# CMP Process Developments for Emerging Microelectronics Device Fabrication

## CMPUG 2024 Winter Symposium

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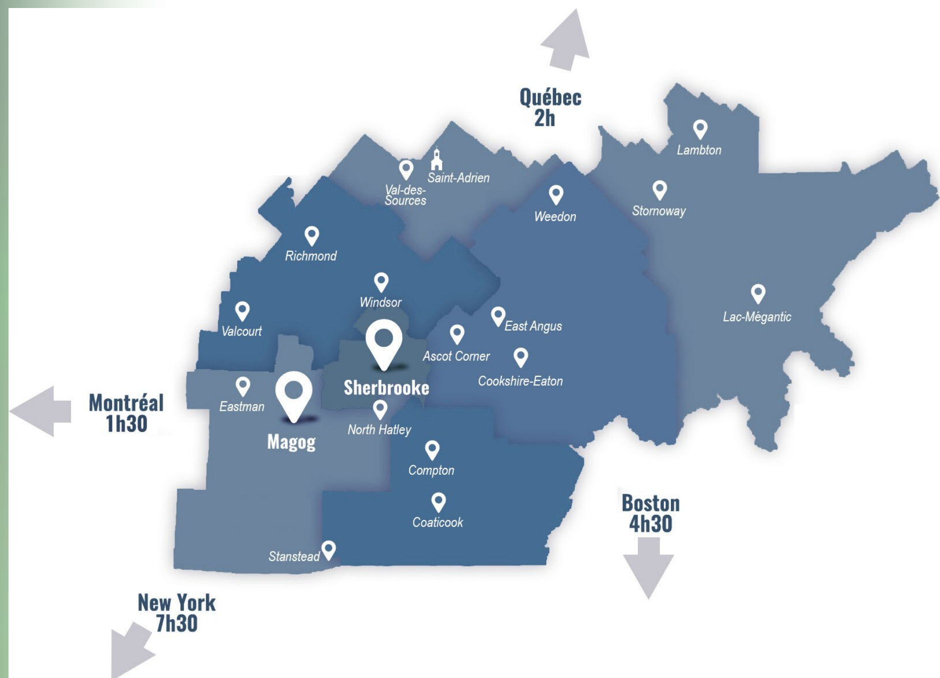
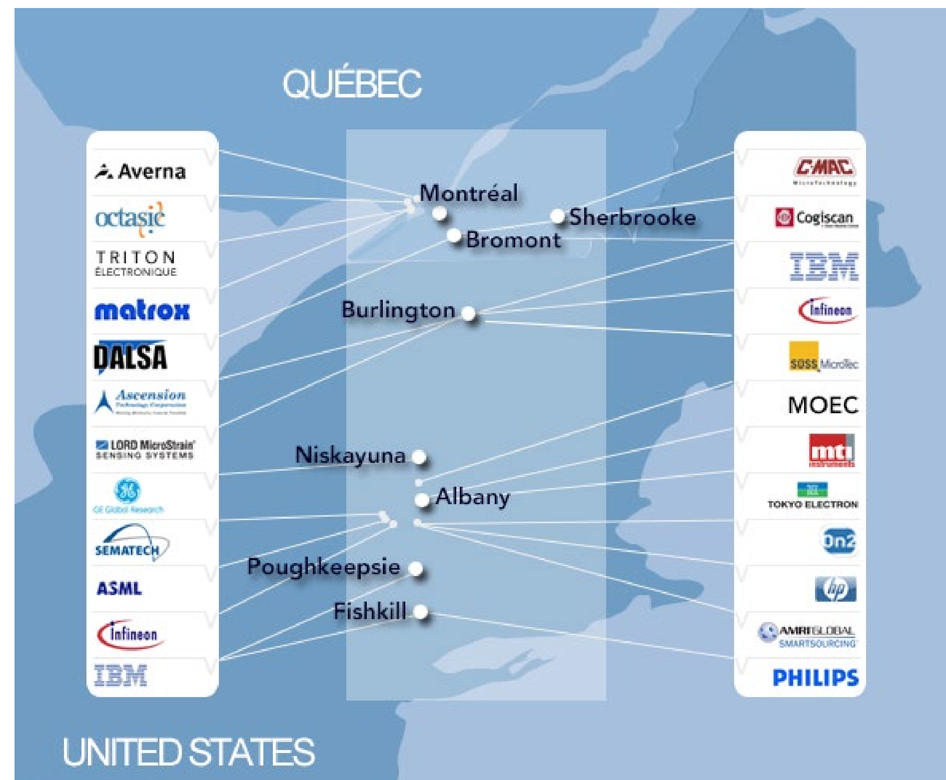
05/12/2024

serge.ecoffey@usherbrooke.ca

# Université de Sherbrooke




UdS Université de Sherbrooke

**31 170** Effectif étudiant

**8 291** Membres du personnel

**4 294** Effectif étudiant

**30** Chaires de recherche

**710 dont 120 Profs** Membres du personnel

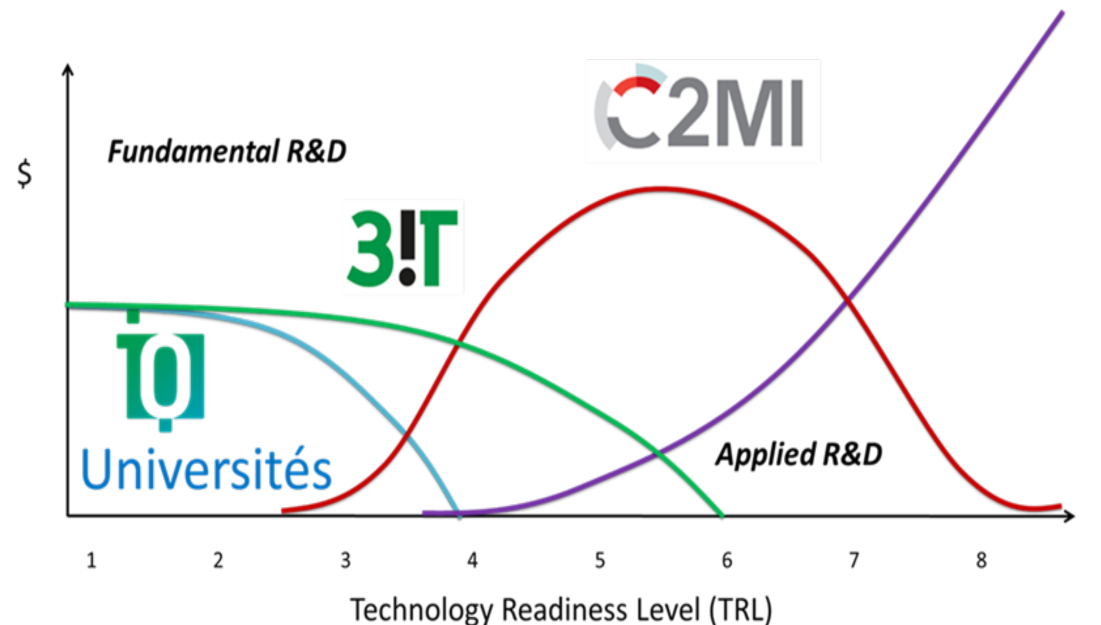
Source: usherbrooke / lebeam.ca / investquebec.com

# Integrated Innovation Chain

From quantum science to …

… to microelectronic devices and systems proof of concept to…

… prototyping and production.



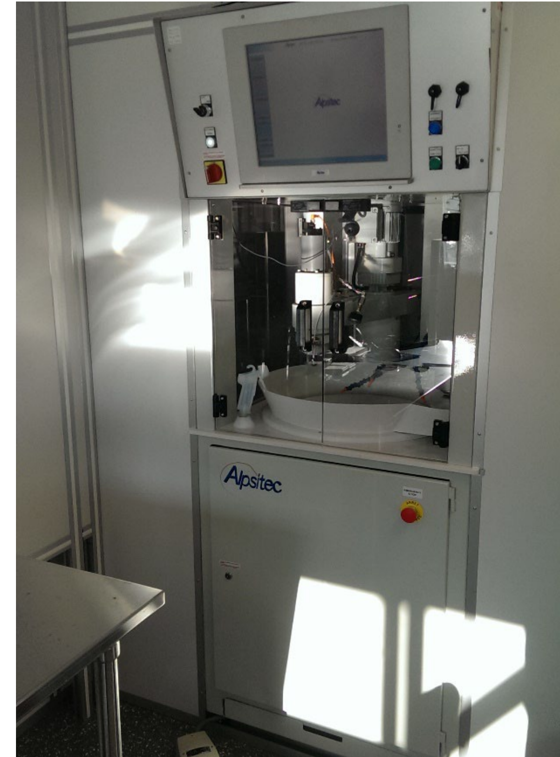

IBM

TELEDYNE DALSA
Everywhereyoulook

3!T

# 3IT.nano

**3IT.nano**
- 530 $m^2$ class 100 clean room (ISO 5)
- 1000 m2 of ISO 8 clean room for test
- 50 M$ in equipment and infrastructure
- Up to 200 mm wafer tools
- 25 full time professionals/technicians
- 3 M$ of operating budget



**Alpsitec E460 R&D tool**
- 4", 10x10 $mm^2$, 22x22 $mm^2$
- Si, Ge, SiGe, ISDP
- SiO2, SiN, Al2O3, NbN
- Ti, TiN, W, Nb, Cu, Al, Au, Pt

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# Content

- Metallic single electron transistors (SET)
- Crossbars BEOL integration
- Nanostructured plasmonic arrays

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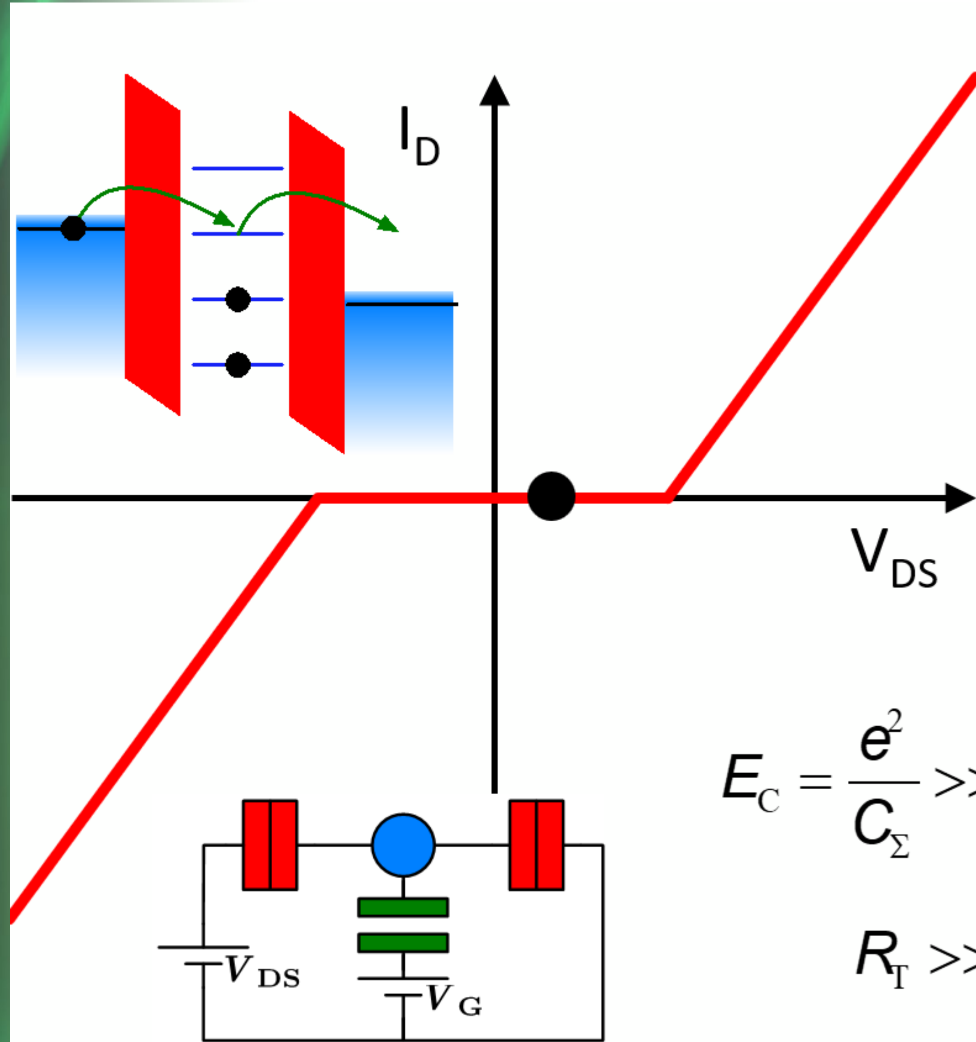
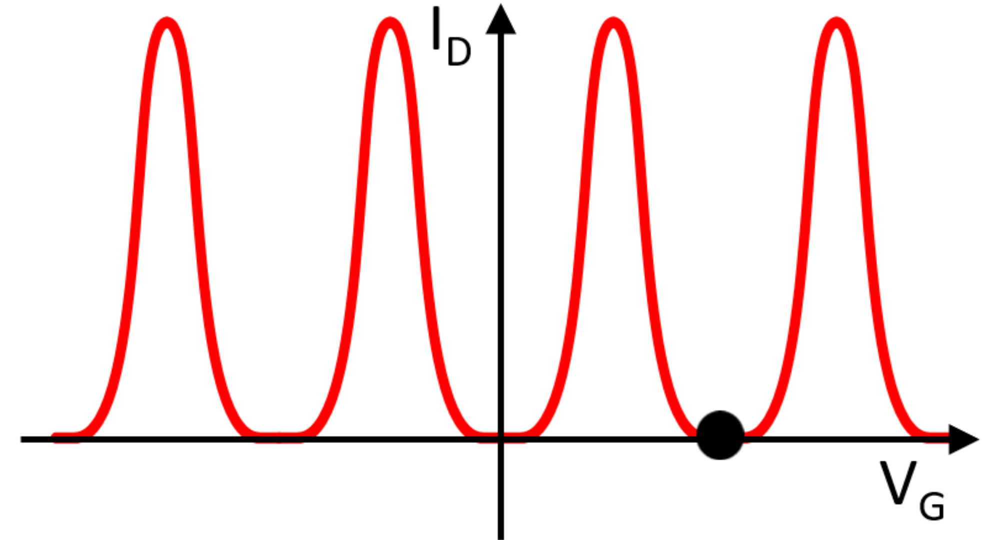
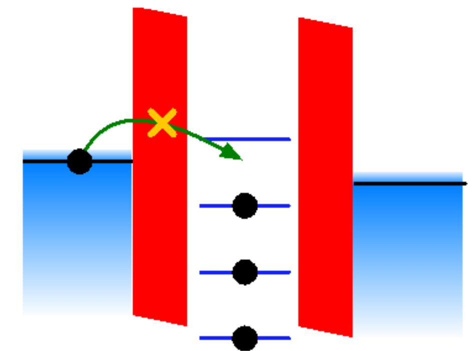
# SET: quick reminder




$$E_C = \frac{e^2}{C_\Sigma} >> k_B T \text{ (~26 meV à 300 K)}$$

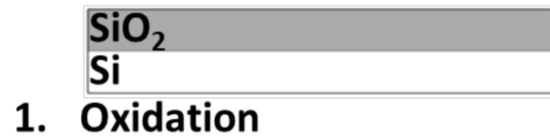
$$R_T >> R_Q = \frac{h}{e^2} = 25{,}8\ \text{k}\Omega$$



G. Droulers, PhD Thesis defense, 2016

# Metallic SET: nanowire

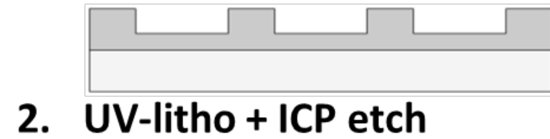
## *Nanodamascene* process flow




1. Oxidation

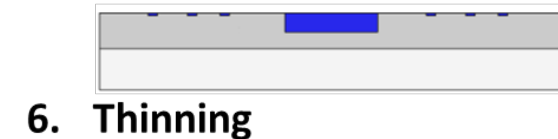
3. E-beam litho + ICP etch

5. Planarization

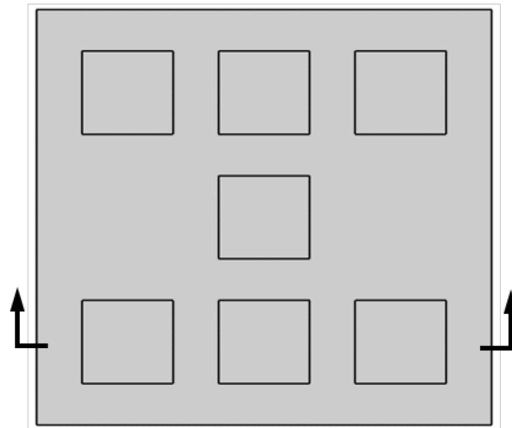


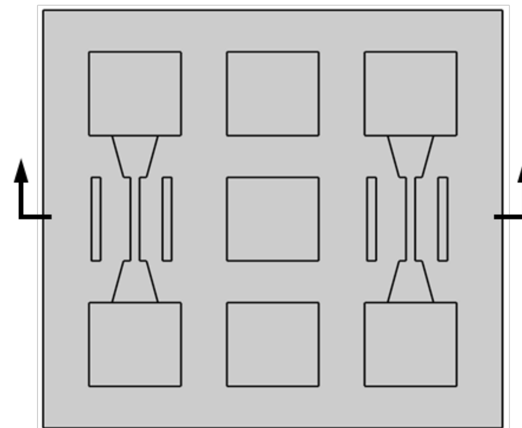
2. UV-litho + ICP etch

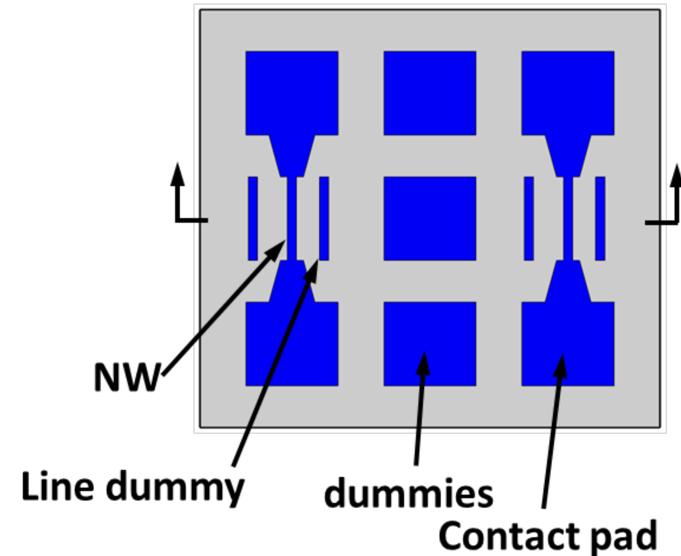
4. Ti sputtering



6. Thinning





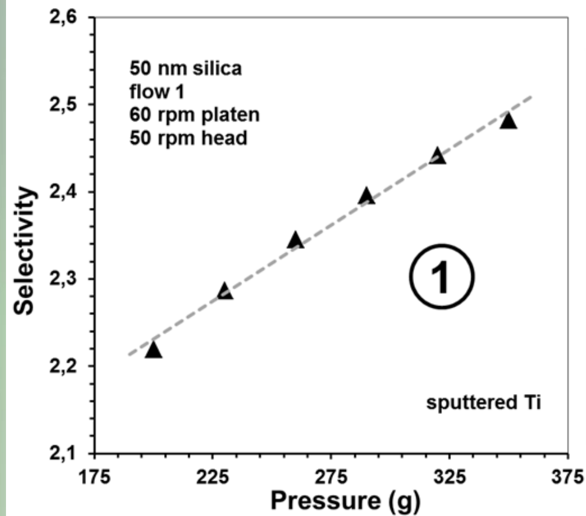


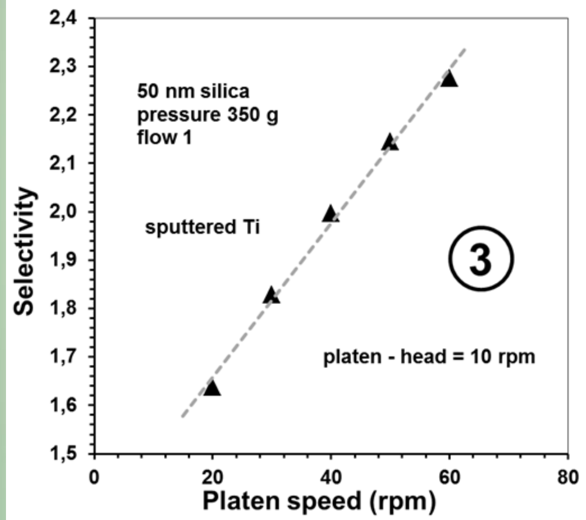

Multiple aspect ratios: 1:1, … , 1:33, … , 1:100
20x20 nm, … , 40 nm x 5 µm

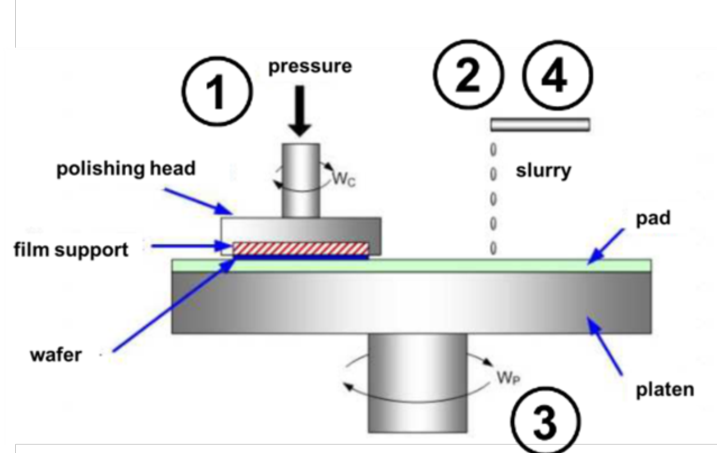
Micro / nano- structures

*M. Guilmain et al,. Nanotechnology 24, 2013.*

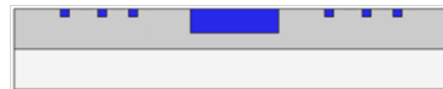
# Metallic SET: nanowire



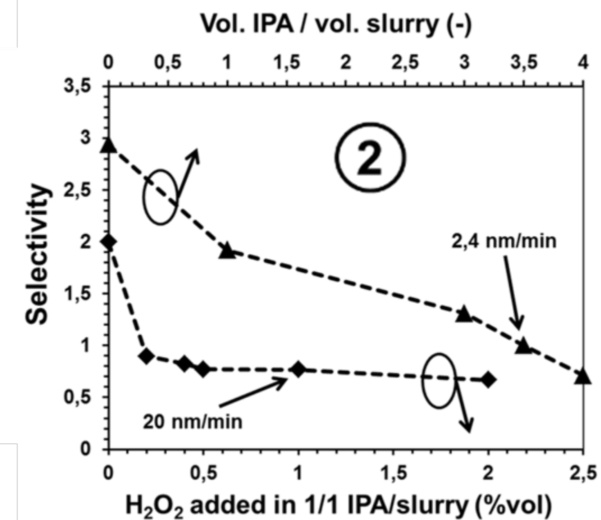



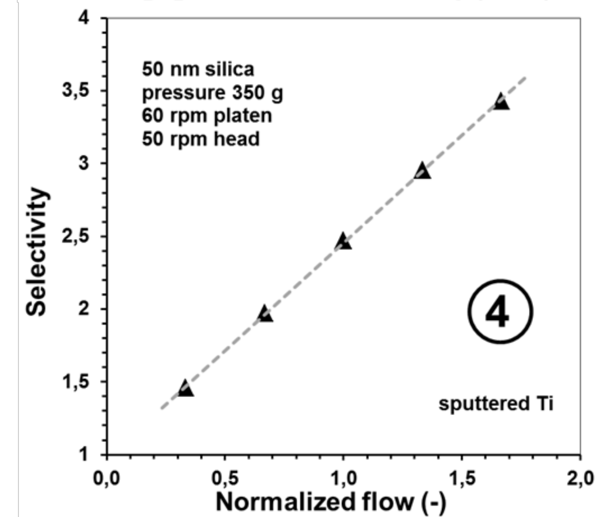




- 50 nm silica slurry
- Low removal rate
- $SiO_2$ mechanical
- Ti chemical etching
- $H_2O_2$ for Ti oxidation
- Dilution decr. $SiO_2$ RR
- IPA dilution
- With / without etch stop



5. Planarization



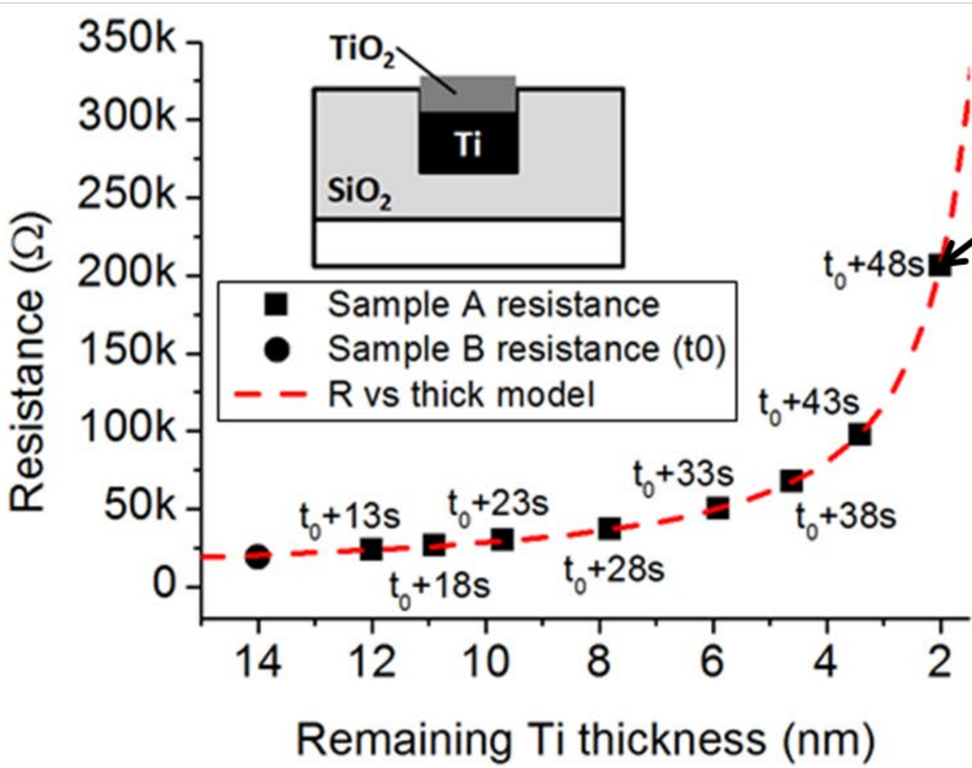



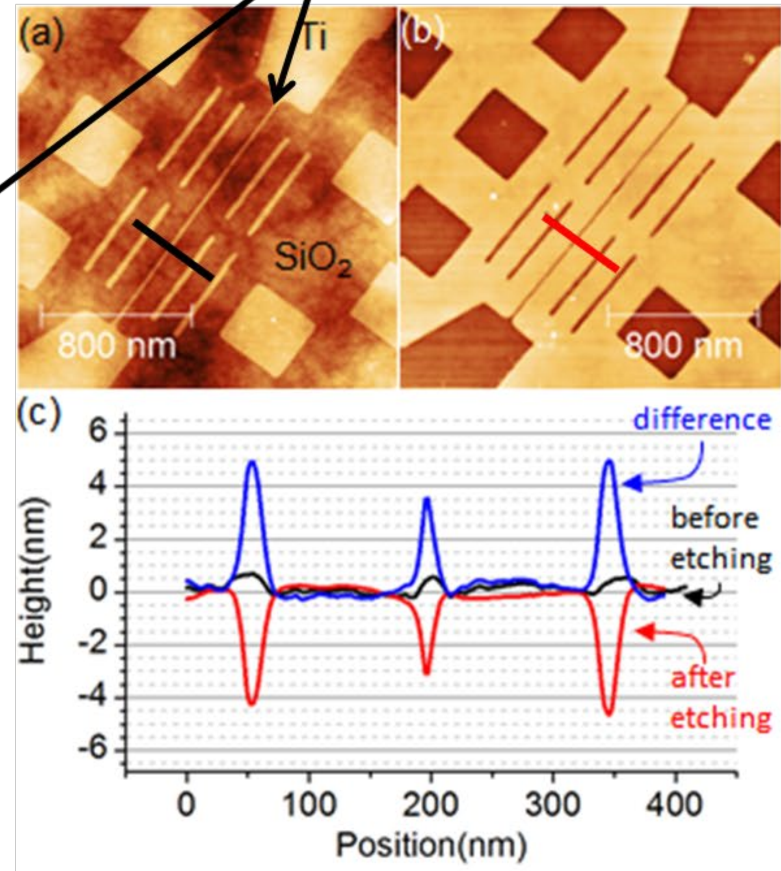

*S. Ecoffey et al,. SPIE Advanced Lithography 2017*

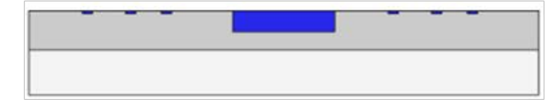
# Metallic SET: nanowire

- **Resistance versus thickness model**
- **In-process non destructive measurement**

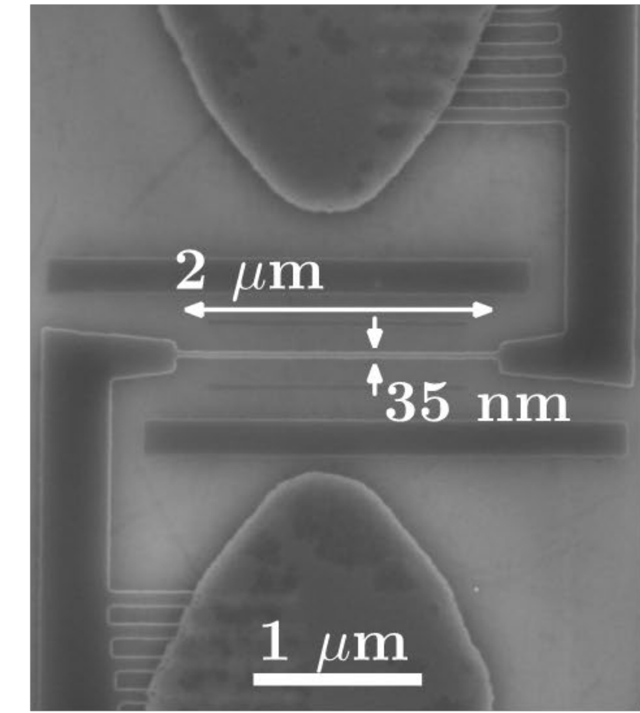
**2 nm x 15 nm x 1,5 µm**



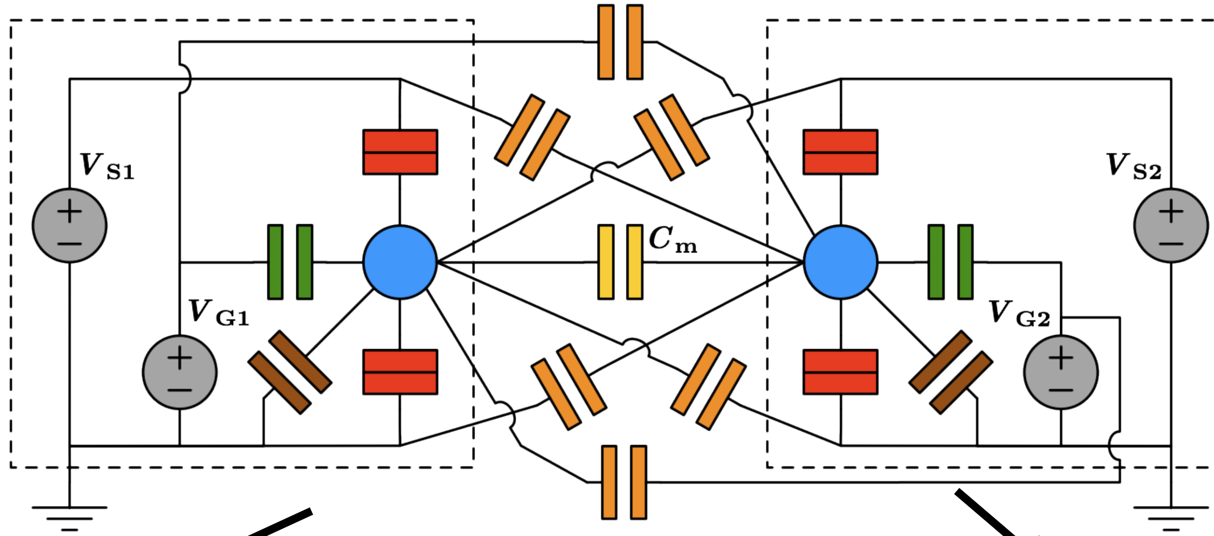
6. **Thinning**



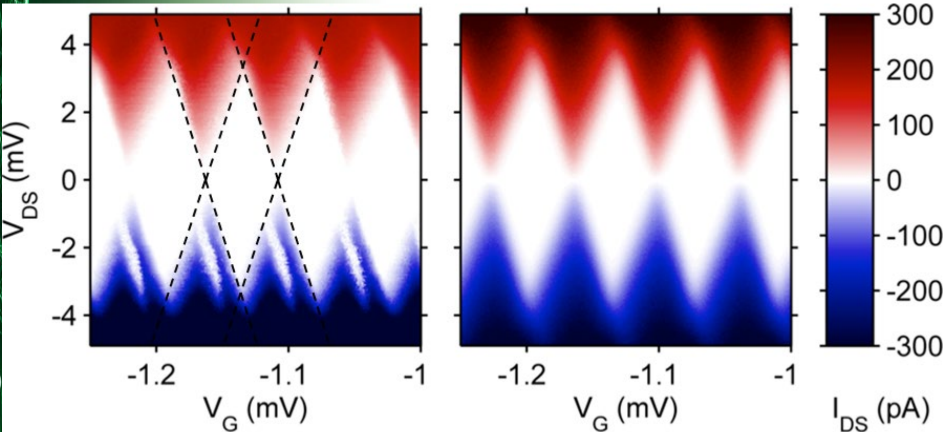

*M. Guilmain et al,. Nanotechnology 24, 2013.*

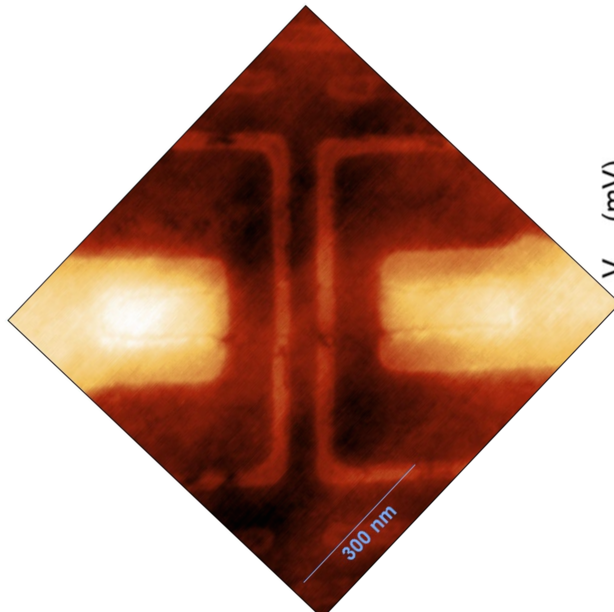
# Metallic SET: charge detection

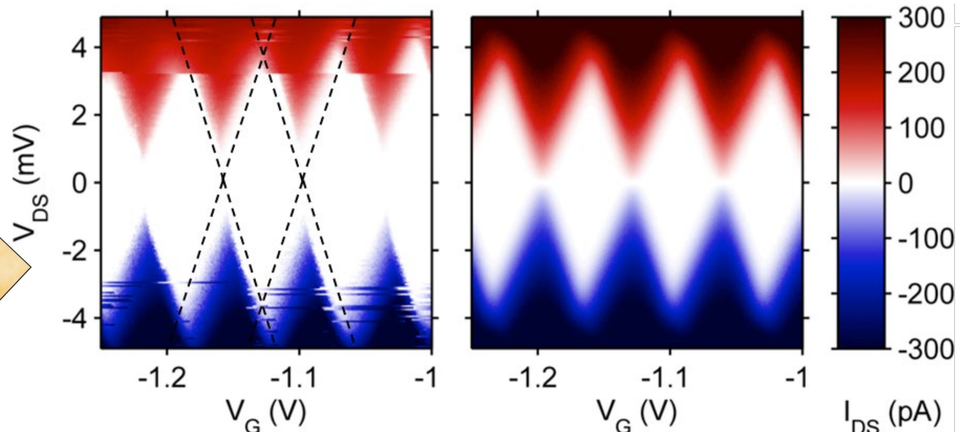
| | Exp | Sim |
|---|---|---|
| $C_1$ (aF) | 21 | 20 |
| $C_2$ (aF) | 21 | |
| $C_g$ (aF) | 2,3 | 2,4 |
| $C_\Sigma$ (aF) | 45 | 42 |
| $E_C$ (meV) | 3,6 | 3,8 |




| | Exp | Sim |
|---|---|---|
| $C_1$ (aF) | 20 | 20 |
| $C_2$ (aF) | 19 | |
| $C_g$ (aF) | 2,6 | 2,6 |
| $C_\Sigma$ (aF) | 42 | 43 |
| $E_C$ (meV) | 3,8 | 3,7 |




G. Droulers, IEEE ESSDERC 2016

*TiO2 (oxidized Ti) junctions*

***Electrical characterization @ 50mK***

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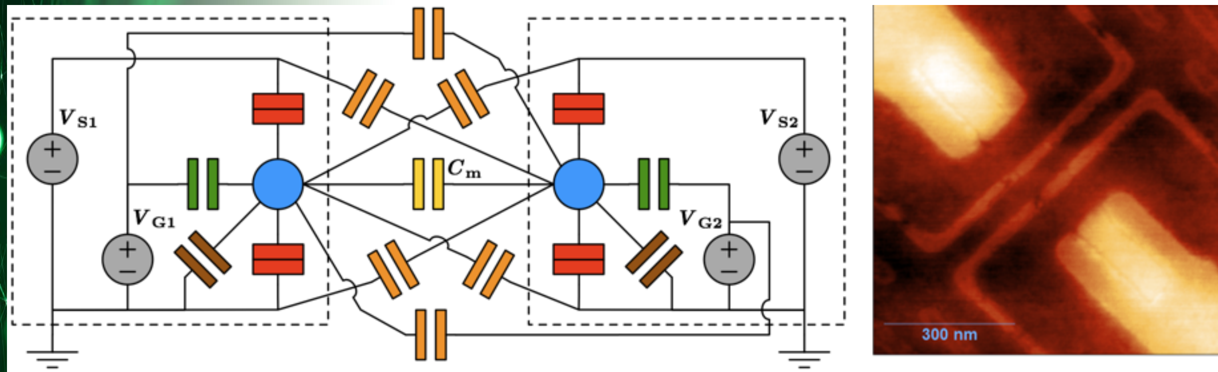
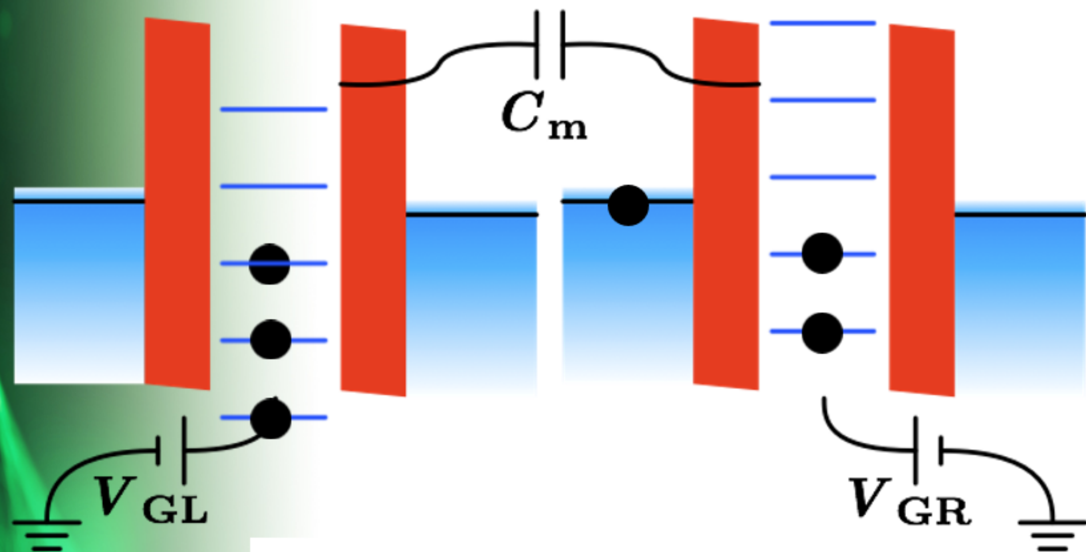
# Metallic SET: charge detection



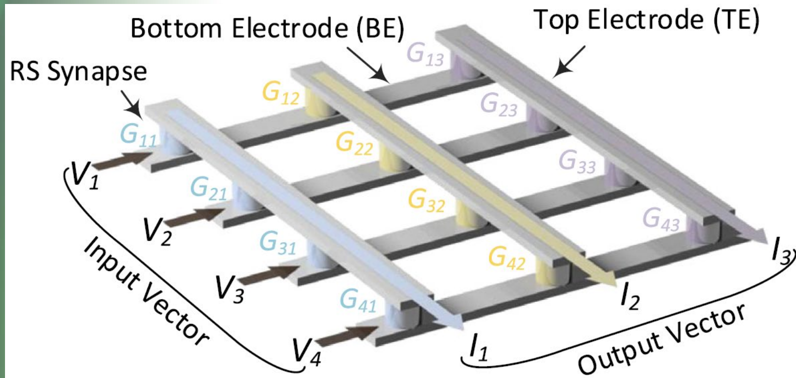

SET operated in charge detection mode with neighboring electron box

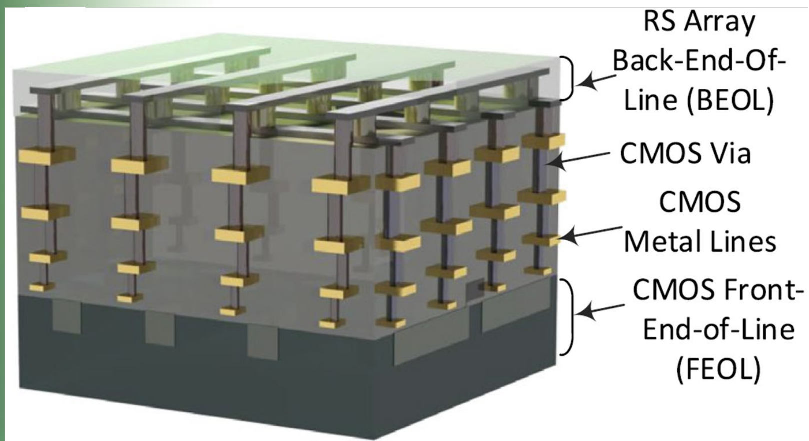


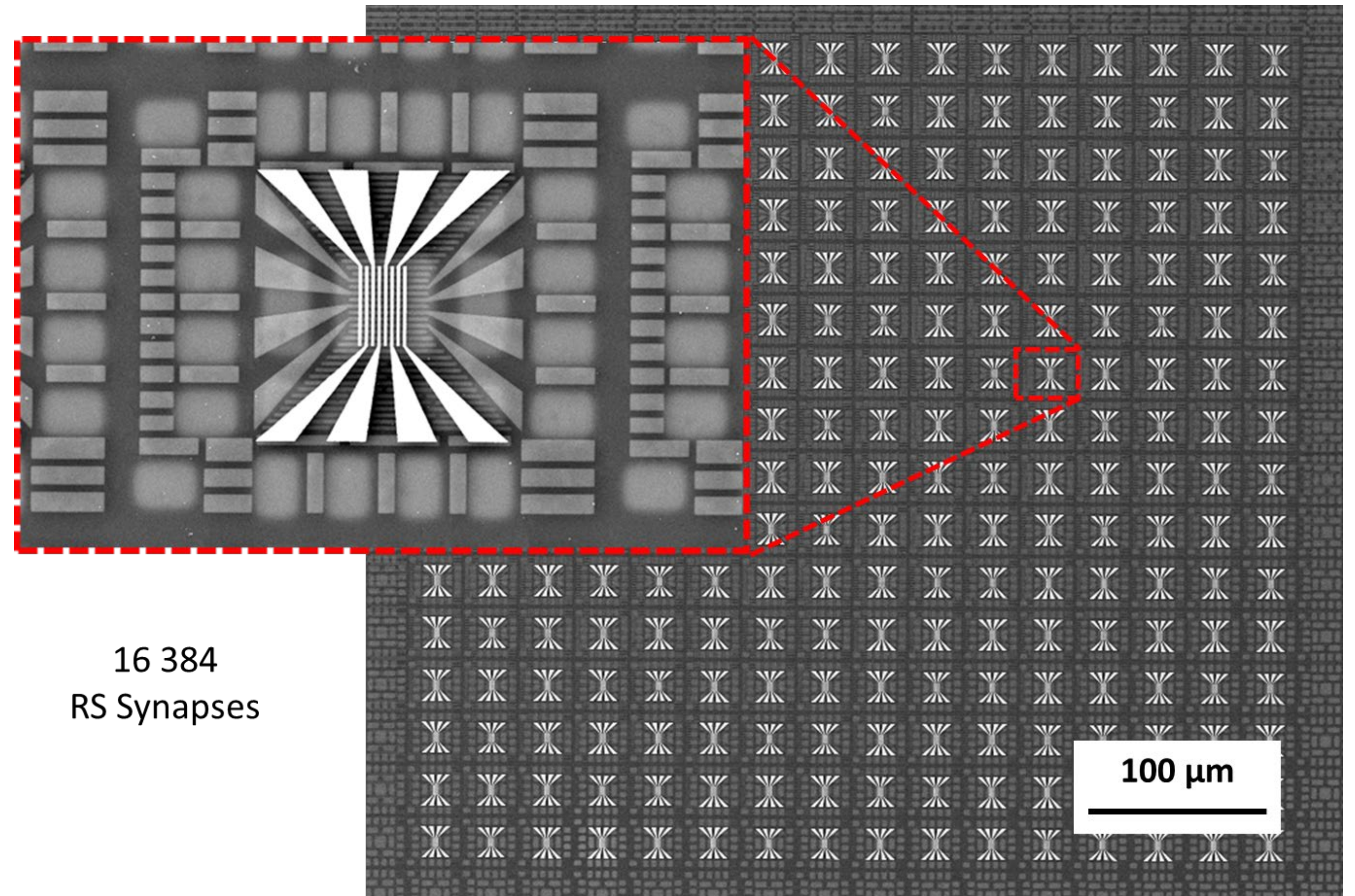

*G. Droulers, IEEE ESSDERC 2016*

Crossbars BEOL integration

# Crossbars BEOL integration



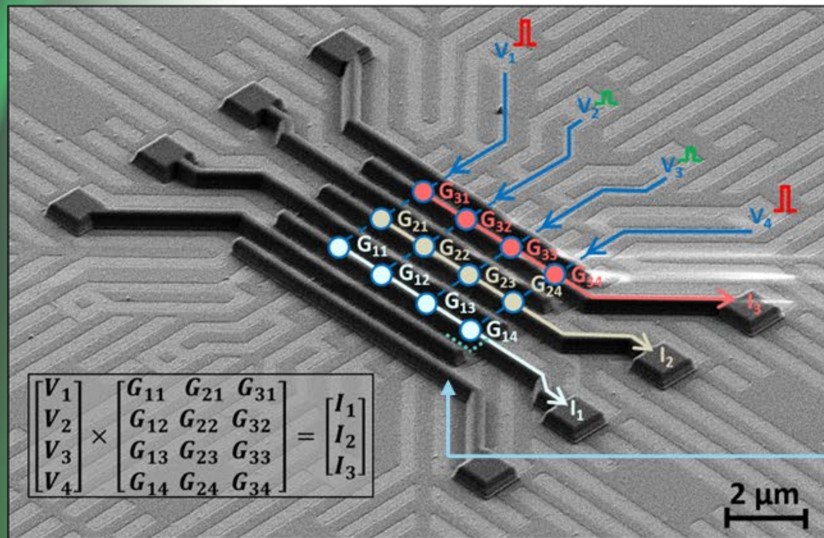



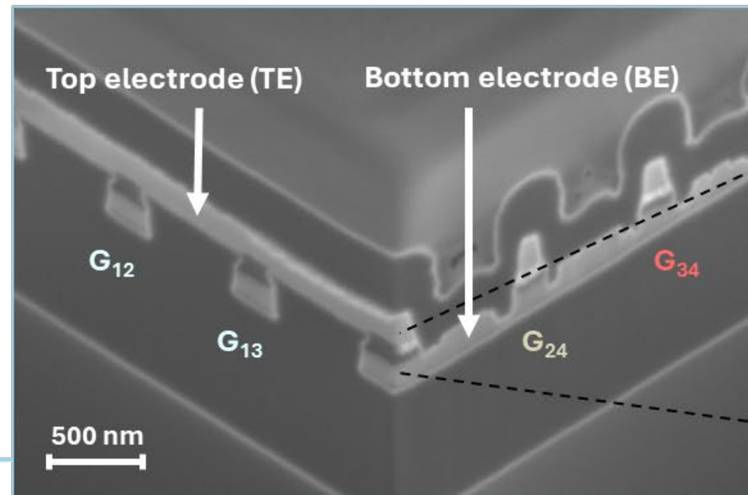



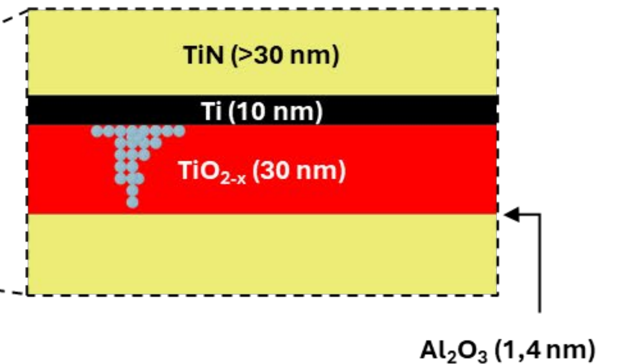

*A. Amirsoleimani, Adv. Intell. Syst. 2020*

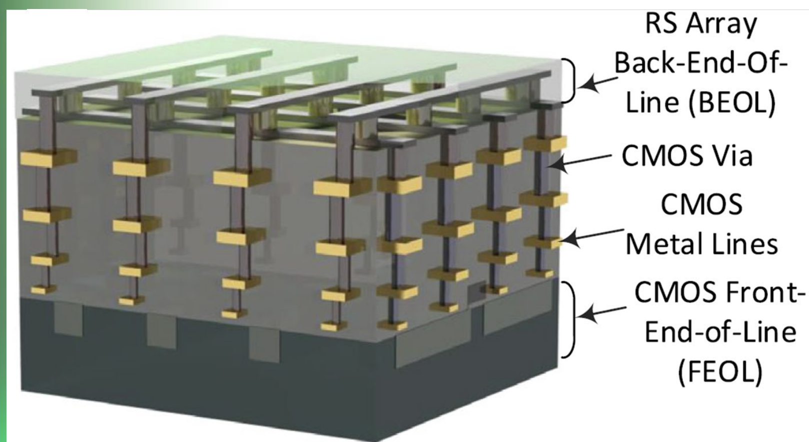
*R. Dawant, PhD thesis, 2024*

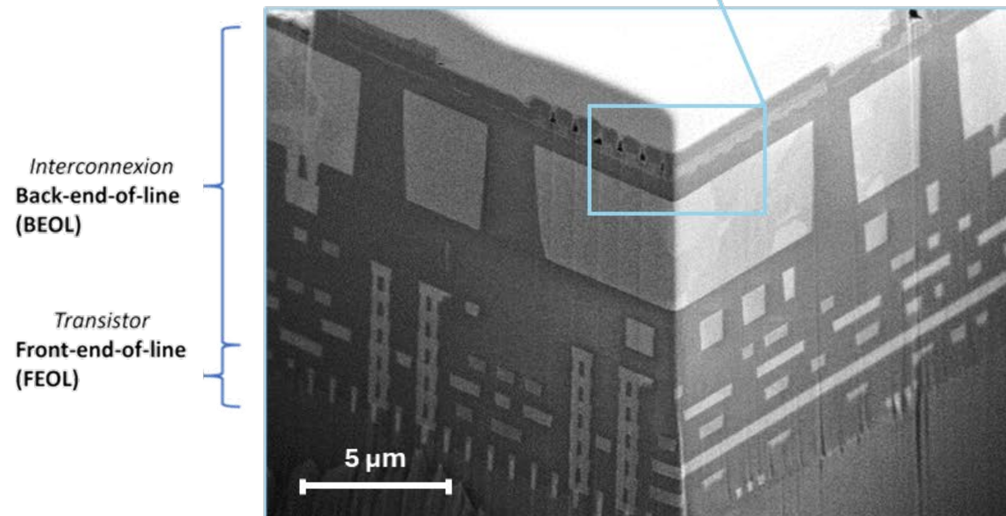
# Crossbars BEOL integration



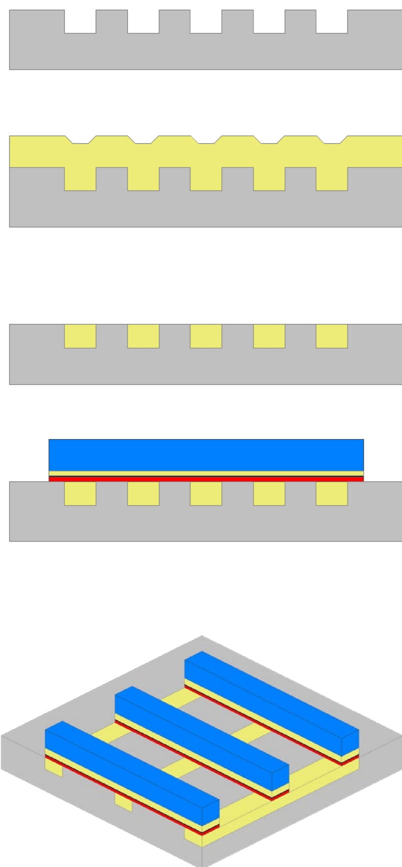

***R. Dawant, PhD defense 2024***

***R. Dawant, Micro and Nano Engineering, 2024***

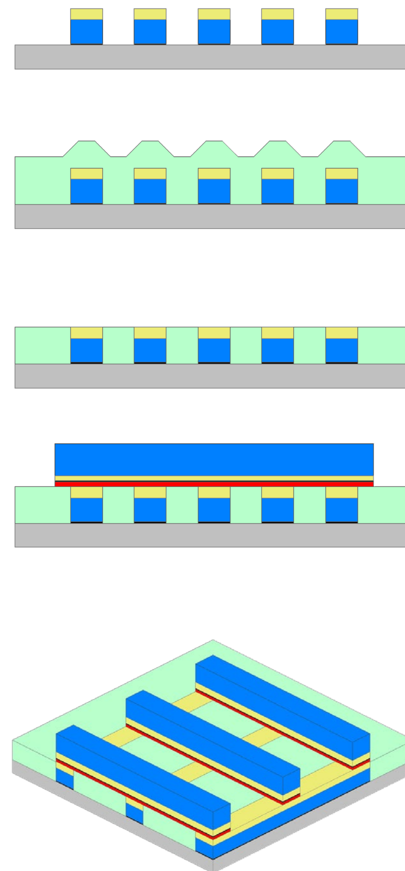
# Crossbars BEOL integration

- 2-step CMP
  1. Silica
  2. Ceria
- High selectivity
- Reasonable RR

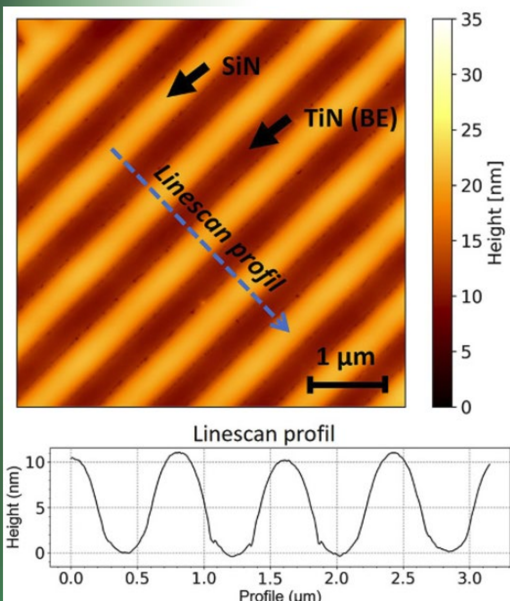
**Damascene**

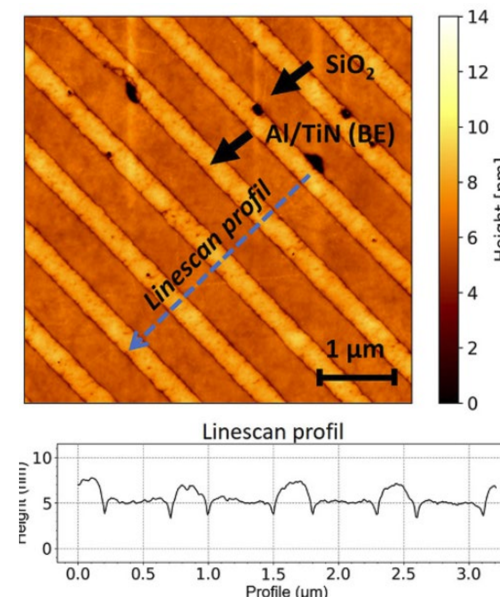


**Substractive**



- Silica slurry
- Selectivity TiN/ SiO2 ≃ 1



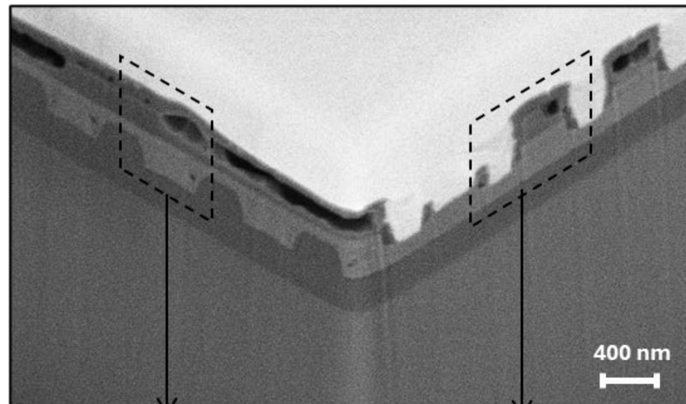



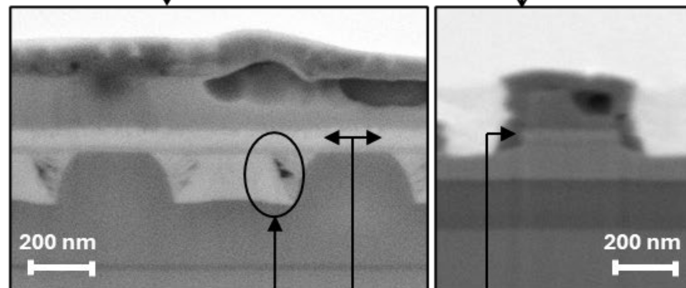

SiN | $SiO_2$ | TiN | $Al_2O_3/TiO_x$ | Ti | Al

*R. Dawant, Micro and Nano Engineering, 2024*

# Crossbars BEOL integration

**Damascene**

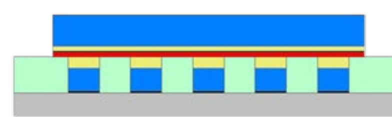


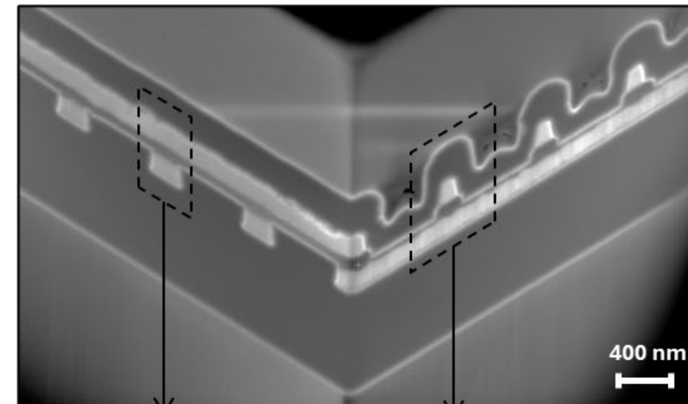



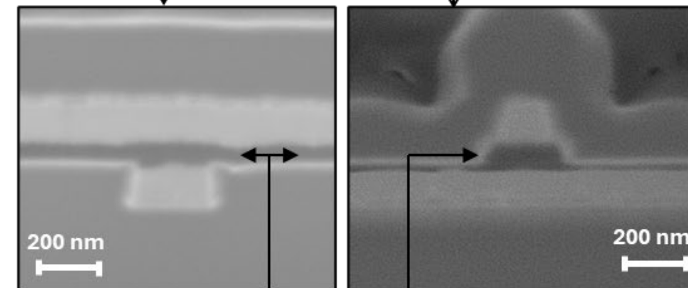

BE trenching

$TiO_{2-x}$/Ti

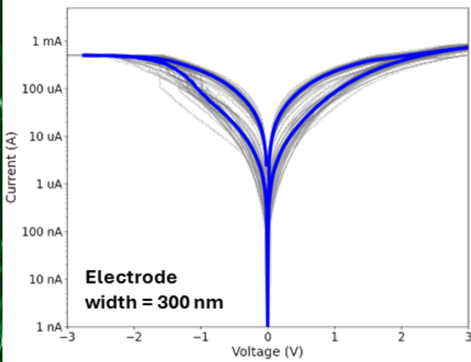
**Substractive**

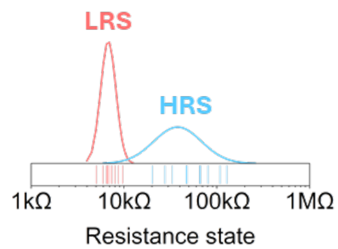


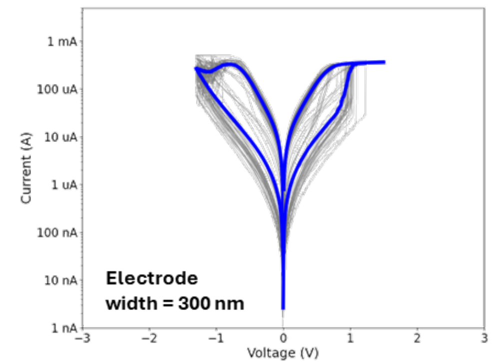


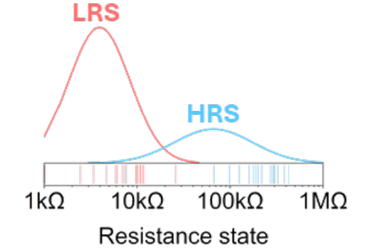




$TiO_{2-x}$/Ti




*R. Dawant, Micro and Nano Engineering, 2024*

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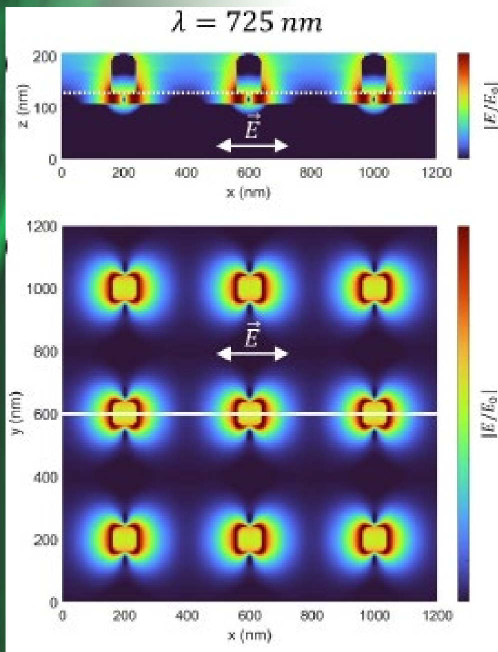
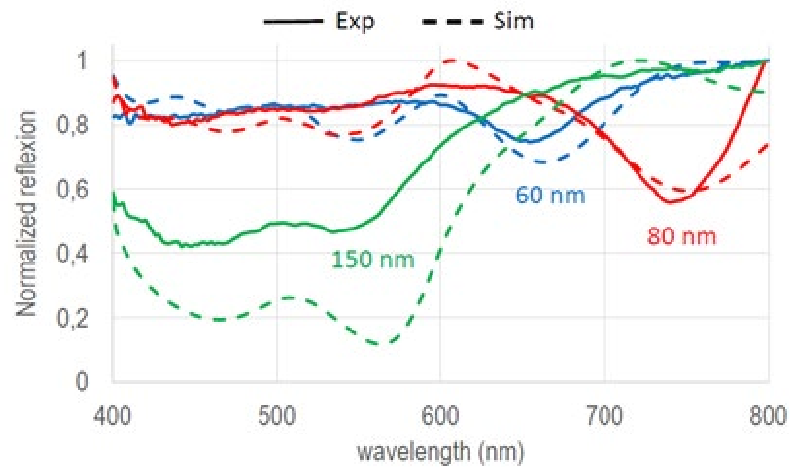
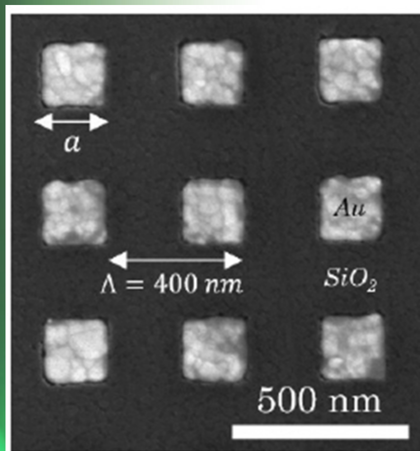
Nanostructured plasmonic arrays

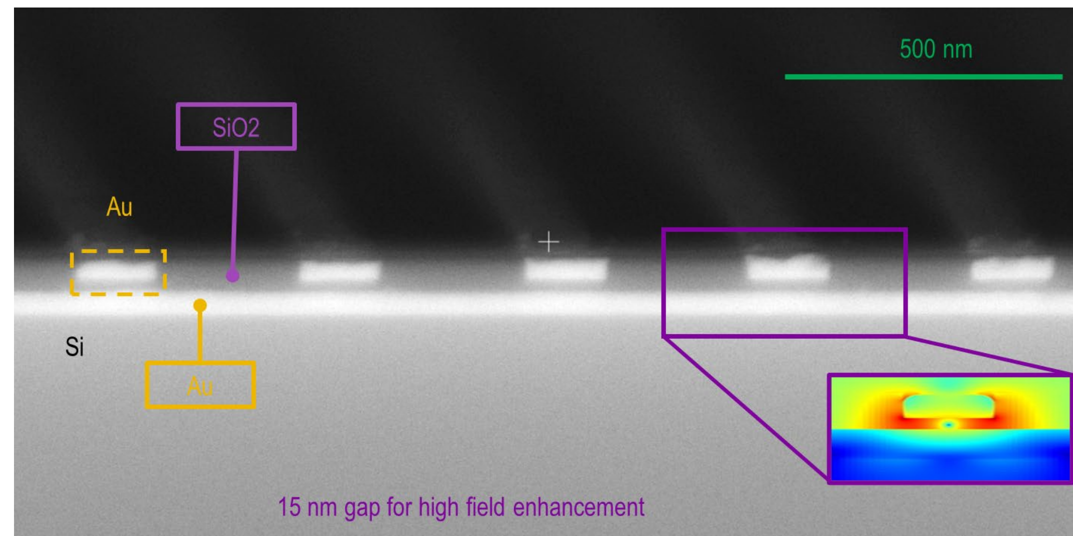
# Nanostructured plasmonic arrays




- Gold nanostructures and/or nanogaps are essential for plasmonic, lab-on-chip, optics, …
- Au plamonic arrays
- Couple light in nanocubes NCs
- Wafer-level Au nanostructuration
- Industry-compatible
- Robust and reproducible process



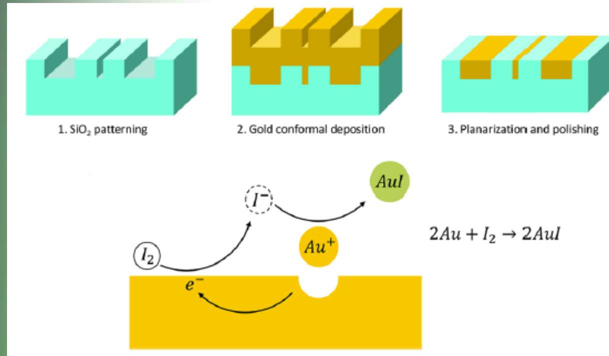




R. Gherman, Photonics North, 2023

R. Gherman, Photonics West, 2024

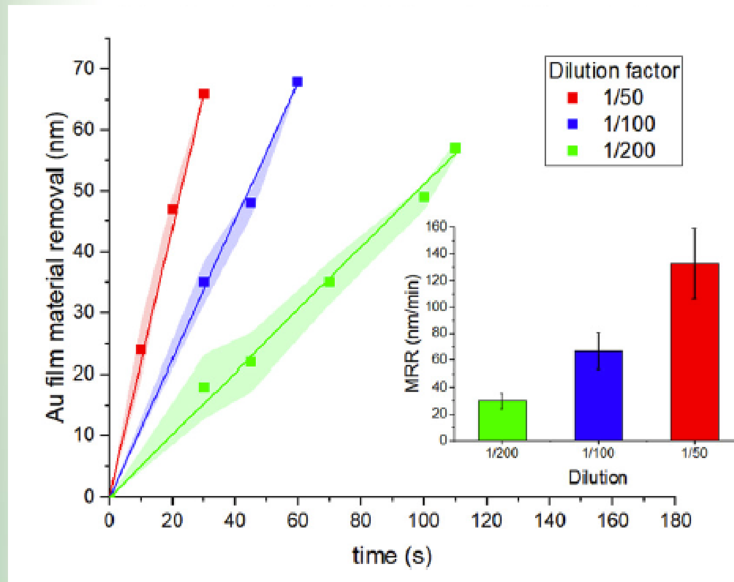
# Nanostructured plasmonic arrays

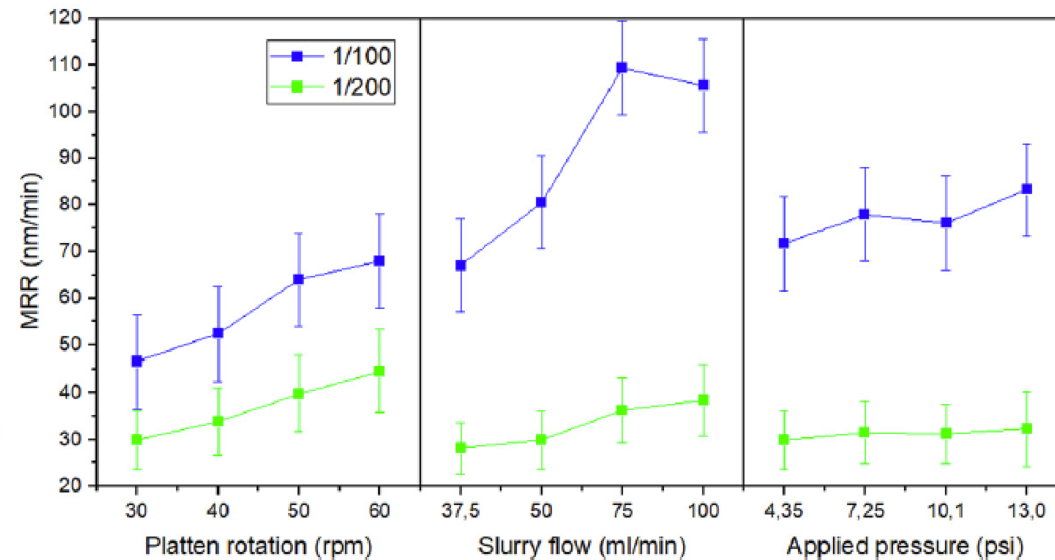
- Abrasive free CMP
- $I_2$ + KI solution




- Au blanket film CMP

| Temperature | 20 °C | 50 °C | 70 °C |
|---|---|---|---|
| Wet etch rate without stirring (nm min$^{-1}$) | 2.7 ± 0.5 | 4.7 ± 0.5 | 9.6 ± 0.5 |
| Wet etch rate with stirring at 300 rpm (nm min$^{-1}$) | 10 ± 2 | — | — |
| CMP MRR (nm min$^{-1}$) | 30 ± 6 | 33 ± 7 | 33 ± 6 |

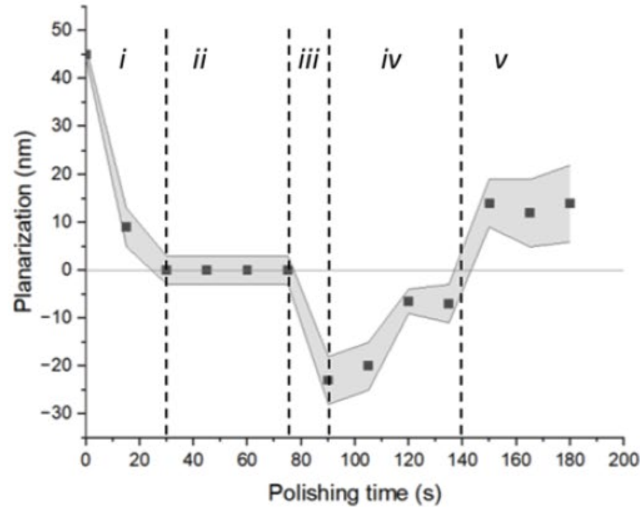


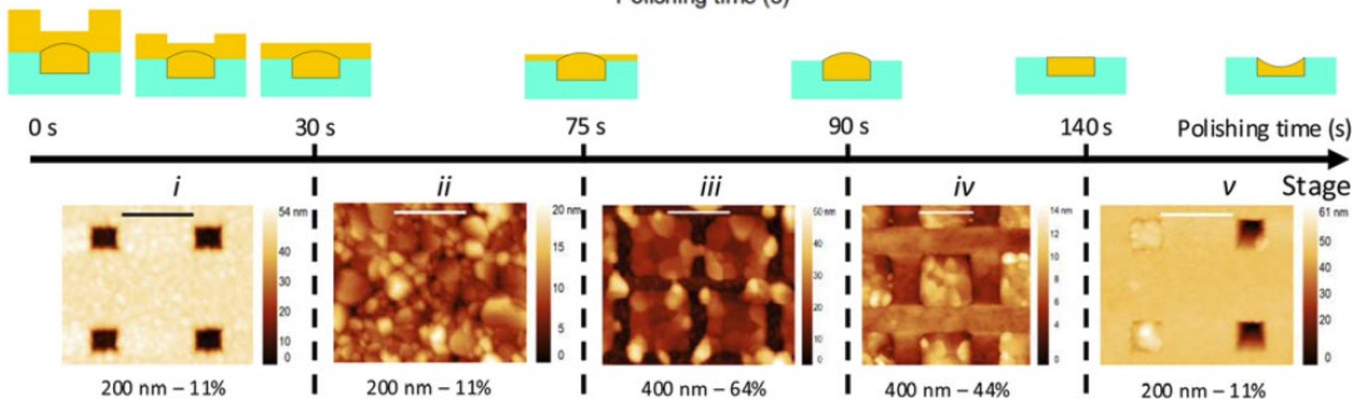




*R. Gherman, RCS Nanoscale, 2024*

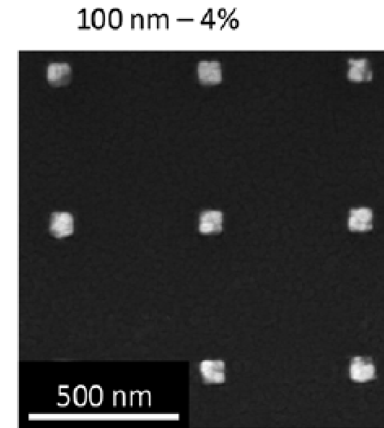
# Nanostructured plasmonic arrays

Au NCs planarization model

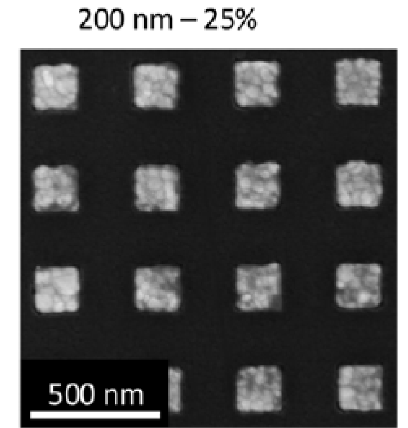


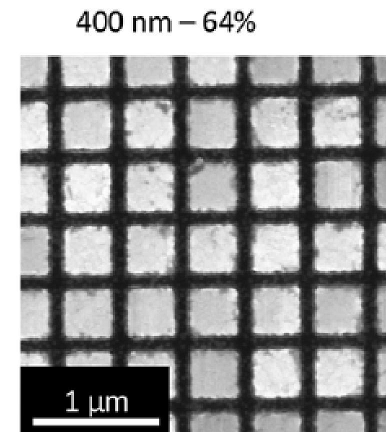

100 nm – 4%




200 nm – 25%




400 nm – 64%

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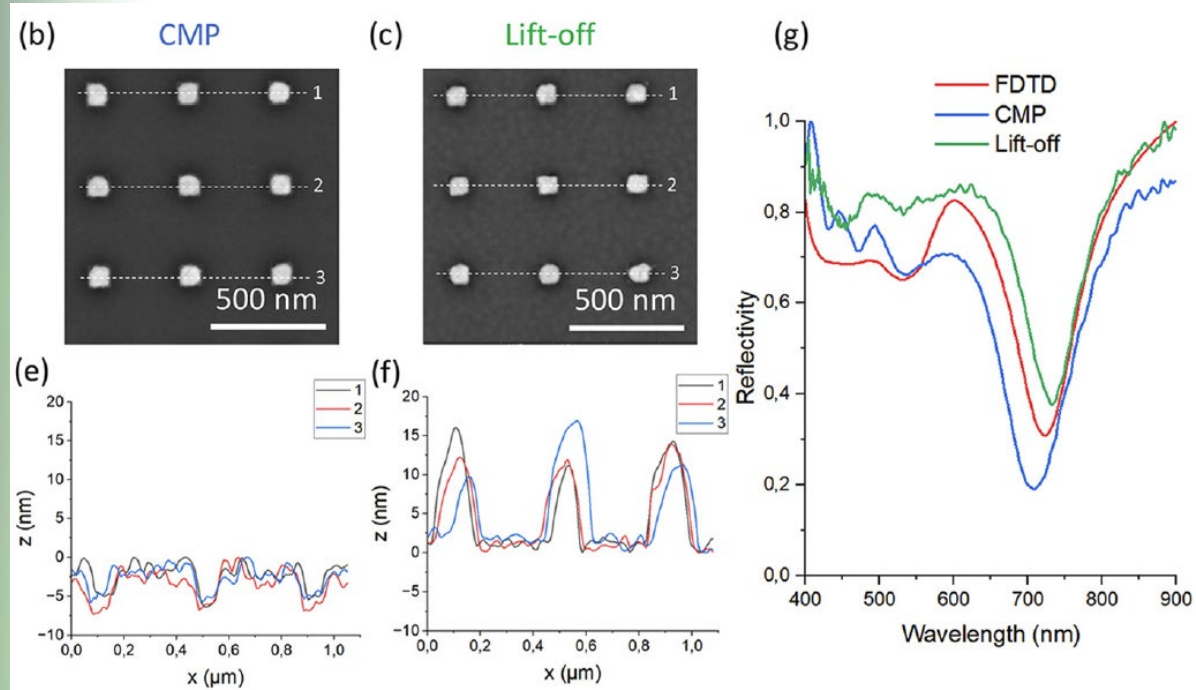
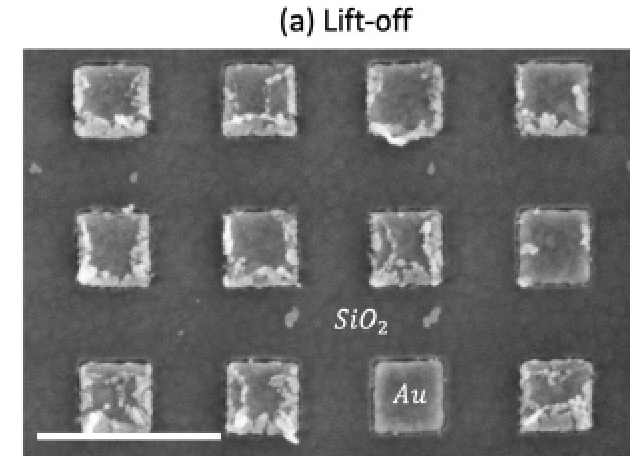
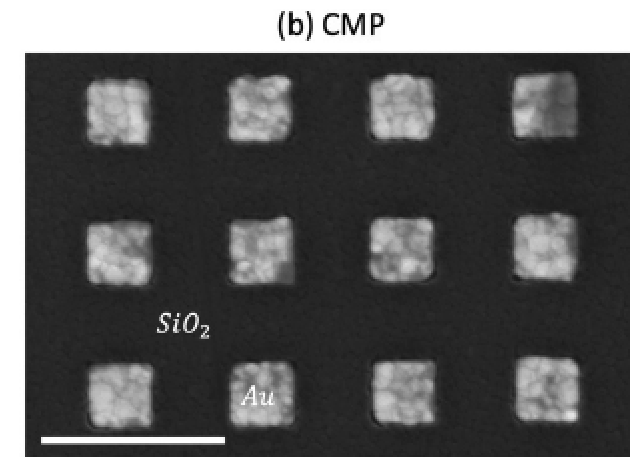
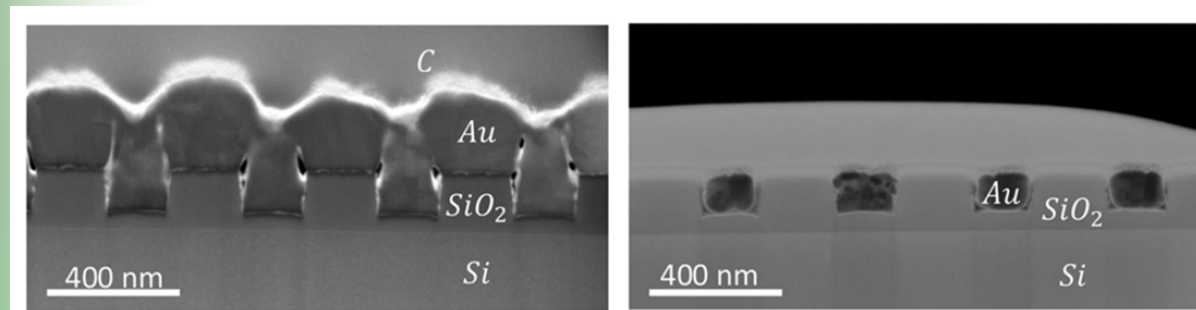
*R. Gherman, RCS Nanoscale, 2024*

# Nanostructured plasmonic arrays

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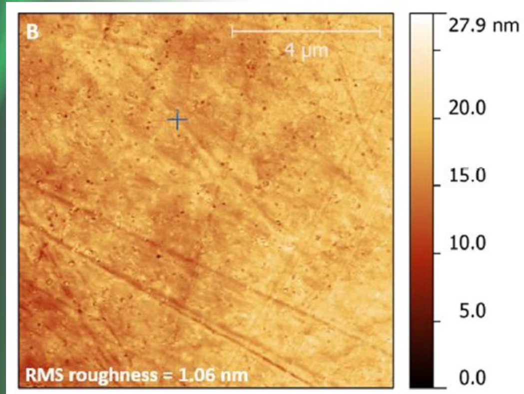
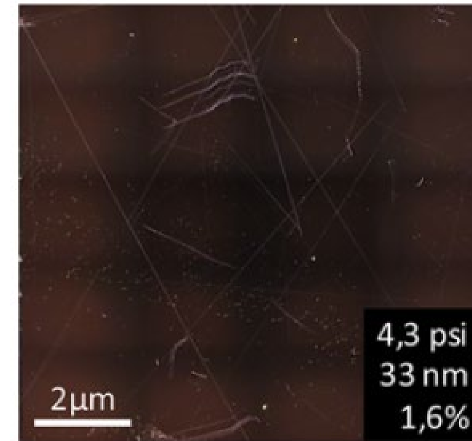
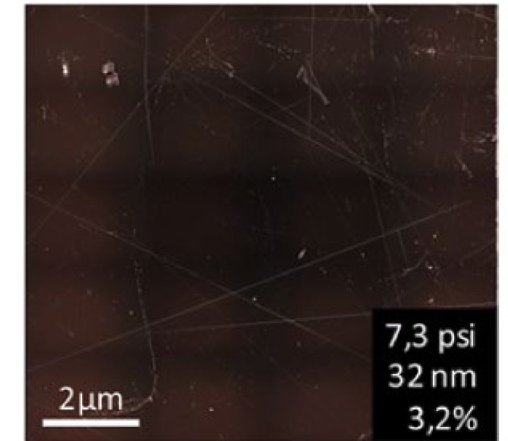
# Abrasive free Au CMP challenges

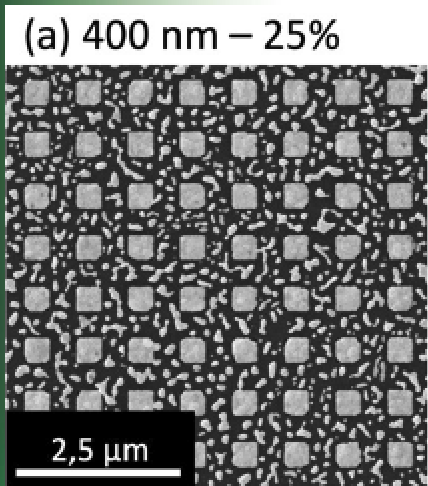



Alumina based slurry CMP

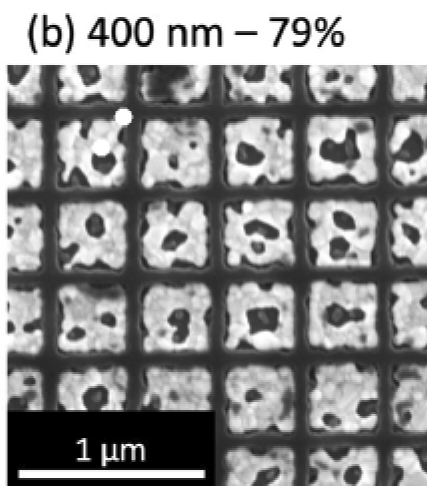


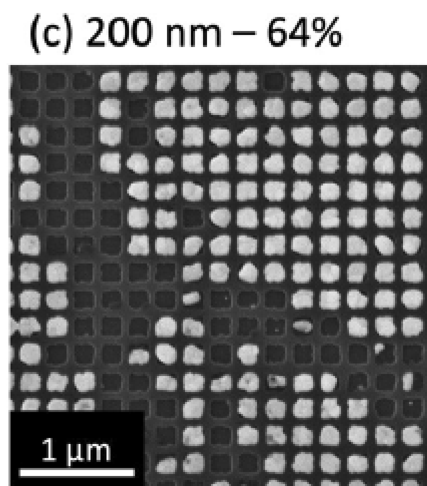

(a) 400 nm – 25%

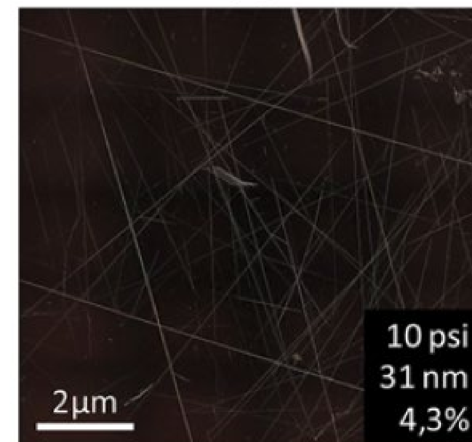


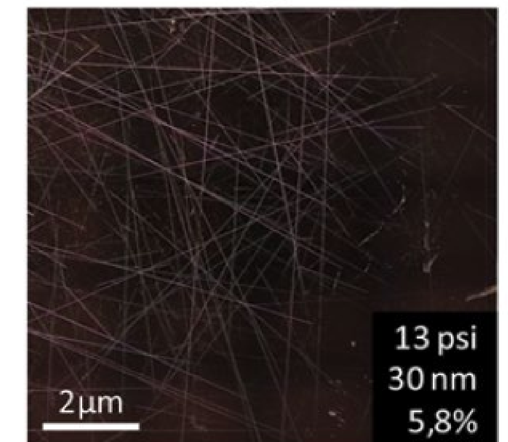

(b) 400 nm – 79%




(c) 200 nm – 64%



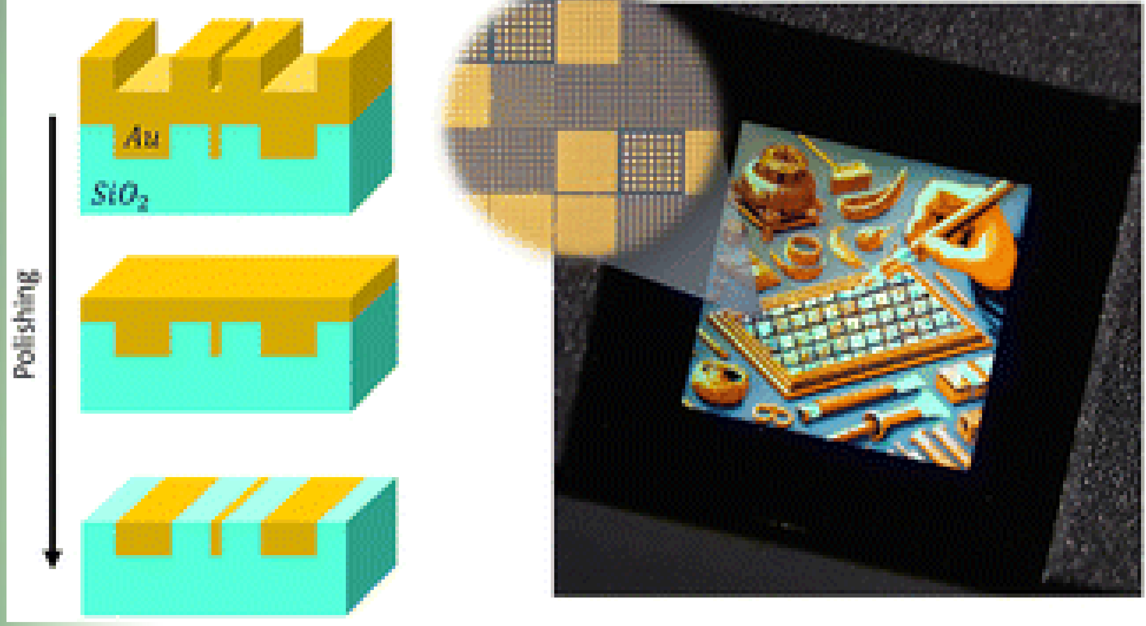



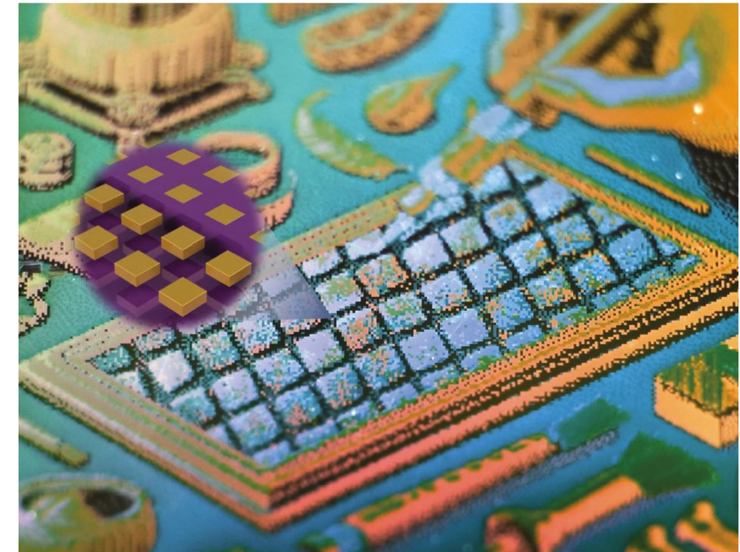

*M. Mehrej, Microelectronic Engineering, 2017*

*R. Gherman, RCS Nanoscale, 2024*

# Nanostructured plasmonic arrays




A little less than 1 million gold nanocubes



PAPER
Raphael Gherman, Serge Ecoffey *et al.*
Abrasive-free chemical-mechanical planarization (CMP) of gold for thin film nano-patterning

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# Thank you

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