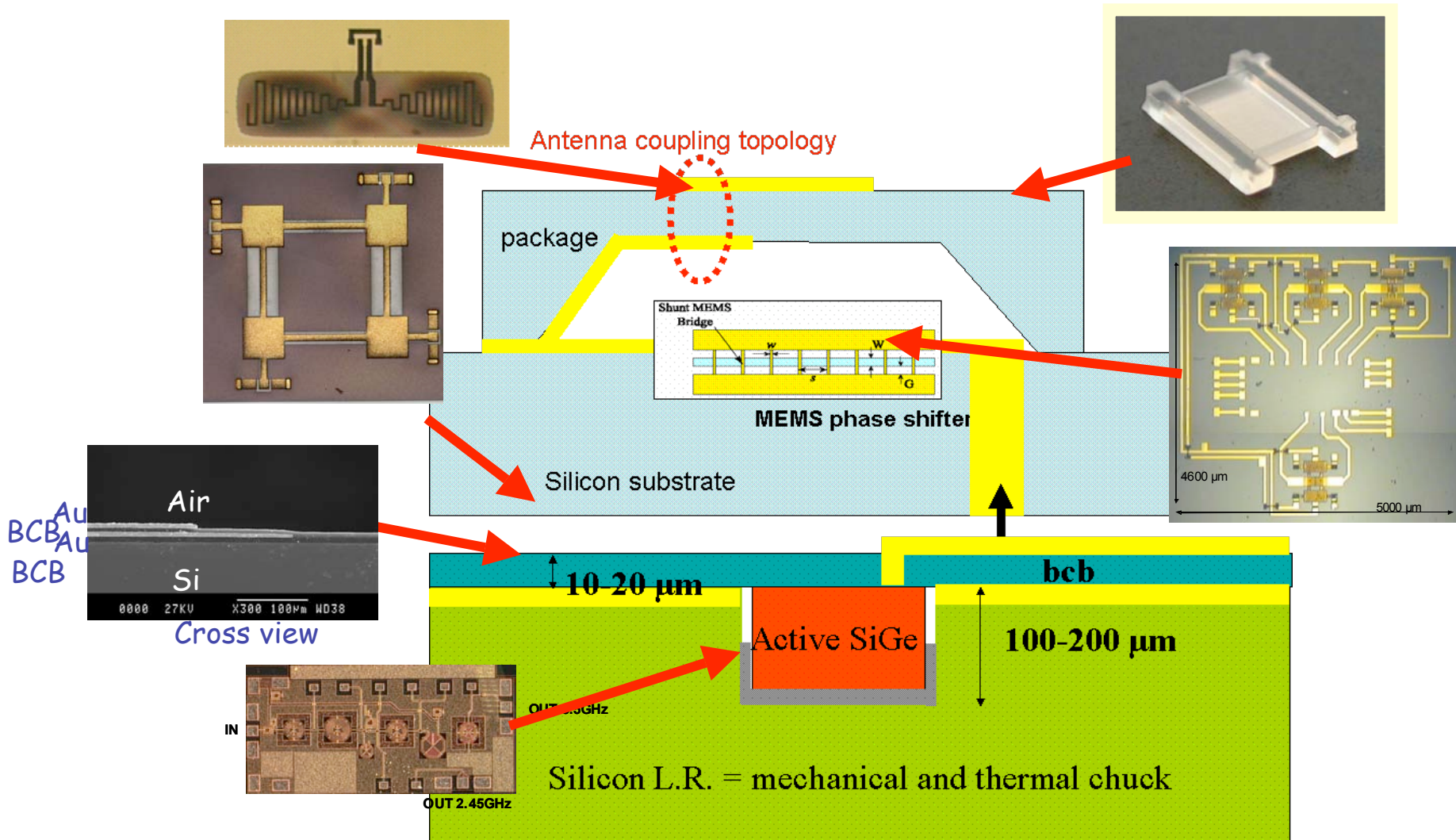


Ultra-Thin Chip Stacking

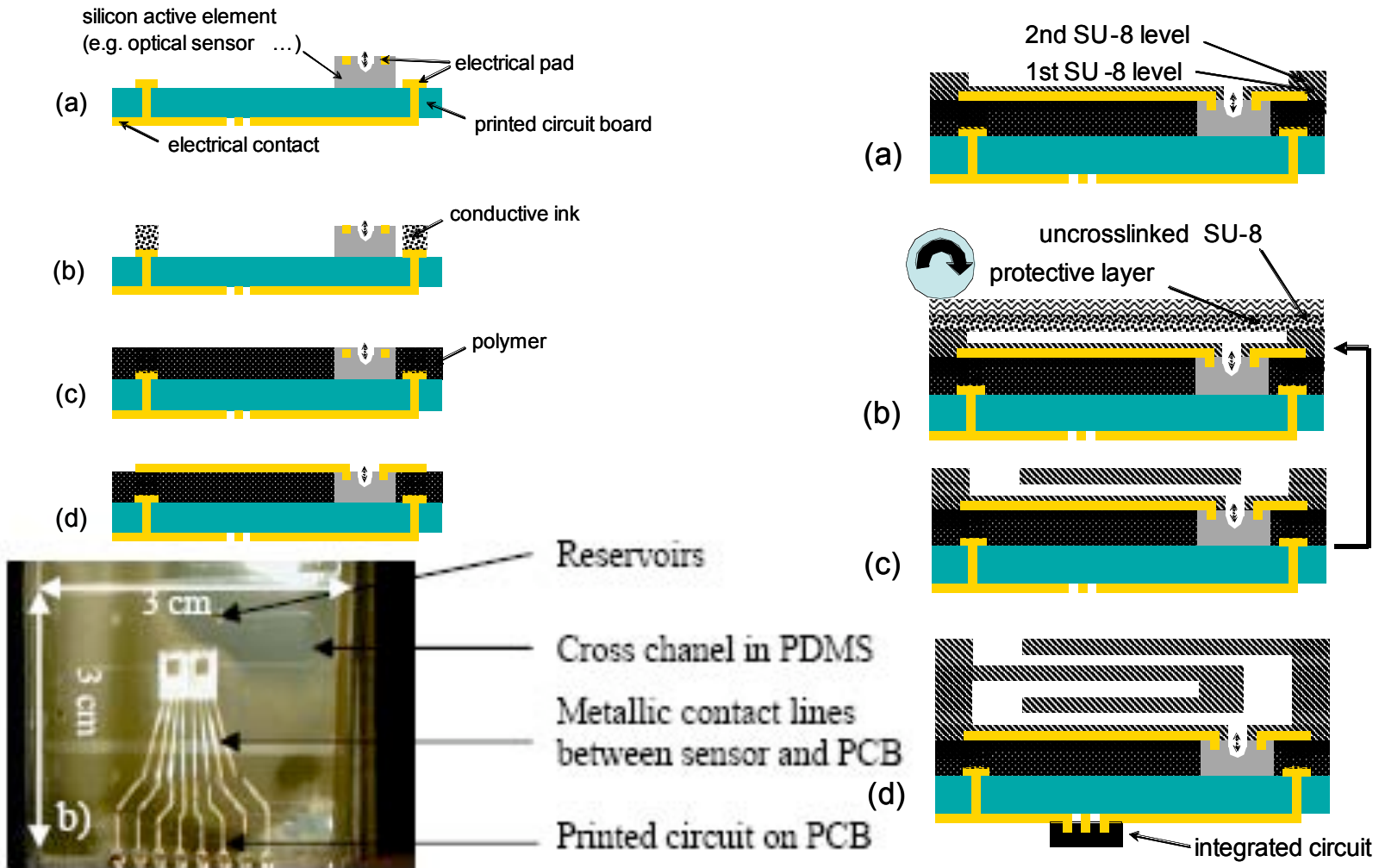


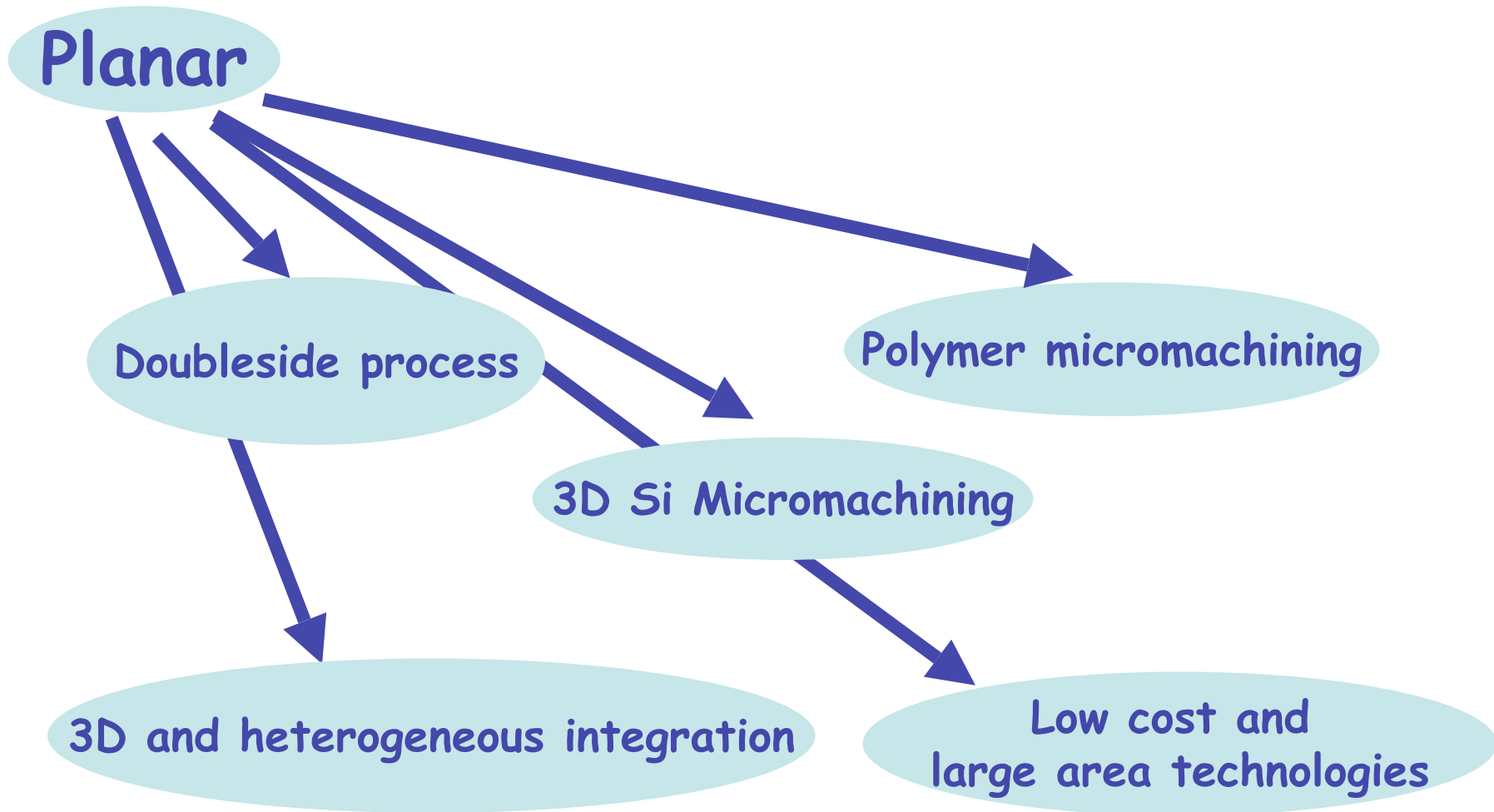
	PCB	MCM-V	3D Ultra-compact
Active volume/ total volume ratio	25x10 ⁻⁶ %	0.003 %	30 %
Mass (gr.)	52	7	0.5
Size (mm)	63x63x5	19.5x19x11	20x20x0.5
Volume (cm³)	20	4.7	0.2

RF Heterogeneous integration



3D and heterogeneous integration





Ink jet technology

(under development)

Micro optics

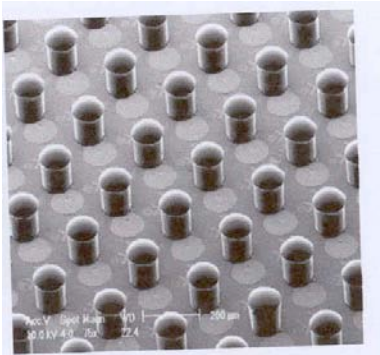


Figure 17. Wafer level fabrication of pedestals and microlenses on VCSEL wafer.

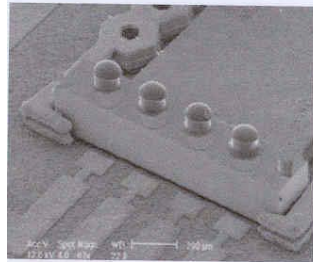


Figure 25. A lensed VCSEL die is positioned by a MEMS clammer.

3D polymer microlenses

ink:

*H₂O 30 to 50% : monitoring of viscosity and surface tension
 Photoinitiator : triarylsulfonium hexafluorophosphate ;
 Hydrolyse (3- glycidyloxypropyl trimethoxysilane) : sol gel*

Wave guides

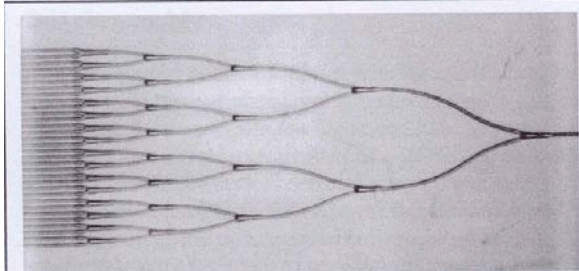


Figure 27: 25mm long, 1-to-32 branching waveguide printed using ink-jet technology.

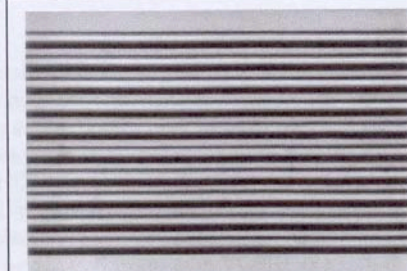


Figure 28: 125µm multi-mode waveguides printed on 150µm centers.

Results :

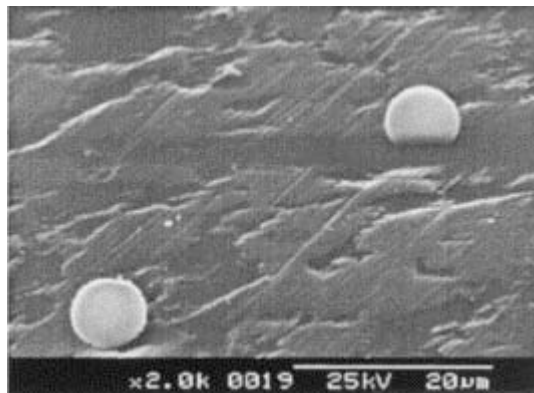
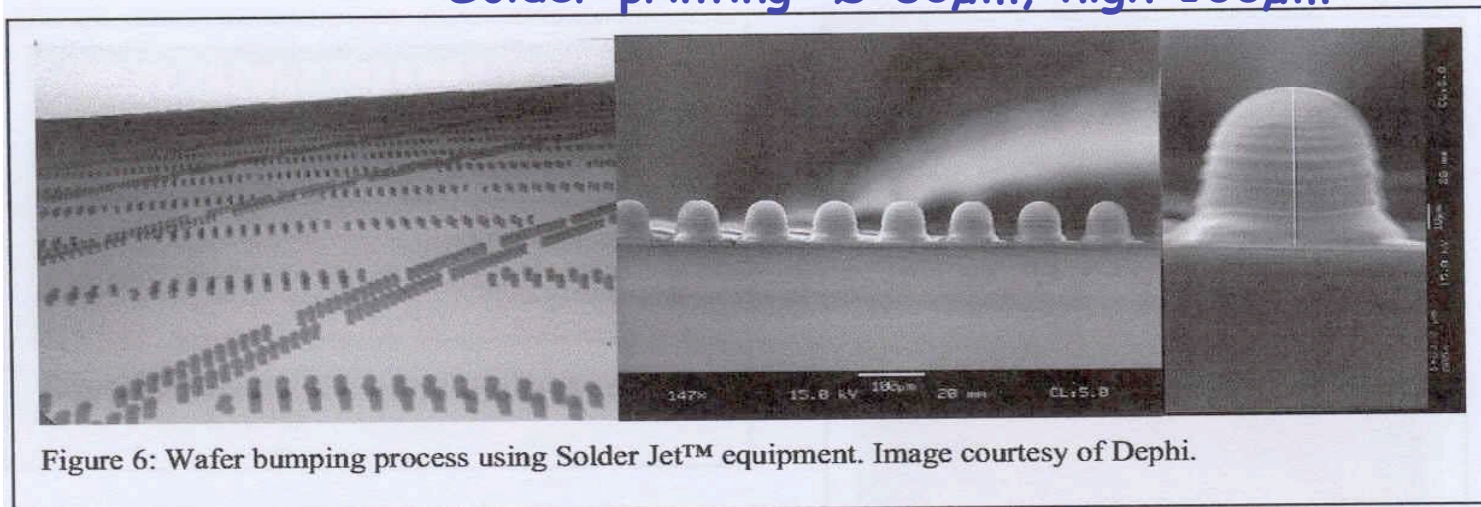
*dimensions : Ø 50 µm to 2 mm ;
 High : 6 µm to 150µm
 Focal length : 100 µm to 2 mm
 Surface roughness: 40 nm
 indice : monitored through sol gel composition*

Ink jet technology

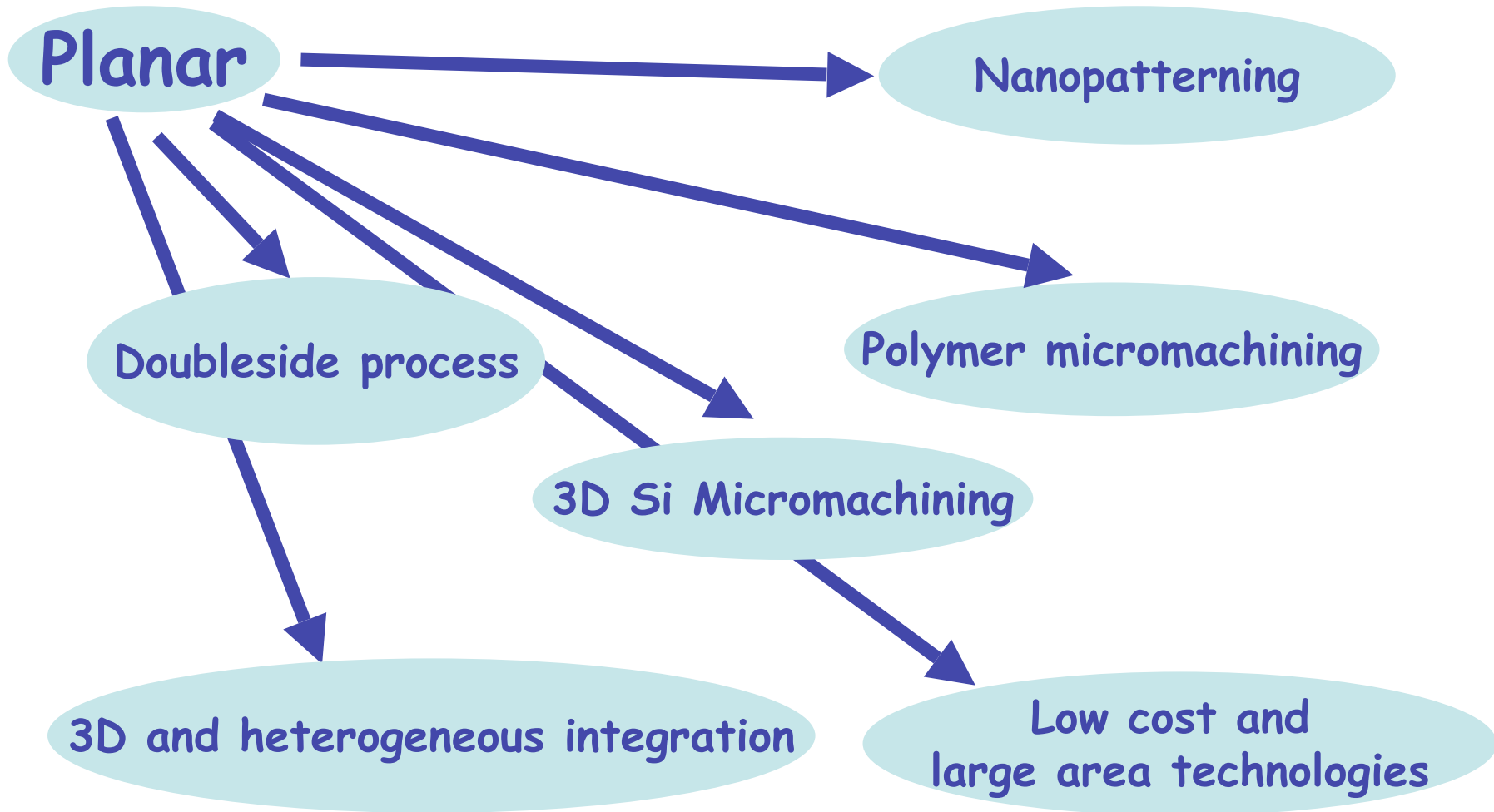
Bumping

(under development)

Solder printing: $\varnothing 80\mu\text{m}$, high $100\mu\text{m}$

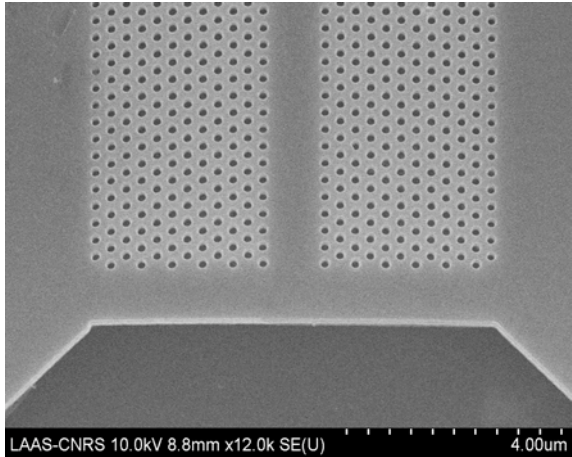


Wedge bumping $\varnothing 100\mu\text{m}$

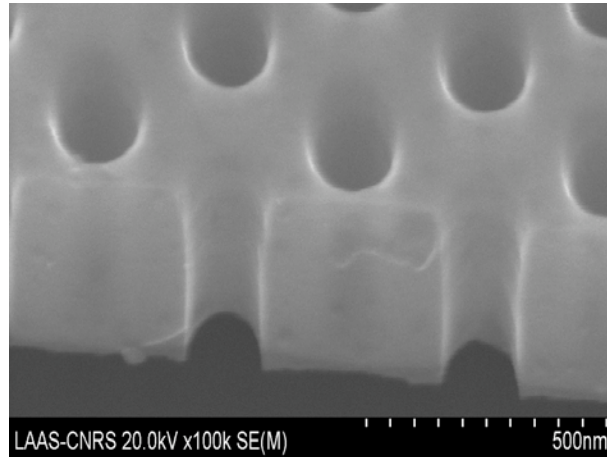


ICP Nanomachining

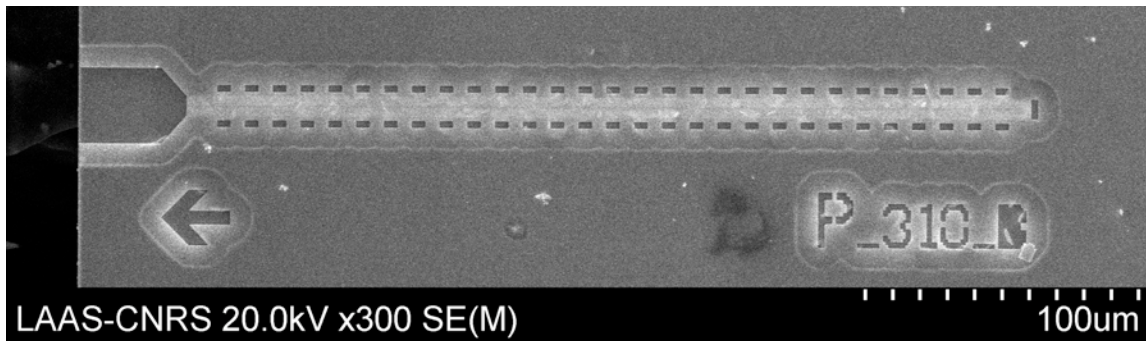
Photonic crystal lasers



15° tilted image of the etched mirror



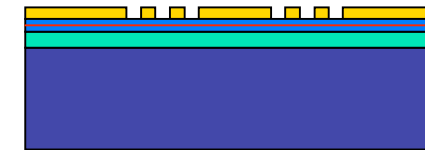
Detail image of a cleaved edge through the PhC holes



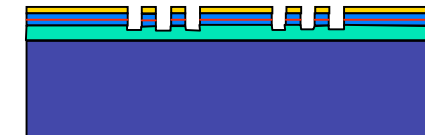
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Growth (MBE (In)GaAs/AlGaAs)



Resist spin coating
Electronic lithography



PhC etching (ICP Cl₂/N₂)



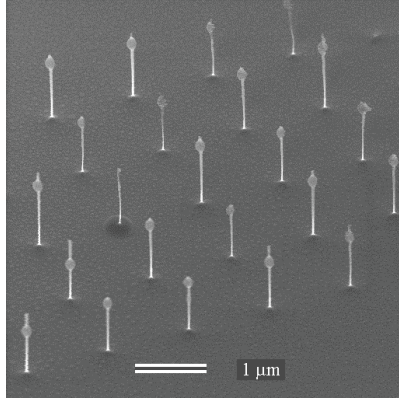
Membrane release (chemical etching)



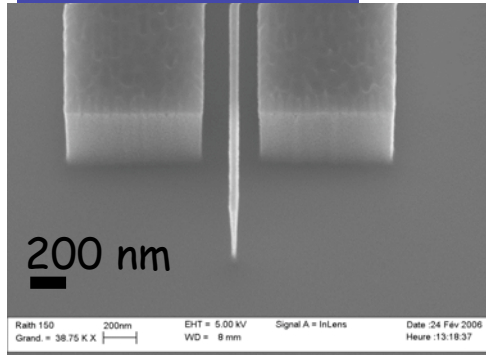
Thinning, cleavage

ICP Nanomachining

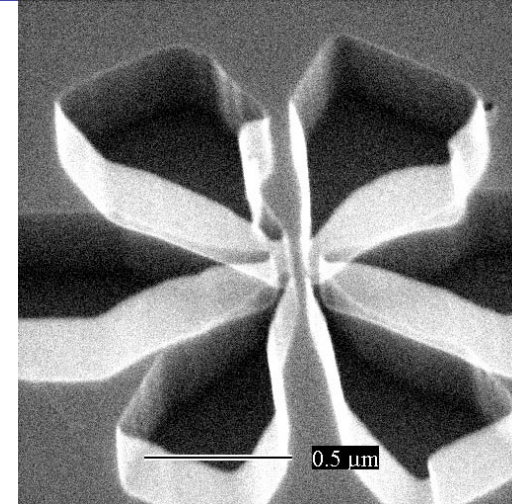
GaAs ICP nanomachining



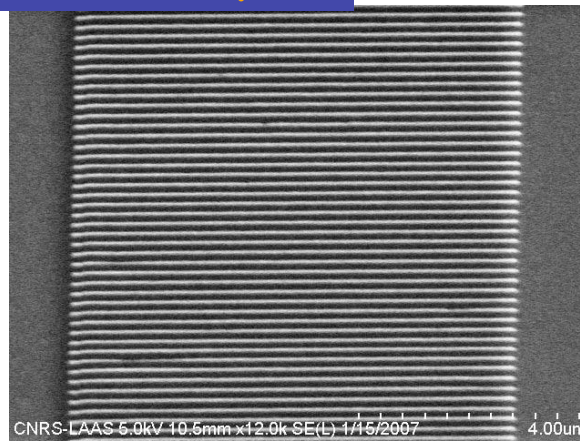
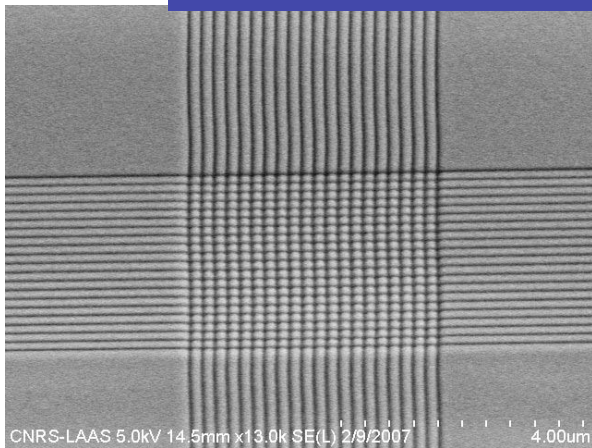
Si nanomachining



Si nanomachining for stamping



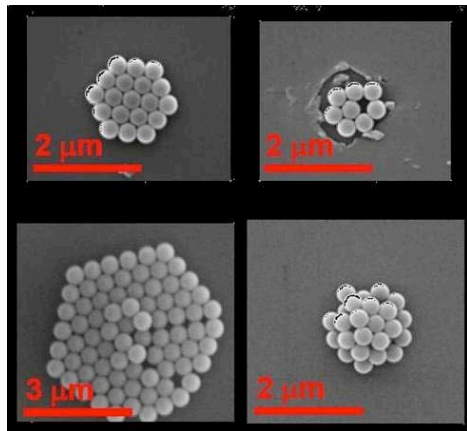
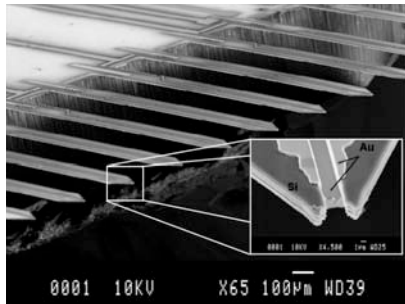
Glass micromachining for nanoimprint



Soft-Lithography and Self-Assembly

Combine top-down and Bottom-up approaches

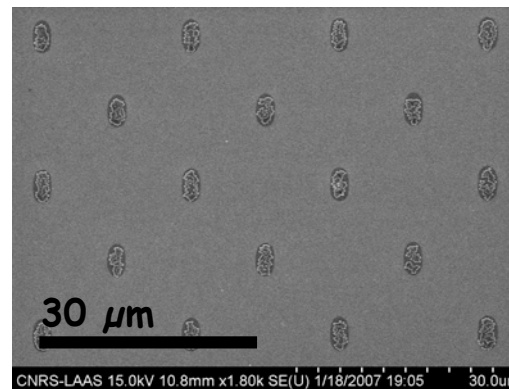
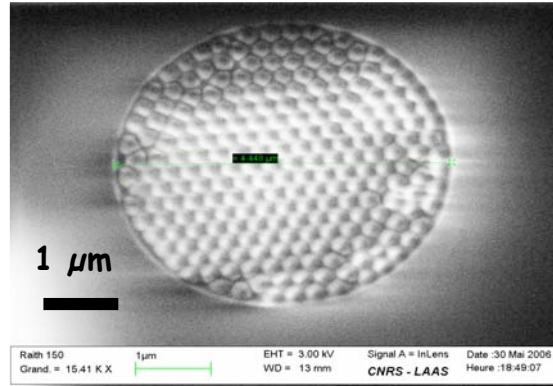
MEMS based spotter for direct self assembly



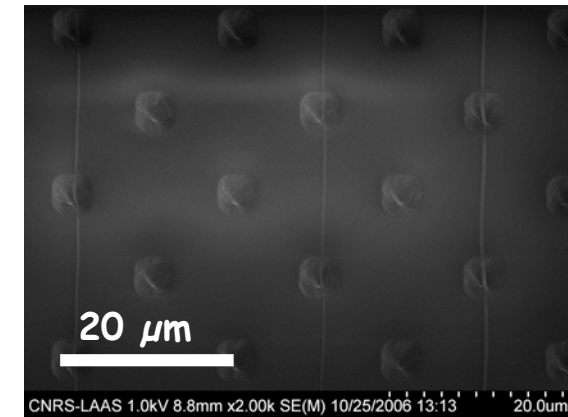
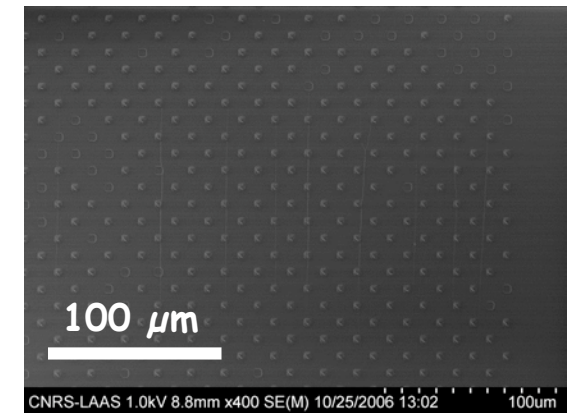
Nanobead cristal formation

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Directed assembly of ordered nanoparticles on patterns



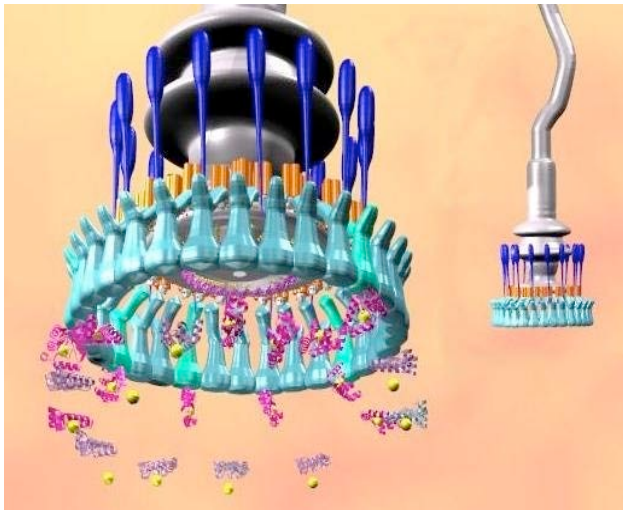
Directed assembly of DNA



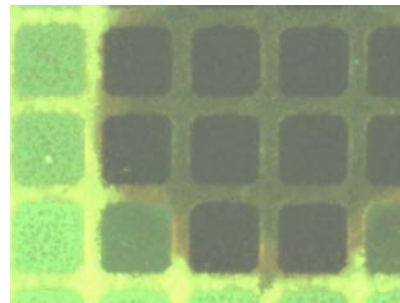
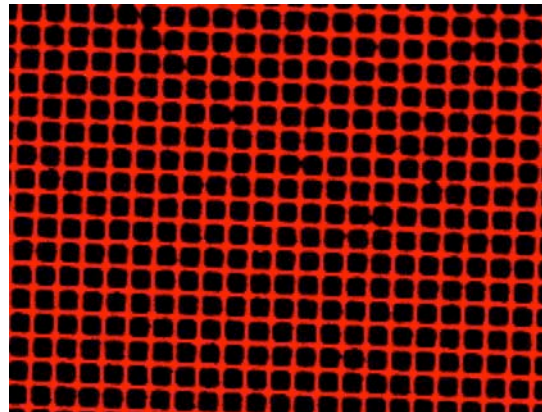
Assembling Nanobiomachines

Assemble the flagellar rotary nano-motor of bacteria on a solid surface

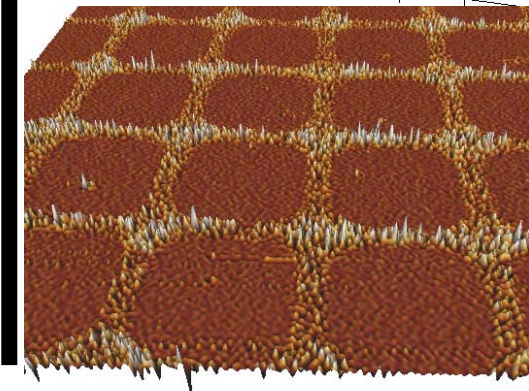
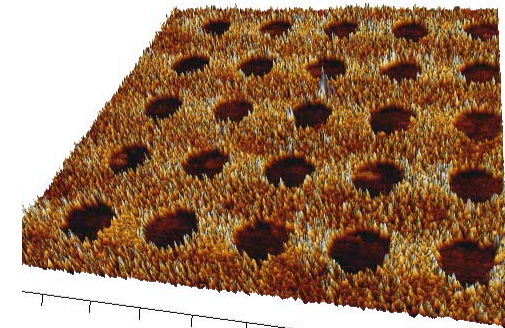
A new model for the flagellar nanomotor



Soft-Lithography and self-assembly techniques for creating nanodomains of supported lipidic membranes



Liquid AFM imaging of the assembly process



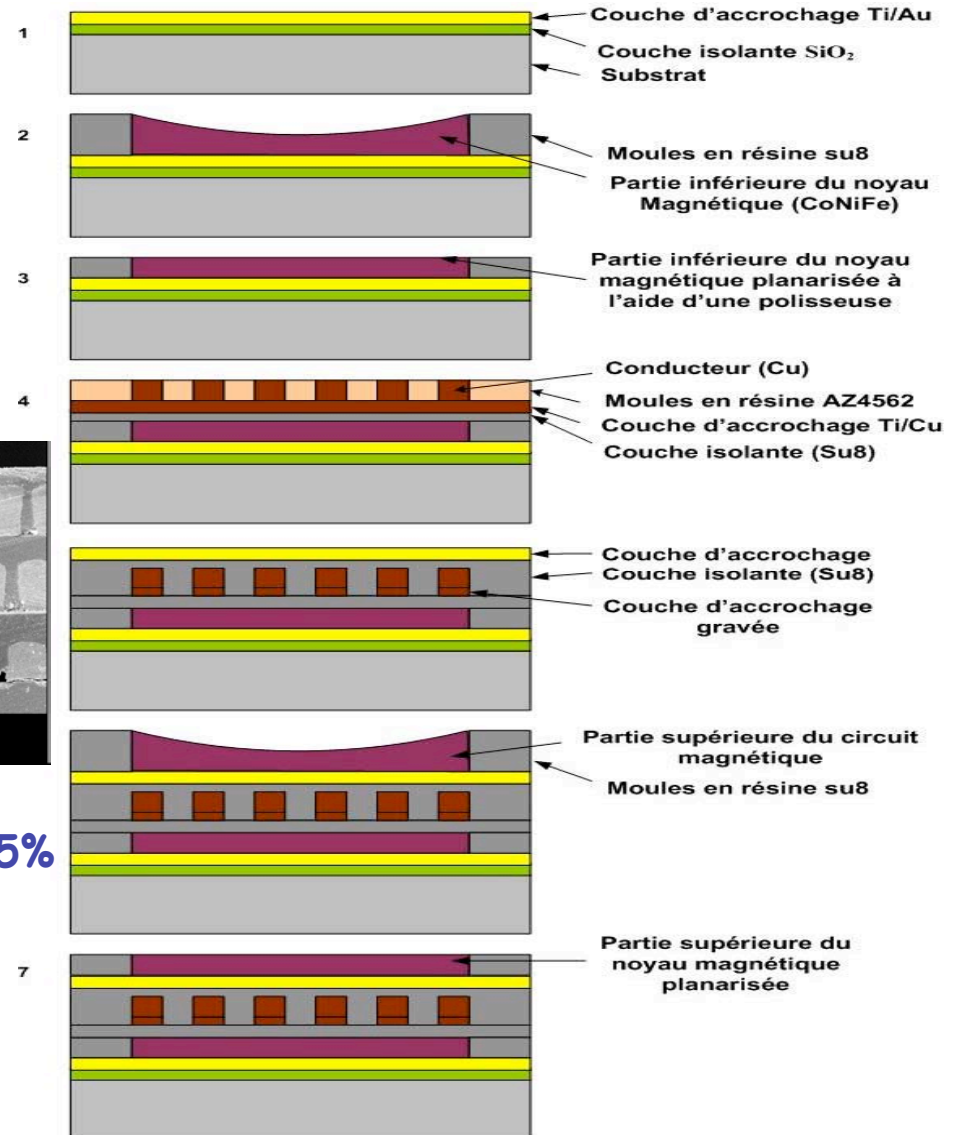
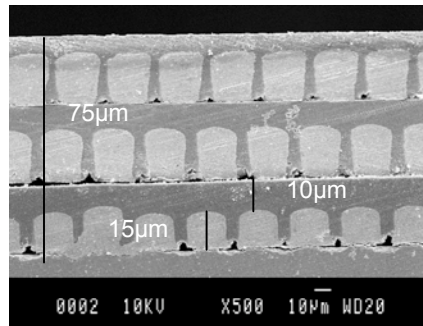
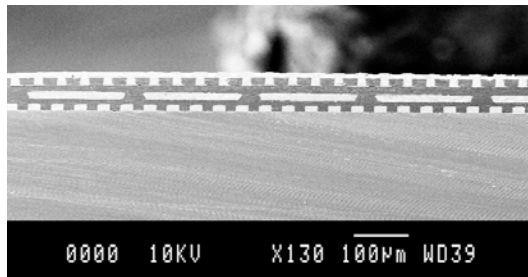
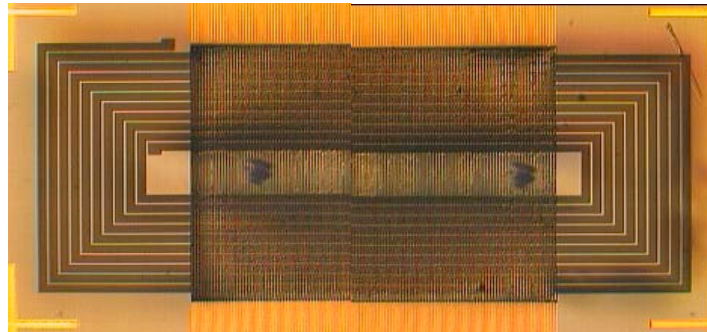


From **s.c.** to multimaterials

s.c. + metal and alloys

Electrodeposition

Magnetic coupling

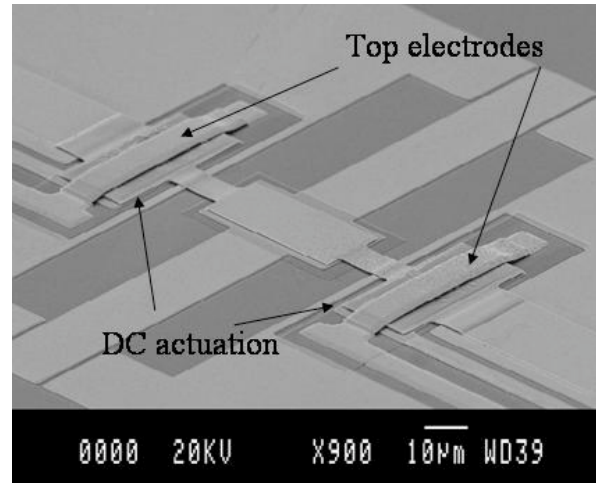
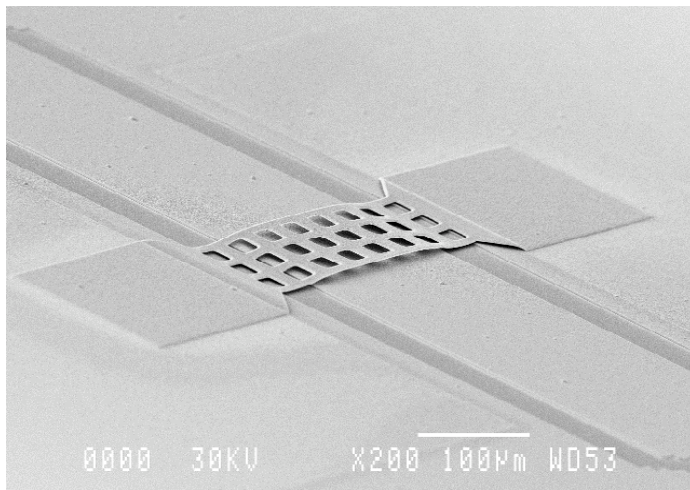


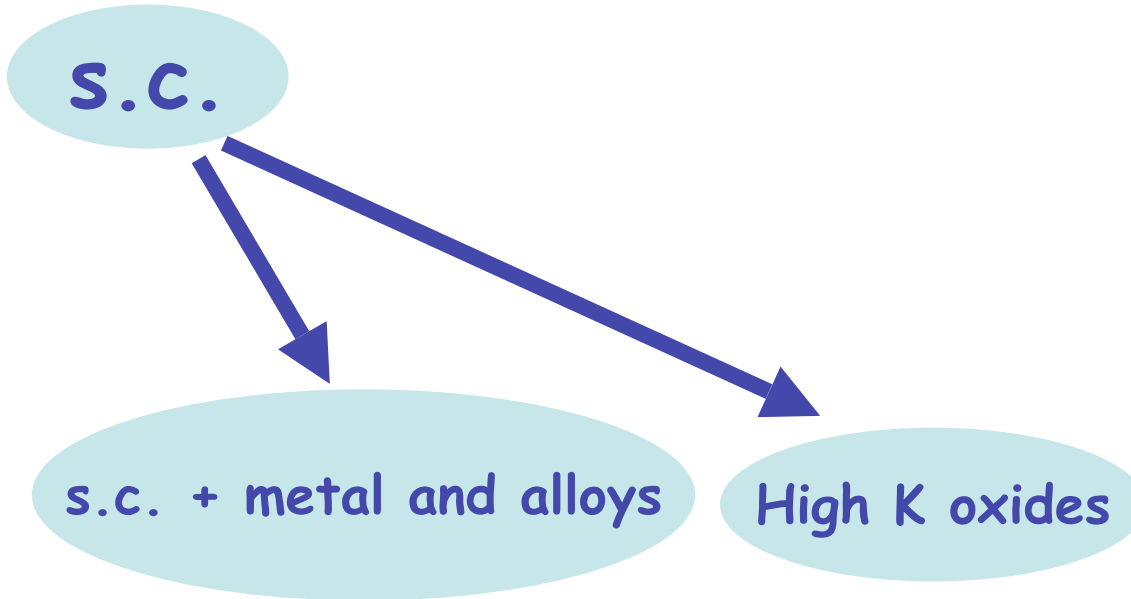
Coil: Cu
 Roughness : 20Å
 $e=20\mu\text{m}$ to several hundred
 Magnetic circuit: Fe₂₅Co₆₀Ni₁₅

Homogeneity : 5%
 Stress : 5 MPa

RF MEMS

- Wafer level gold deposition
- $e = 10\mu\text{m}$
- Homogeneity : 5%
- Roughness : 20Å
- Stress : 10 MPa

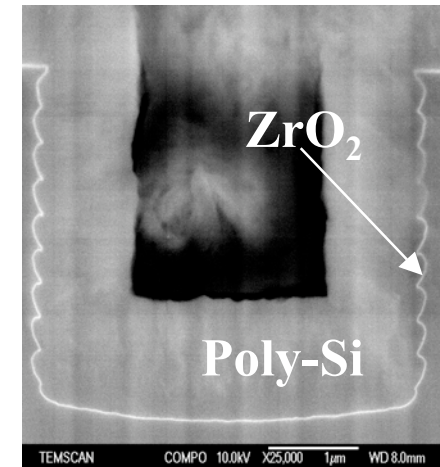
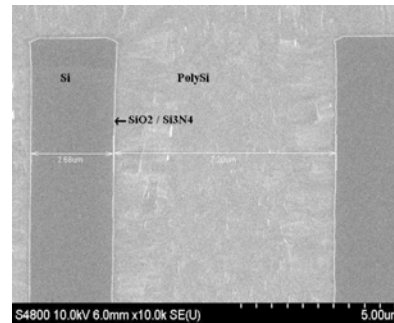
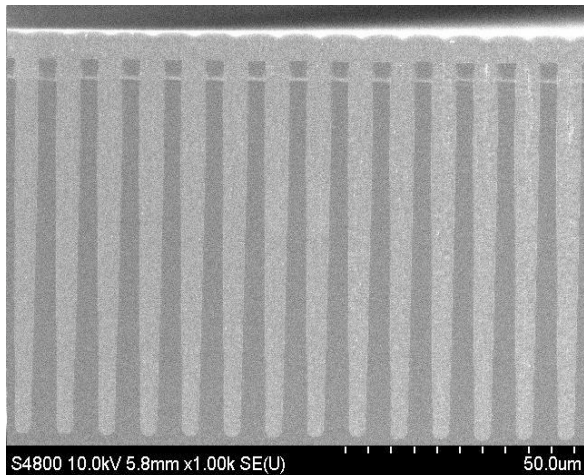
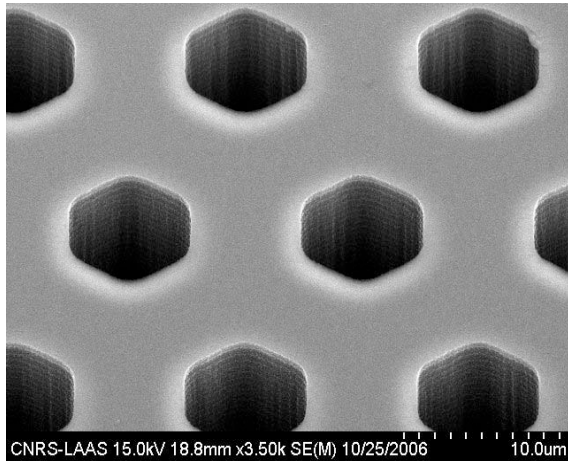




3D capacitors

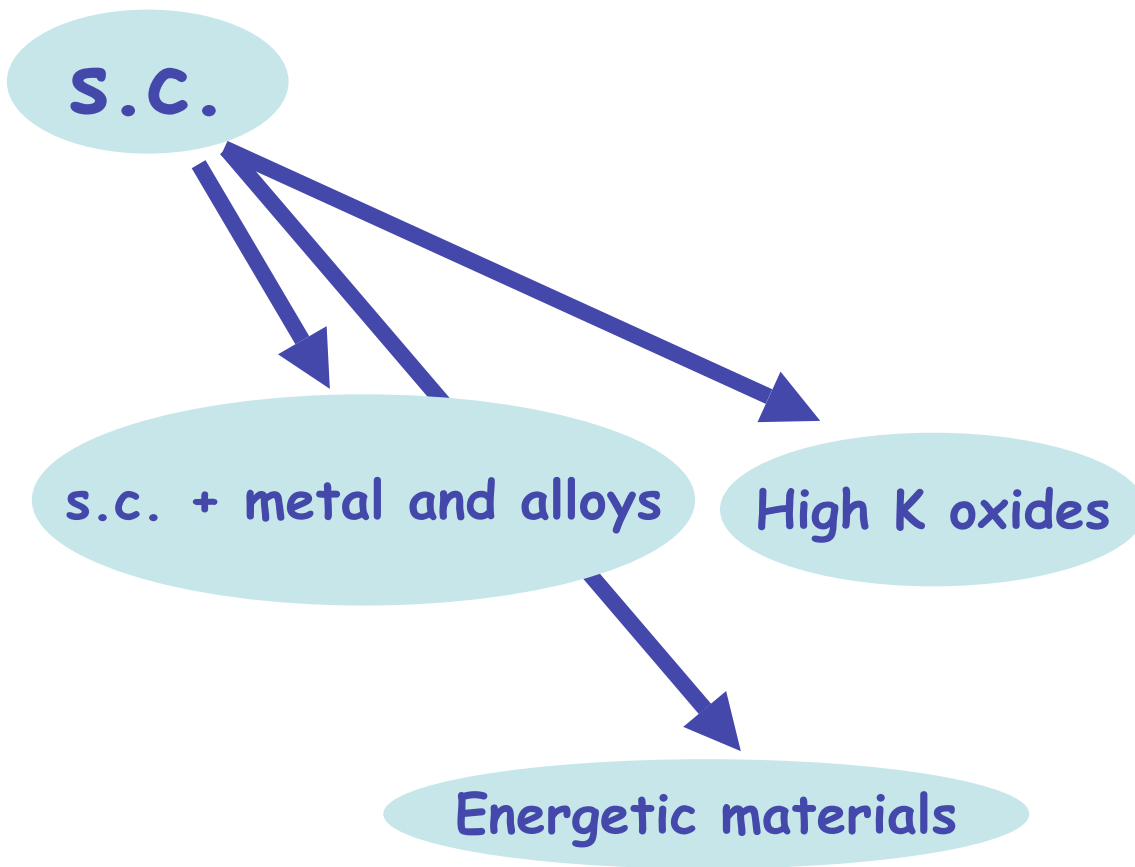
Goal: 500 nF/mm²

- Deep silicon etching (high ratio)
- Electrochemical etching
- High K deposition in trenches



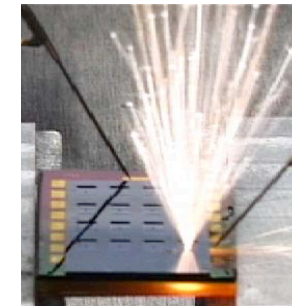
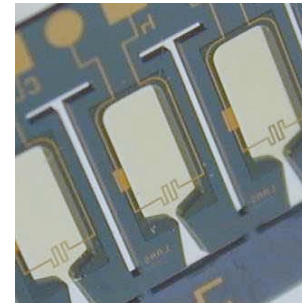
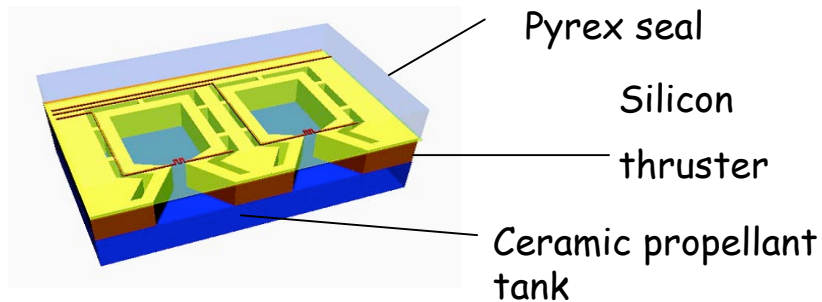
Anne-Marie Gué, 9 Novembre 2007

Partnership:
LAAS, INL, LEMHE, LCC



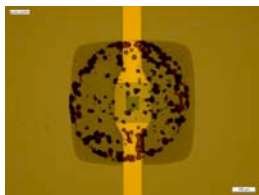
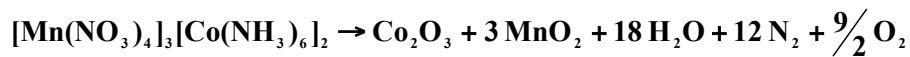
Energetic (Nano) materials for micro sources

Pyrotechnical μ thrusters



Pressure micro sources (Collaboration with LCC)

Energetic materials « gas generation » :

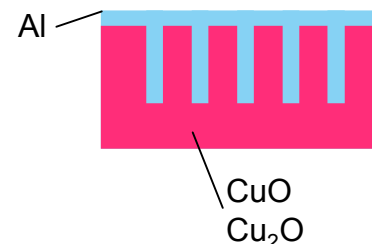
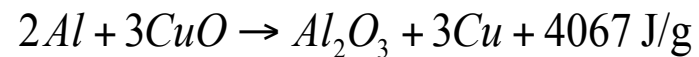


Ink jet deposition: drop $\varnothing \sim 100\mu\text{m}$
Thickness : $1.4\mu\text{m}$
Deposited mass : 195ng

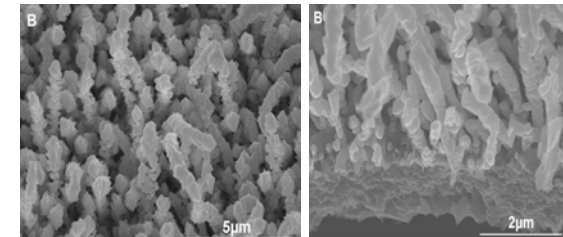
Temperature: 223°C
Energy release $\Delta H = 333\text{J/g}$
gaz : $\text{N}_2, \text{O}_2, \text{H}_2\text{O}$

Heat micro sources (Collaboration with CIRIMAT)

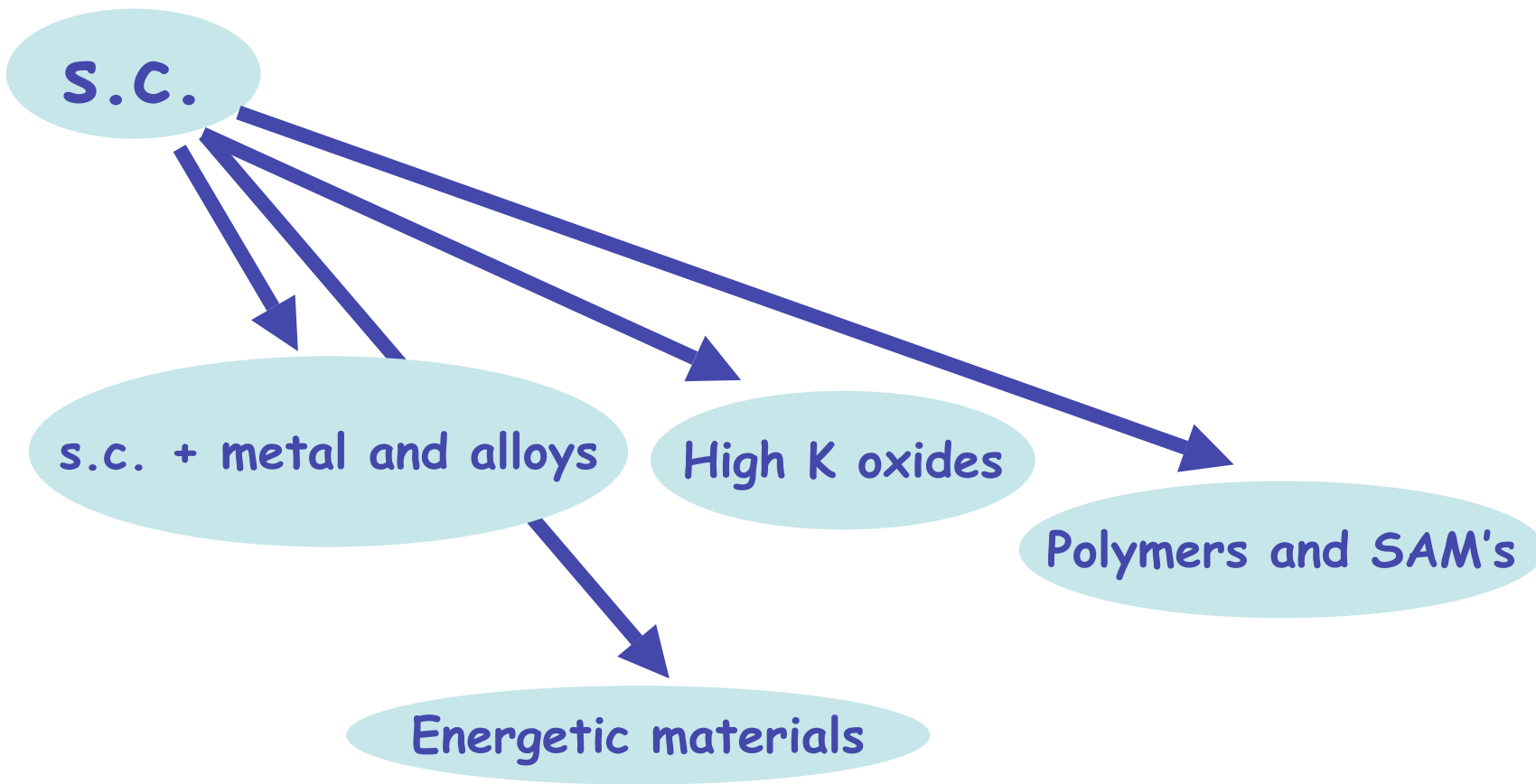
Ex: composite Al/CuO nanostructured by Al evaporation Al on a network CuO nanowires ($\varnothing : 10\text{-}50\text{nm}$)



Structure and material design



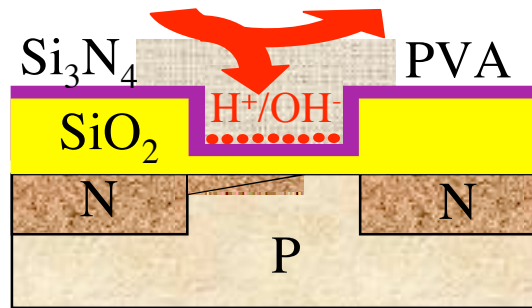
SEM photo : CuO/Al nanowires of 10nm as diam.



(Bio) Chemical Sensitive layers

Chemically-sensitive, photosensitive polymers using spin coating and photolithography standard techniques

enzymatic reaction



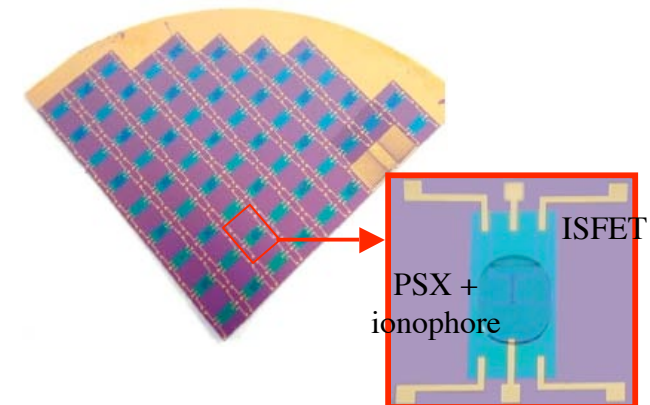
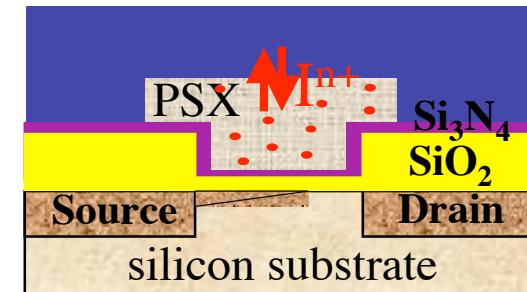
Integration of poly vinyl alcohol (PVA) based enzymatic layers on the pH-ISFET sensitive gate: realisation of EnFETs:

- Urease: $\text{CO}(\text{NH}_2)_2$ (urea) + H_2O ----> 2NH_3 + H_2CO_3
- Creatinine deiminase:
créatinine + H_2O ----> N-methyl-hydantoïne + NH_3
- Others hydrolases...

Integration of ionophores using polysiloxane-based polymers: realisation of ion-sensitive layers

Application to standard ionophores

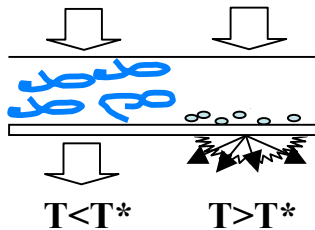
- Nonactin for the NH_4^+ ion detection
- Tetradodecyl ammonium nitrate (TDDAN) for the NO_3^- ion detection
- Valinomycin for the K^+ ion detection
- Monensin for the Na^+ ion detection
- ...



Active polymers for micro optics

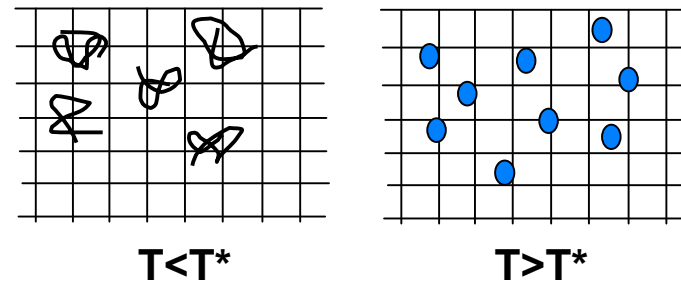
Light diffusion

PNIPAM in H₂O



0.3 s / 3s; [670-1070] nm
attenuation \approx 38 dB,
for all polarizations

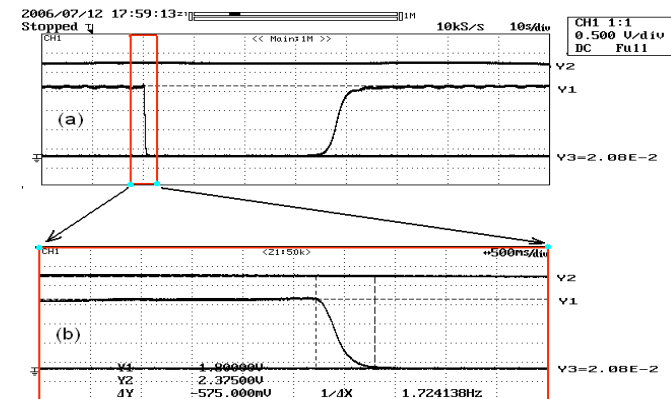
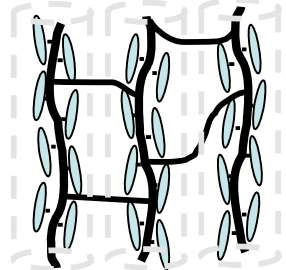
PNIPAM encapsulated in Hydro gel



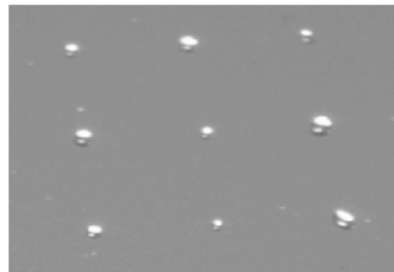
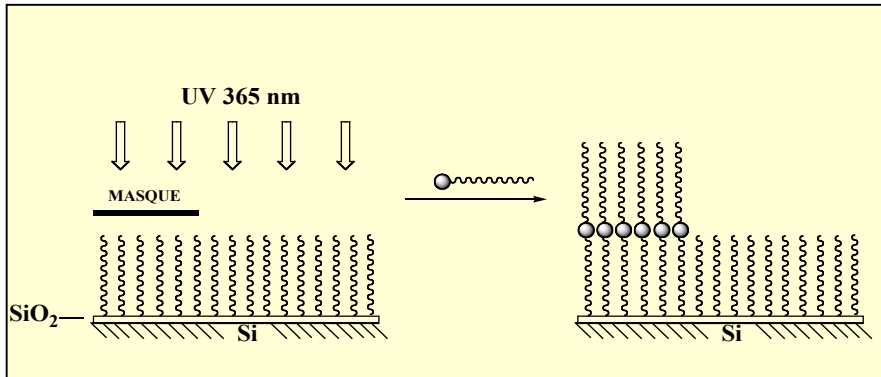
Phase modulation through thickness variation

Gel and liquid cristal : electro active

Coll. P. Keller (Inst. Curie)
L. Mager, S. Mery (GMO-IPCM, Strasbourg)



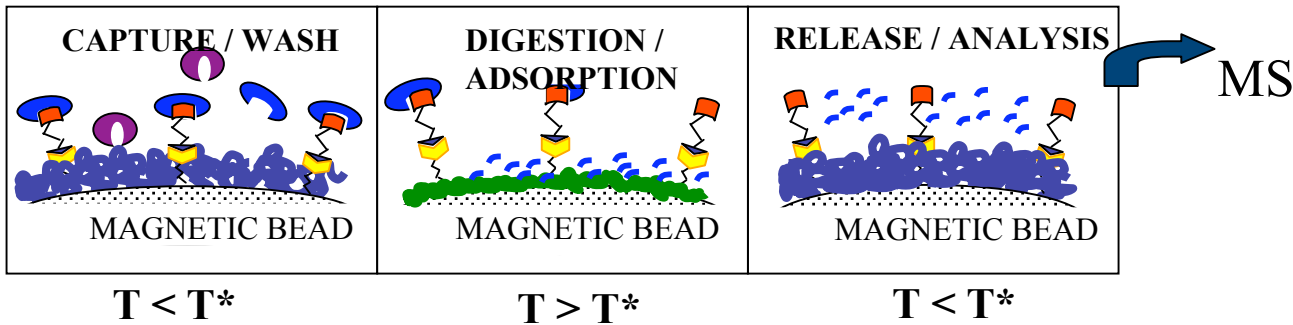
Patterning hydrophilic and hydrophobic areas using standard photolithography (365 nm)



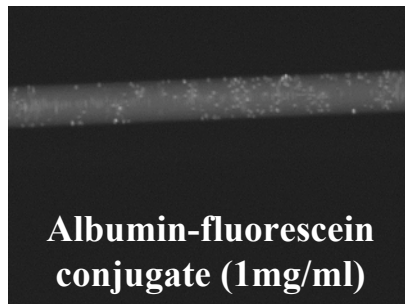
Hydrophilic spots
10 to 100 μm

Contact Angle
 $\theta = 112^\circ$
 $\Delta\theta = 77^\circ$

Stimuli responsive surface



ΔT \updownarrow 32°C



Chemical genomics

Concluding remarks

- We are ready to take up the challenge ...
- ... but it is a huge task and almost a new job
- We need partners !!! :

material synthesis and elaboration, chemistry, surface chemistry, biochemistry, physics of fluids and interface, ...

- Many thanks to all of my colleagues
- Thank you for your attention