



Synthesis of self-assembled 3D nanostructures for UV-NIR broadband absorber

M. Ziegler, A. Dathe, S. Thamm, L. Stolle, U. Huebner, D. Wang and P. Schaaf

Leibniz IPHT Competence Center for Micro- and Nanotechnologies (CMNT)

- Microsystem- and Nanotechnology



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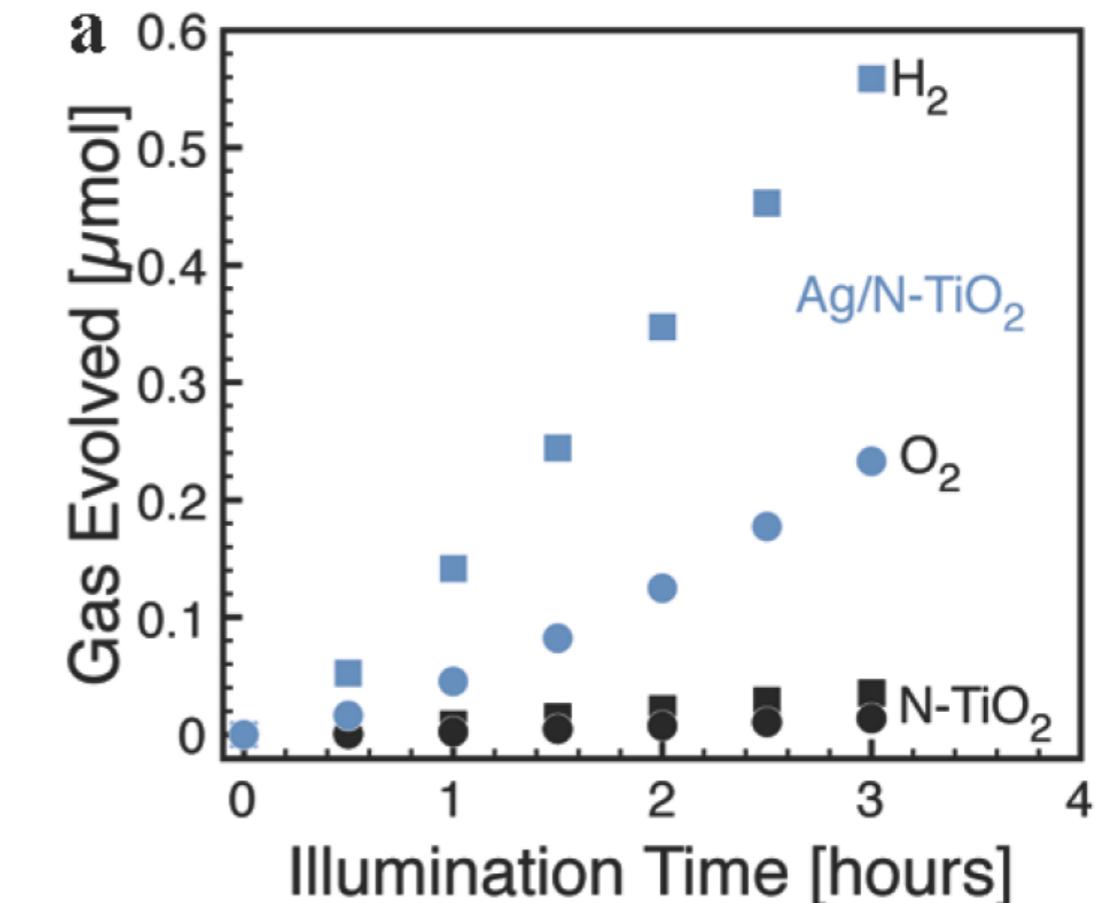
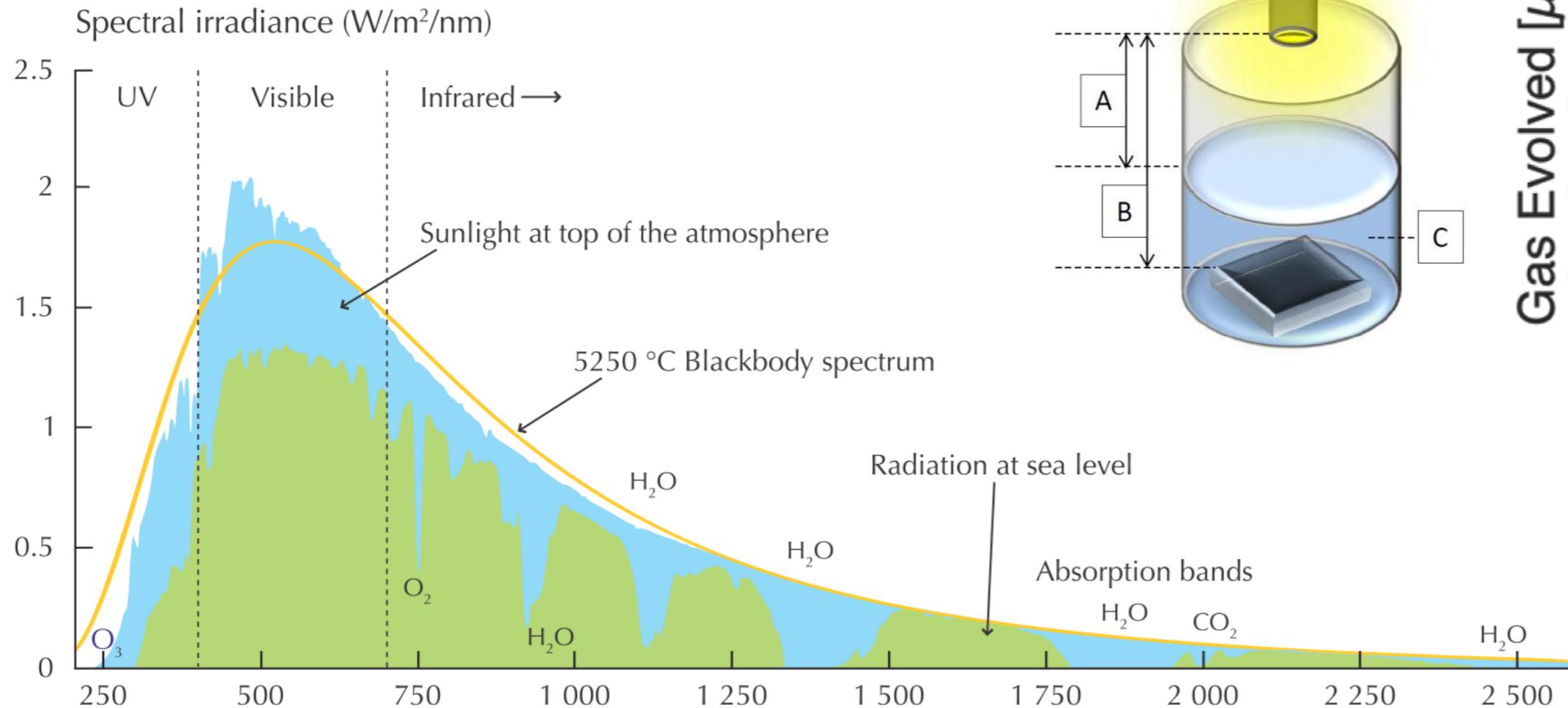


What can you do in 90 minutes? (Don't worry, I will not ask the auditorium)

- Clean a room
- Watch 5 Ted Talks
- Have a nap
- Watch a Hollywood blockbuster (e.g. "Stand by me")
- Play a game of football
- Busdriving through Florence (Busticket valid for 90 minutes)
- Browse Reddit for an hour and a half



What can you do in 90 minutes?



minutes)

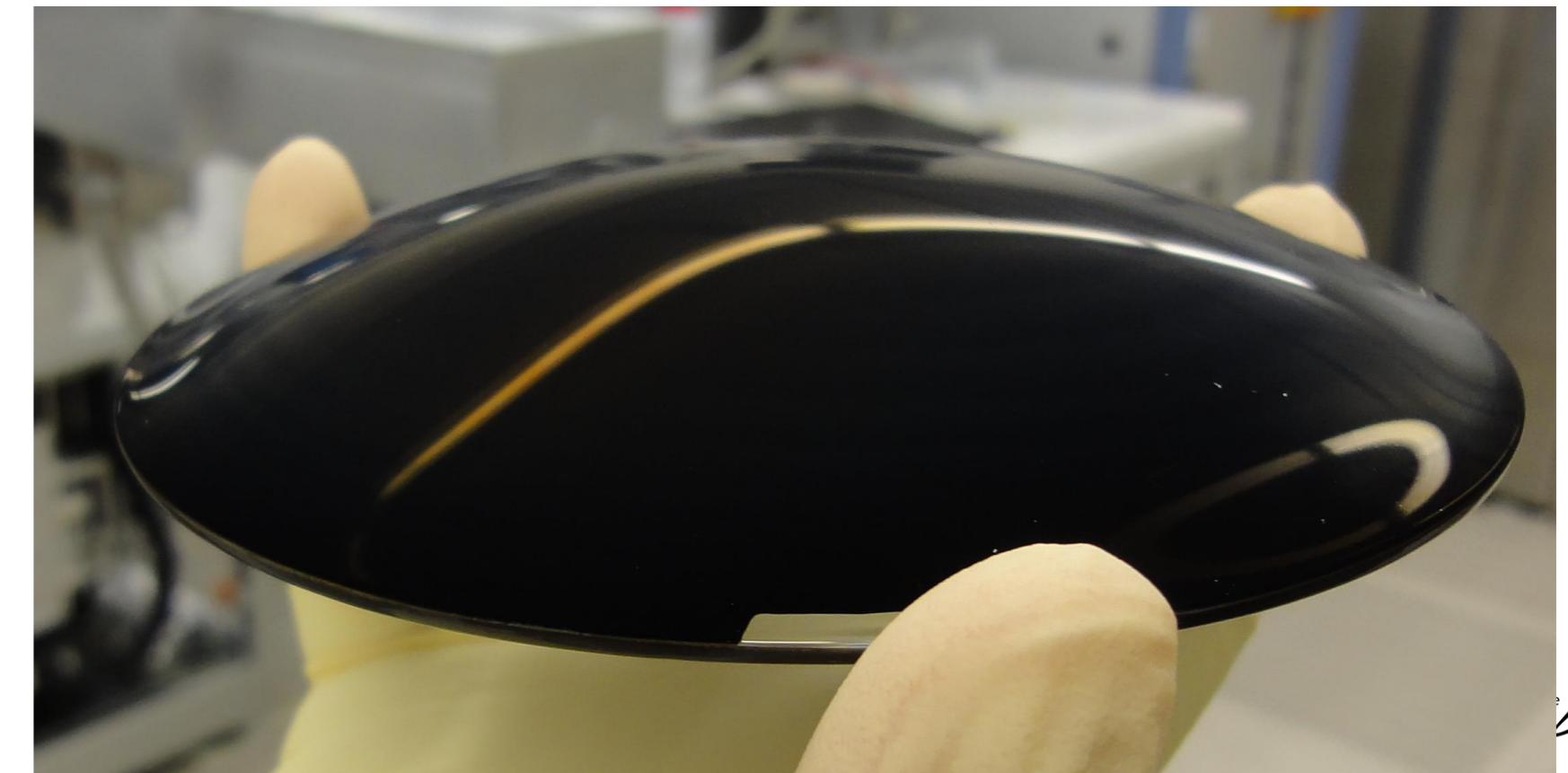
- Exploit the sun radiation to satisfy the energy needs of the whole world for one year
 - Broadband plasmon induced photocatalysis

How?

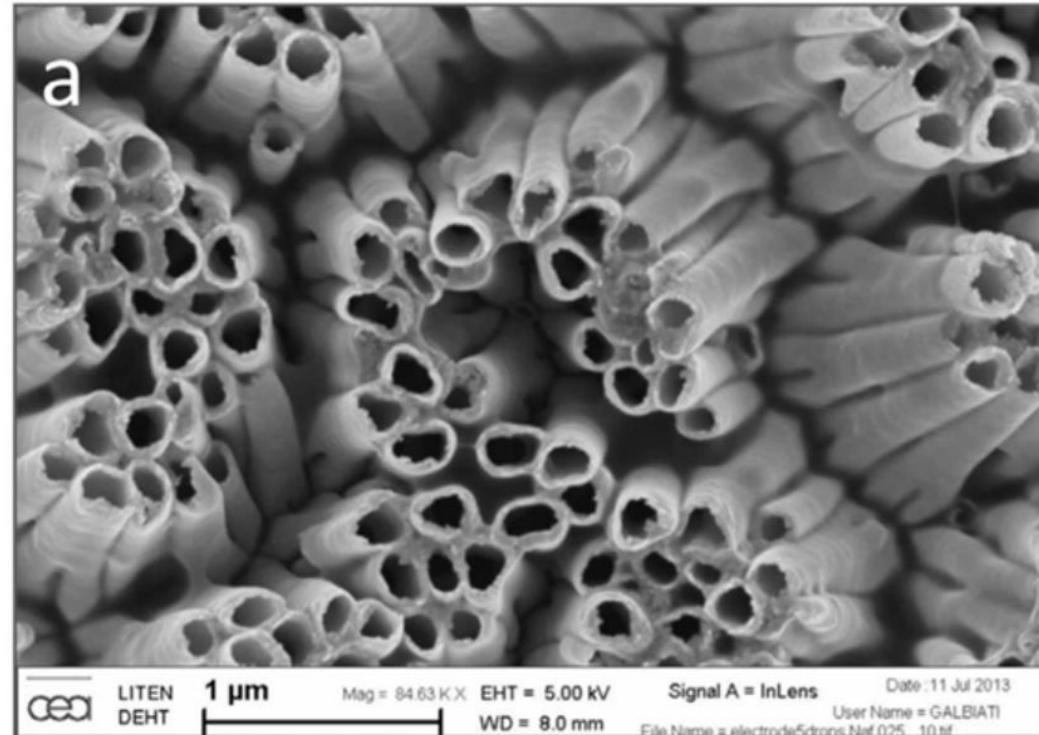
ALD based generation of self-assembled 3D plasmonic structures (**high absorption from 250 nm to 2.500 nm – black coatings**)

Metastable atomic layer deposition (MS-ALD) promises:

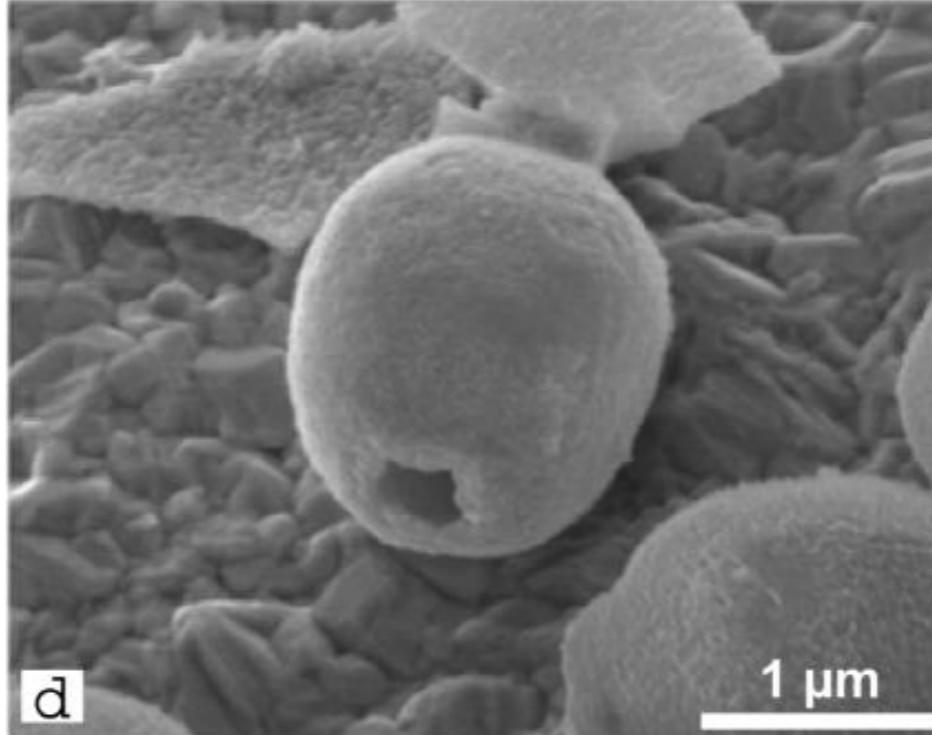
- **Fine-tuning properties:** allowing precise surface engineering
- **Flexible:** a variety of materials and compositions depositable
- **Self-assembled nano-structures & particles:**
 - Cost-effective
 - Light-distribution from 2D to 3D to increase absorption characteristics



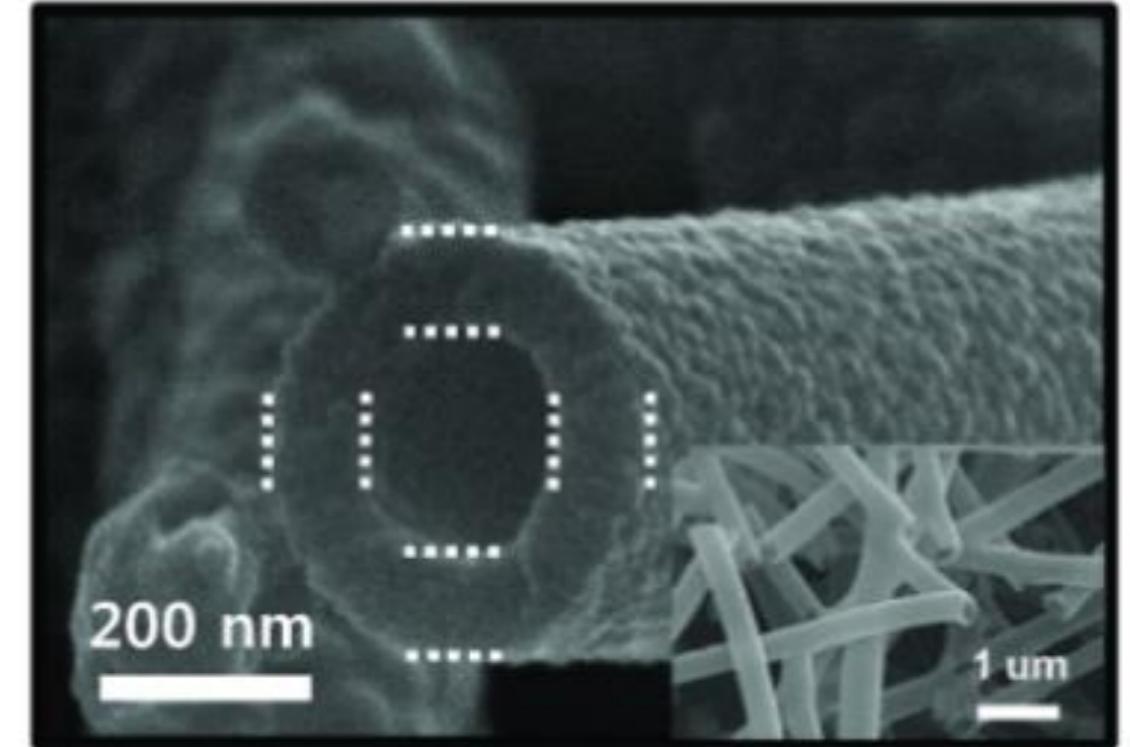
Common ALD 3D synthesis – some examples



Galbiati, S. *Electrochimica Acta* **125**, 107–116 (2014).



Lagner et al., *Appl Phys A* **2008** (93), 399–403



Park et al., *Nanotechnology* **2010** (21), 475601

⌚ 16:40 - 17:00

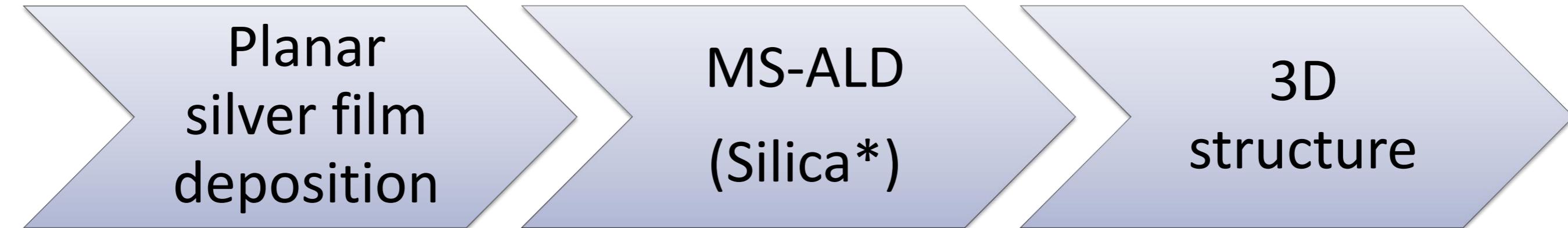
Insight into the formation of 3D structures during atomic layer deposition of WS₂

● Session C

📍 Room 2



MS-ALD approach



Metastable Atomic layer deposition – Structure evolution

Further increase of porosity with each cycle

- isolated particles of the substrate material
- increase in height

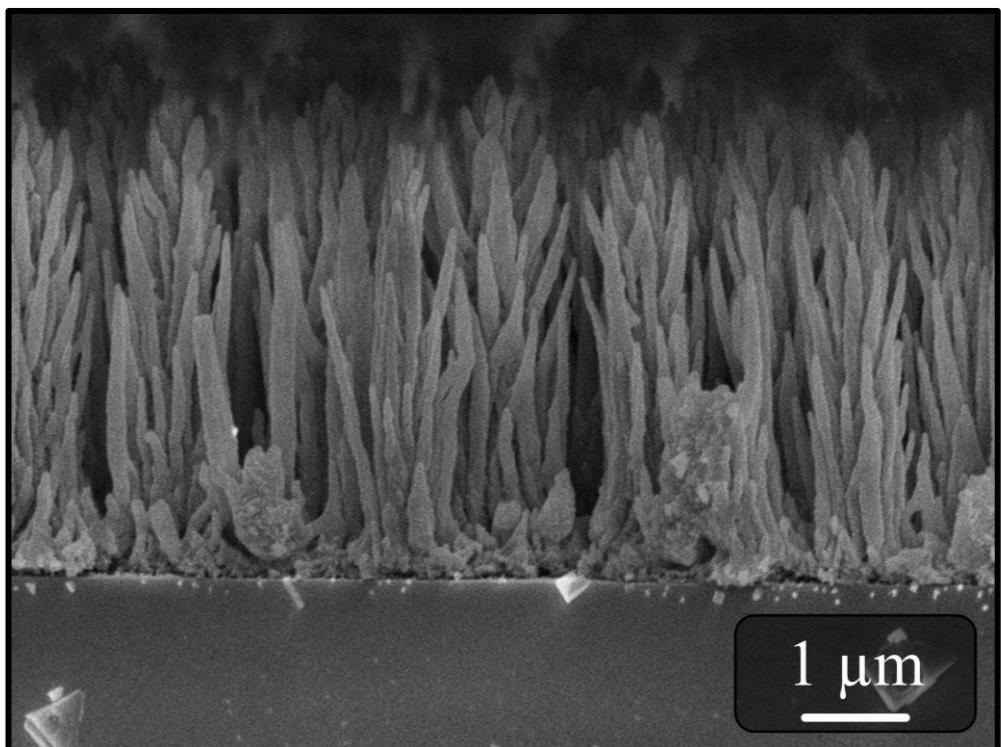
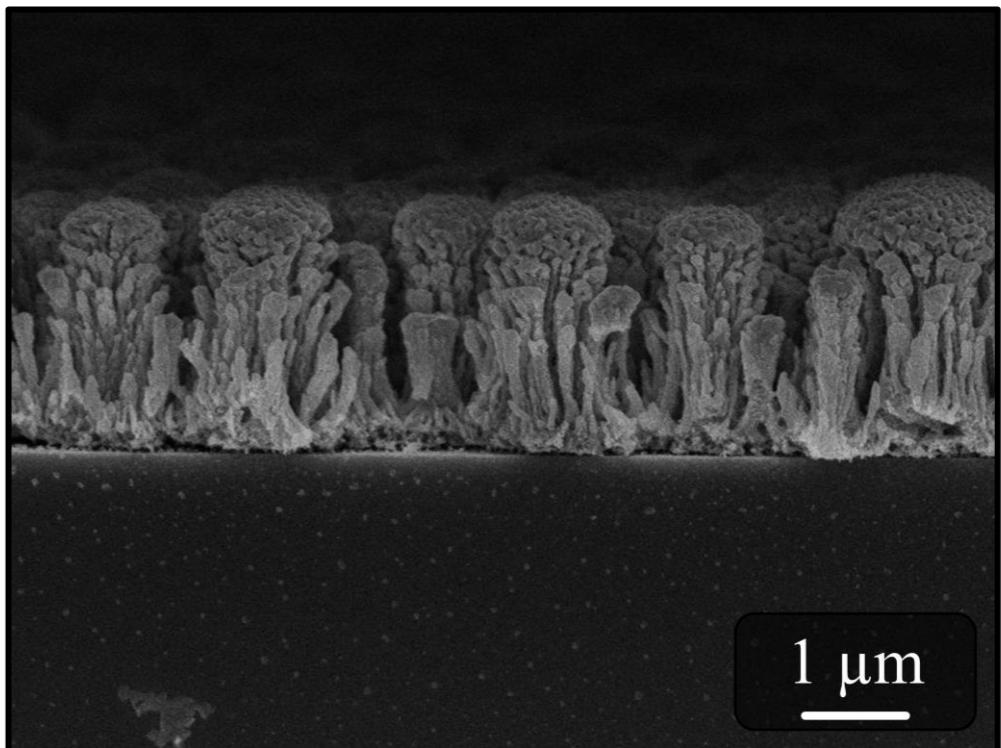
precursor A + precursor B → film + byproducts

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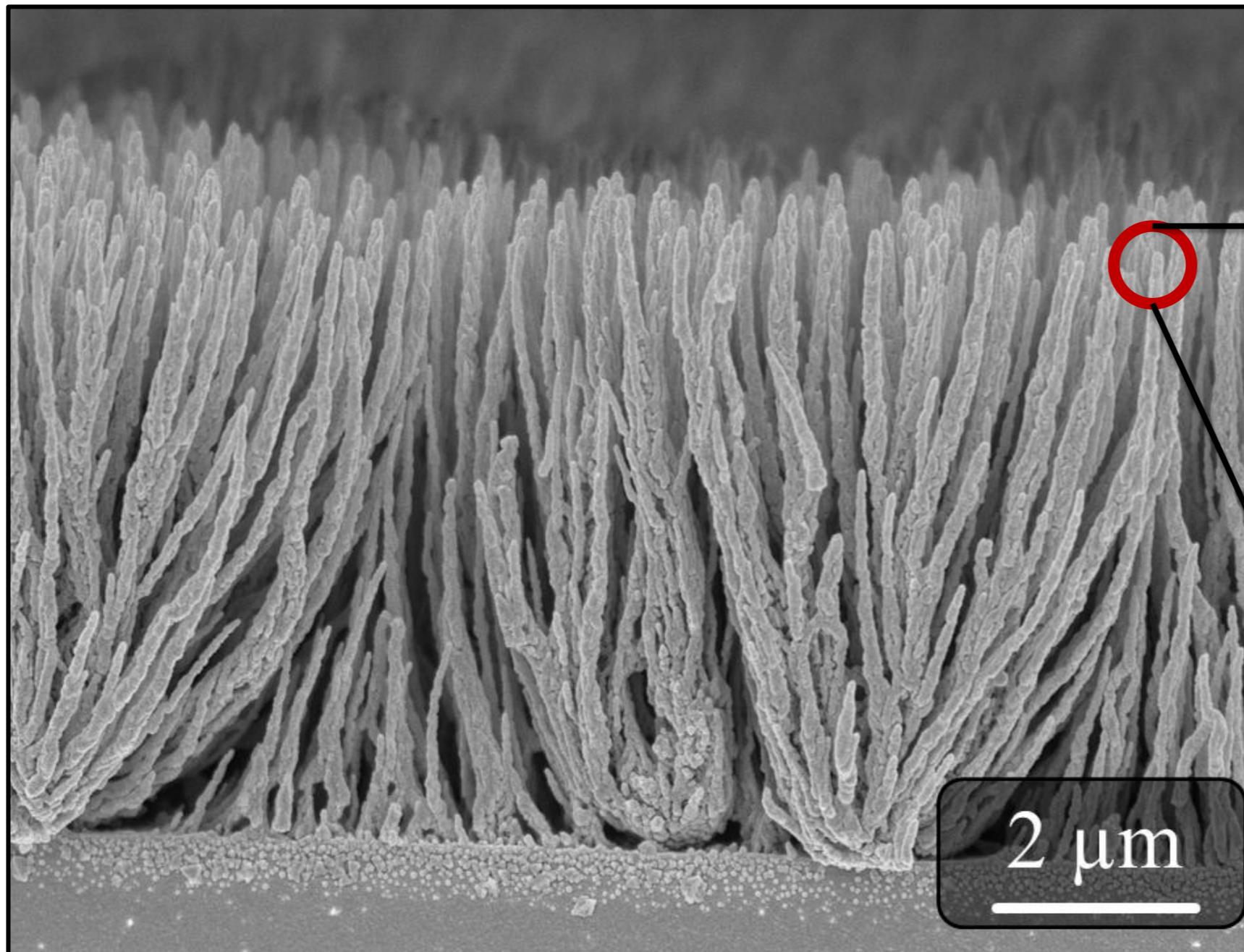
precursor B + substrate A → **substrate B***

substrate B* + precursor A → **film B** + byproducts
substrate A

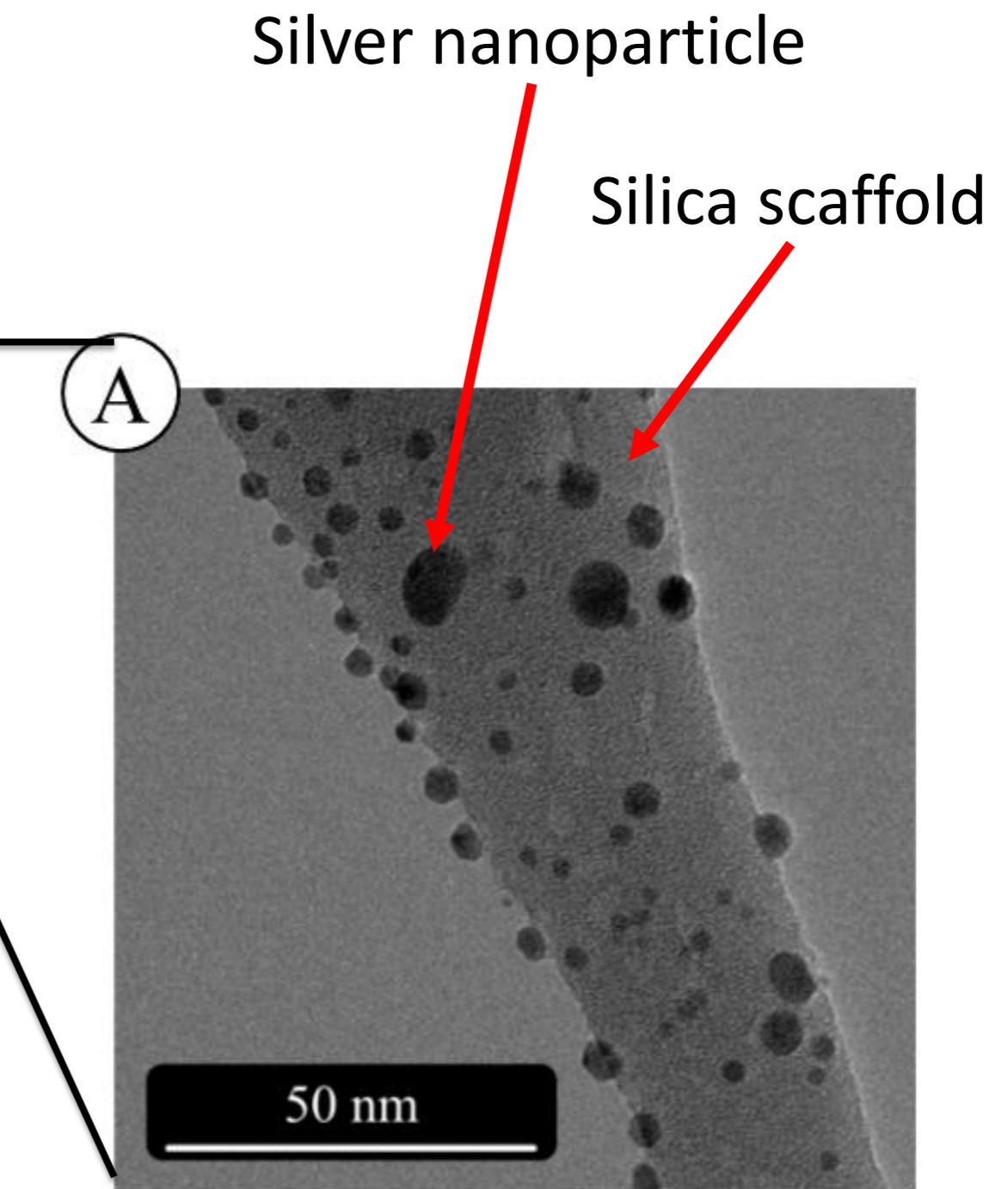
precursor A + precursor B → **film A** + **film B**
+ byproducts



Complex 3D architecture – silica scaffold with silver nanoparticles

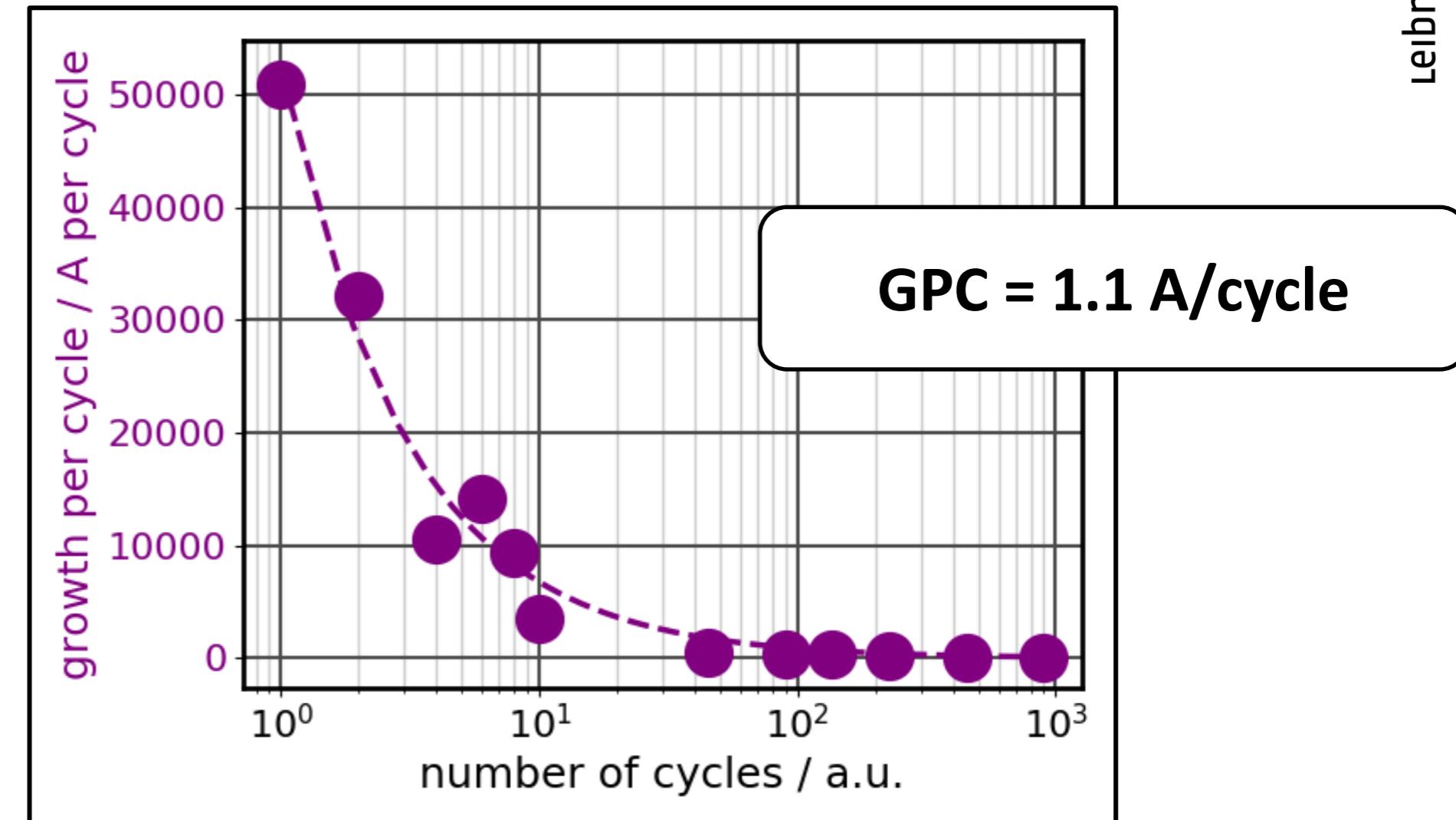
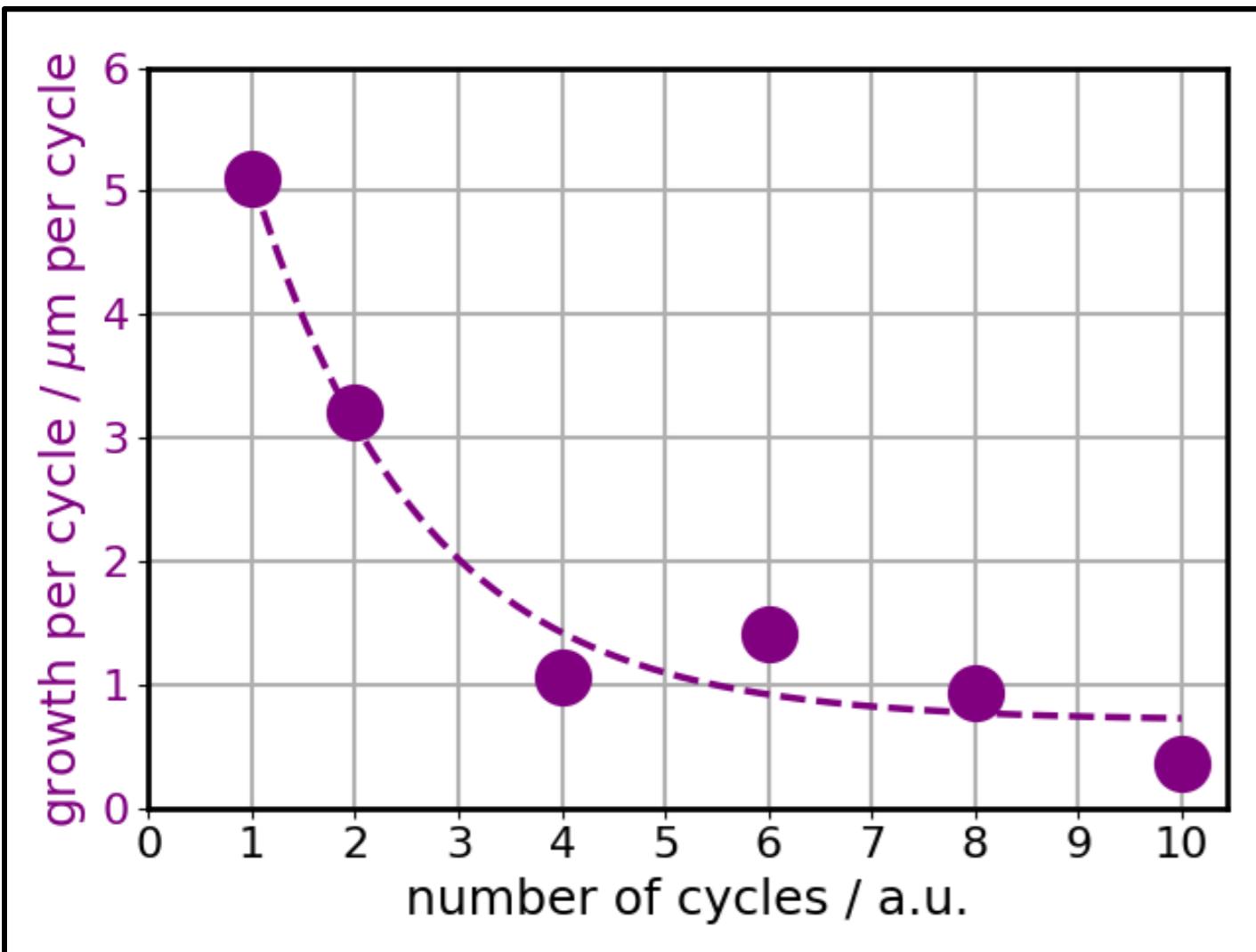


SEM cross section image of MS-ALD structure



TEM image of isolated needle

Number of cycles – growth per cycle



Template parameter: Process parameter (NoC < 10): Process parameter (NoC > 45):

- Silver: 300 nm
- Thermal evaporation
- TDMAS dose: 30 min
- Oxygen plasma dose time: 810 s
- 1 cycle: approx. 50 min

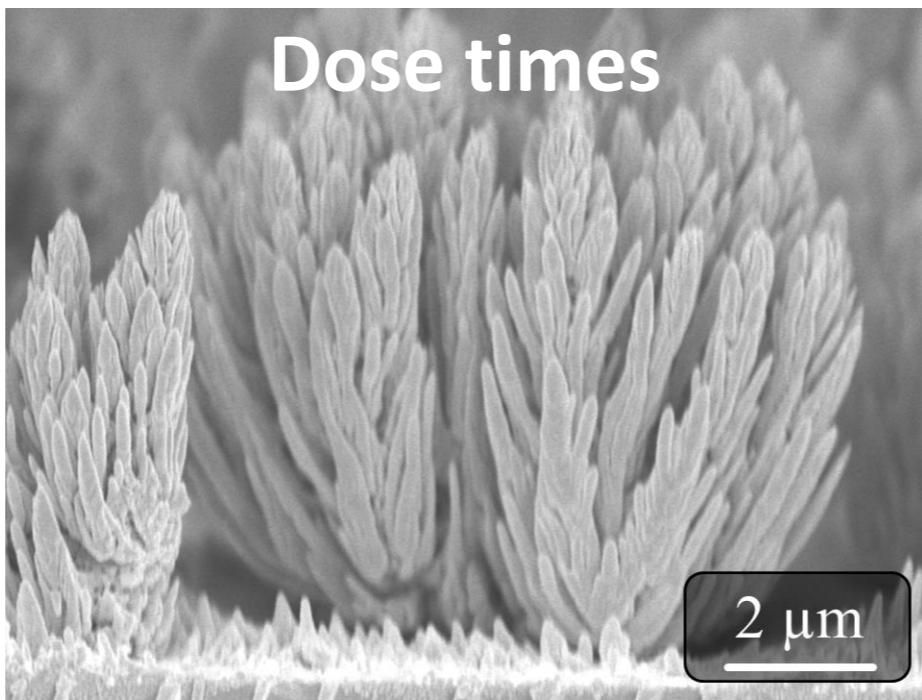
- TDMAS dose: 50 ms
- Oxygen plasma dose time: 6 s
- 1 cycle: approx. 18 s

Architecture as a function of the applied parameter

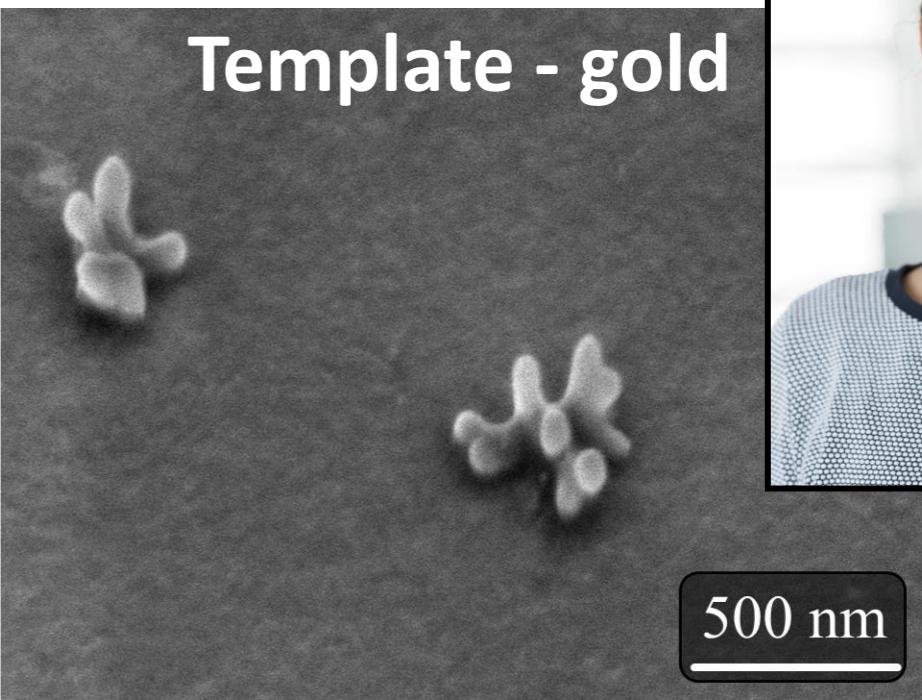
Number of cycles



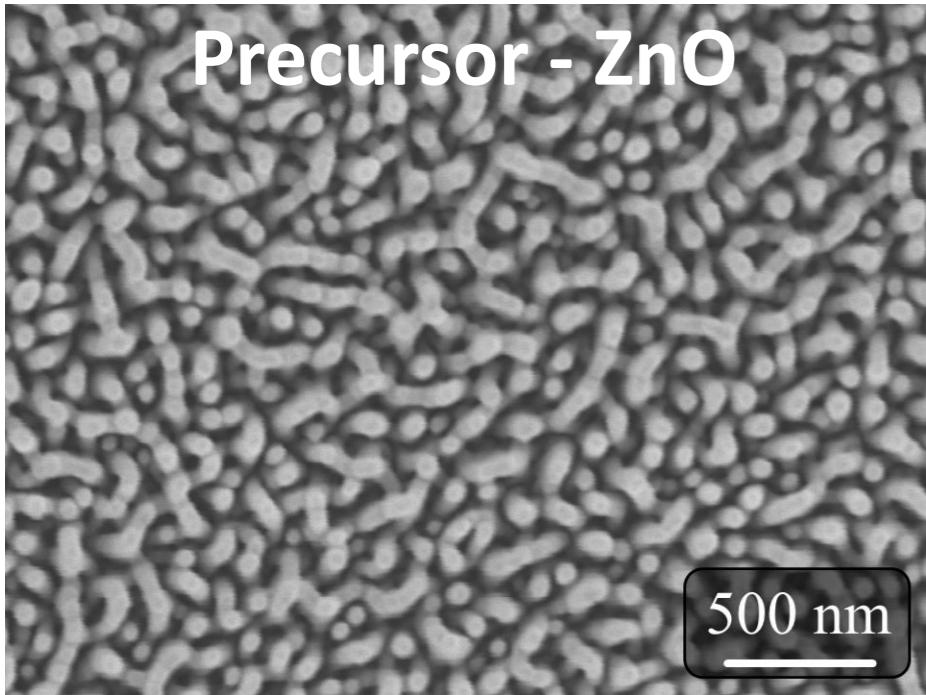
Dose times



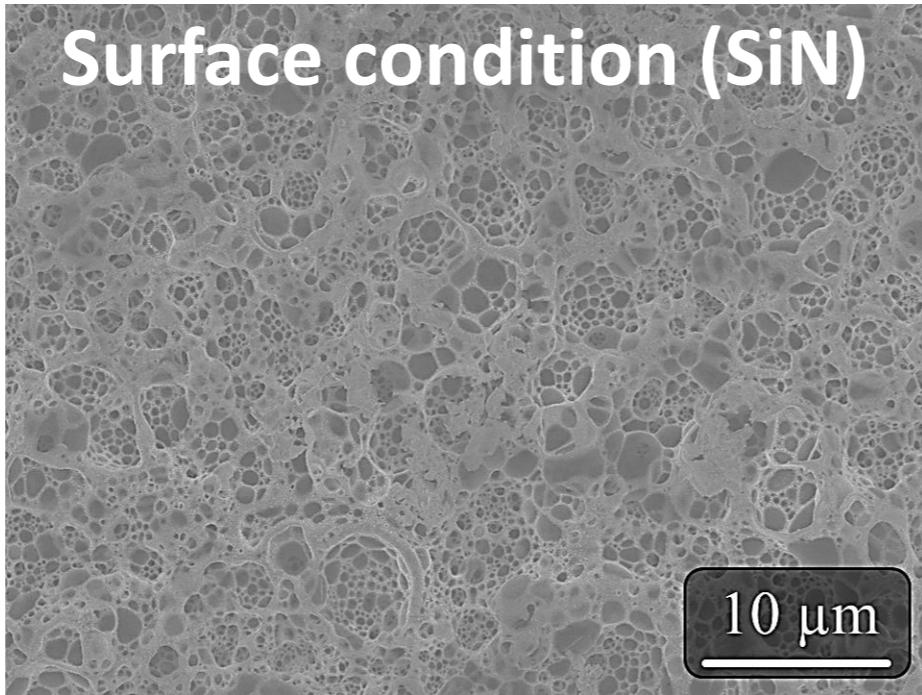
Template - gold



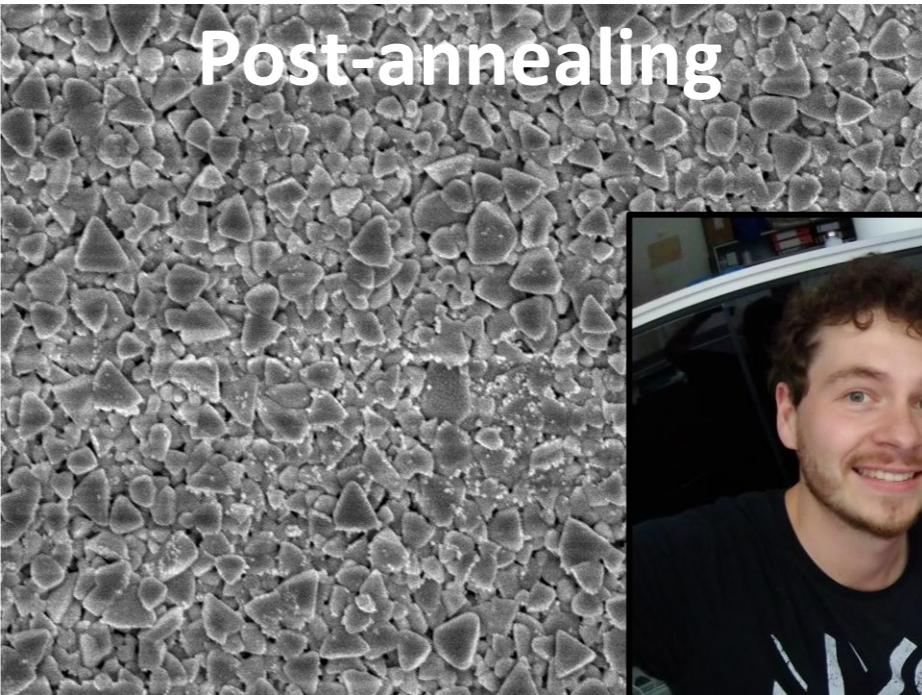
Precursor - ZnO



Surface condition (SiN)



Post-annealing



Sophie Thamm

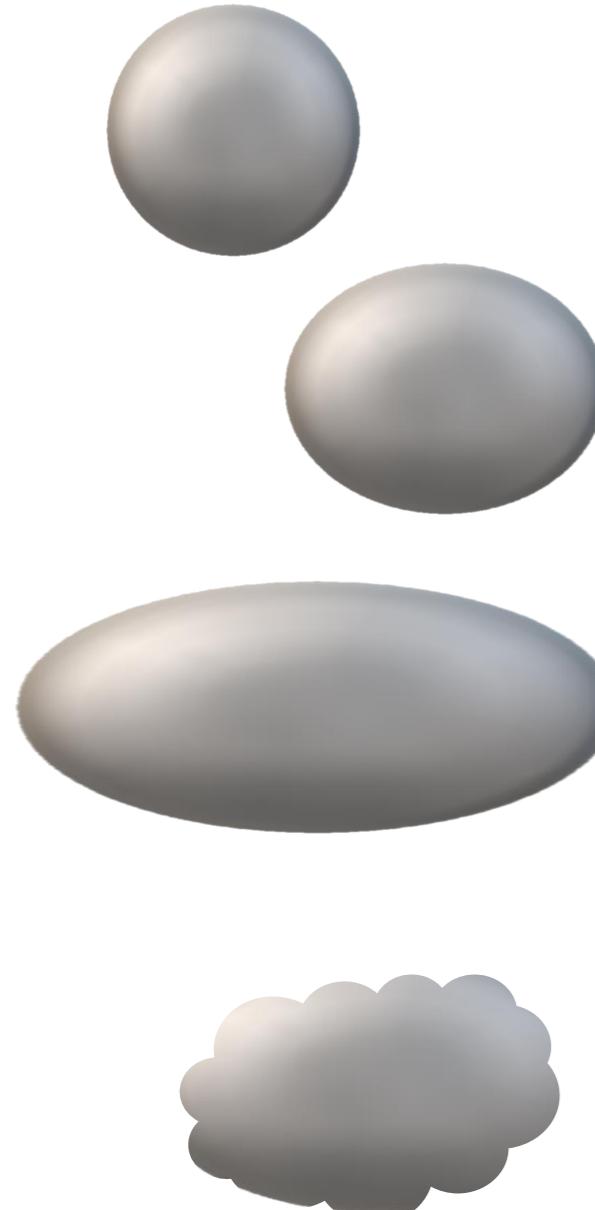


Sebastian Goerke

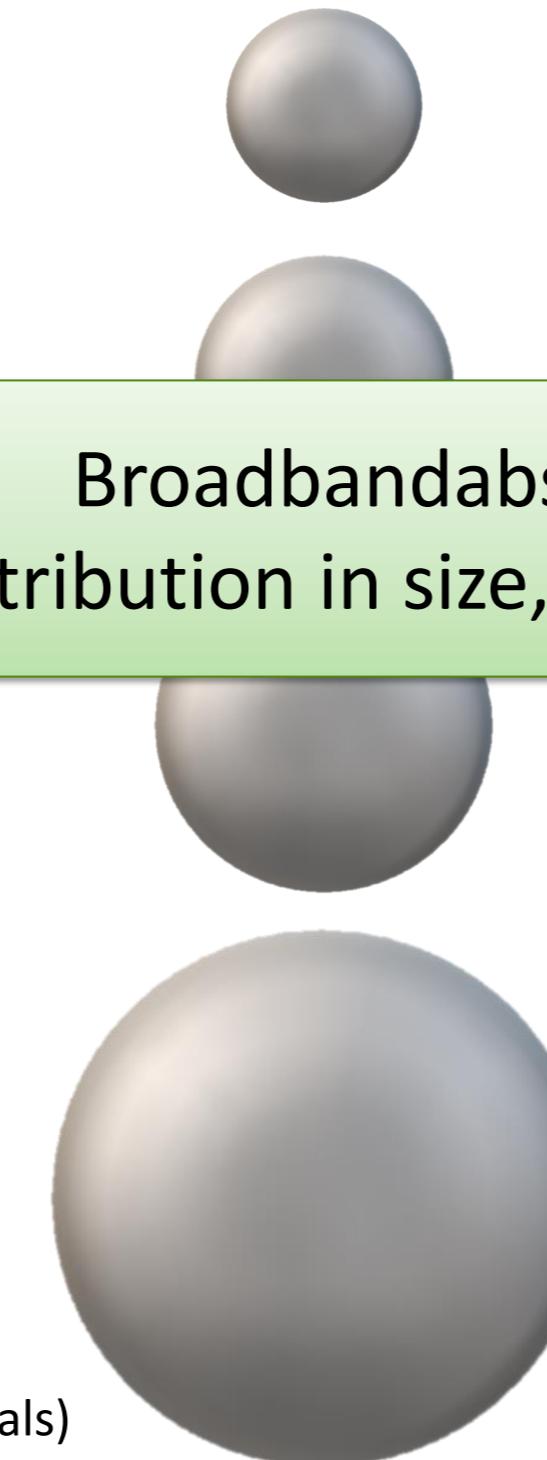
Absorption – Localized surface plasmon resonance - Theory

3 main effects for broadening the absorption (IR-shift):

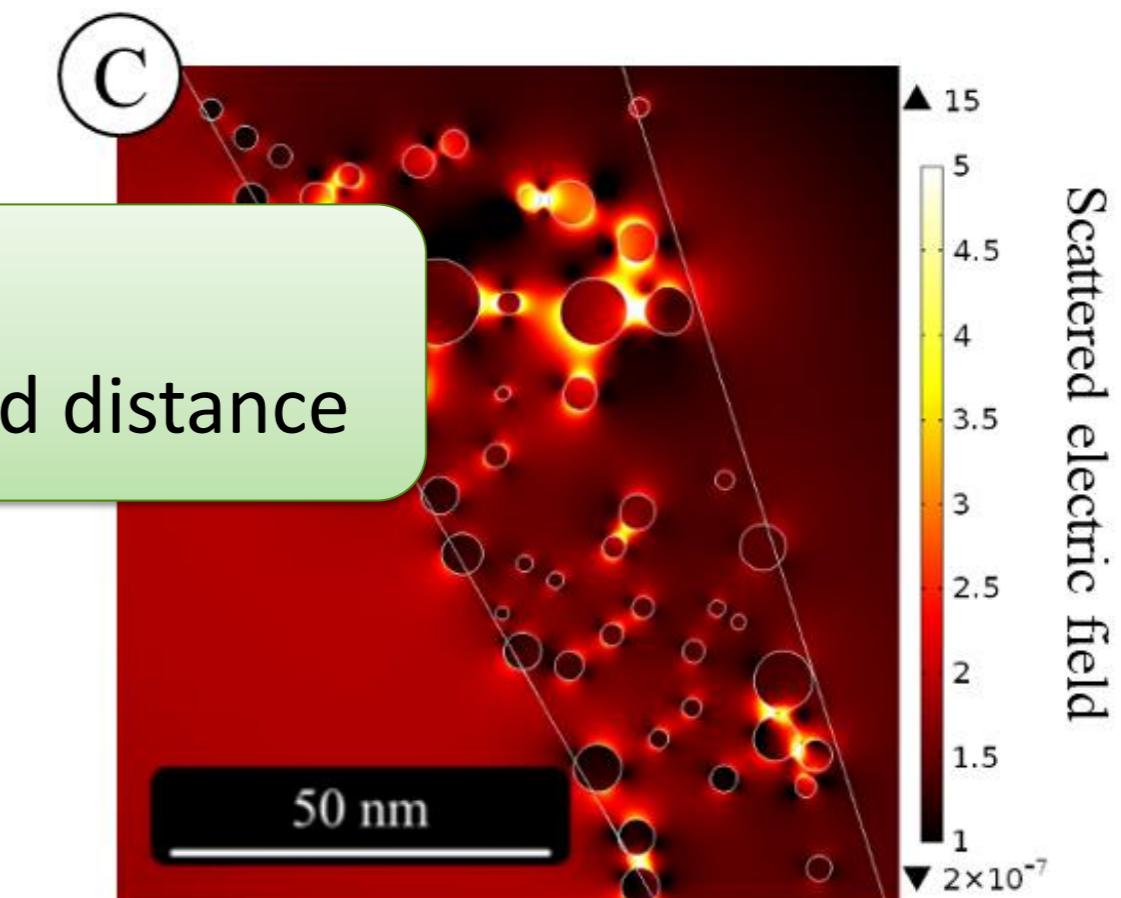
- Distribution in shape



- Distribution in size



- Interaction between particles
(Plasmon hybridization)



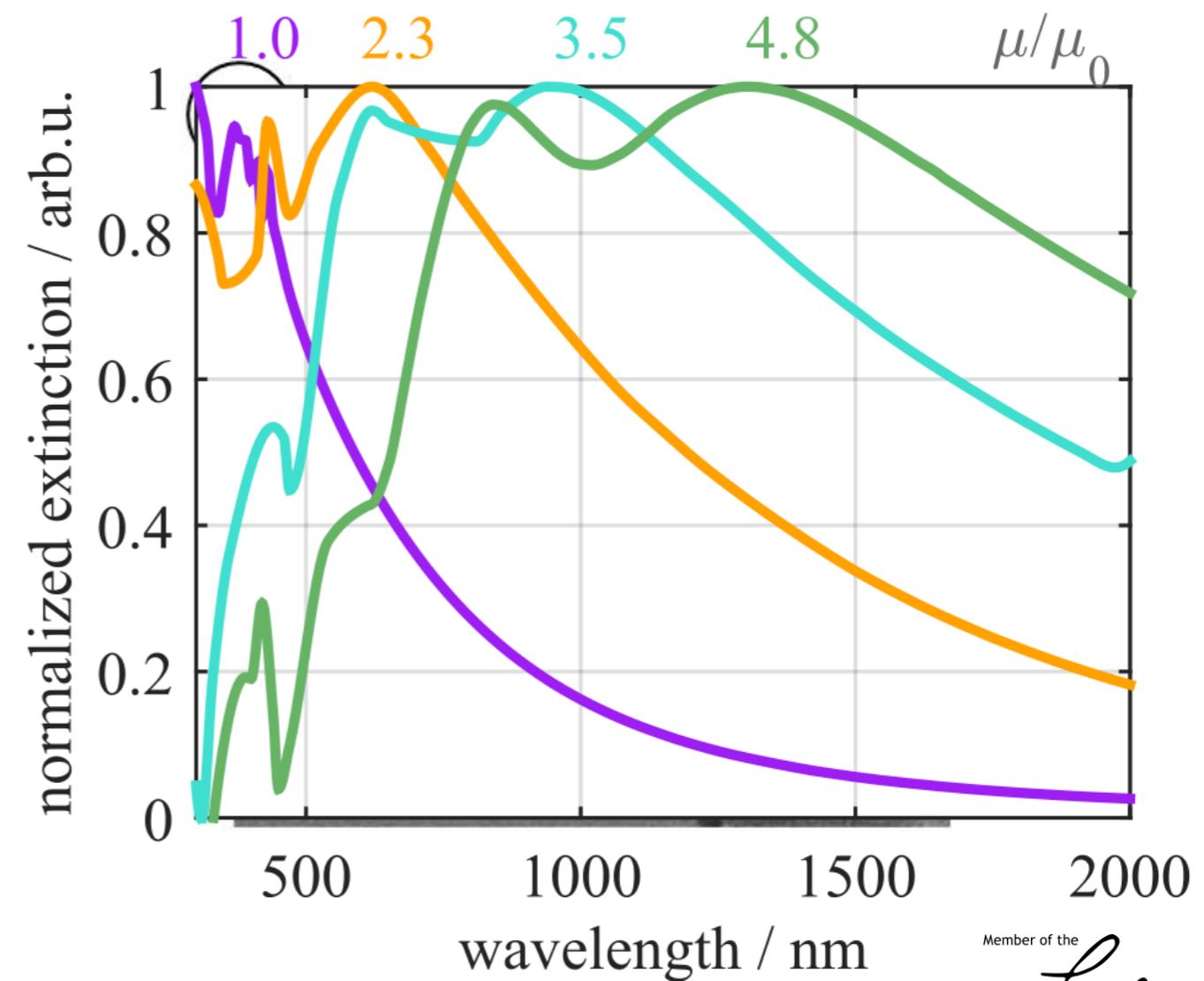
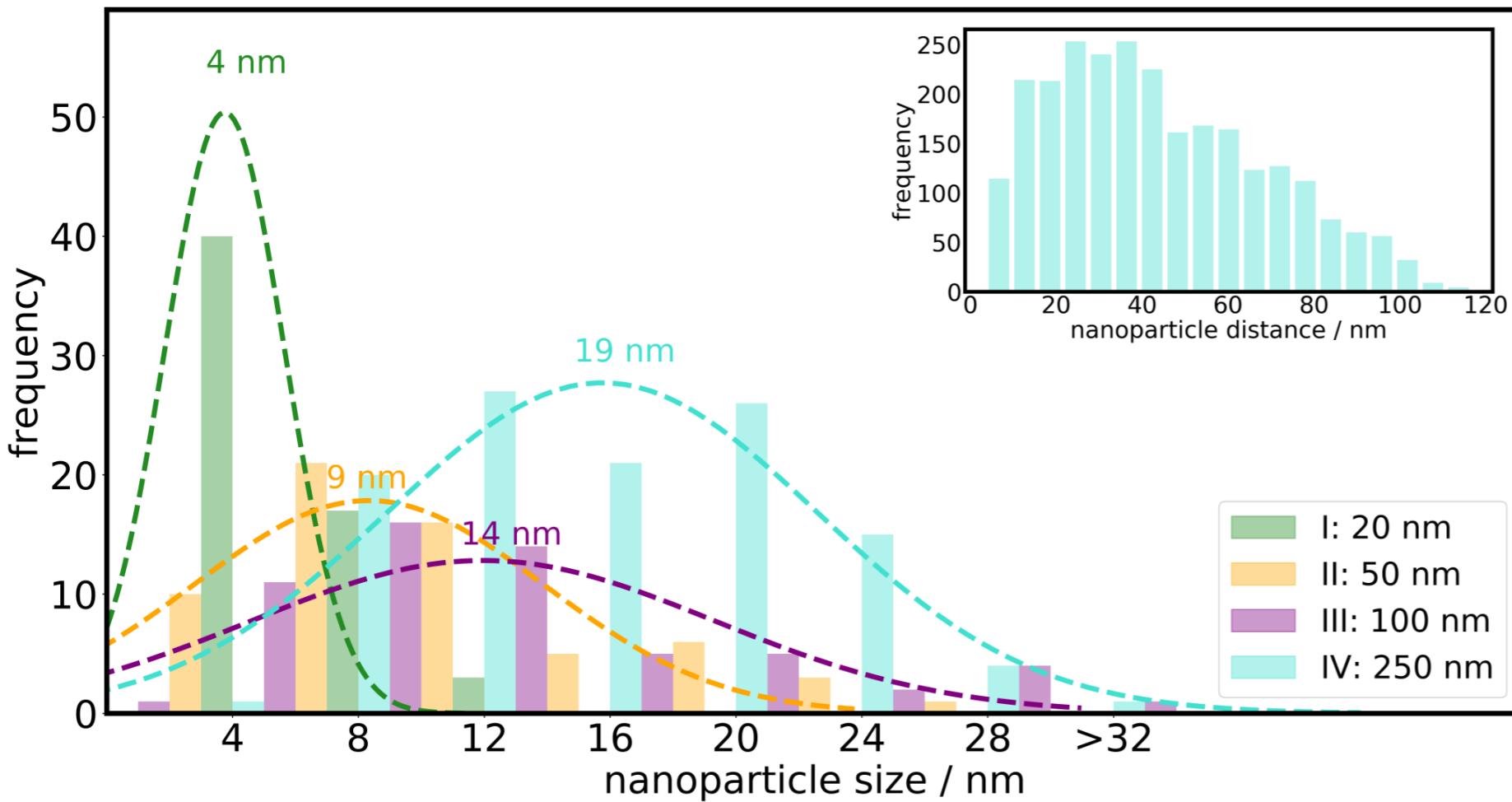
Absorption – Localized surface plasmon resonance - Simulation



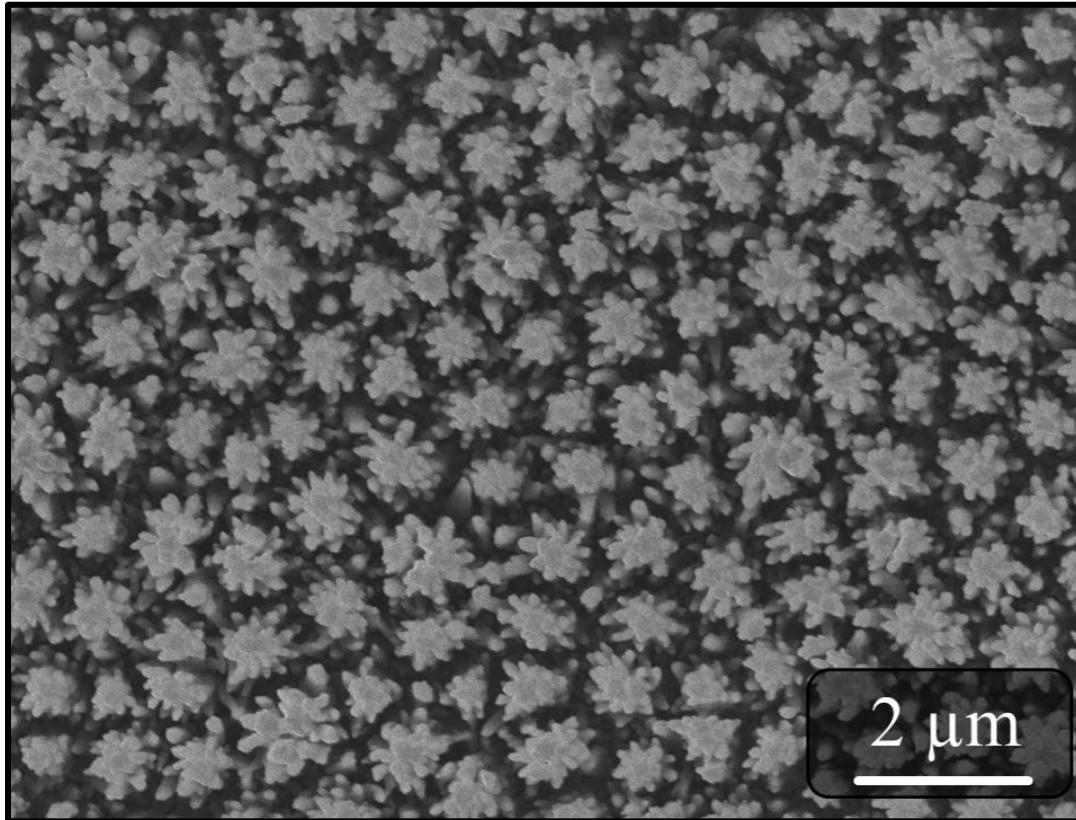
3 Effects for broadening the absorption (IR-shift):

1. Distribution in shape
2. Distribution in size
3. Interaction between particles (Plasmon hybridization)

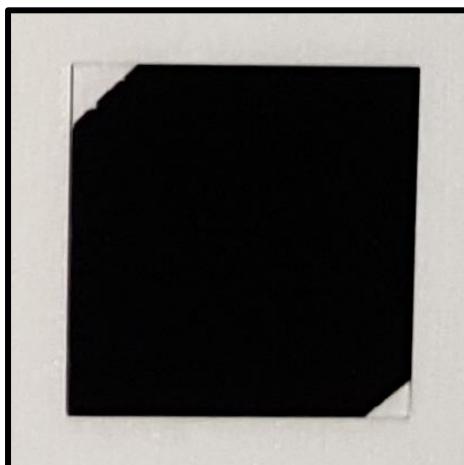
André Dathe



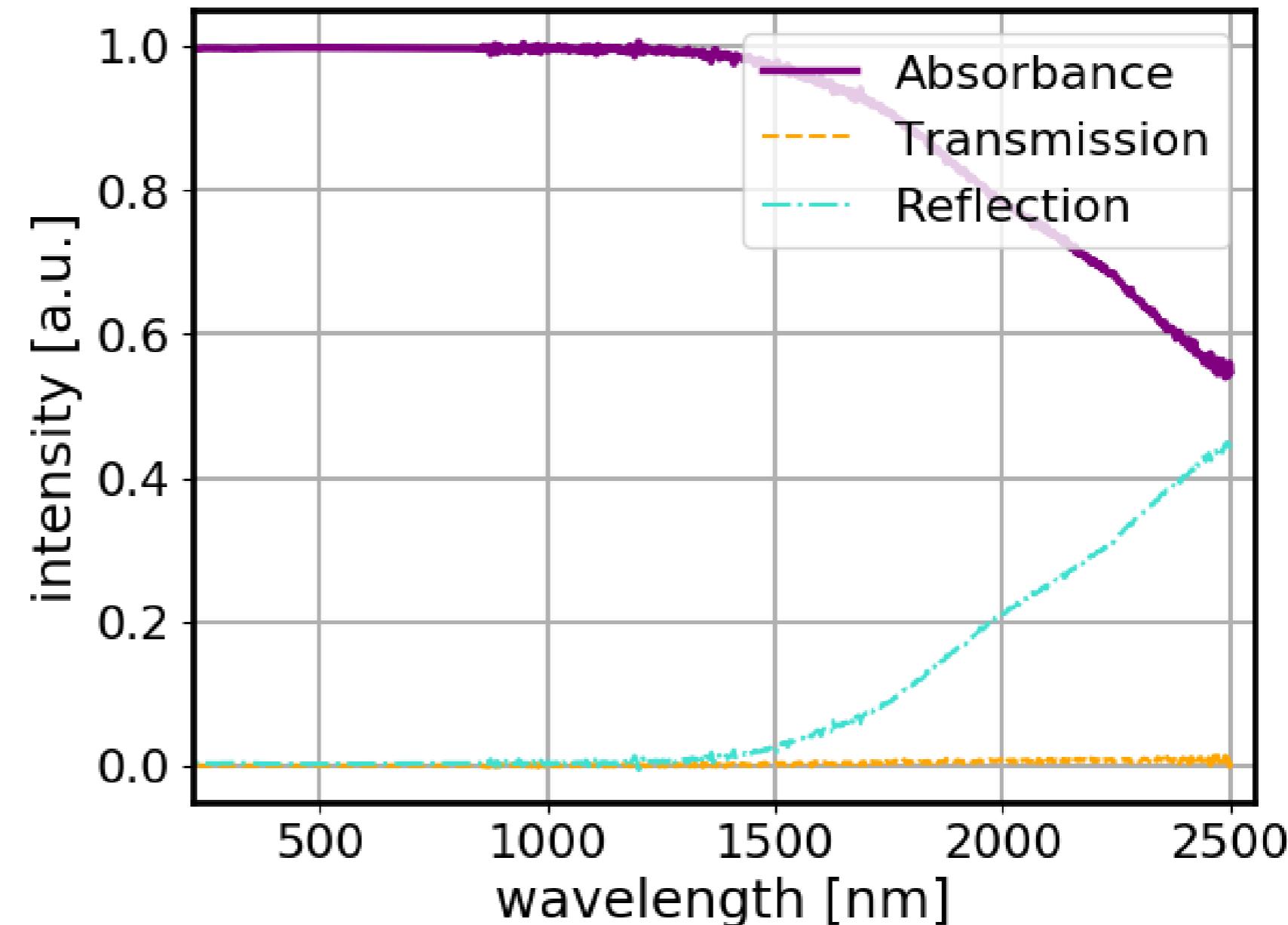
High absorption from UV to NIR



SEM image of MS-ALD structure

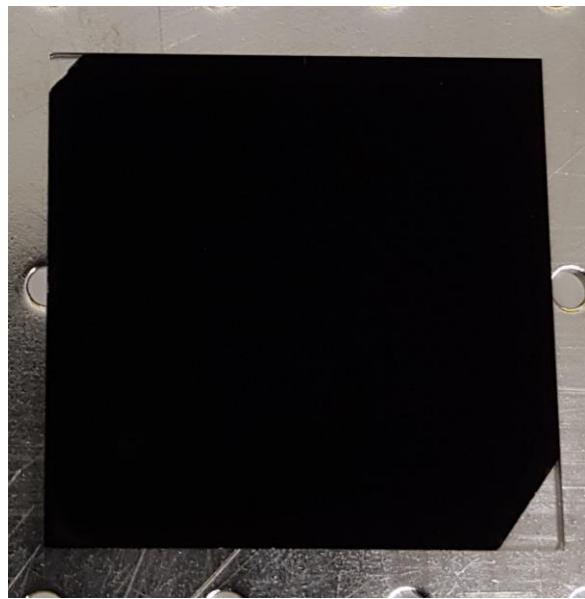


Sample size: $2.5 \times 2.5 \text{ mm}^2$ [‡]
Substrate: borofloat glass

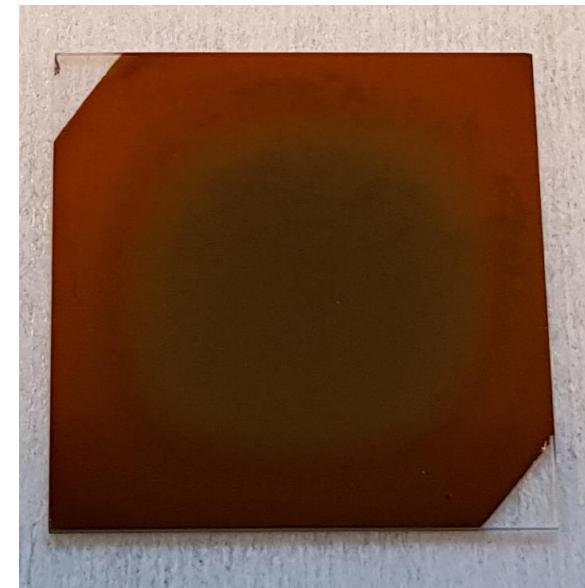


high absorption (> 99 %) from
220 nm to 1330 nm

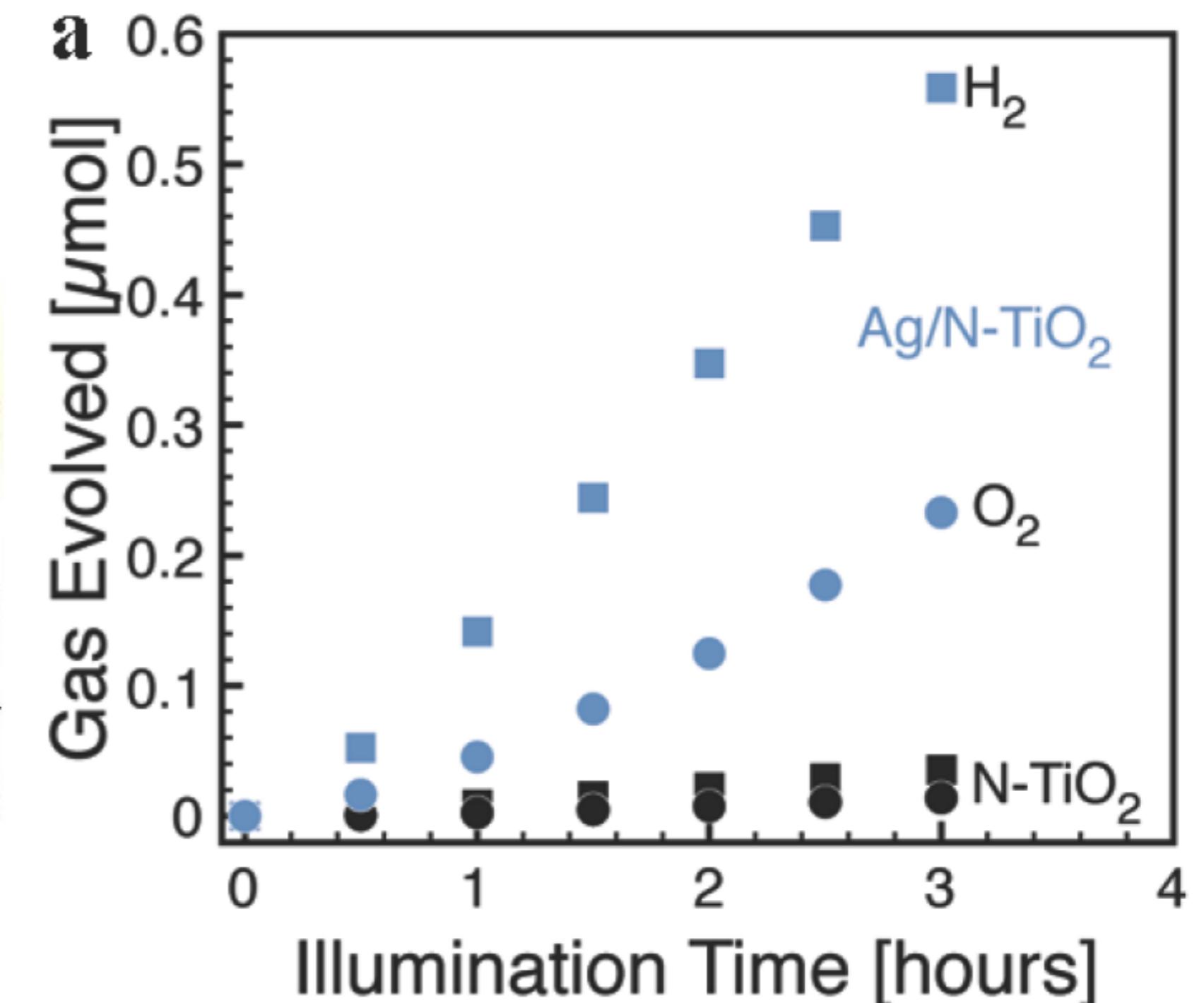
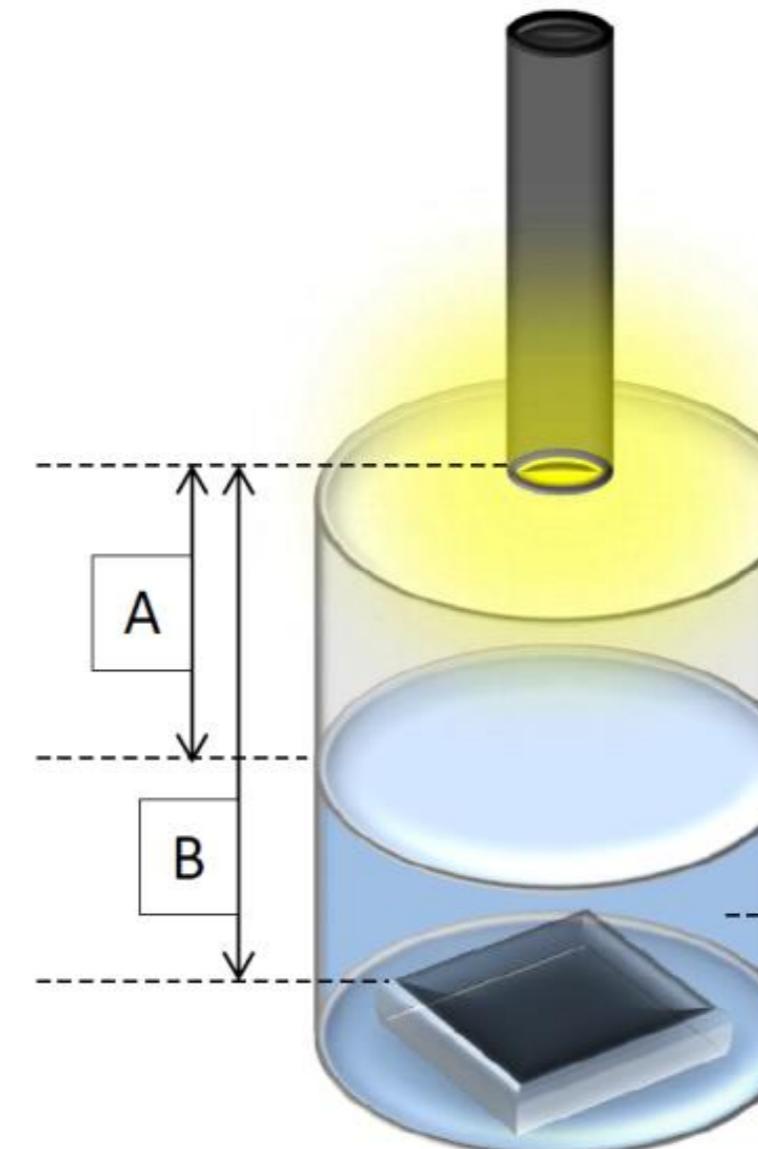
Application scenario → Plasmon-induced photocatalysis (Not tested)



AgNP on SiO₂



AgNP on ZnO

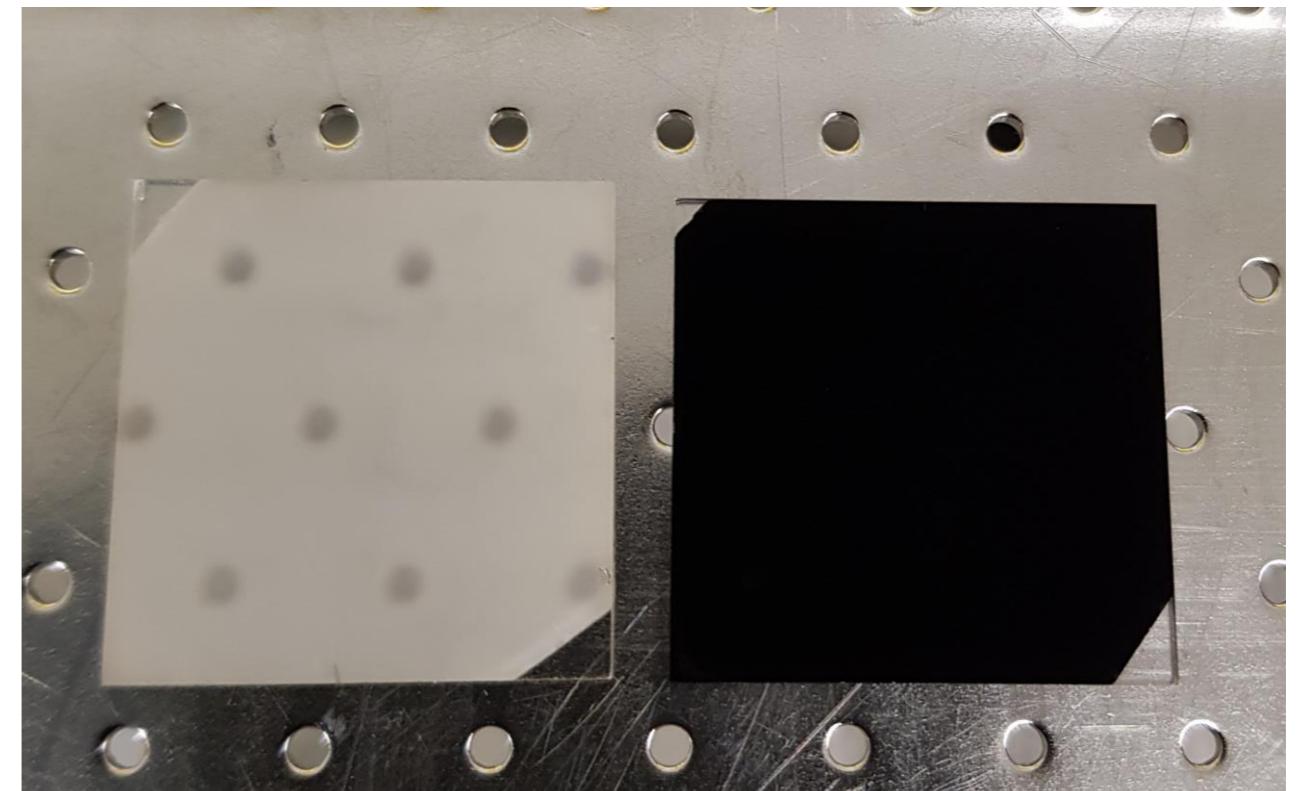


Ingram et al., J. Am. Chem. Soc. 133, 14, 5202-5205

Summary

- ✓ New method MS-ALD for 3D synthesis developed
- ✓ 3D templateless structures defined by applied deposition parameters
- ✓ High absorption from 220 – 2.500 nm
- Application scenarios
 - High Absorption layer for UV-VIS
 - Spectroscopy (SERS) – not shown here
 - Hydrogen generation (TiO_2 or ZnO needed)
- Outlook
 - Proof of concept: TiO_2 and ZnO scaffold
 - ***Find a fancy name!***

125 mm convex glass



1 sq inch: glass needles, Ag-NP decorated glass

Thank you for your kind attention!

Acknowledgment

- U. Hübner, P. Schaaf, D. Wang, A. Dathe, L. Stolle, T. Trautvetter, S. Goerke, P. Voigt, S. Yüksel, D. Cialla-May, K. Weber, K. Pippardt, K. Kandera, M. Sossna, A. Ihring, G. Zieger, D. Franke, E. Herbst, B. Steinbach, W. Morgenroth, R. Knipper, J. Belkner, A. Schwuchow



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