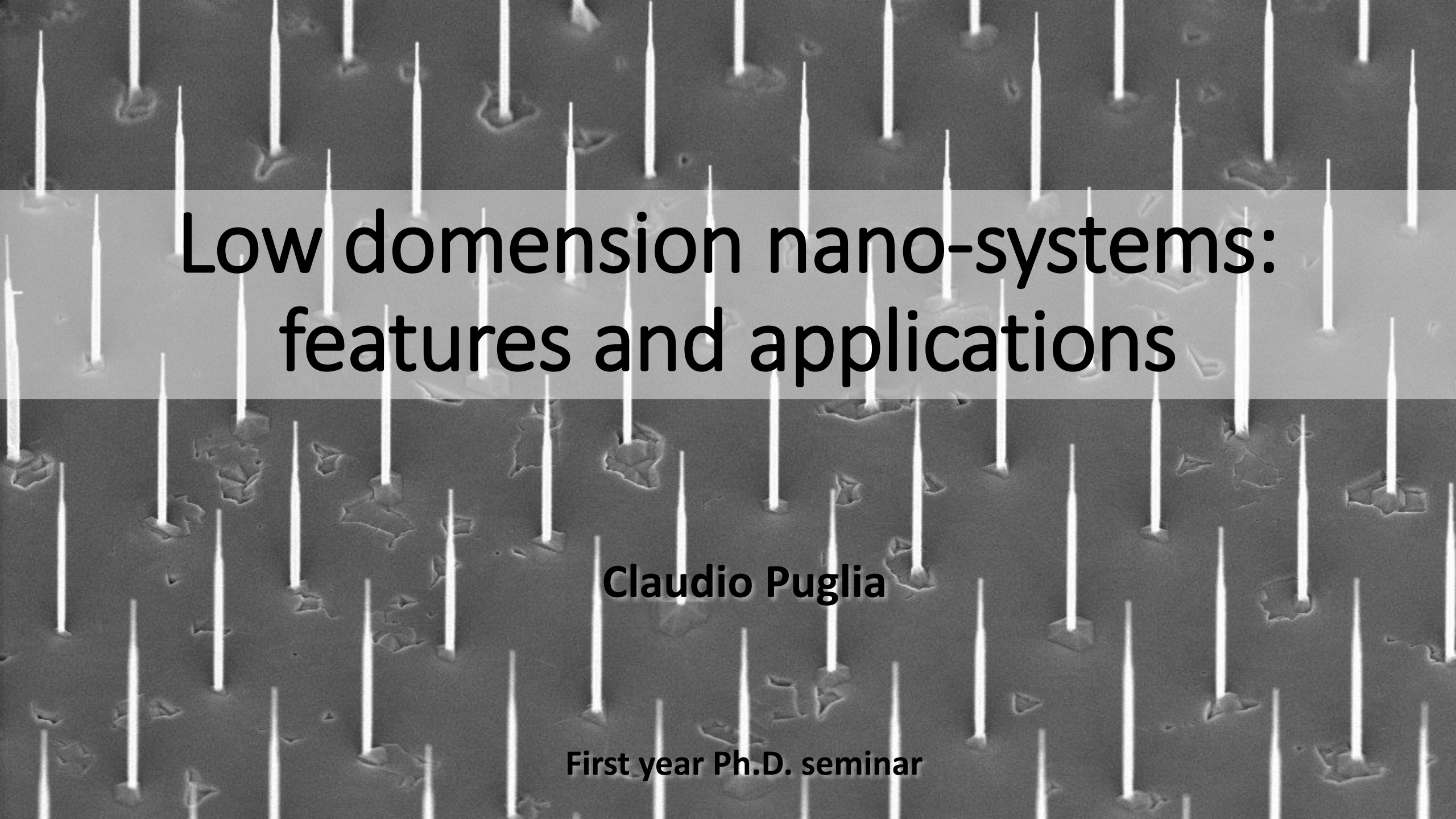


Low domension nano-systems: features and applications

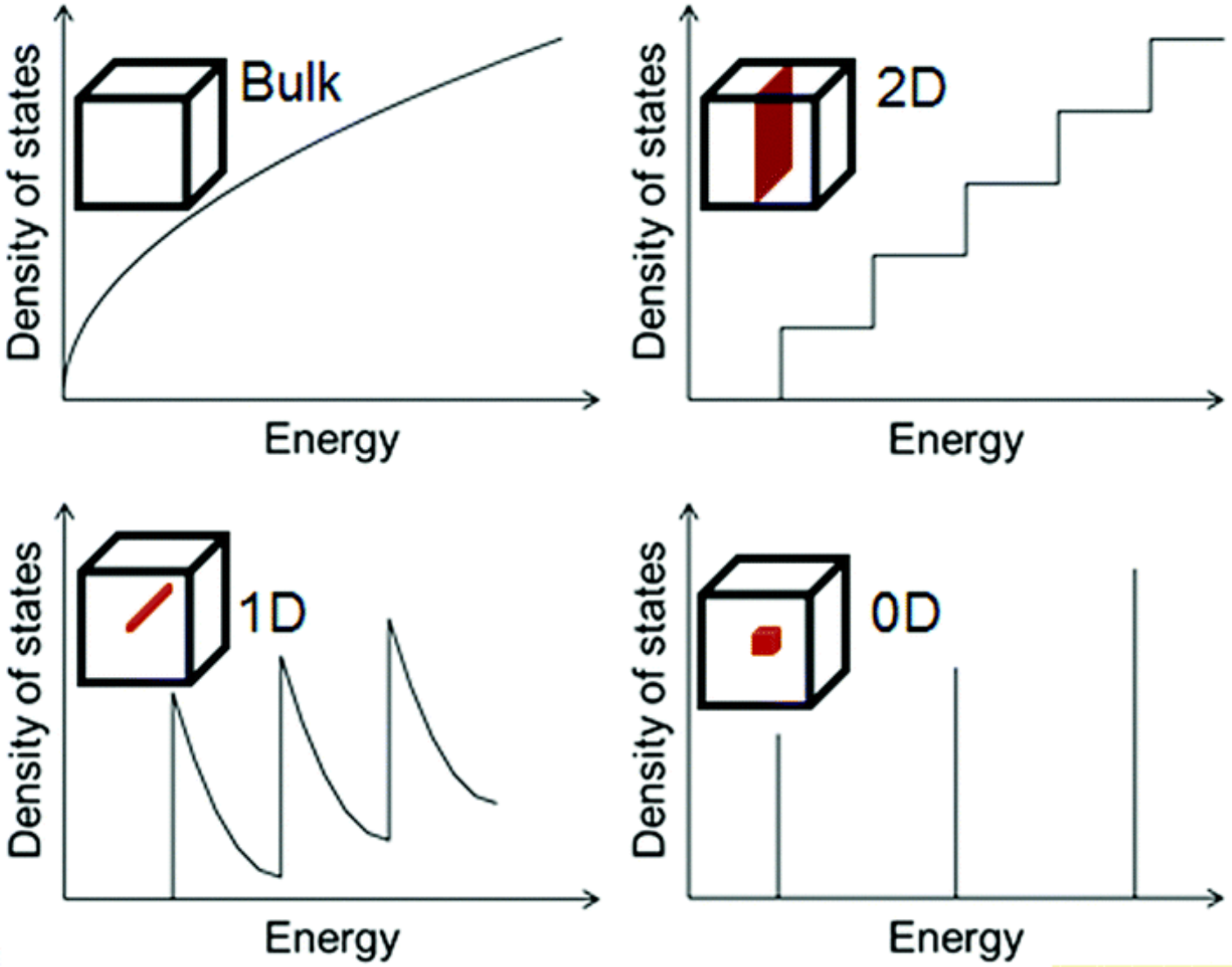
Claudio Puglia

First year Ph.D. seminar

Outline

- What are low dimensional nano-systems?
- Fabrication
- Applications
- Conclucions and Q&A

Low dimensional nano-systems



Lower D

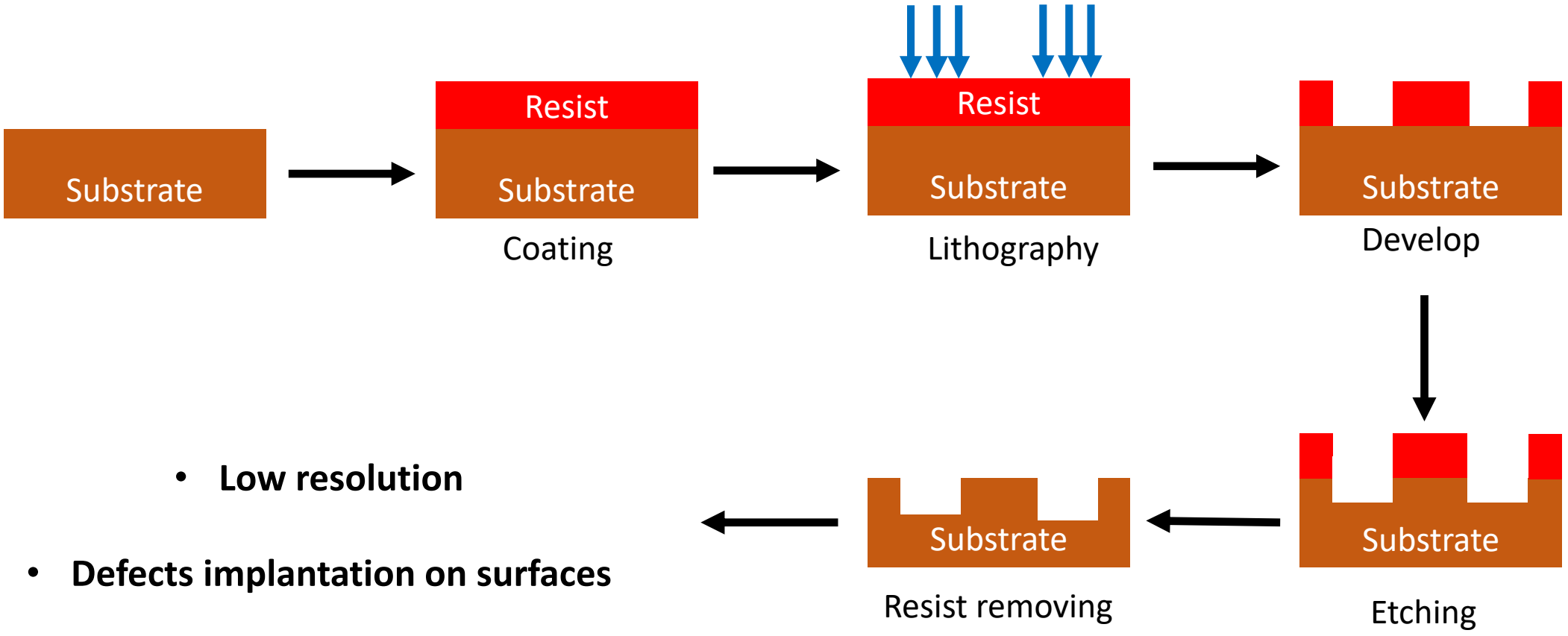
↓

Sharper D.o.S.

↓

Potential advantage for optical and electronic devices

Fabrication: Top-Down method



- **Low resolution**
- **Defects implantation on surfaces**

Etching

Wet

The sample is immersed in an acqueous solution which selectively dissolves the substrate but not the mask (es: KOH for Si, HF for SiO_2, etc.)

Simple, versatile, cheap, isotropic, ...

Isotropic, capillary forces when drying, mask adhesion issues...

Dry

RIE (Reactive Ion Etching)
ICP (Inductively Coupled Plasma)

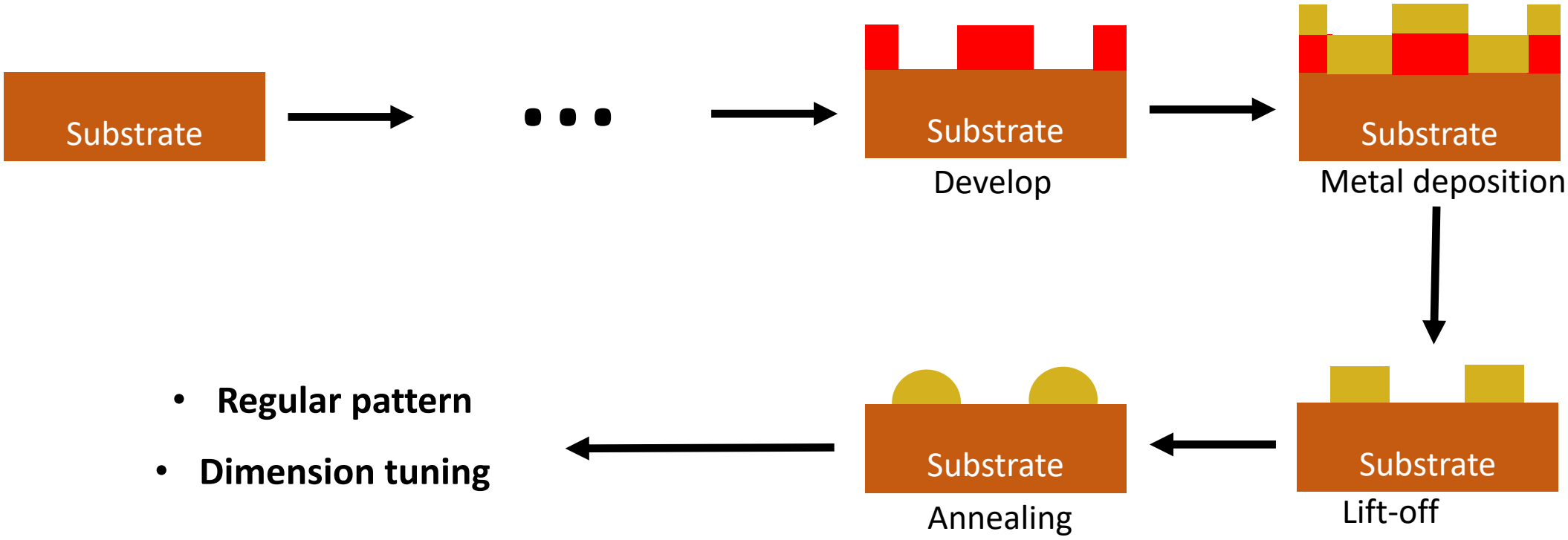
Reactive gases (usually ionized) selectively dissolve the substrate but not the mask with a combination of chemical and physical factors (es: CF_4)

Directional, no capillary forces, very suited to certain material combinations

Requires complex (expensive!) facilities, and dangerous gases

Fabrication: Bottom-Up method

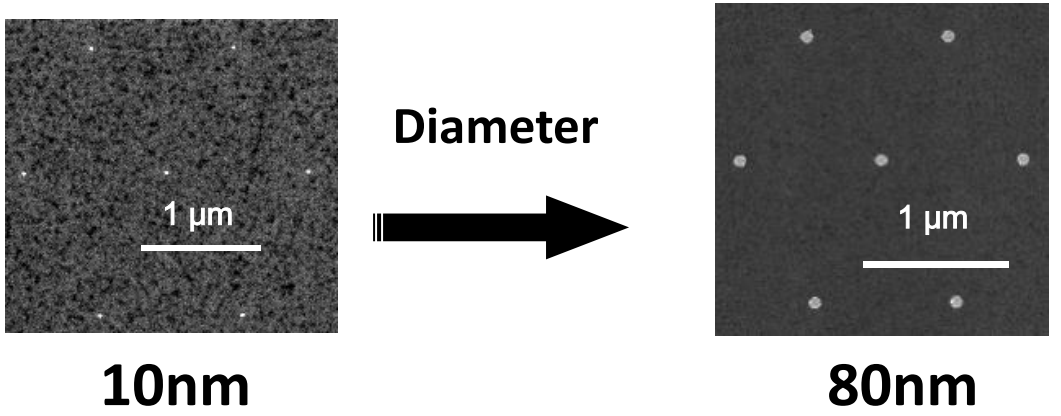
Vapor-Liquid-Solid (VLS) *growth occurs when an alloy droplet starting from a* ***metal catalyst*** *becomes supersaturated with material from a gaseous reactant. The material then precipitates from the solid-liquid interface to form a nanowire.*

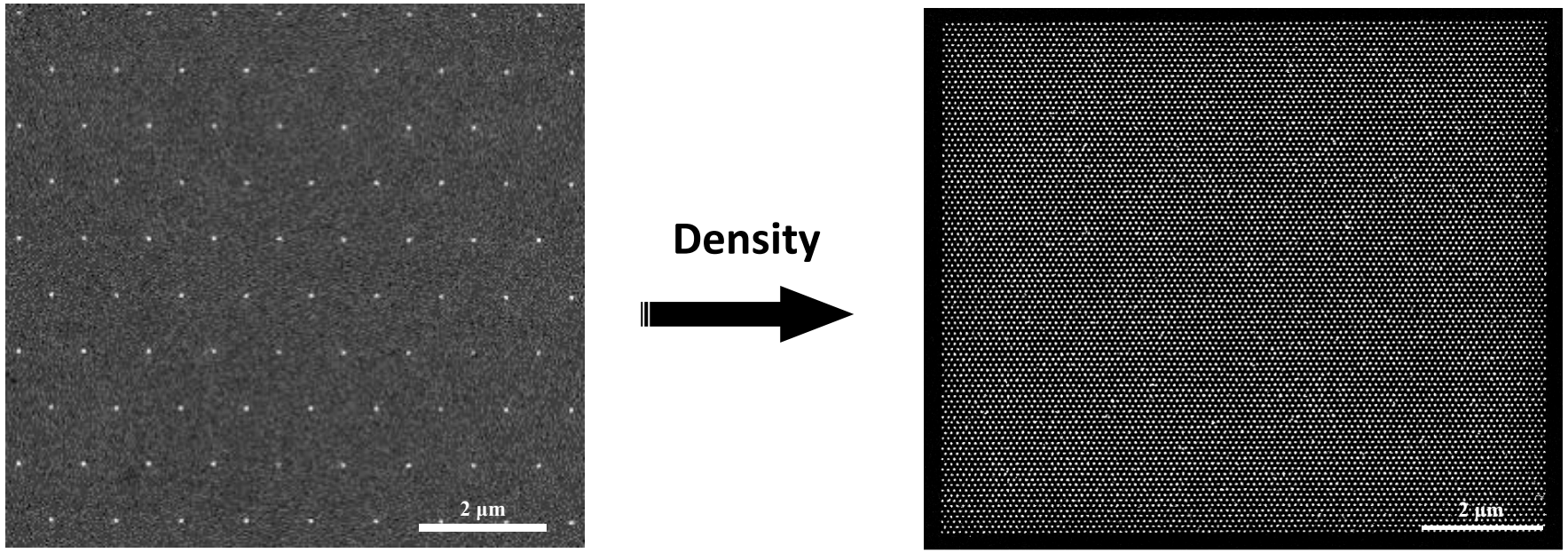


- **Regular pattern**
- **Dimension tuning**

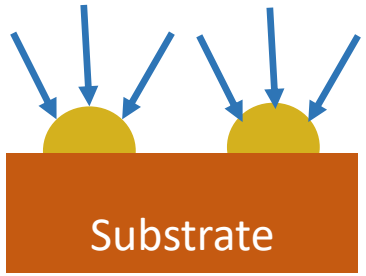
Fabrication: Bottom-Up method

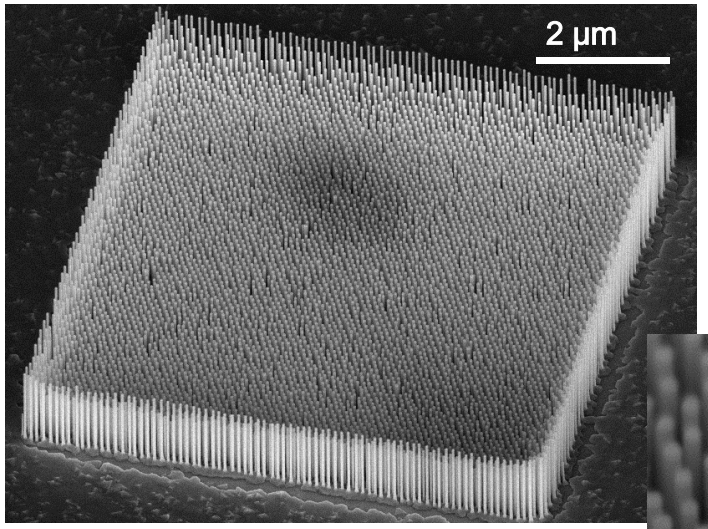
Vapor-Liquid-Solid (VLS) *growth occurs when an alloy droplet starting from a* ***metal catalyst*** *becomes supersaturated with material from a gaseous reactant. The material then precipitates from the solid-liquid interface to form a nanowire*



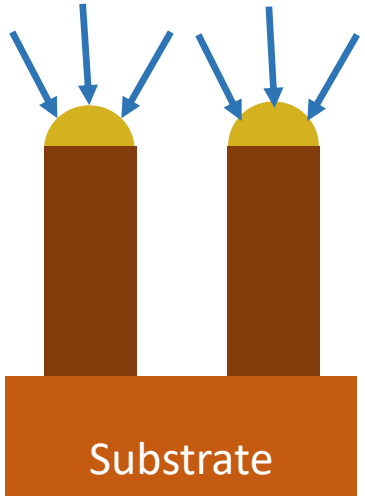


Fabrication: Bottom-Up method



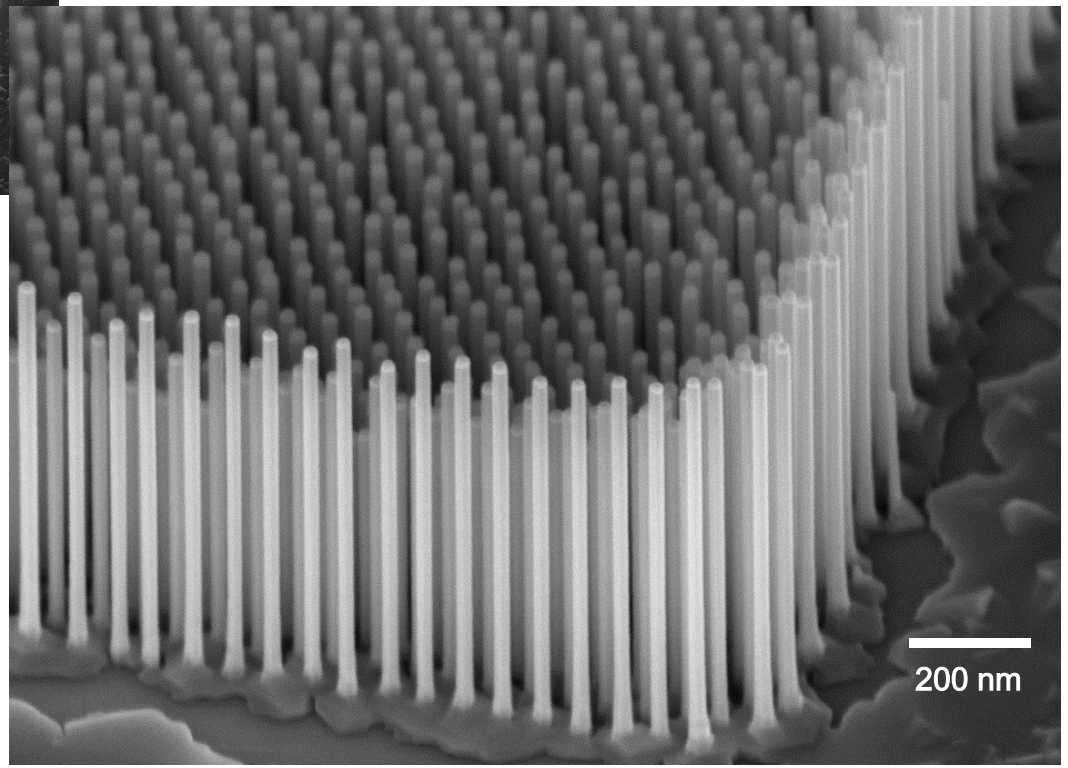


Center-to-center distance 100nm

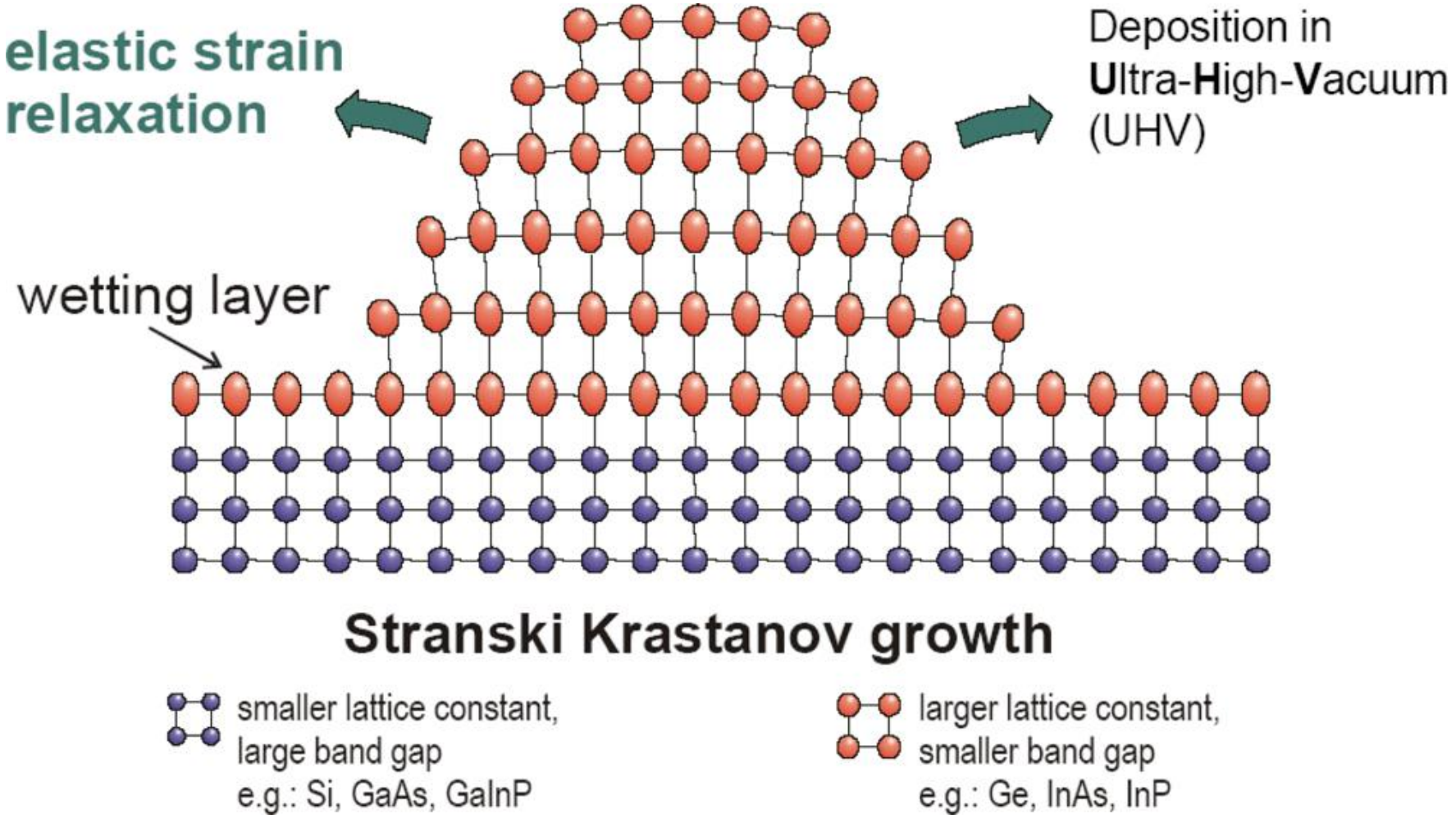


Pitch =100 nm

Density =115 µm^{-2}

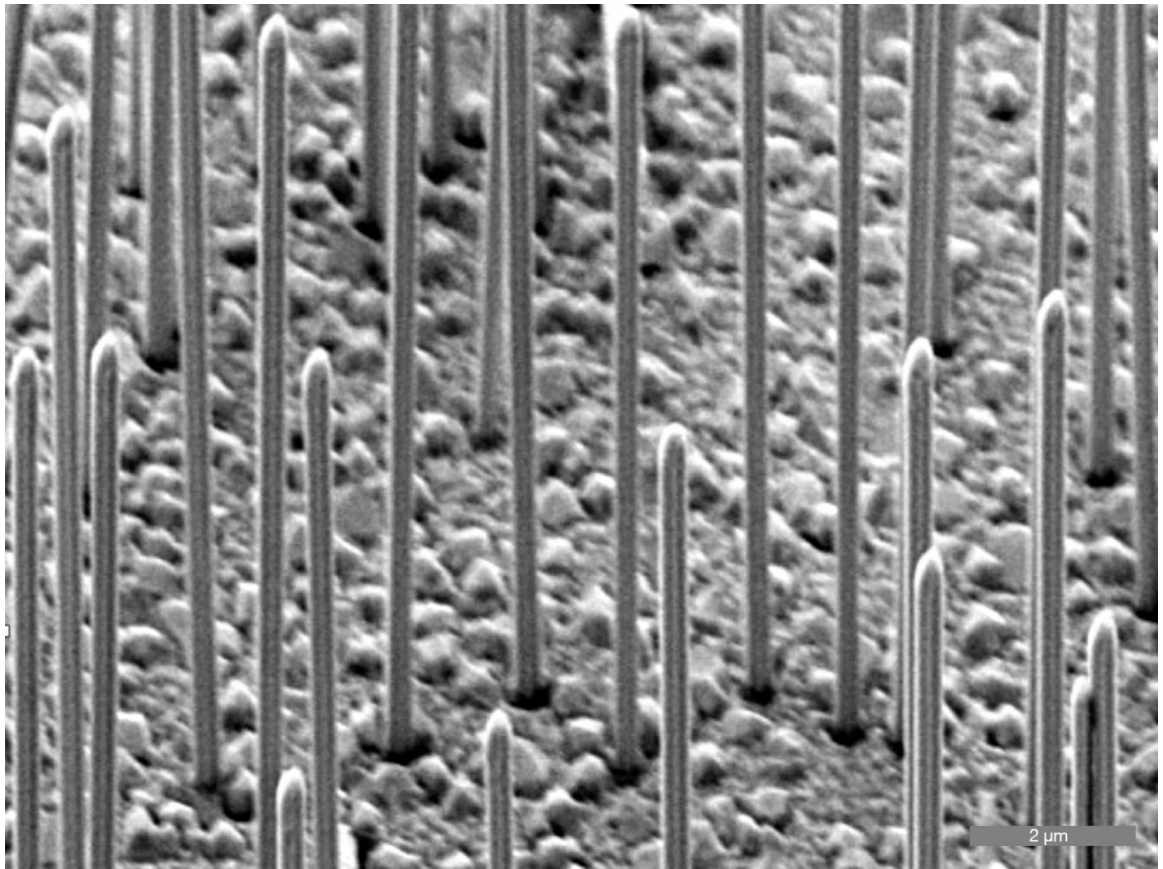


Fabrication: Bottom-Up method



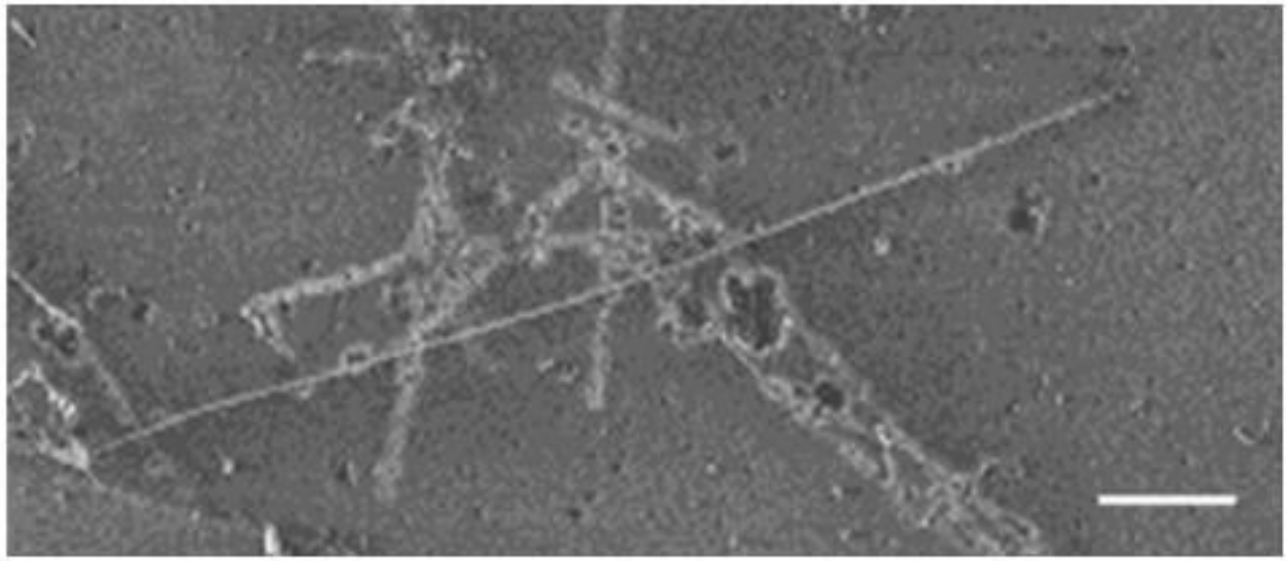
No control over position and dimension

Quantum nanoWiRe (QWR)



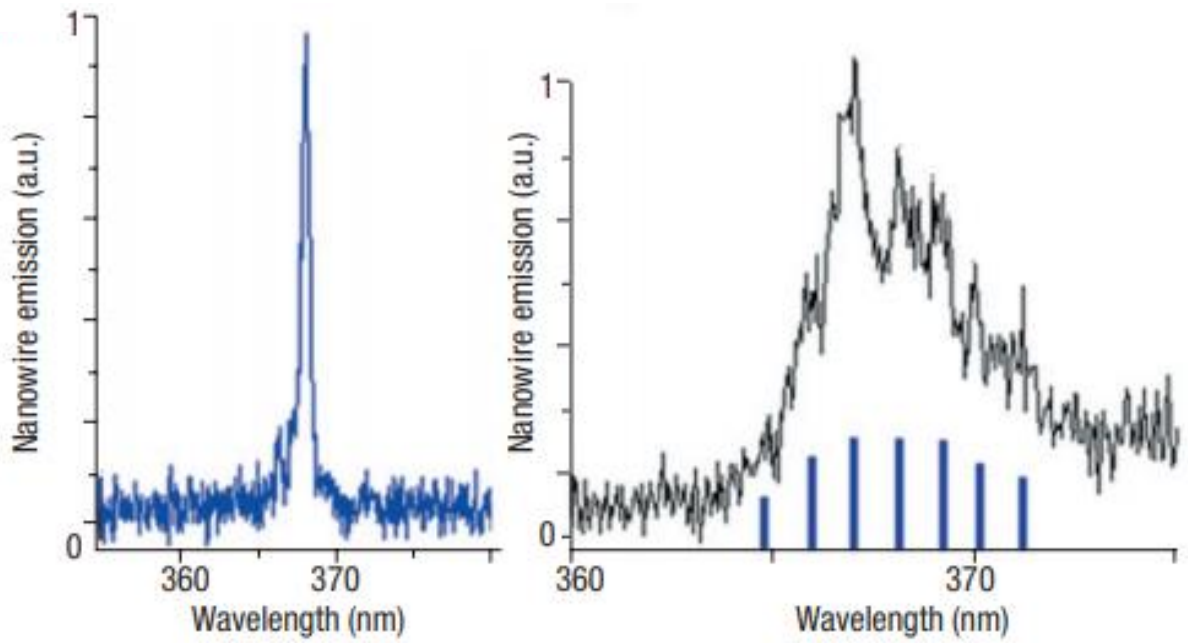
- **Investigation of 1D system properties**
- **Photo electric applications**
- **Transport properties**
- **Extension of Moore's law**

Nanowire application: Laser



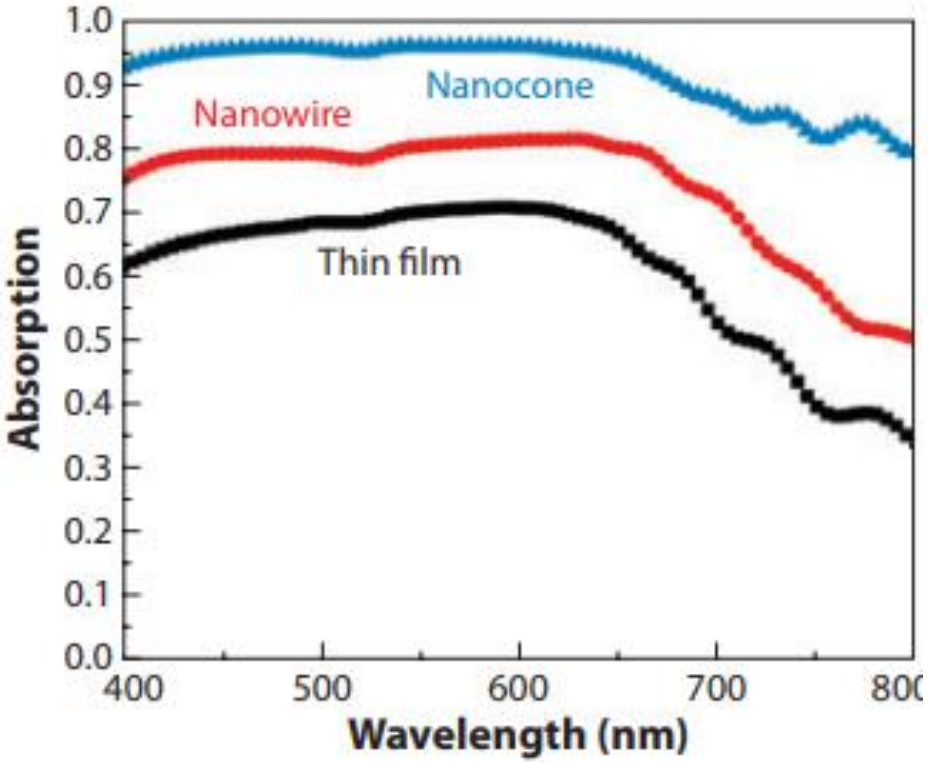
Optical pumping with a far infrared pulsed laser (OPA 1170-1600nm)

GaN nanowires from VLS tecnique

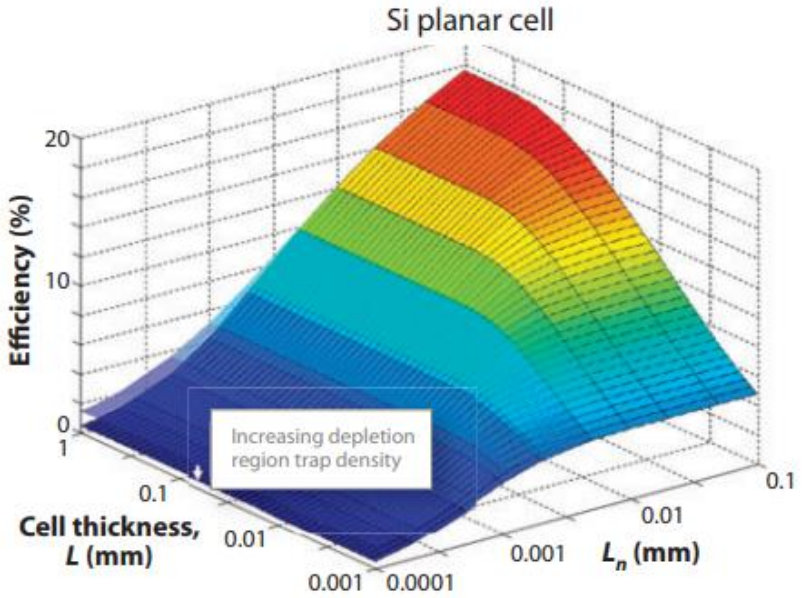


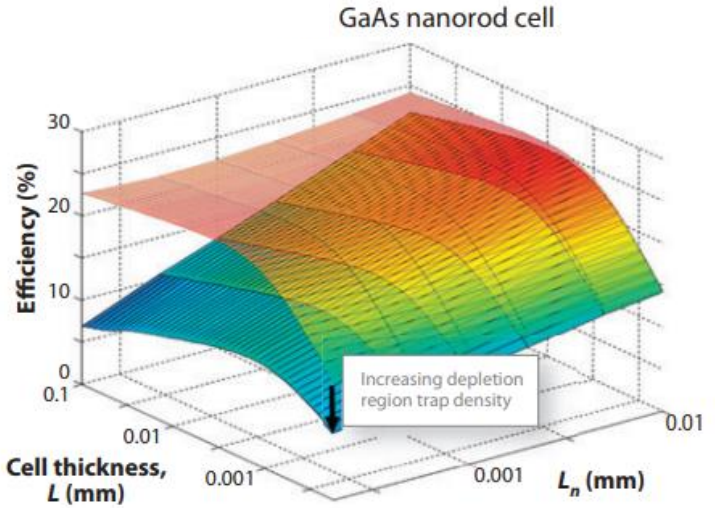
J. C. Johnson, et al. Nature Mater. 1, 106 (2002).

Nanowire application: Solar Cell



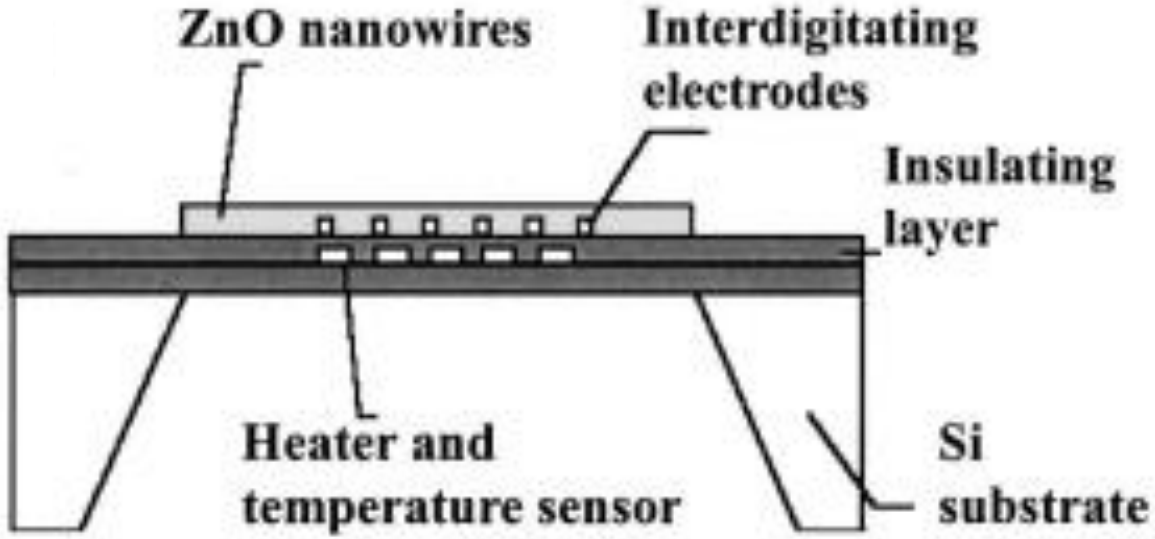
- **Higher absorption**
- **Potentially less cost**
- **Not yet scalable**

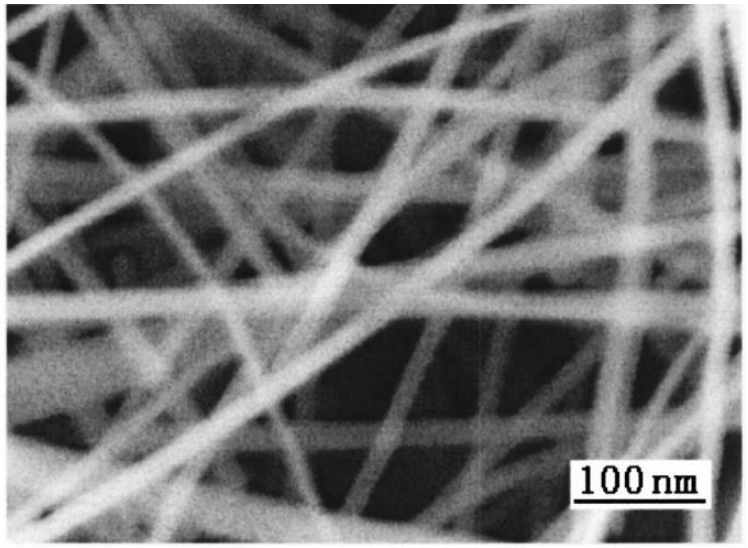


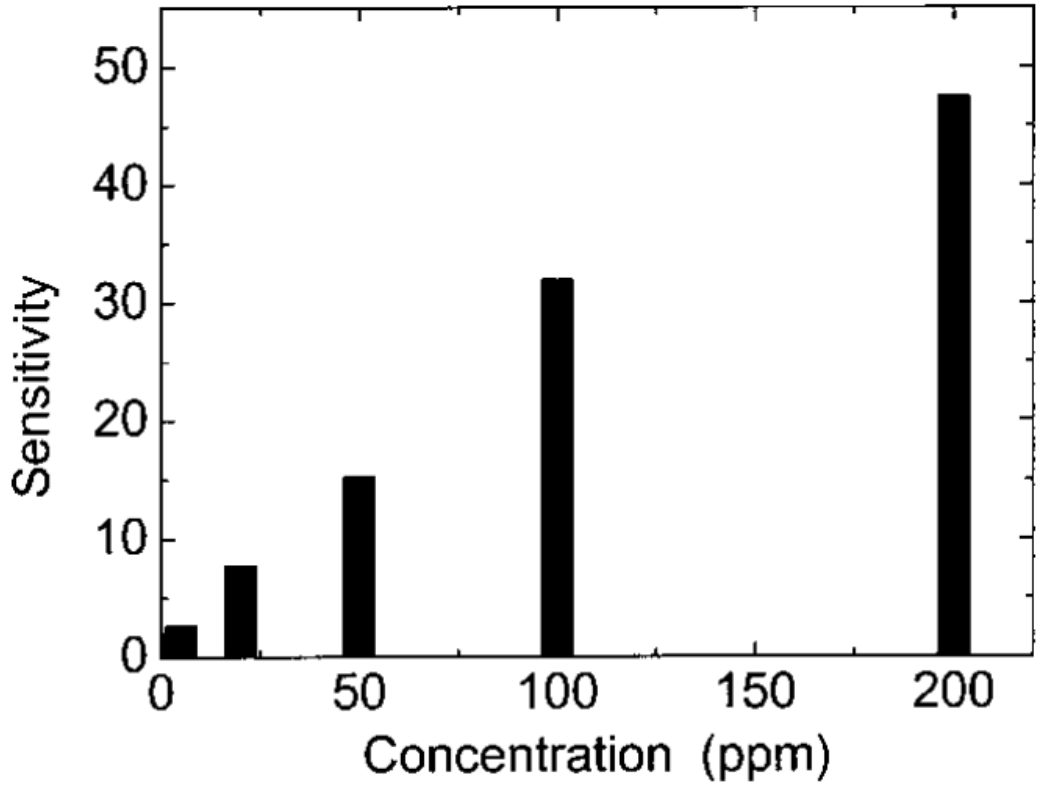


Garnett, E. C. et al. (2011). Nanowire Solar Cells. Annual Review of Materials Research, 41(1), 269–295.

Nanowire application: Ethanol sensor

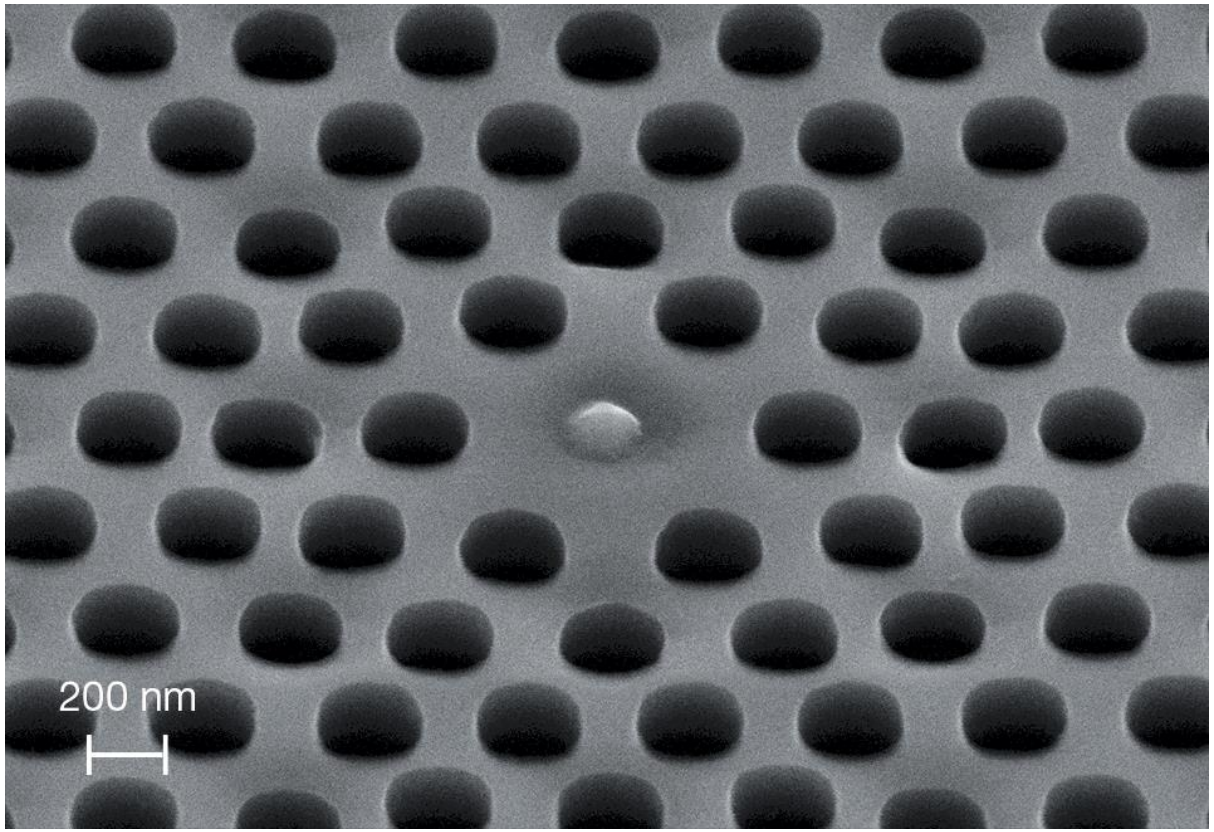






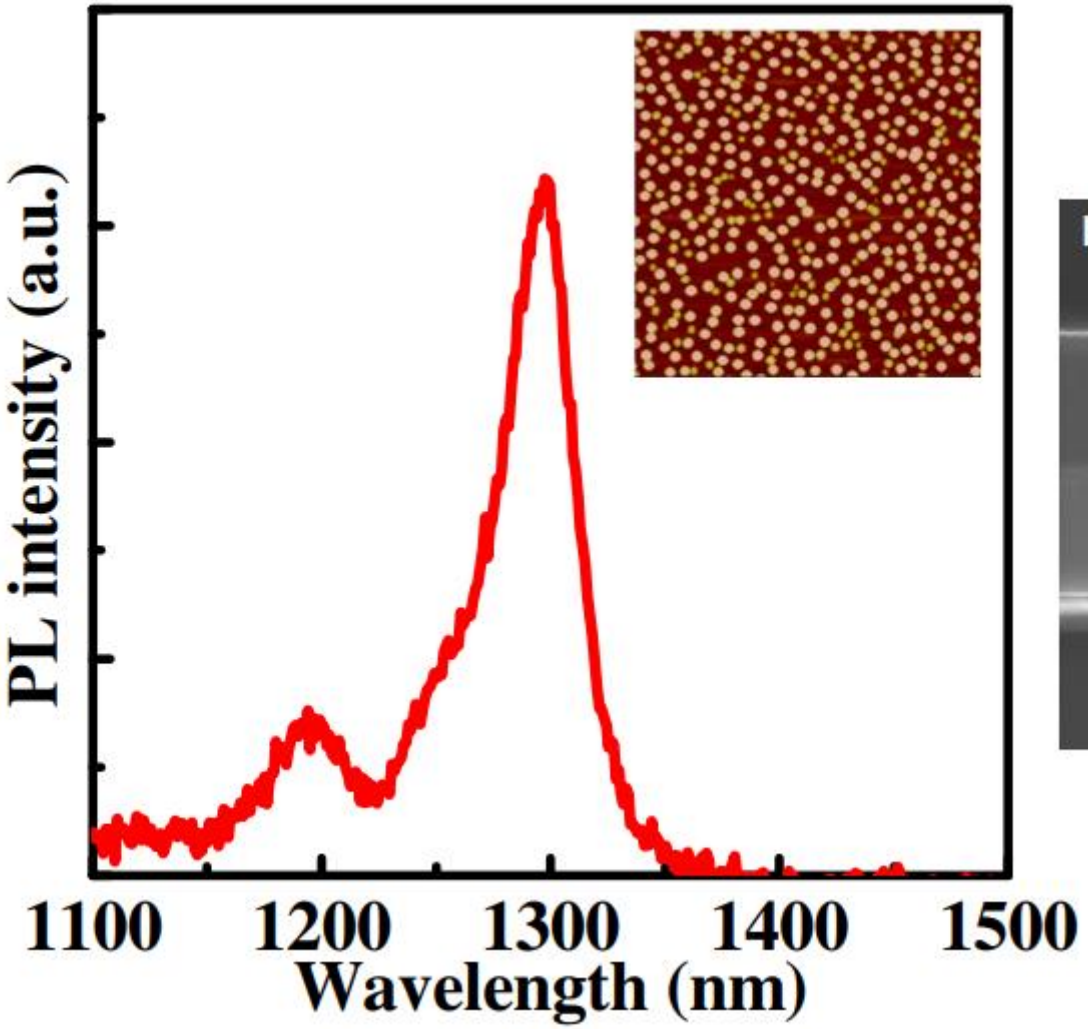
Fabrication and ethanol sensing characteristics of ZnO nanowire gas sensors
Appl. Phys. Lett. 84, 3654 (2004)

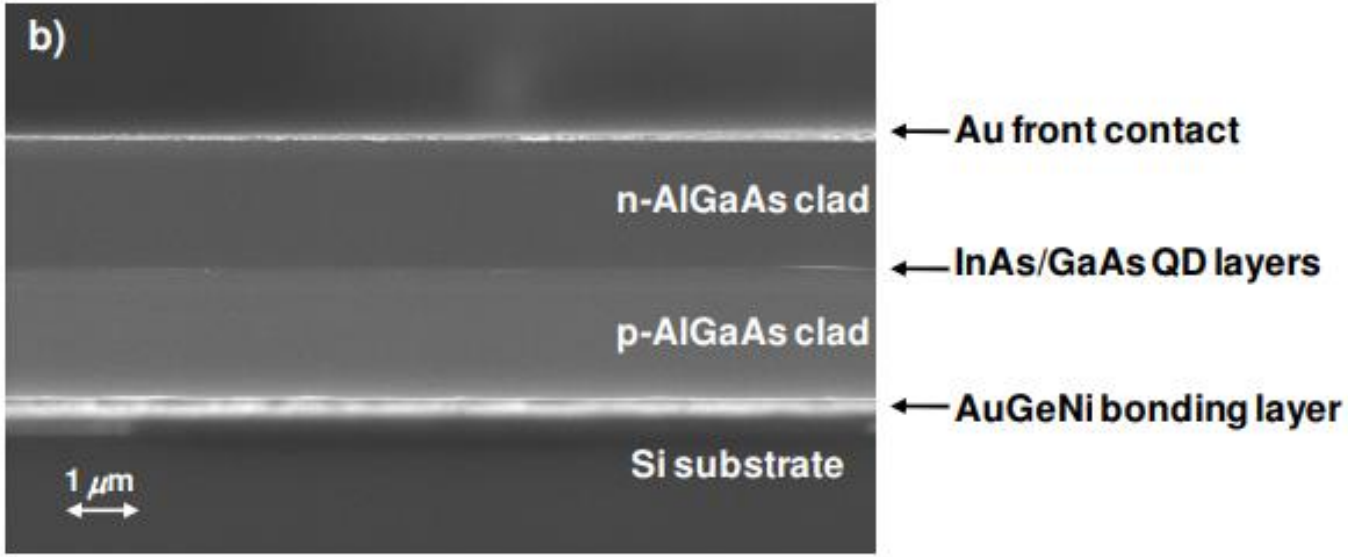
Quantum Dot (QD)



- **A quantum dot is a zero-dimensional object in which electrons are confined in all three dimensions.**
- **Confinement leads to improved performance of advanced optoelectronic devices (lasers, …)**
- **Applications also in quantum information technology**
- **Quantum dots can be obtained by strain-driven self-assembly (Stranski-Krastanov growth mode)**

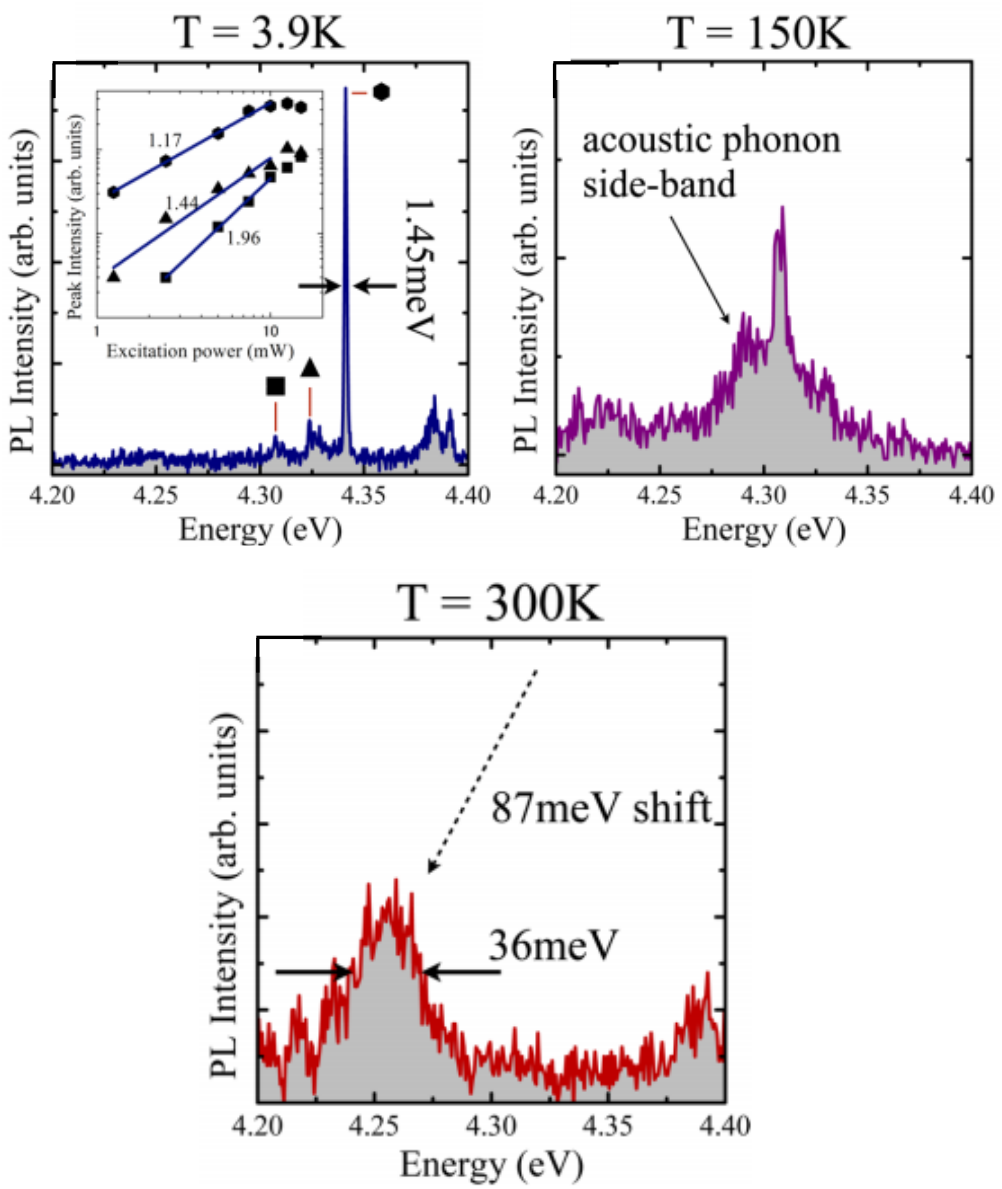
Quantum Dot application: Laser

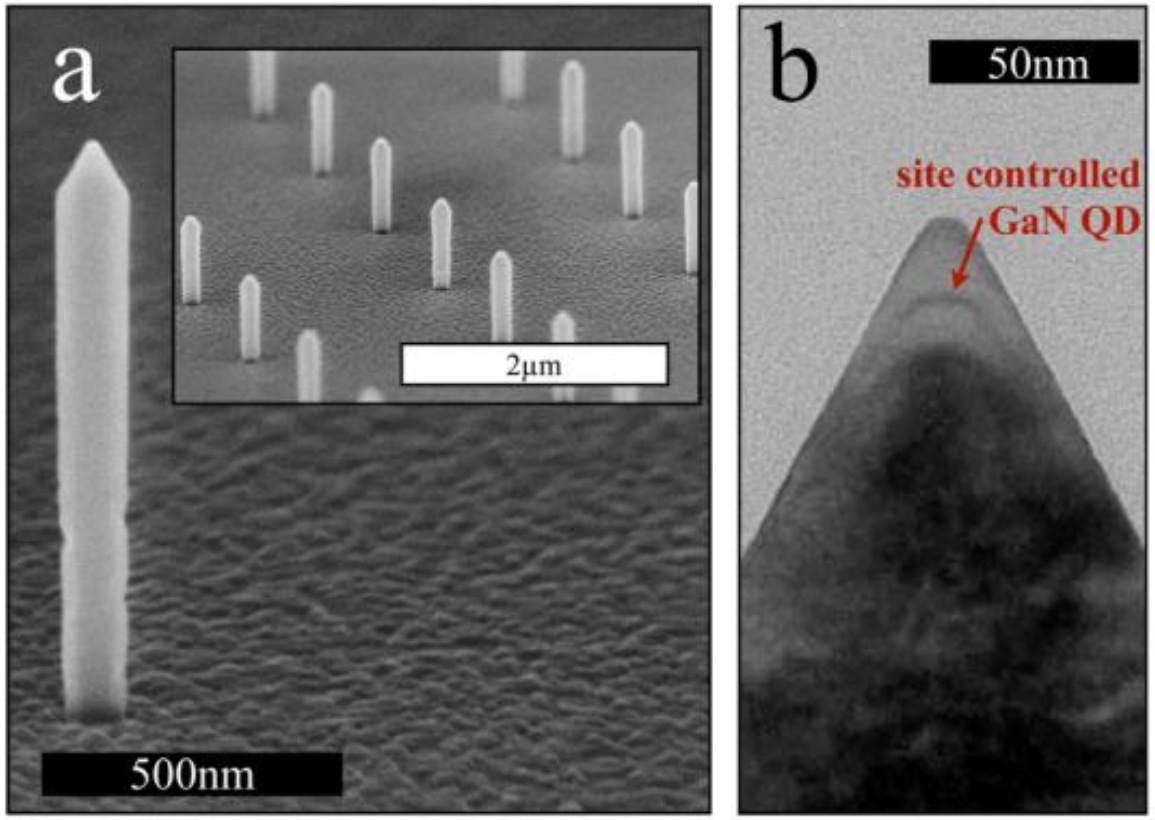




Wang, T., et al. Optics Express, 19(12), 11381.

Quantum Dot application: Single Photon source





Senellart, P.,et al.. (2017). High-performance semiconductor quantum-dot single-photon sources. Nature Nanotechnology, 12(11), 1026–1039.

Conclusions

Nanowires

1. Well developed fabrication techniques
2. Mid-term commercial applications
3. Sensor-friendly technology

Quantum Dot

1. Less controllable fabrication process
2. Possible High Output power laser
3. Quantum communication applications