On chip integration of piezolectric nanowires

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EUROSENSORS XXX in Budapest, Hungary

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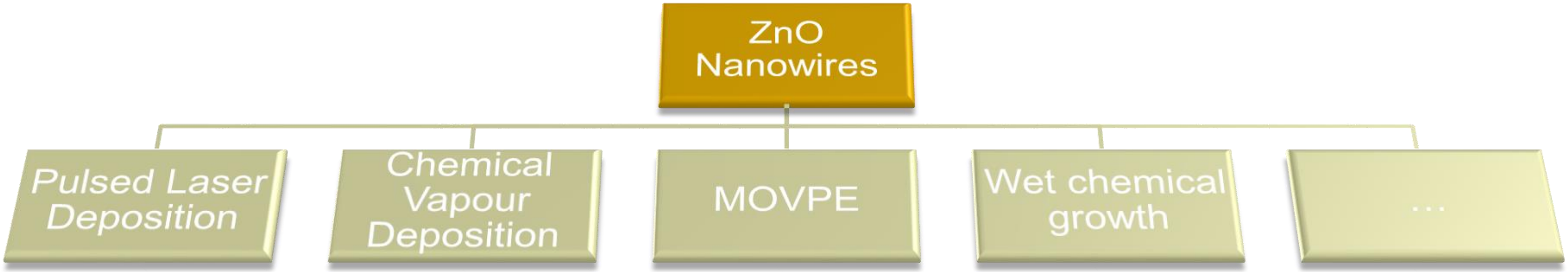
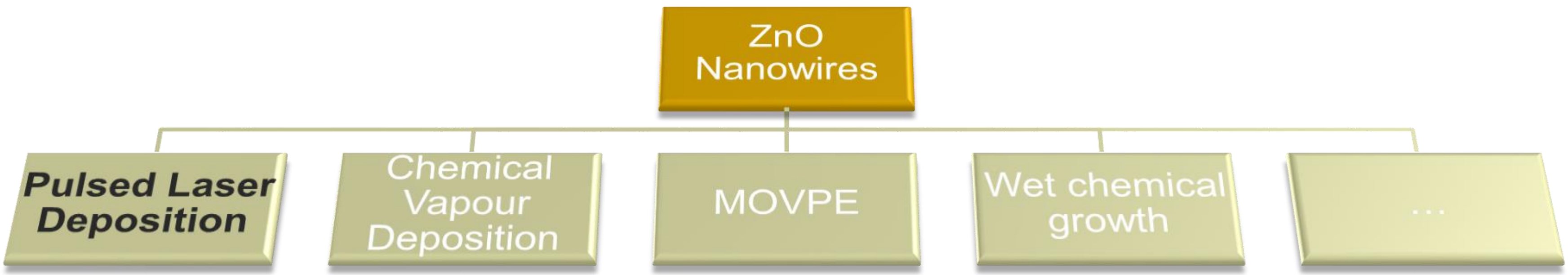
SEVENTH FRAMEWORK PROGRAMME

EU Project No. 611019

Growth of ZnO Nanowires



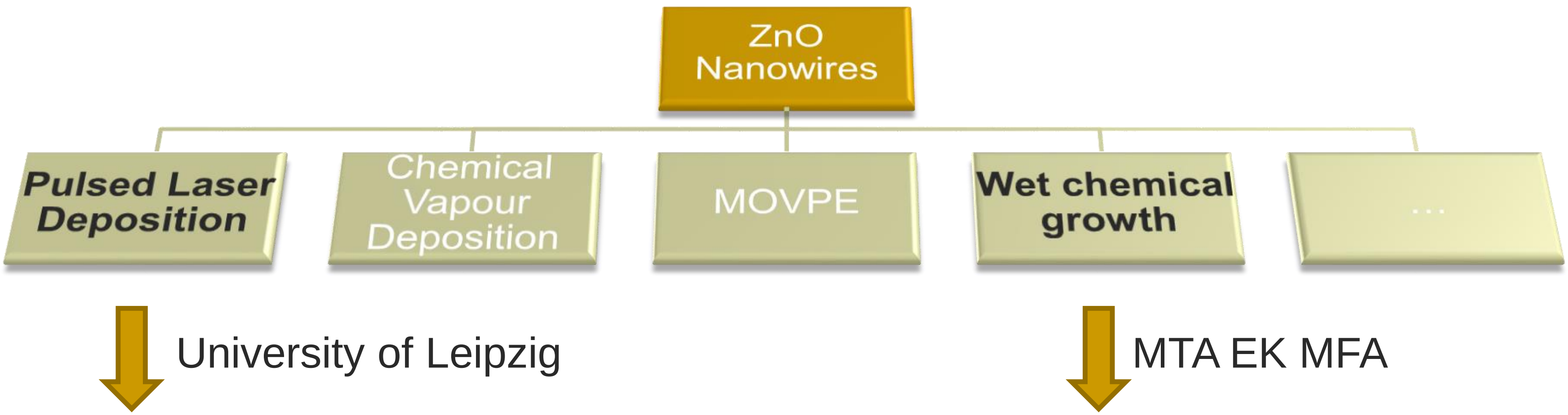
Growth of ZnO Nanowires



University of Leipzig

- excellent trade-off between simplicity and control
- can be grown catalyst free
- self organized growth
- high growth temperatures

Growth of ZnO Nanowires



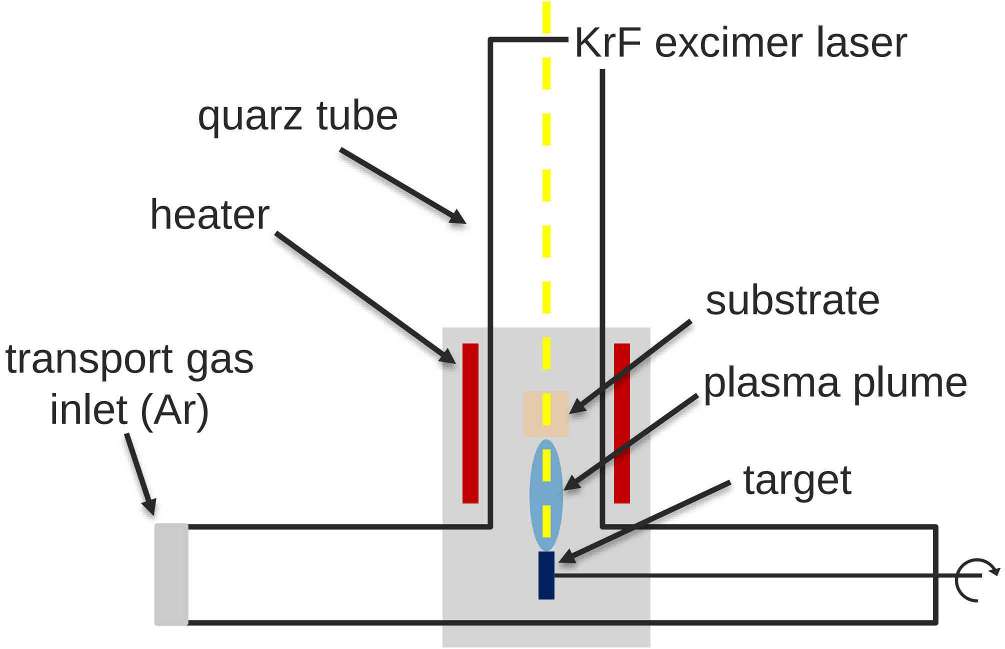
- excellent trade-off between simplicity and control
- can be grown catalyst free
- self organized growth
- high growth temperatures

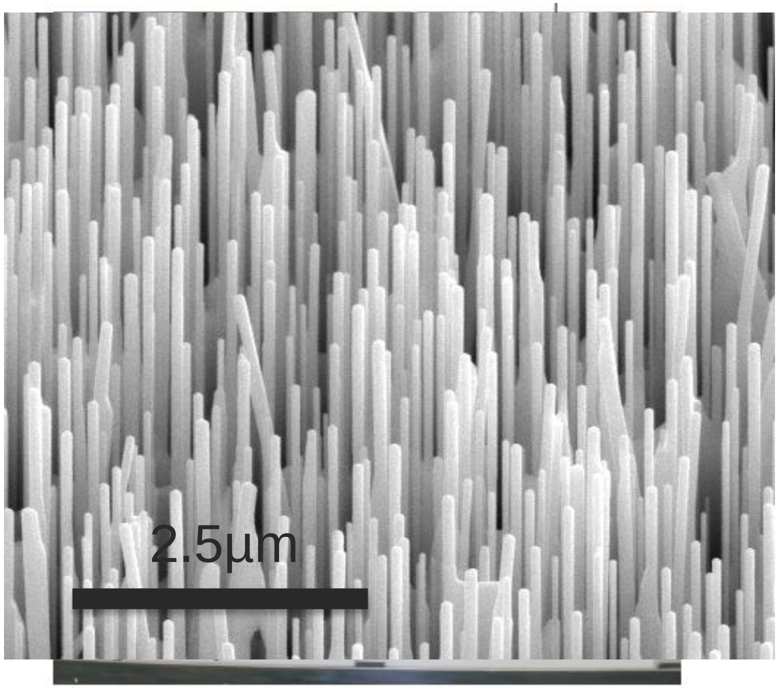
- easy to carry out
- growth at room temperature

Nanowires grown by Pulsed Laser Deposition

Pulsed Laser Deposition - Experimental Setup

- use high pressure pulsed laser deposition

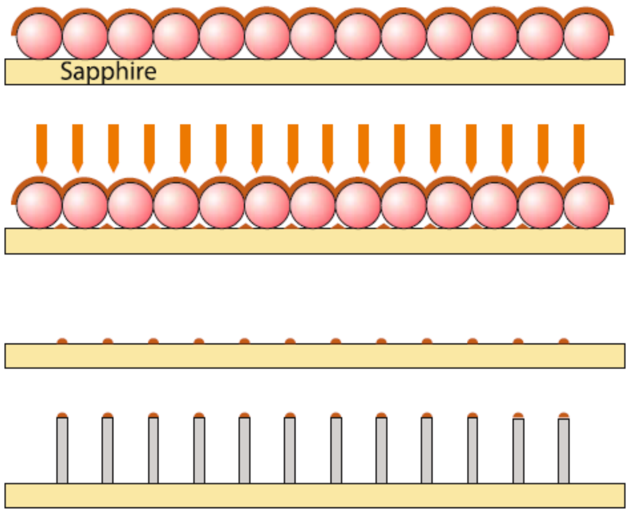


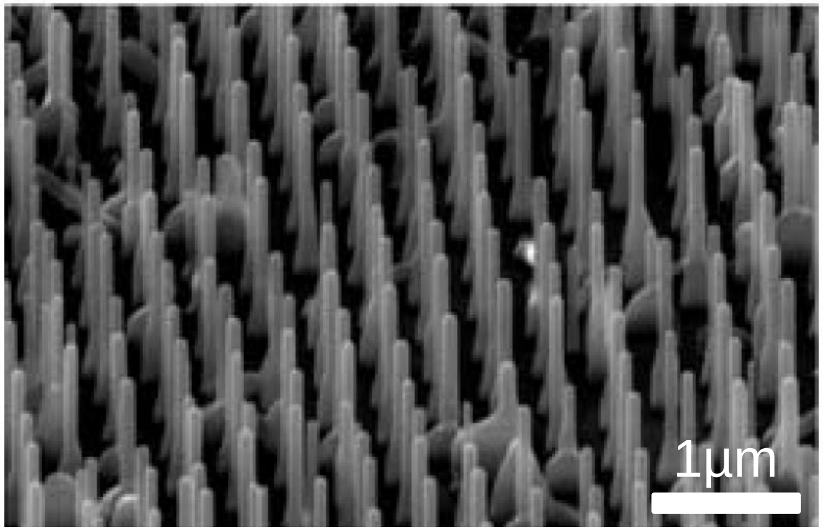


- no metal catalyst required
- on sapphire substrates high density (> $10\mu m^{-2}$)
  - high density not always desired, e.g. growth of nanostructures

Manipulation of the nanowire density

- use catalytic metal nanoparticles, e.g. gold





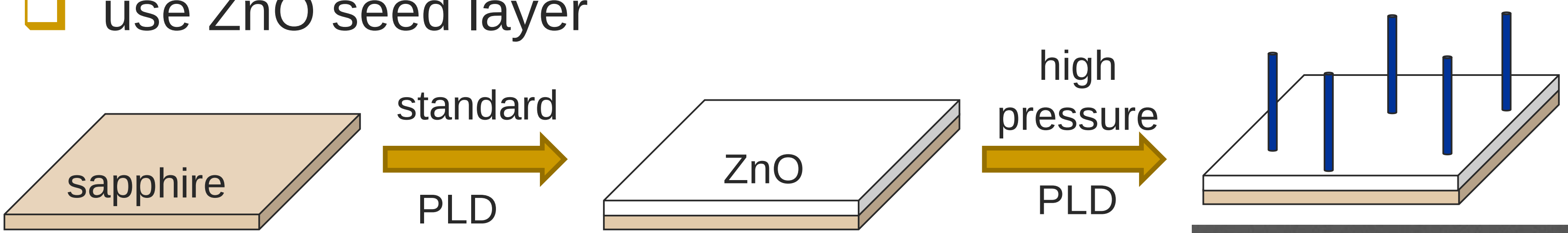
☺ selective growth of nanowires
☹ low yield of nanowires
☹ supports diffusion of metal particles into the nanowire

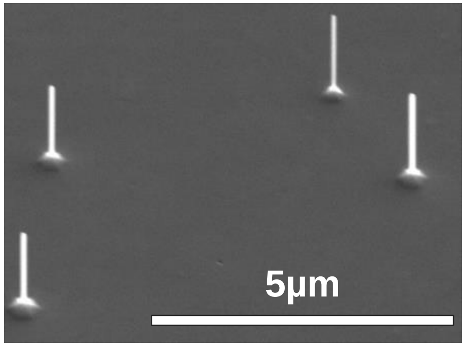
A. Rahm *et al.*, Appl. Phys. A **88**, 31 (2007)

Manipulation of the nanowire density

- use catalytic metal nanoparticles, e.g. gold
  - ☹ low yield of nanowires
  - ☹ supports diffusion of metal particles into the nanowire

- use ZnO seed layer



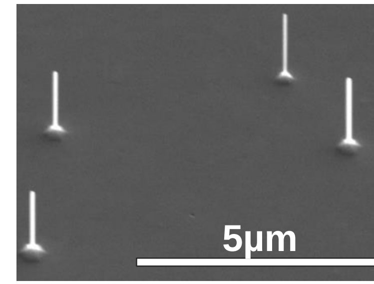


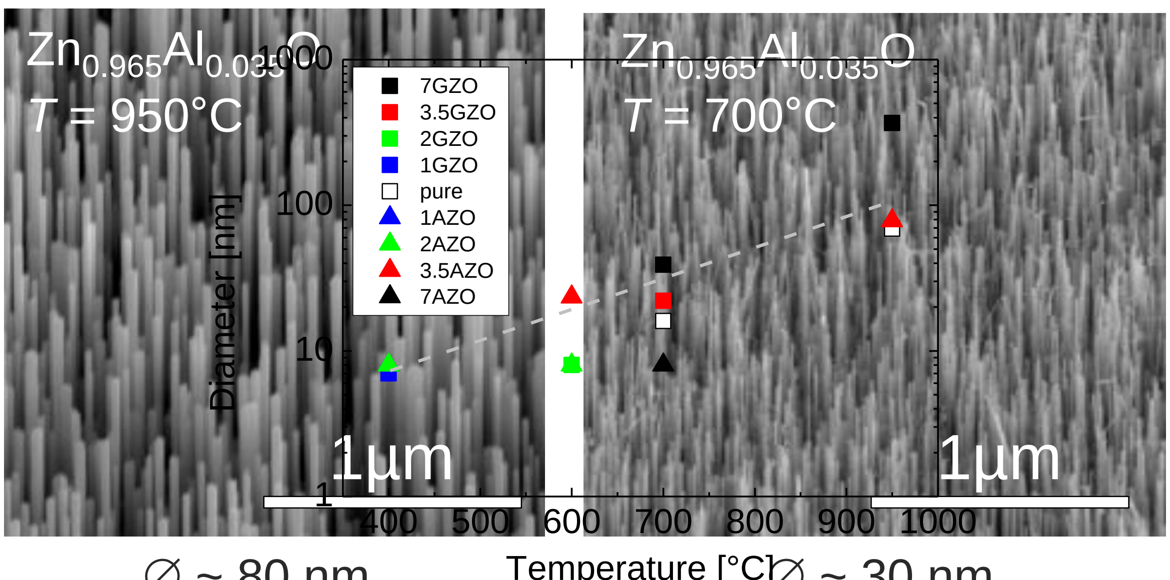
☺ properties of the nanowires can be controlled by the ZnO seed layer

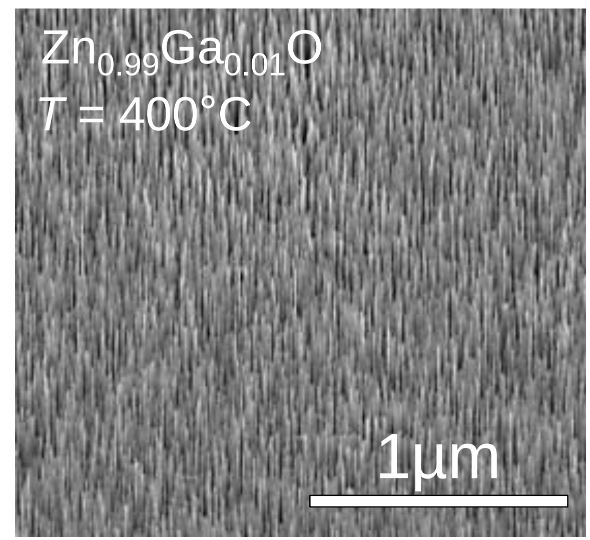
B. Cao *et al.*, J. Mater. Chem. **20**, 3848 (2010)

Manipulation of the nanowire morphology

- doping of the seed layer change → control of:
  - density and optimum growth temperature
  - nanowire diameter





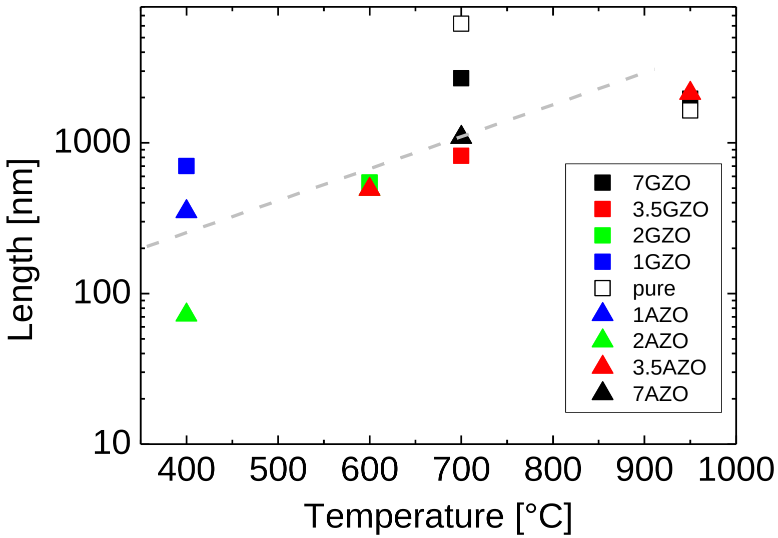


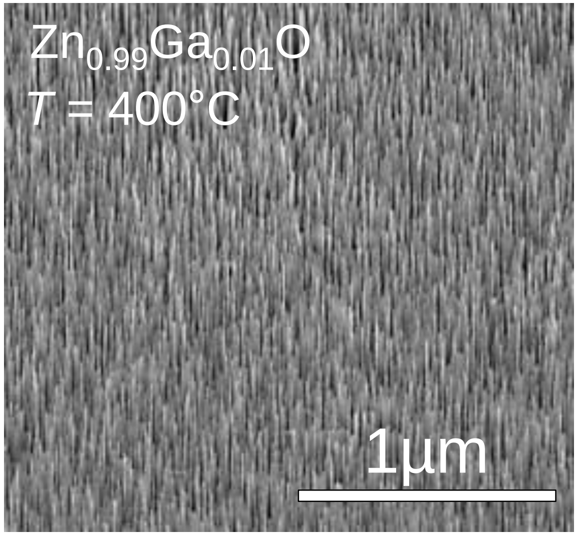
∅ ~ 80 nm ∅ ~ 30 nm **∅ < 7 nm**

- successful growth of ultrathin nanowires (∅ < 7 nm)

Manipulation of the nanowire morphology

- doping of the seed layer change ➞ control of:
  - density and optimum growth temperature
  - nanowire diameter and length



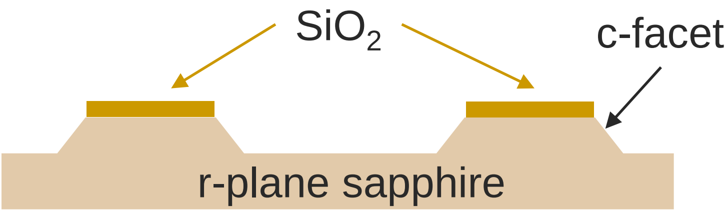


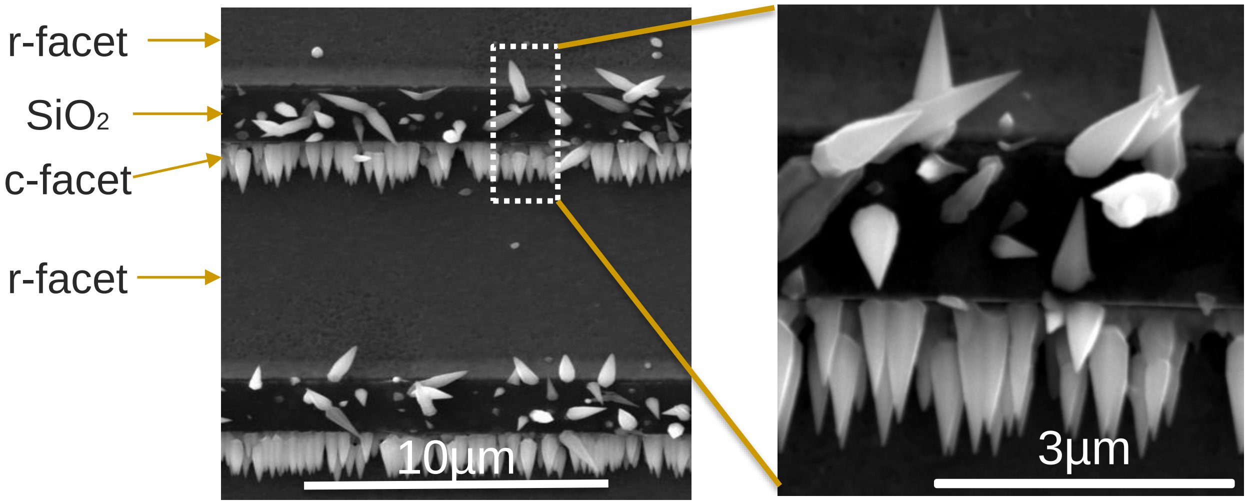
∅ < 7 nm

- successful growth of ultrathin nanowires (∅ < 7 nm)
- nanowire growth at T = 400°C

Orientation of the Nanowires

- use pre-structured substrates





- selective growth of nanowires
- orientation of nanowires can be adjusted

A. Shkurmanov *et al.*, AIP Advances (accepted)

substrate provided by:
F. Tendille, P. De Mierry (CNRS-CRHEA) and G. Feuillet (CEA/LETI)

Orientation of the Nanowires

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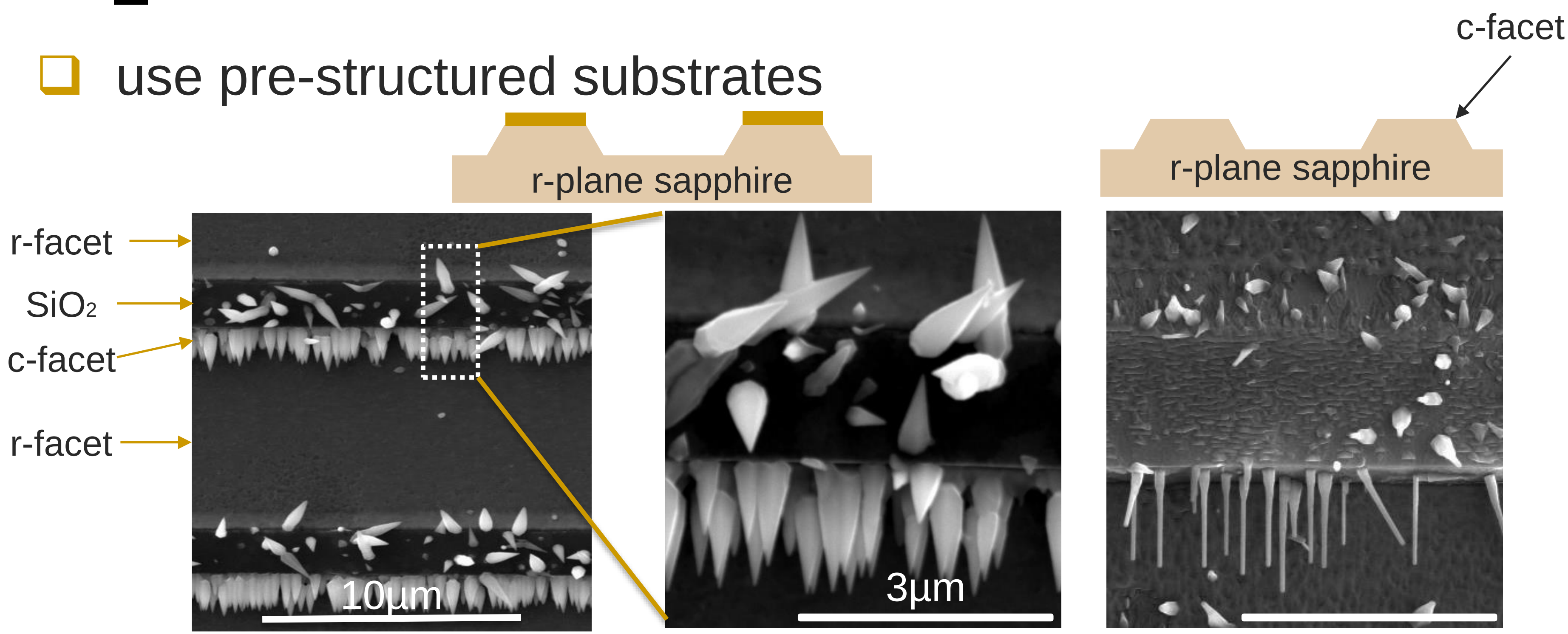

- selective growth of nanowires
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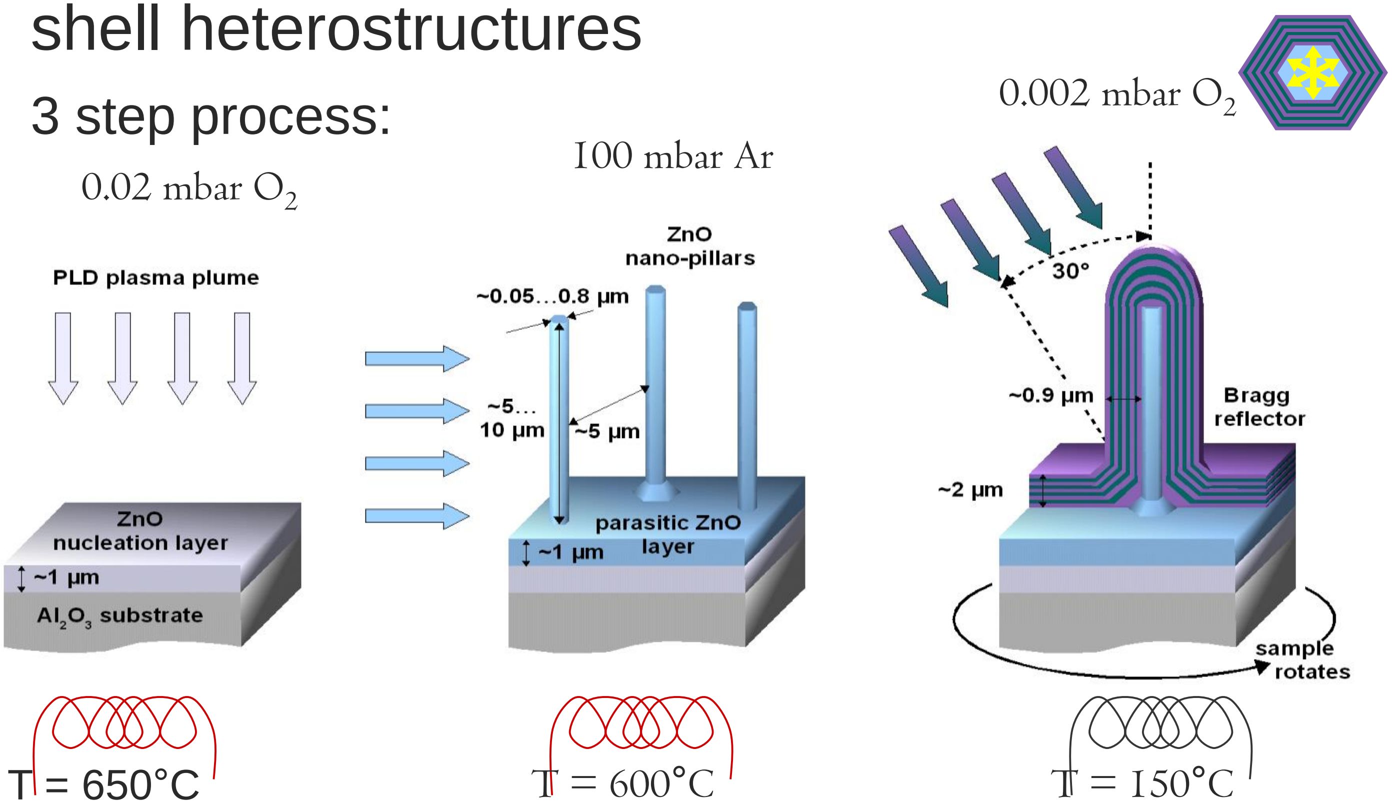
Nanowire Heterostructures

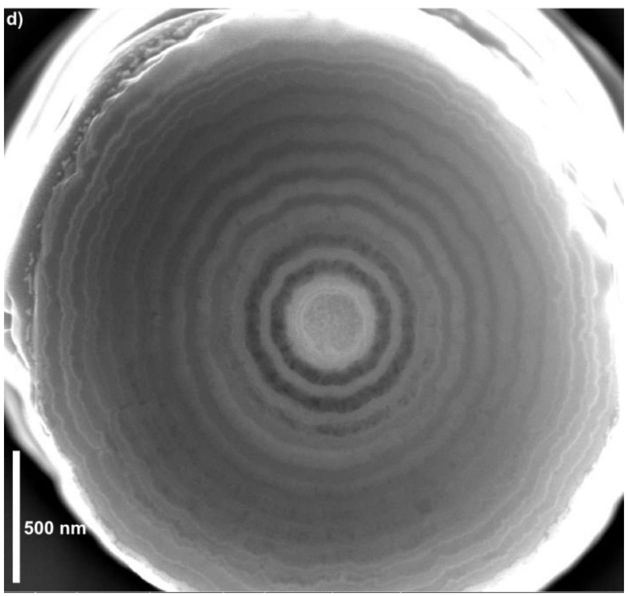
- shell heterostructures

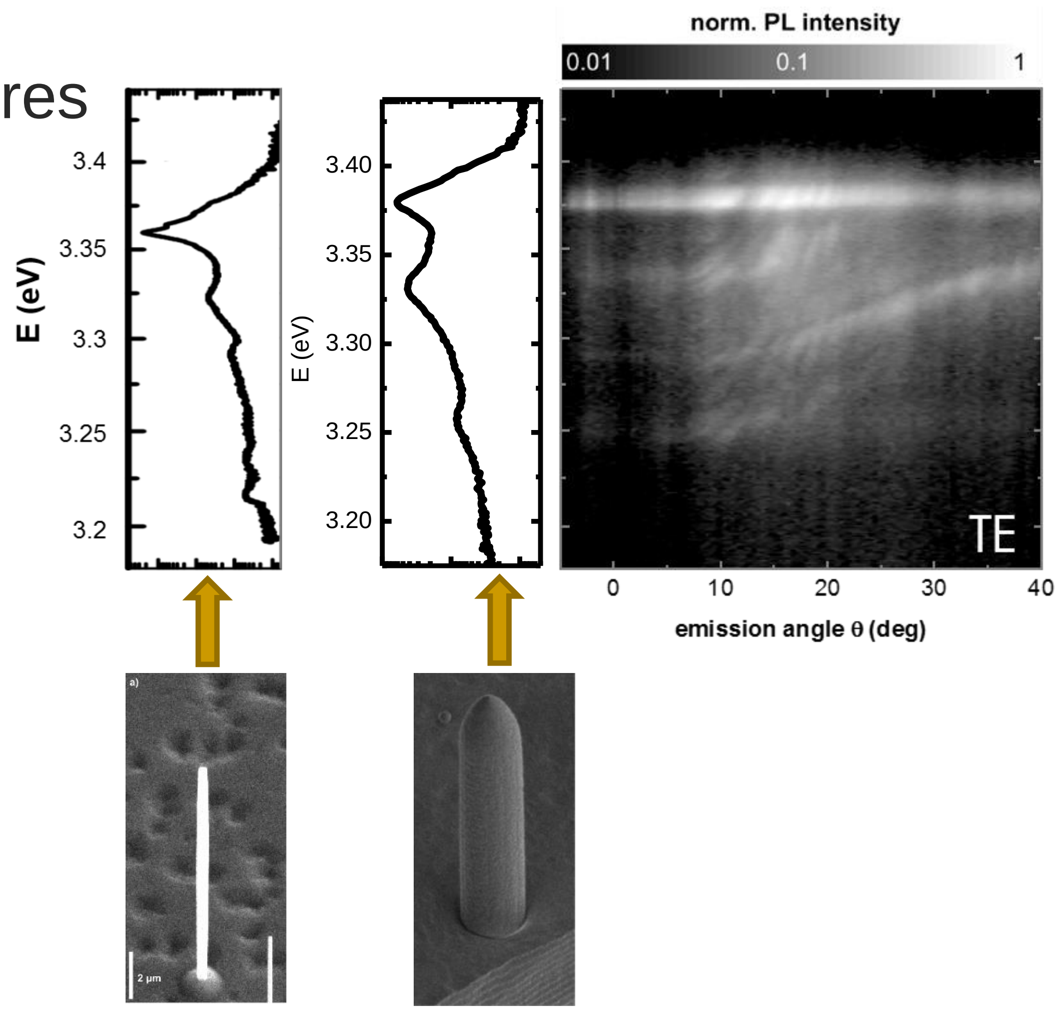
3 step process:



Nanowire Heterostructures
Coating

- shell heterostructures e.g. Bragg layers:

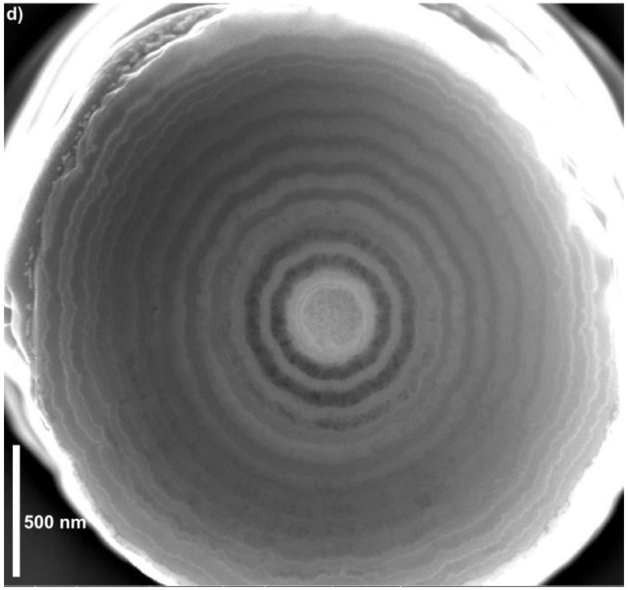


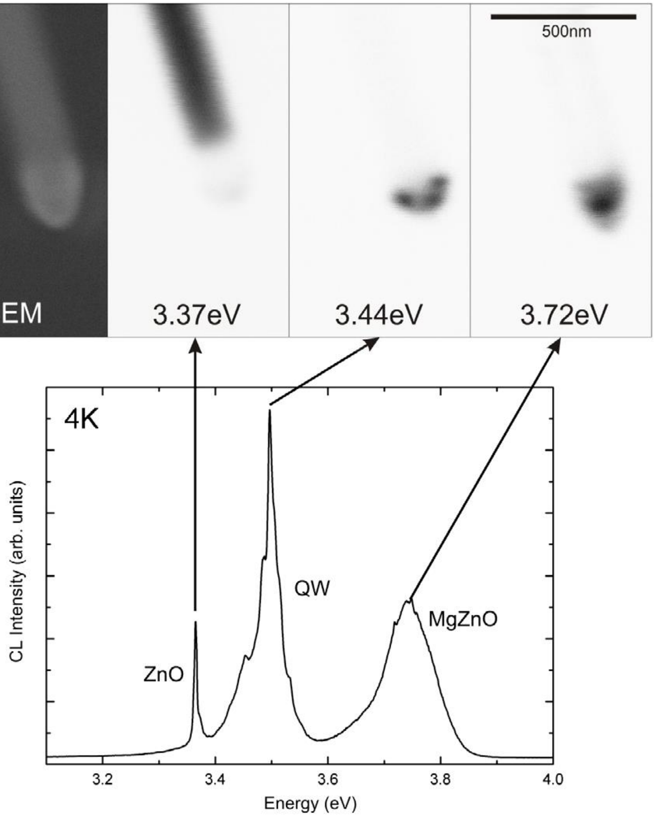


R. Schmidt-Grund *et al.*, phys. stat. sol (A) 247, 1351 (2010)
T. Michalsky *et* al., Eur. Phys. J. Appl. Phys. **74**, 30502

Nanowire Heterostructures Coating

- shell heterostructures e.g. Bragg layers:
- axial quantum wells





C. Czekalla *et al.*, Nanotechnology **19**, 115202 (2008)

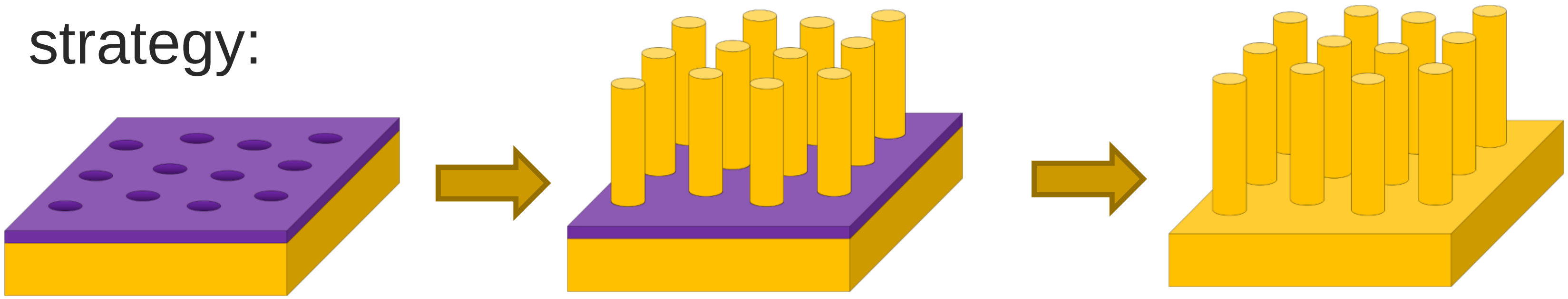
PiezoMAT

Nanowires grown by Wet Chemical Growth

SEVENTH FRAMEWORK PROGRAMME

Experimental

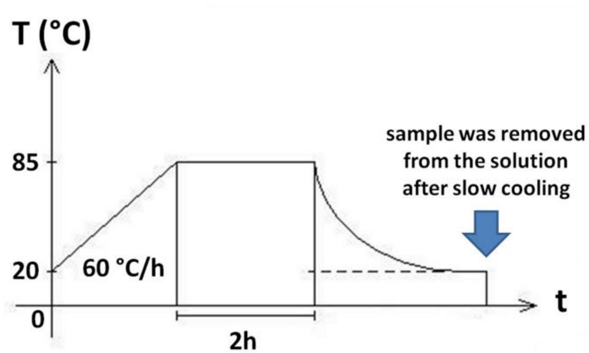
- strategy:



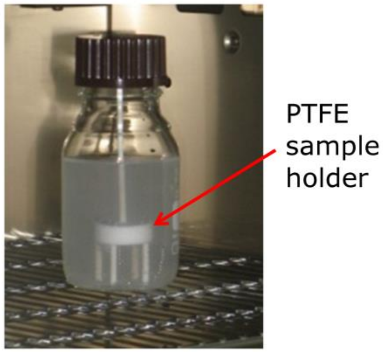
- spincoating and patterning of the resist

- hydrothermal growth
- $Zn(NO_3)_2$, $(CH_2)_6N_4$
- catalyst free
- t = 2 – 12h / T = 85 – 95°C

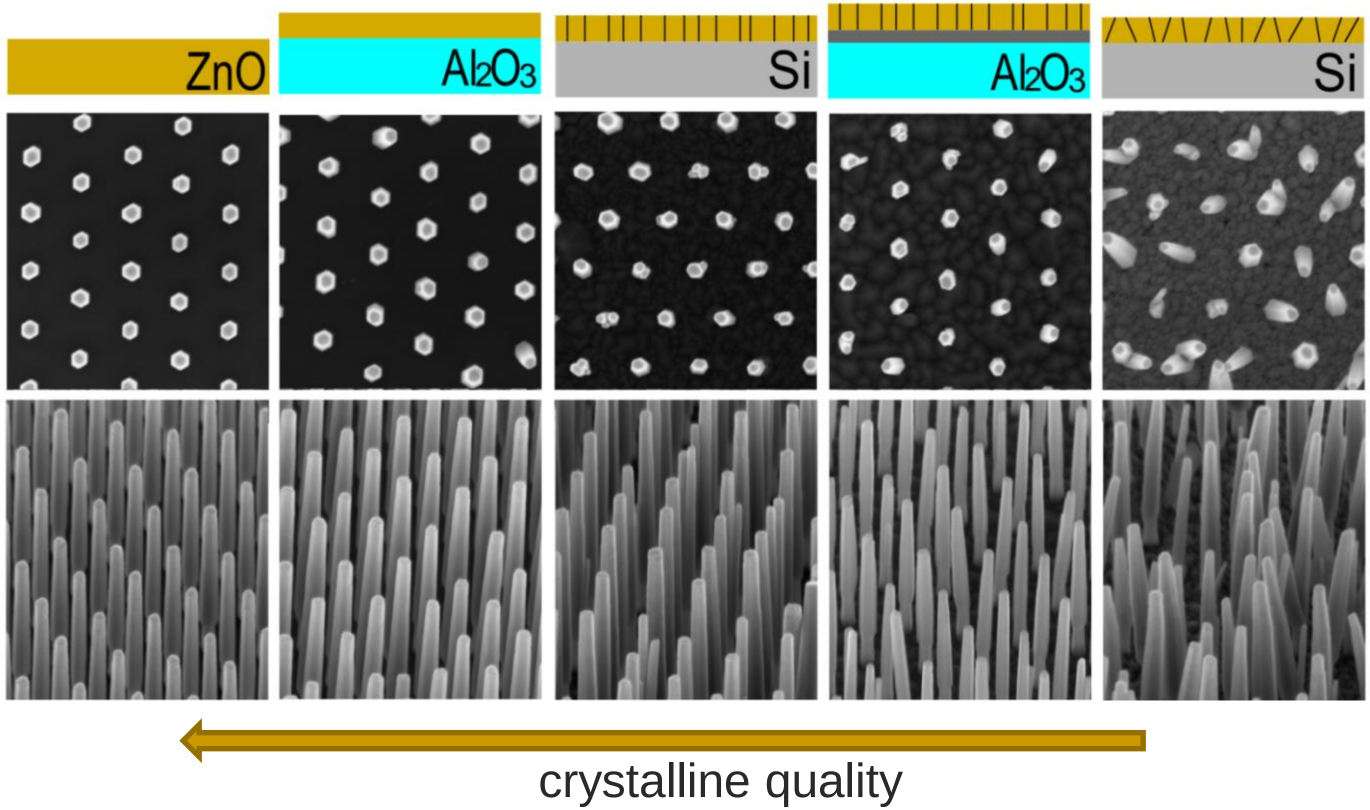
- lift-off



(f)



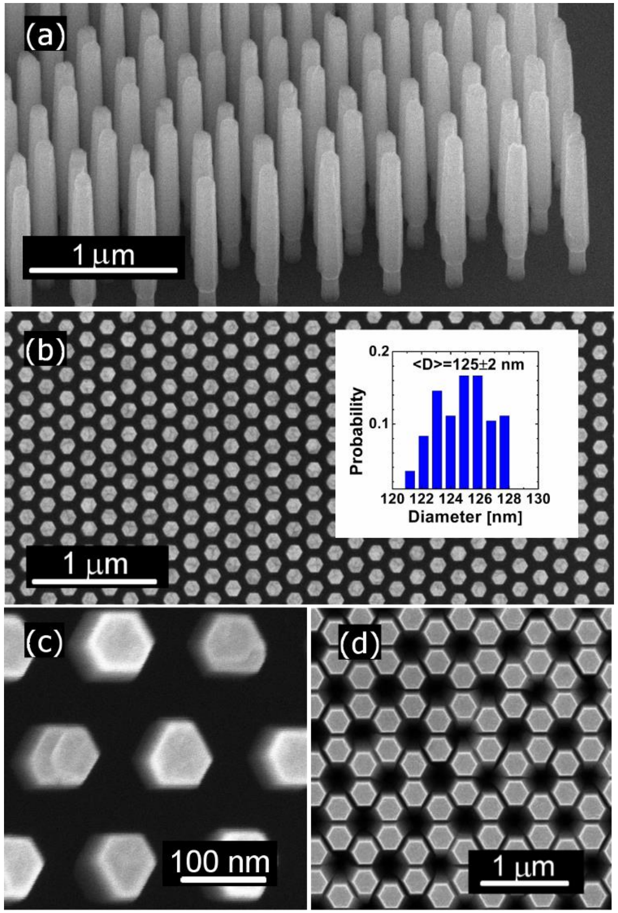
Nanowire Growth

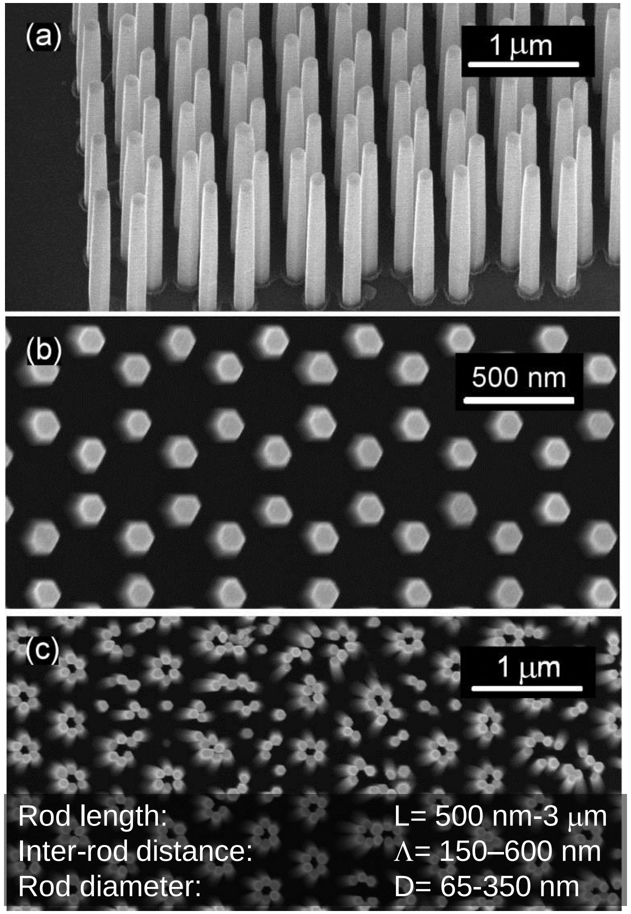


- crystalline quality of the seed layer determines nanowire alignment

R. Erdélyi *et al.*, Cryst. Gr. & Des. **11**, 2515 (2011)

Nanowire Growth





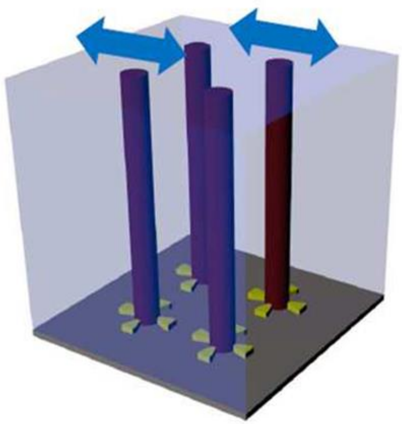
- highly uniform arrays of nanowires on ZnO single crystal

Nanowires for Fingerprint Sensing

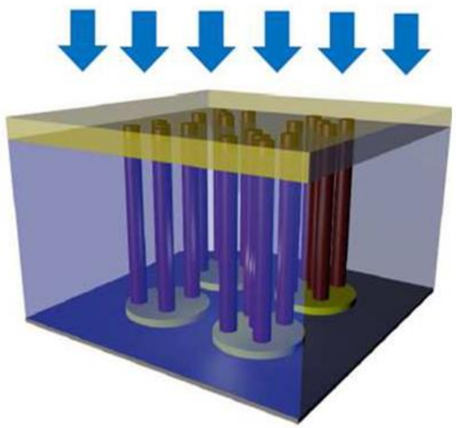
Sensor: Idea

- two strategies for fingerprint sensing

bottom-bottom-contacted (bending)	top-bottom-contacted (compression)

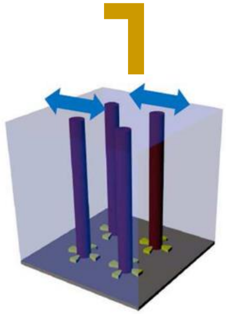


- non-conductive seed layer
- bottom electrode

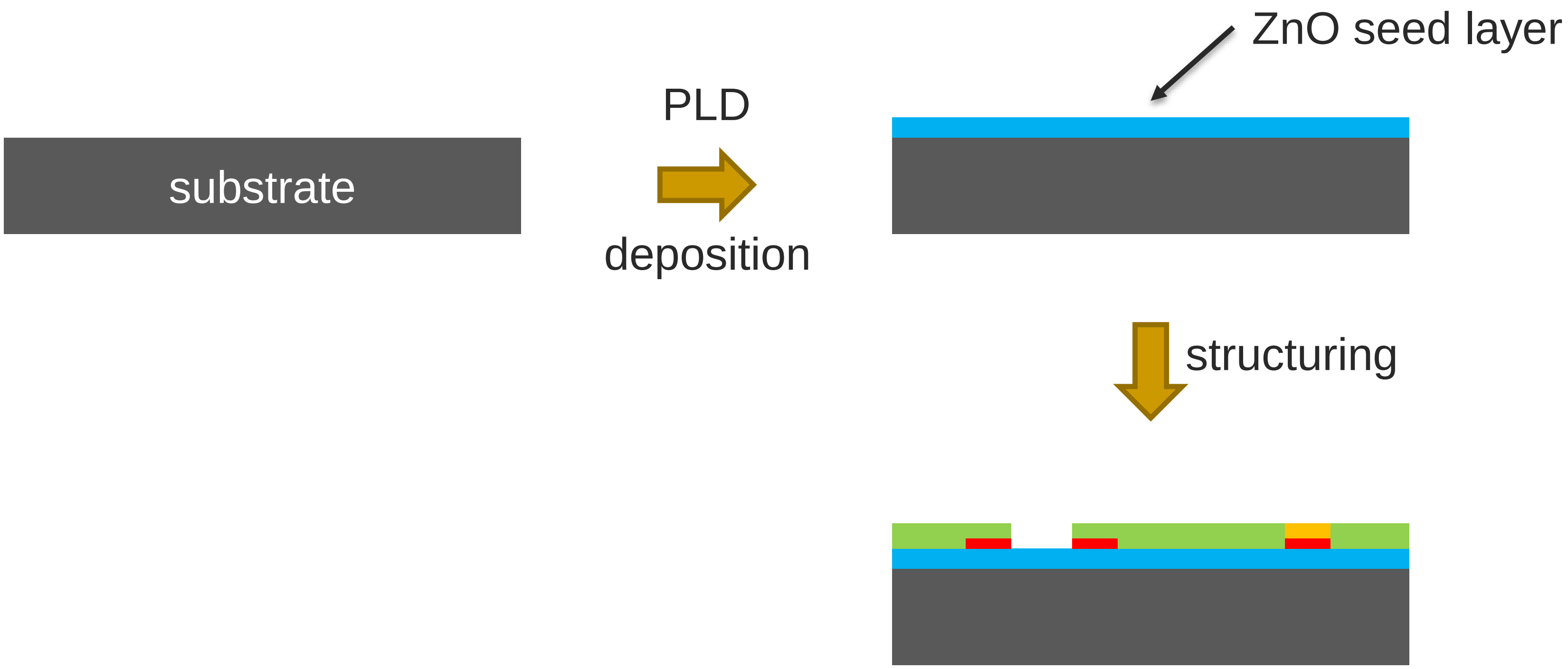


- conductive seed layer
- top and bottom electrode

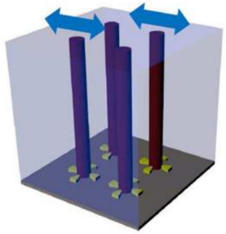
Nanowires for fingerprint sensing - bending



- growth on structured chips (fabricated by MFA)
  - substrate: sapphire and Si wafer



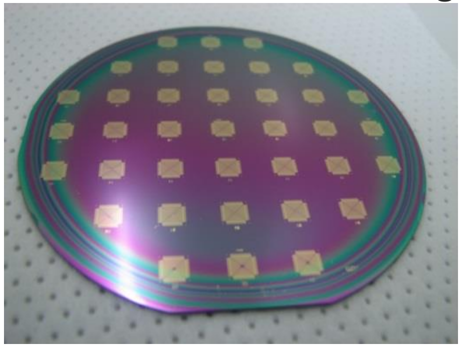
Nanowires for fingerprint sensing - bending



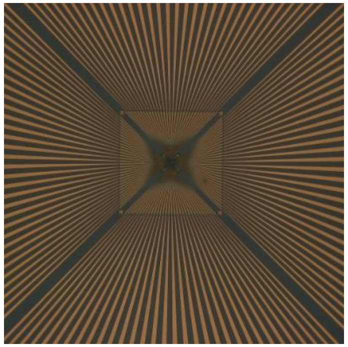
- growth on structured chips (fabricated by MFA)
  - substrate: sapphire and Si wafer

number of NW	8 × 8
NW diameter	400 nm
contacts per NW	2
resolution	5080

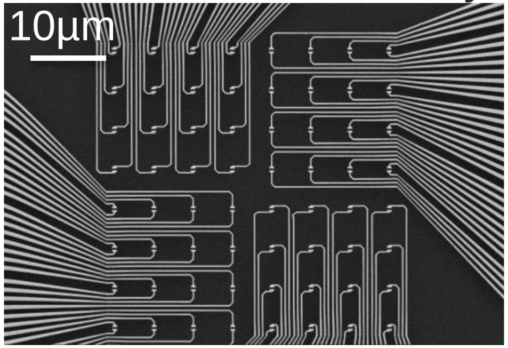
Si wafer before dicing



Interconnects



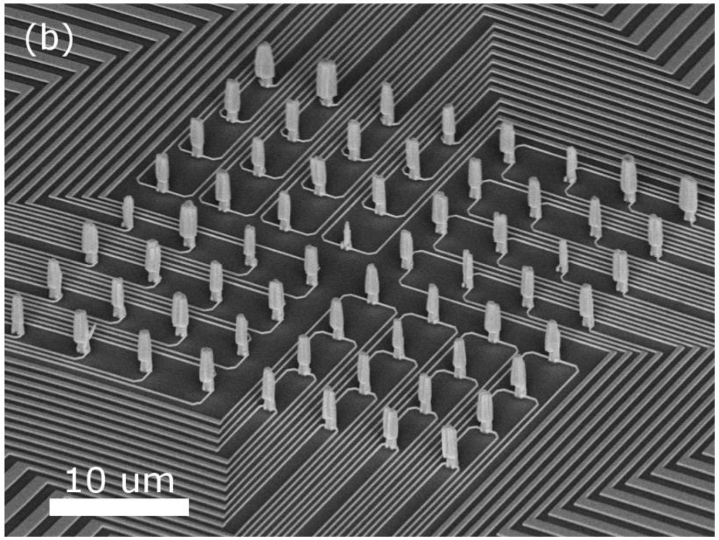
Fine lines for 8x8 array



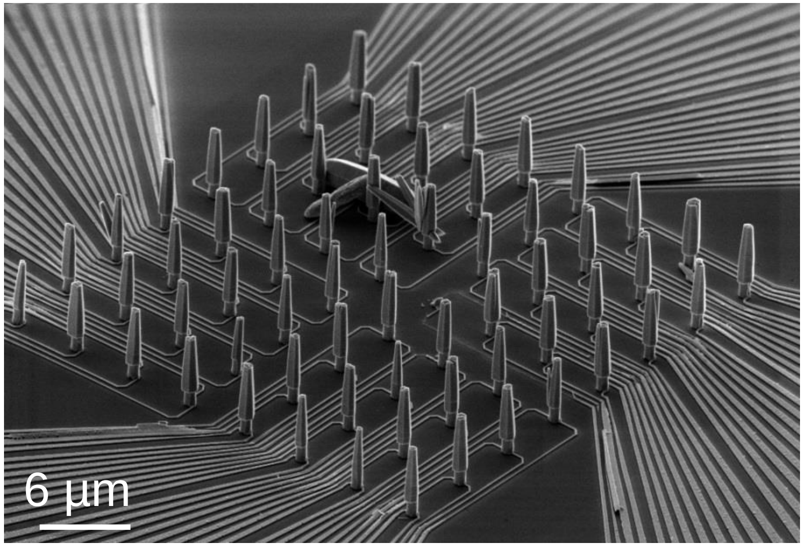
Nanowires for fingerprint sensing - bending

- growth on structured chips (fabricated by MFA)
  - use sapphire and Si wafer

- 3” silicon wafer

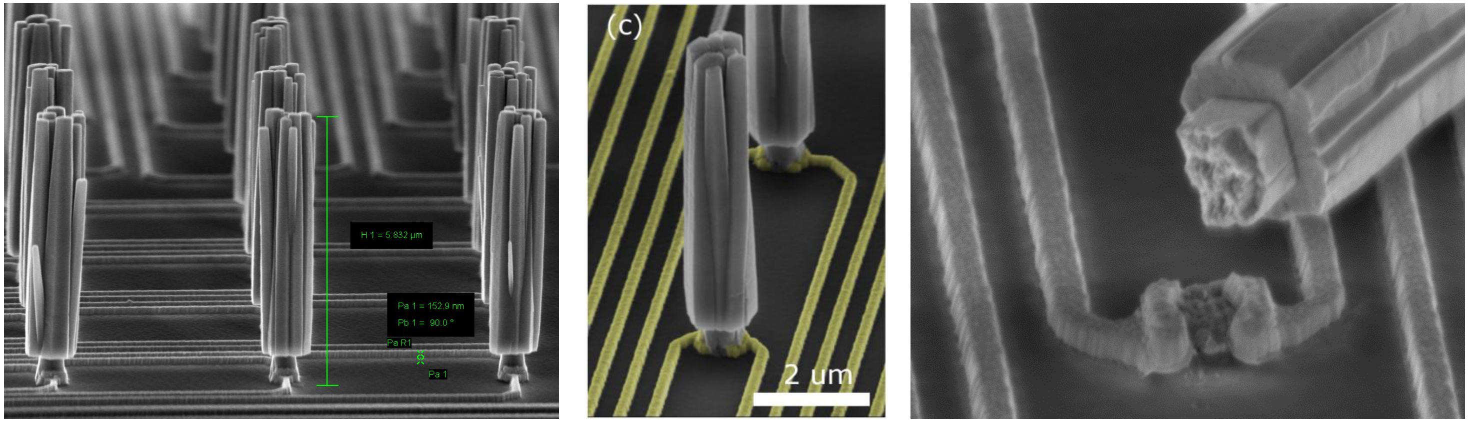


- 3” sapphire wafer



☺ growth of vertical aligned nanowires

Nanowires for fingerprint sensing - bending

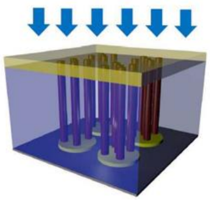


☺ Double sided electrical contacts

☹ Mechanical robustness is to be improved

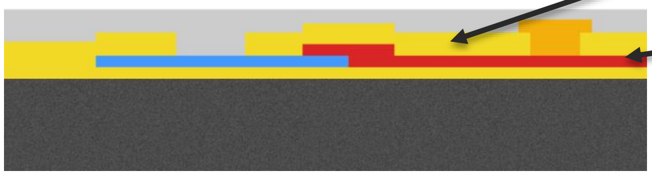
polymer encapsulation is needed (next talk)

Nanowires for fingerprint sensing - compression



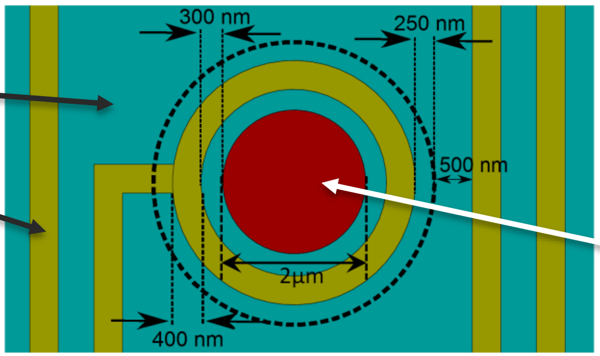
- growth on structured chips

  (fabricated by CEA)

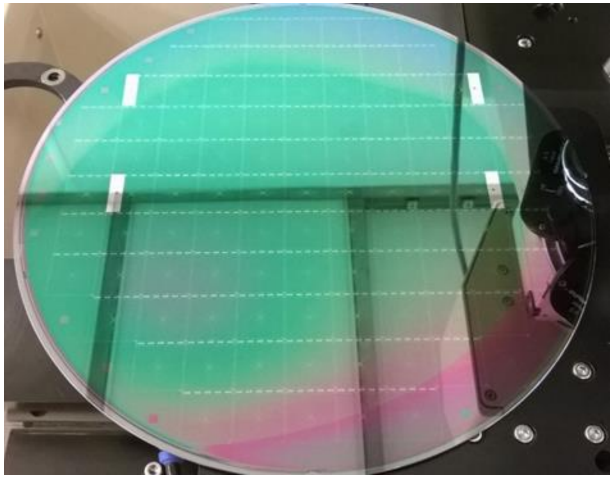


SiO_2

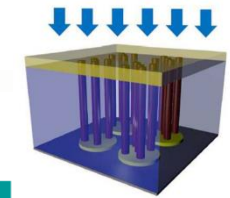
metal lines



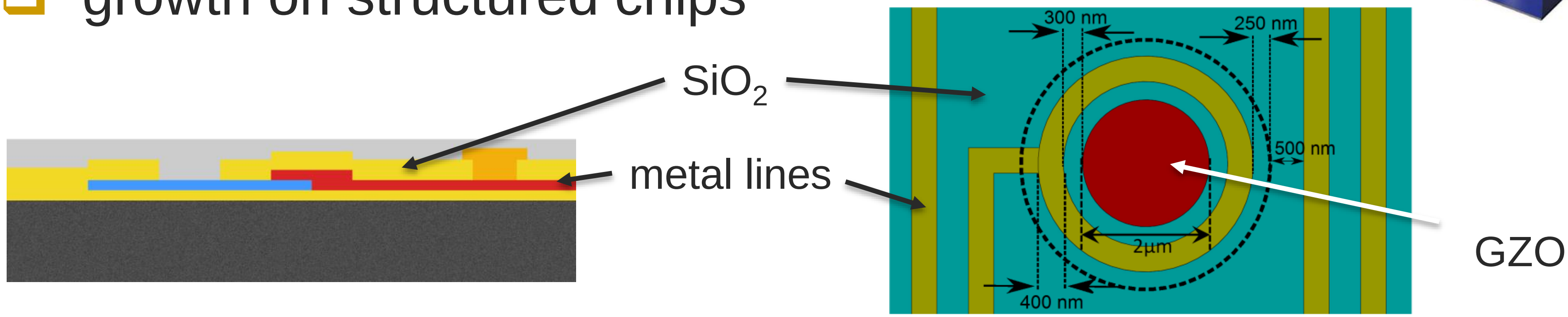
GZO

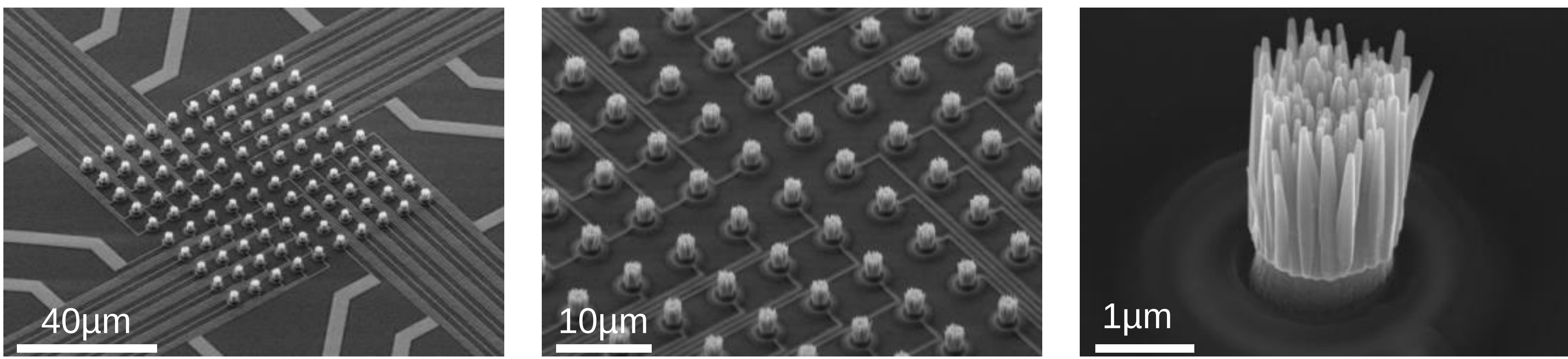


Nanowires for fingerprint sensing - compression



- growth on structured chips

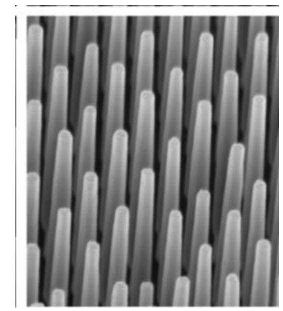




☺ growth of vertical aligned nanowires

Summary

- growth of ZnO NWs by PLD and WCG



- properties of the NWs can be controlled

Thank you for your attention

- on chip integration is possible