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AT THE FOREFRONT OF NANOSCIENCE

Synthesis of aerosol nanoparticles and nanowires at LNL

Martin H. Magnusson

Solid State Physics / NanoLund

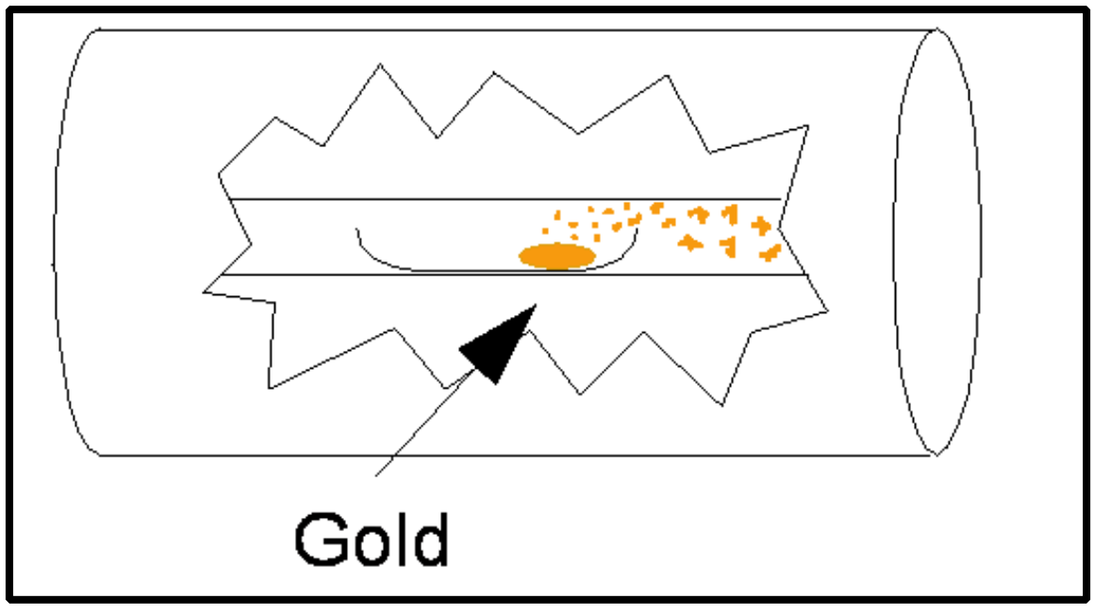
Lund University, Sweden

Nanoparticle synthesis at Lund Nano Lab

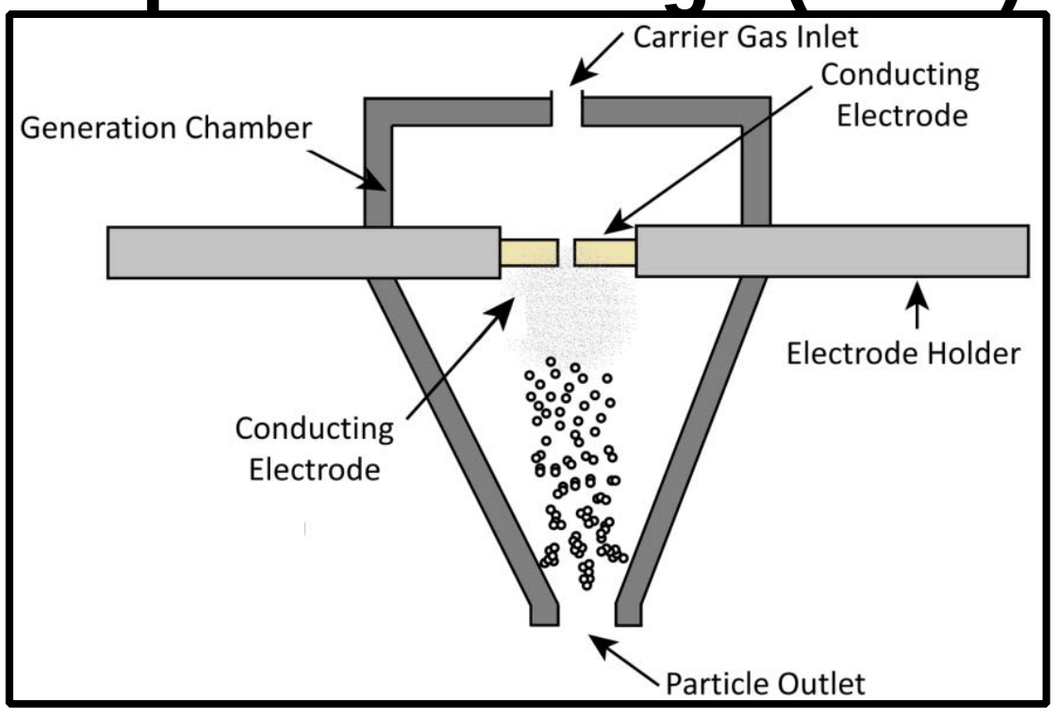
- Metal and semiconductor particles
- Three main principles:
  - Evaporation of seed/core material
  - Modification of the particles
  - Tandem DMA setup
- Main uses:
  - Seeding nanowire growth on substrates
  - Metallic particles for catalysis
  - Nanotoxicology
  - Aerotaxy

Nanoparticle Generation

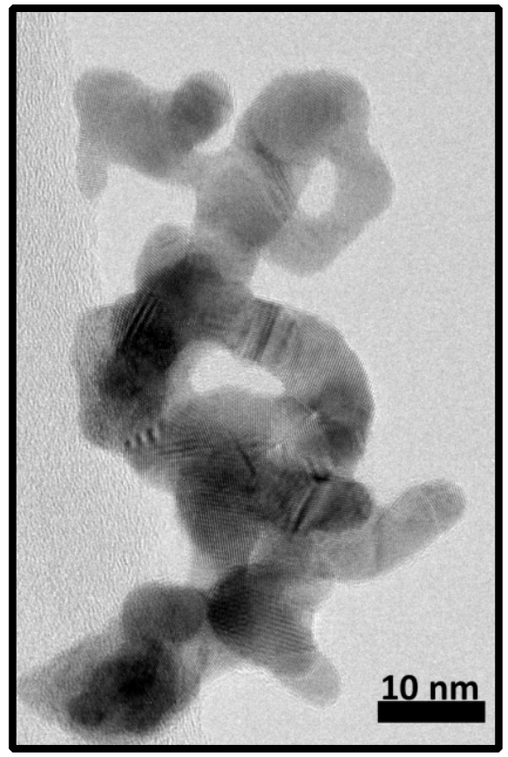
Evaporation/Condensation



Spark Discharge (SDG)

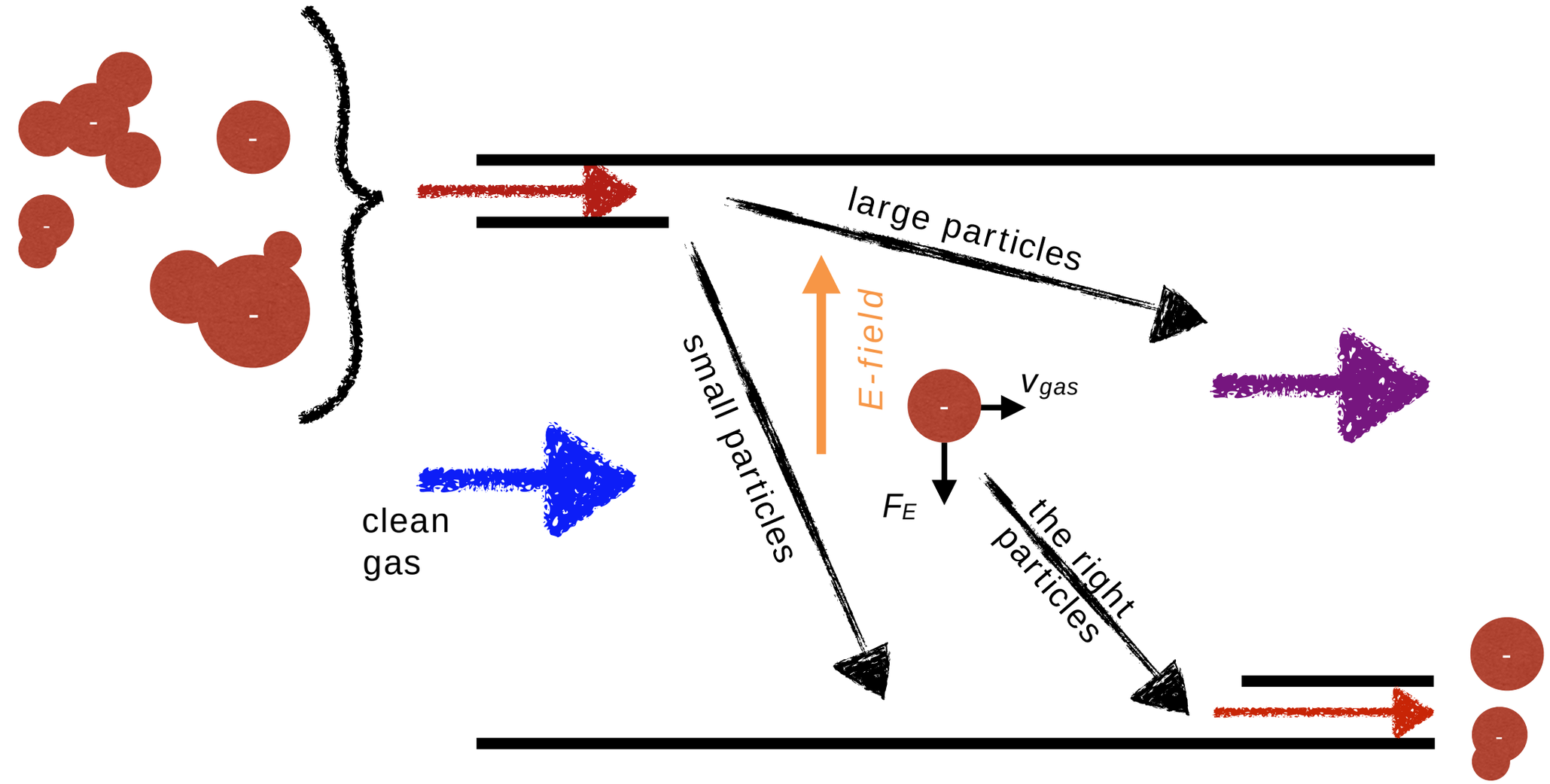


Agglomerate Particles

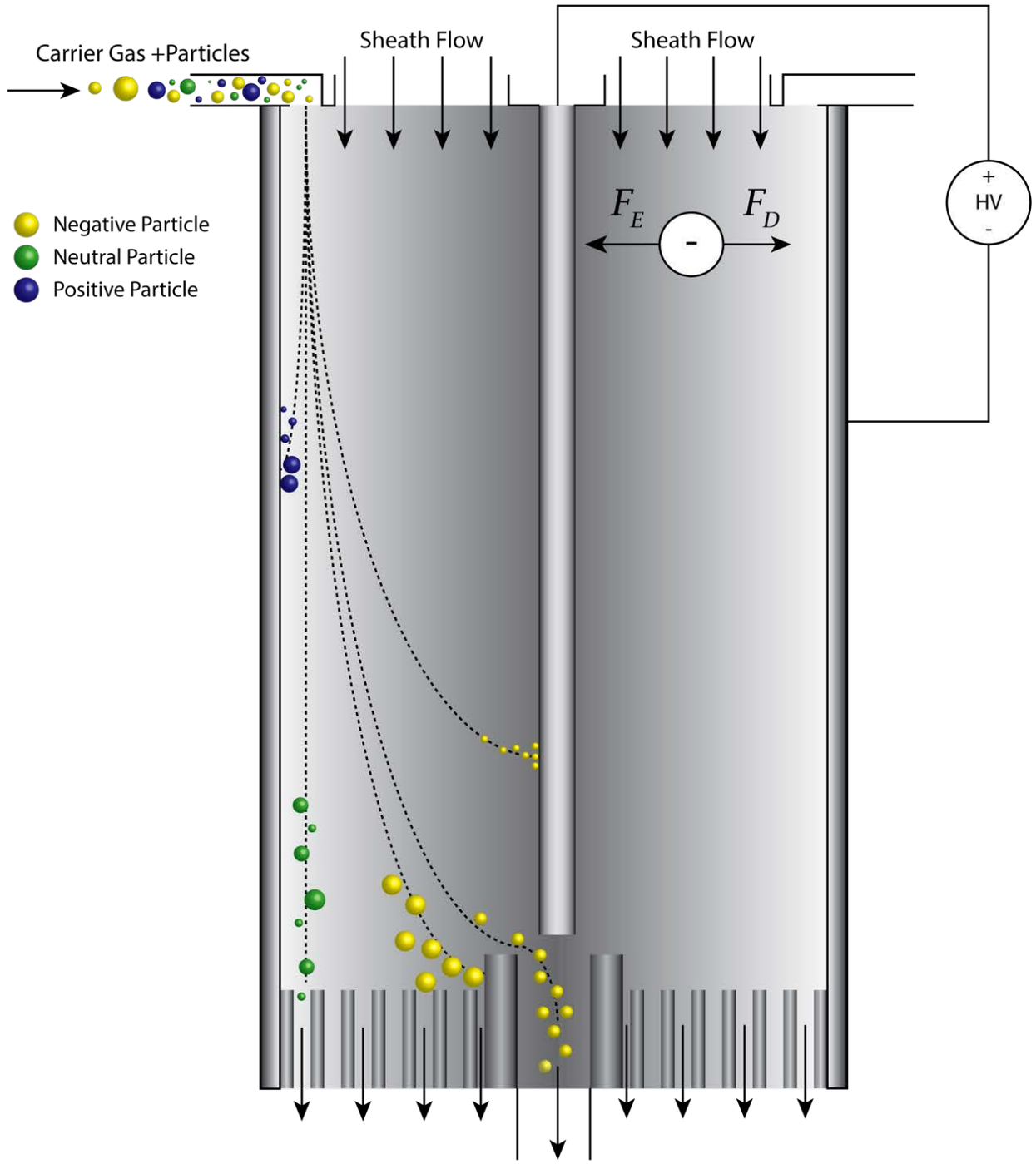


Size control – DMA

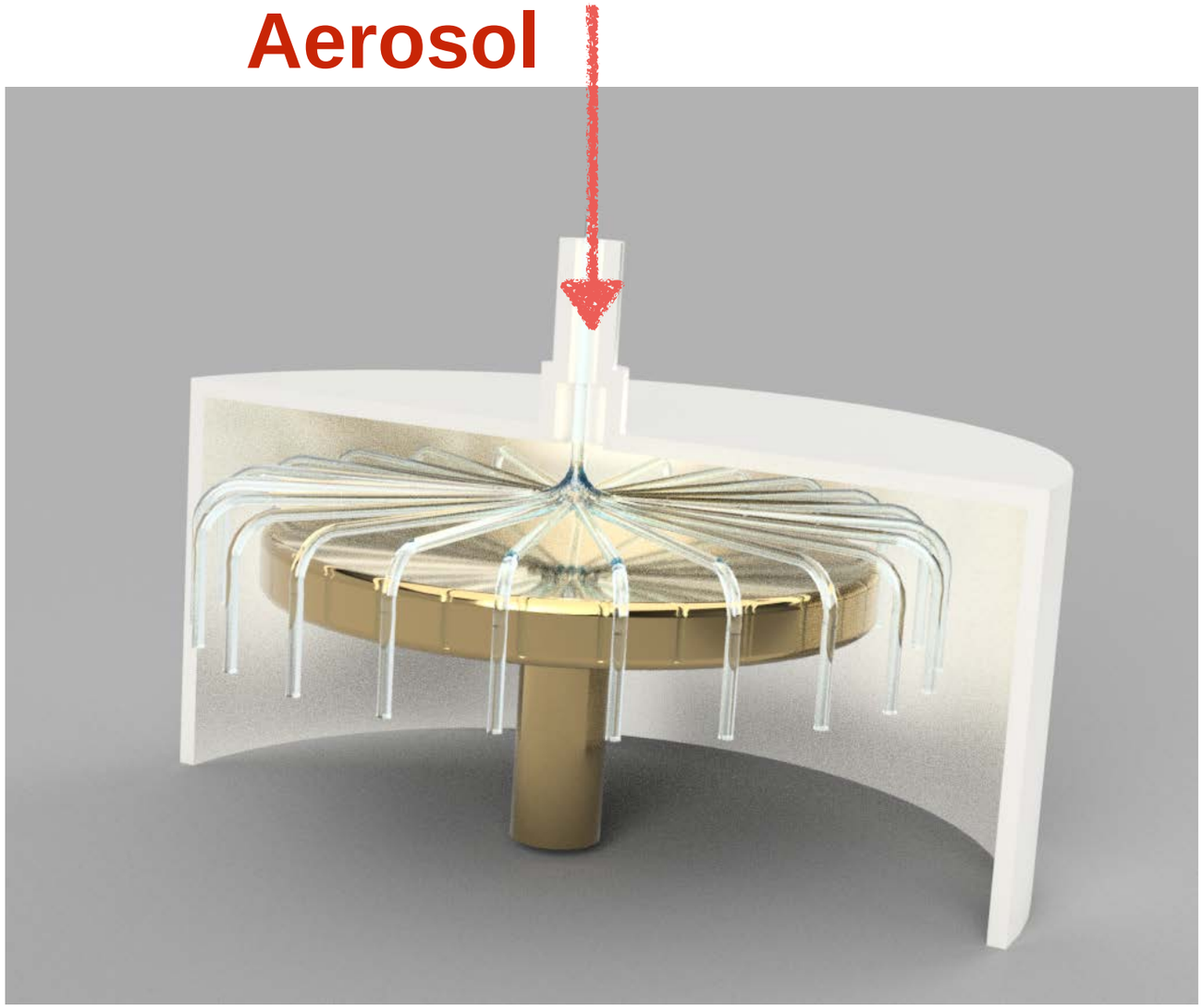
Differential *Mobility* Analyzer

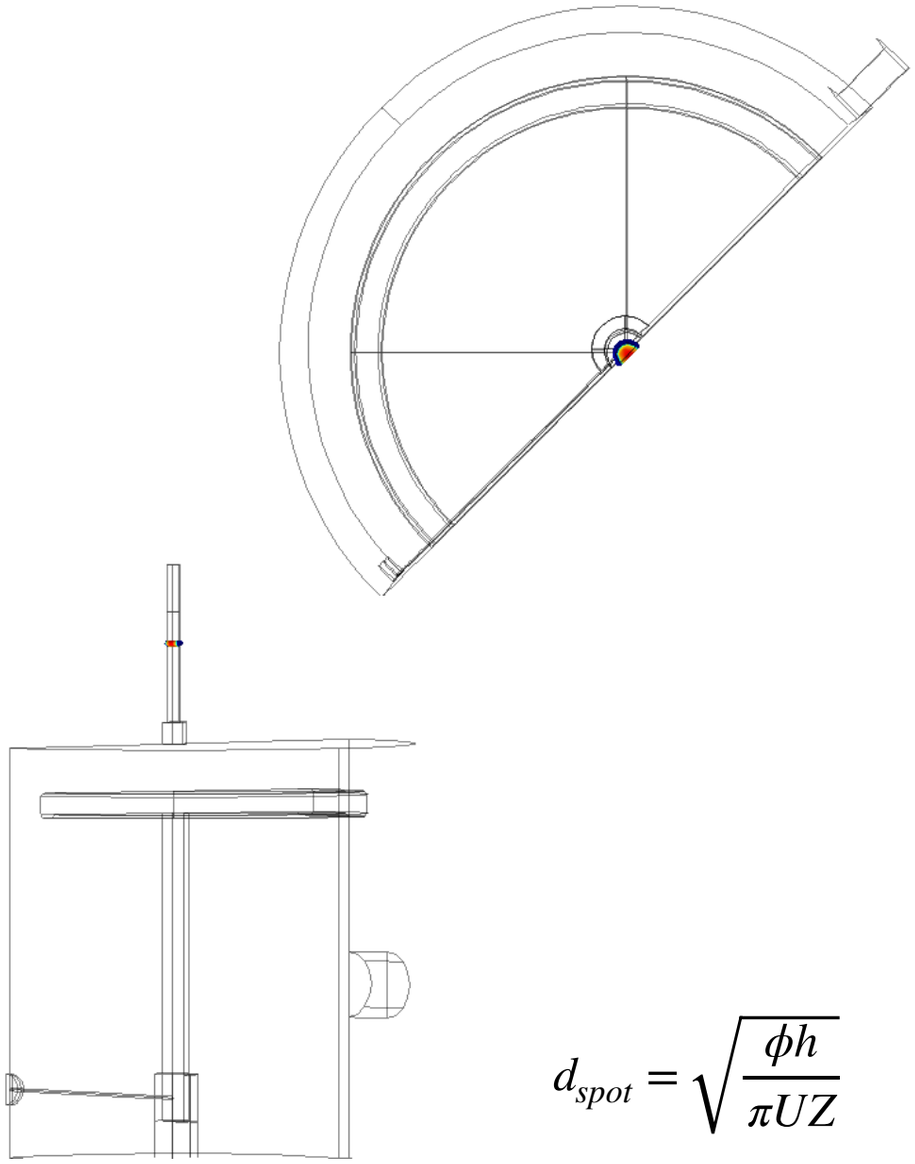


Cylindrical DMA



Electrostatic precipitator (ESP)



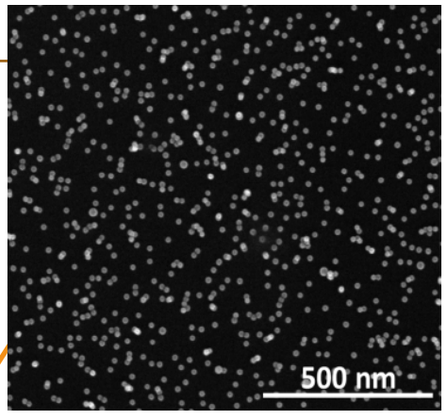


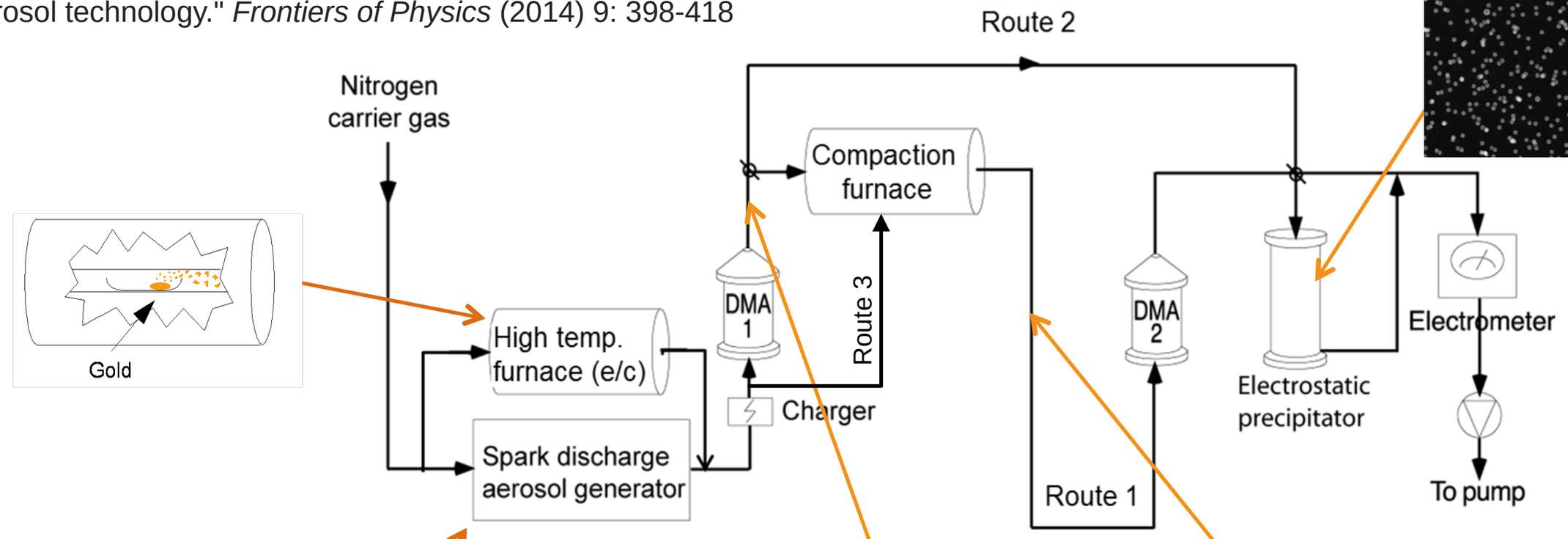
$$d_{spot} = \sqrt{\frac{\phi h}{\pi U Z}}$$

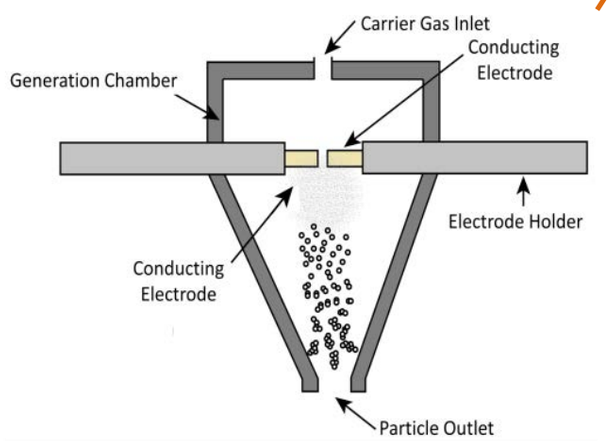
C. Preger et al., J Aerosol Sci Technol (2020), *Accepted*

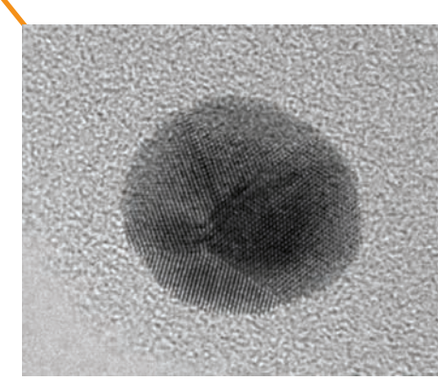
Aerosol particle generation system

Magnusson, M. H., et al. "Semiconductor nanostructures enabled by aerosol technology." *Frontiers of Physics* (2014) 9: 398-418



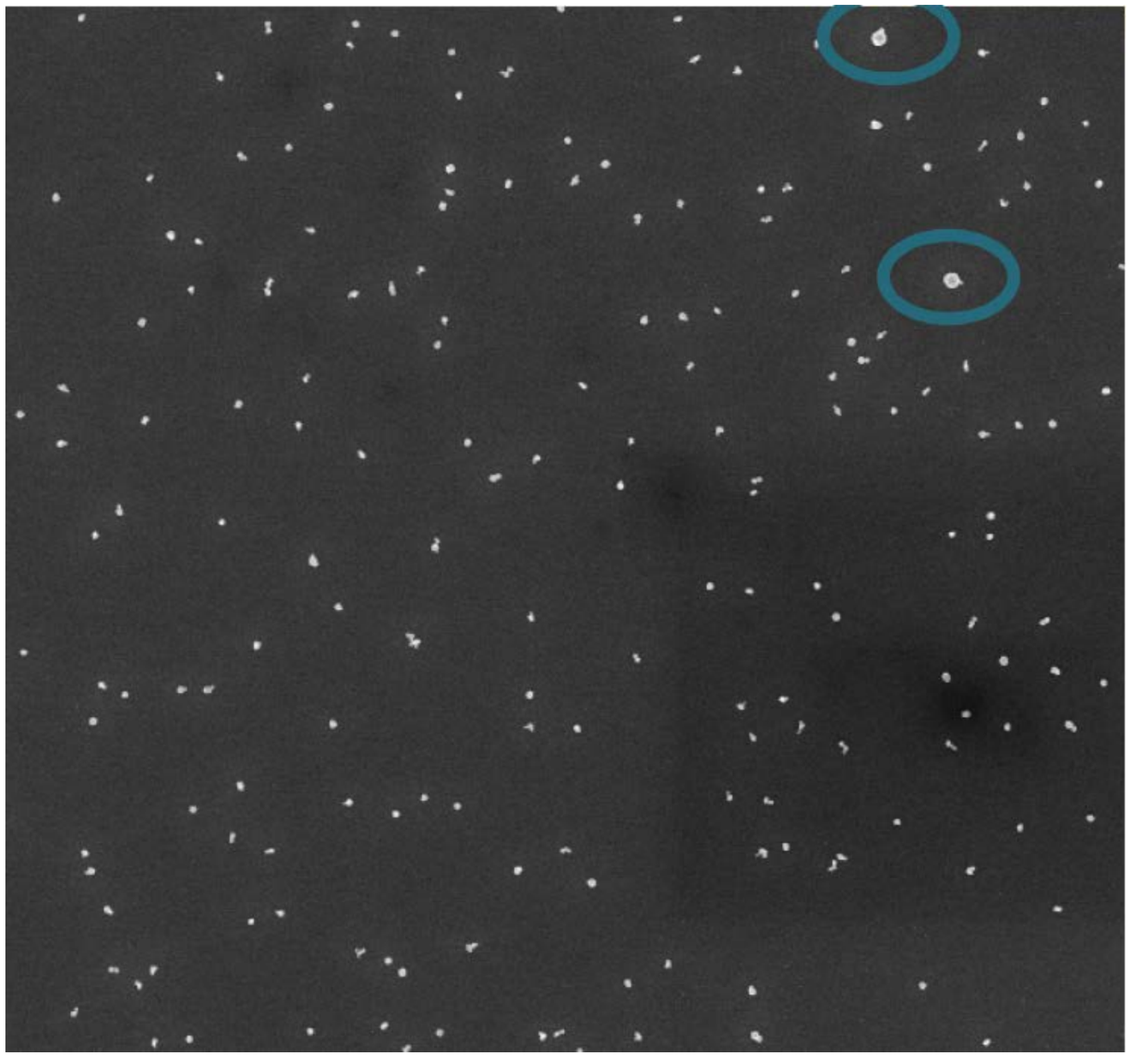






The real system

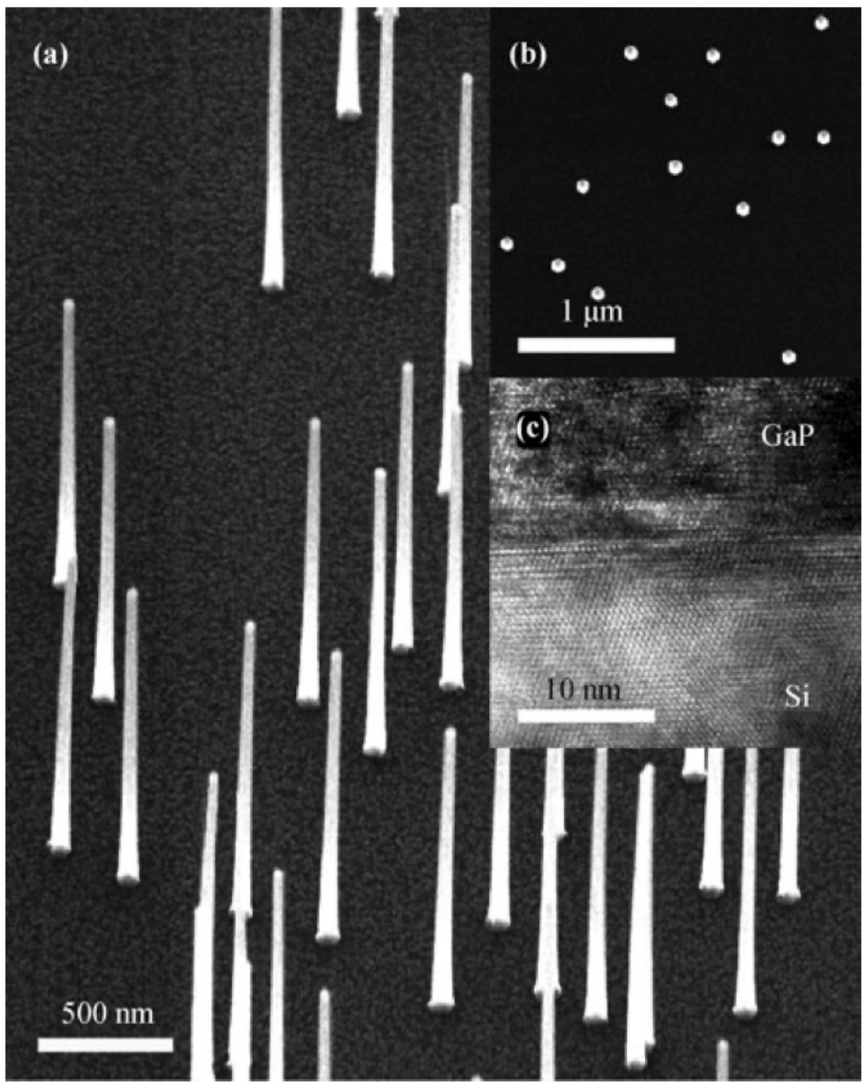
Substrate with gold nanoparticles



- 2 DMAs gives higher quality
  - Better size control
  - More well-defined particles
- 1 DMA gives higher concentration
  - Especially at larger sizes
  - Often good enough
  - Example at left
  - 80 nm 2 μm^{-2}

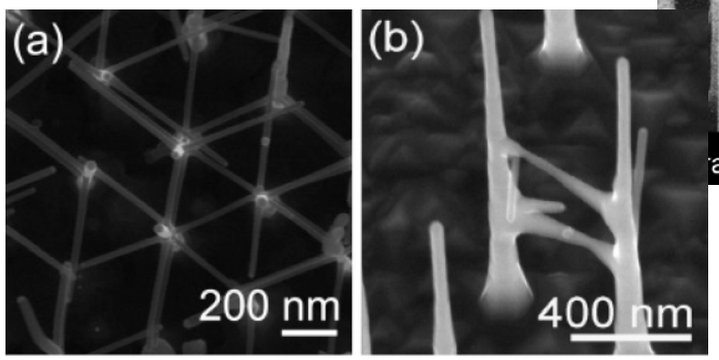
Use of particles

Seeding nanowire growth



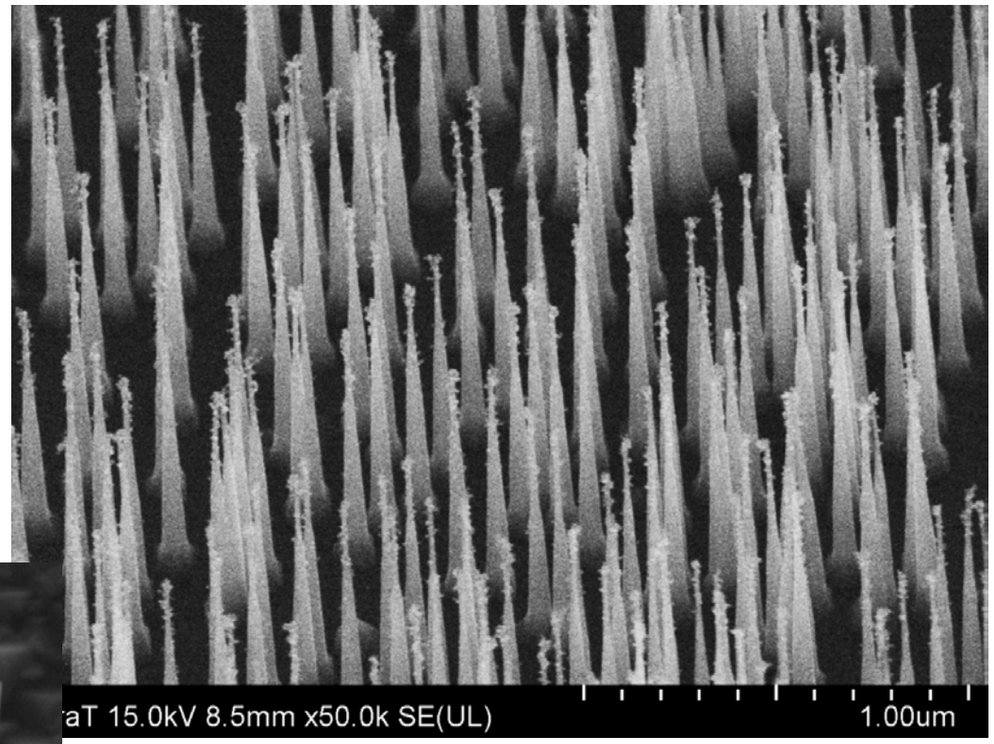
T. Mårtensson et al., Nano Lett. (2004) 4: 1987

Nanotrees



K.A. Dick et al., Nano Lett. (2006) 6: 2842

Nano-catalysis



S. Franzén et al., *In preparation* (2020)

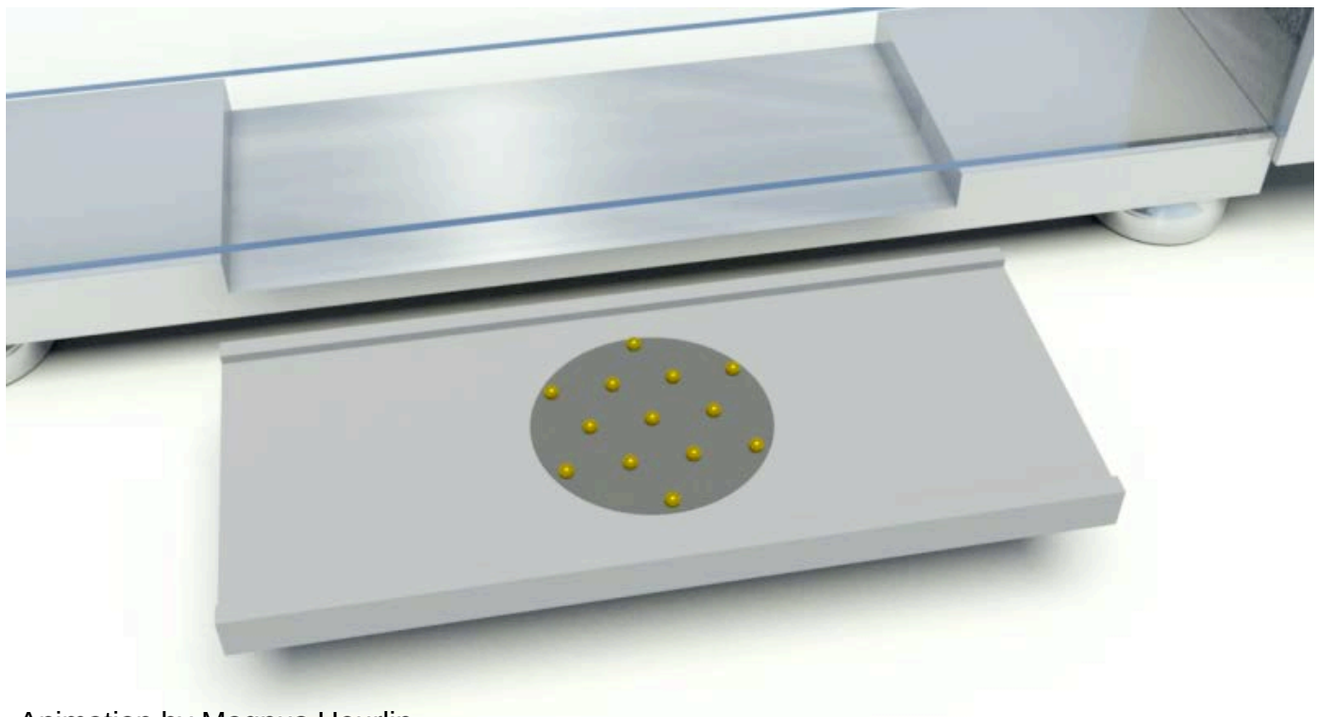
Magnetic particles

Exploratory materials science

Nanotoxicology

Mass production of nanowires?

- Nanowires are normally grown by MOVPE
- Batch process, cycle time ≥ 30 min (today 2 h)
- Largest machine can handle a few 300 mm wafers
- Wires typically grow 1–10 nm/second
- Currently not an alternative for large surfaces



Animation by Magnus Heurlin

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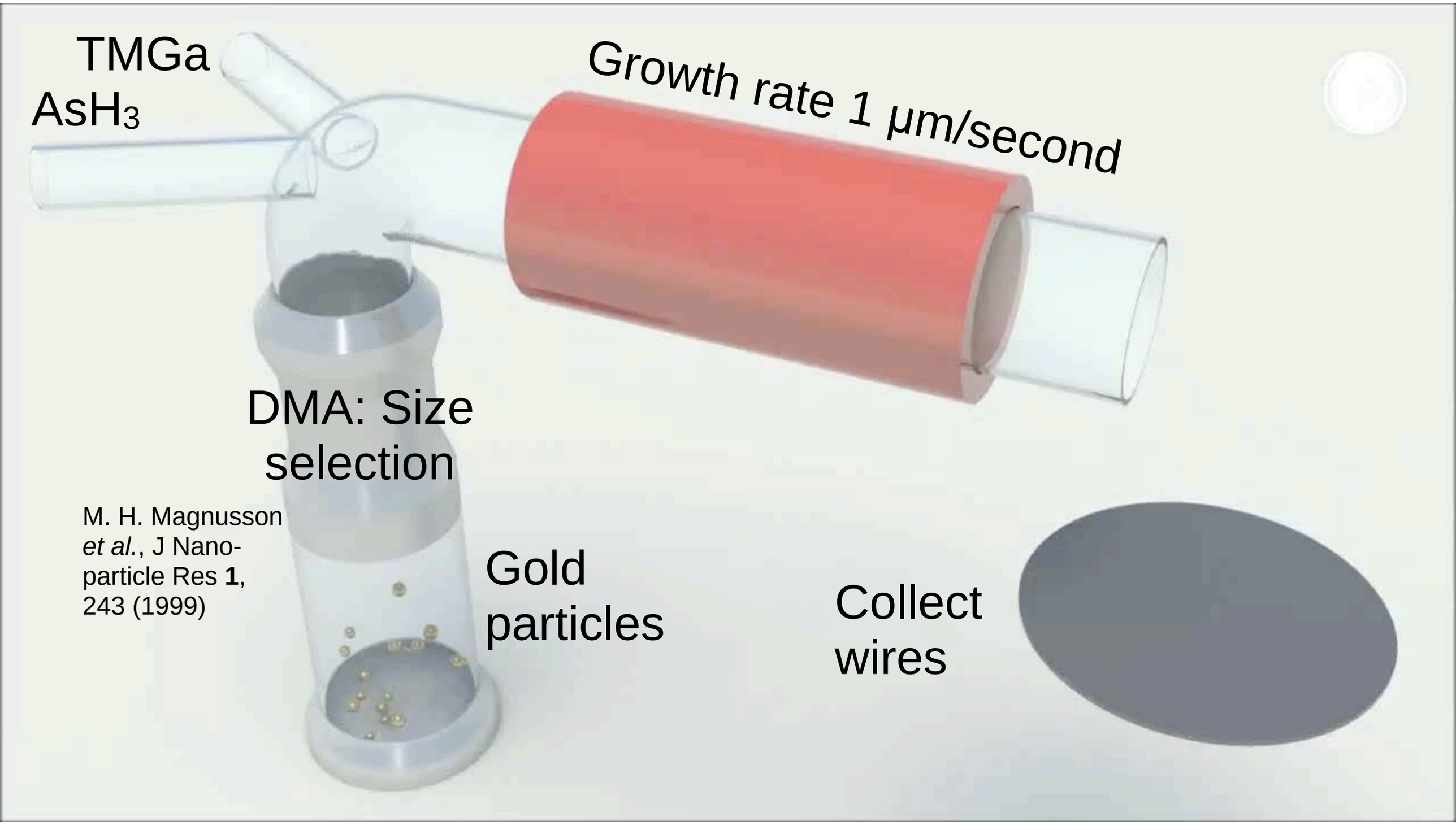
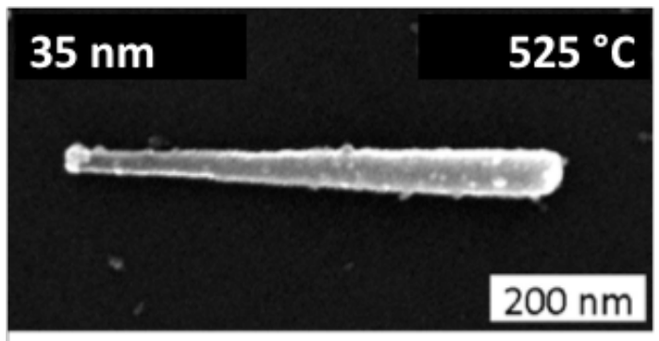
Aerotaxy principle



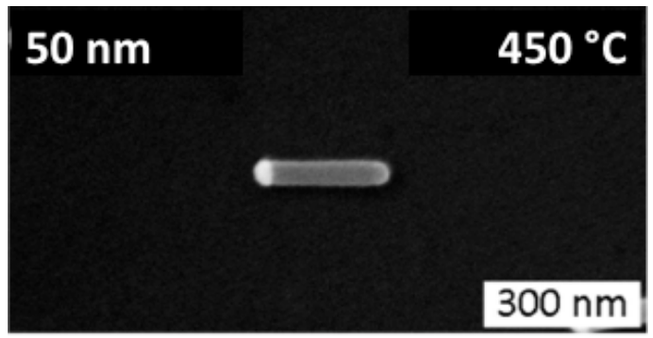
M. H. Magnusson *et al.*, J Nano-particle Res **1**, 243 (1999)

Growth dependence on…

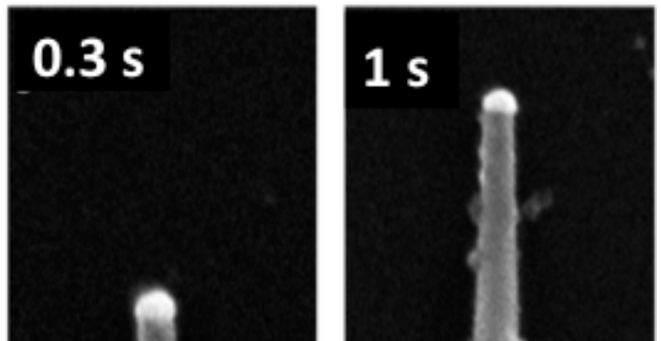
Seed particle size



Temperature



Time



M. Heurlin *et al.*,
Nature **492**, 90 (2012)

Aerotaxy tool "Gen. 3.5"

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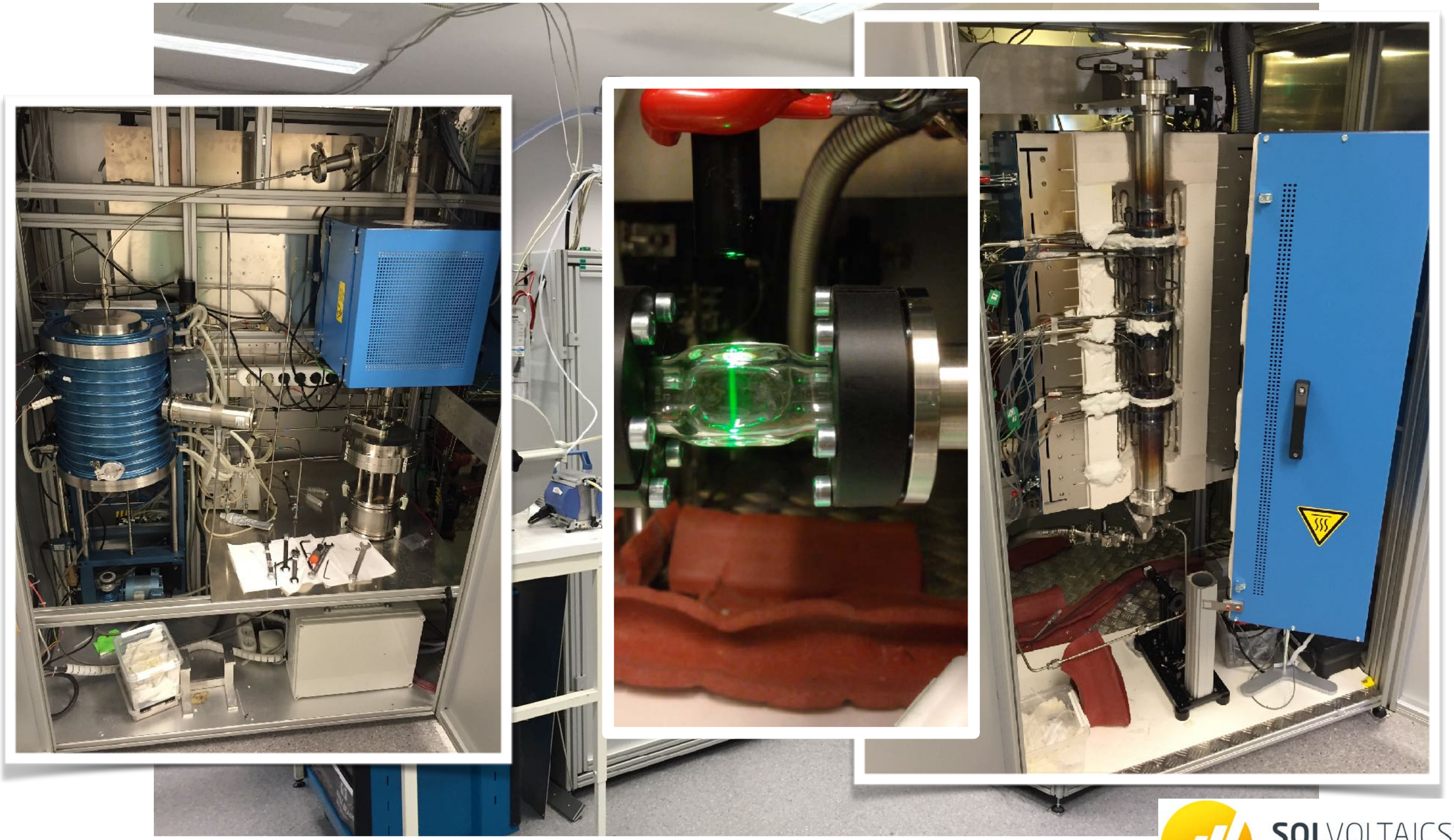
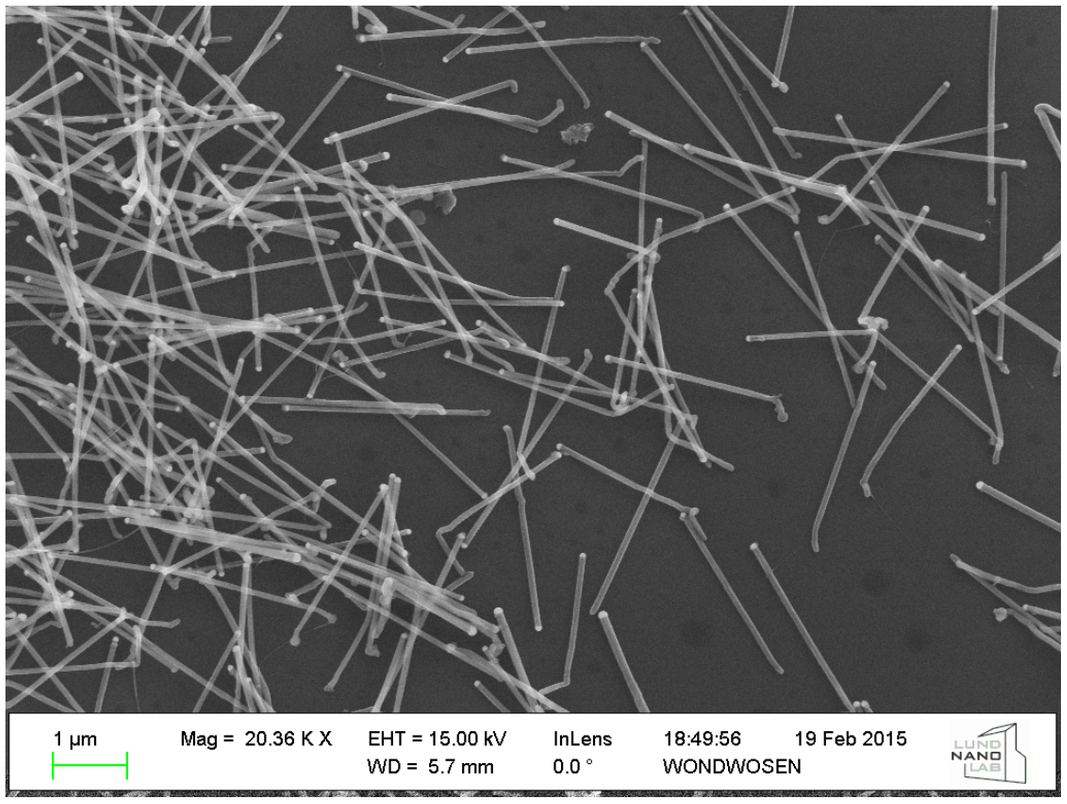
SOLVOLTAICS®

Aerotaxy tool "Gen. 3.5"



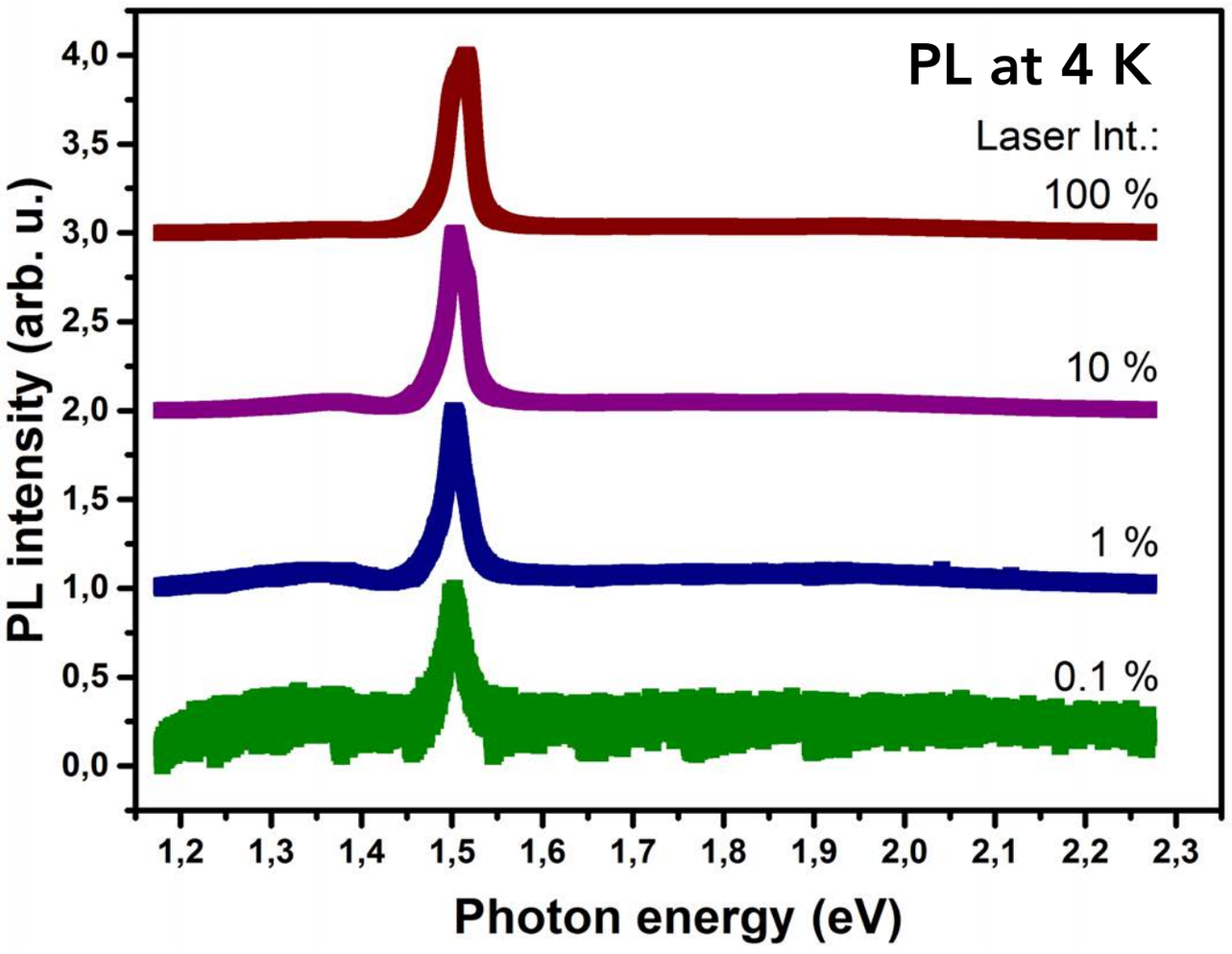
Y. Chen et al., Submitted to Nanotechnology (2019)

Baseline GaAs Nanowires



80 nm diameter ± 20 %

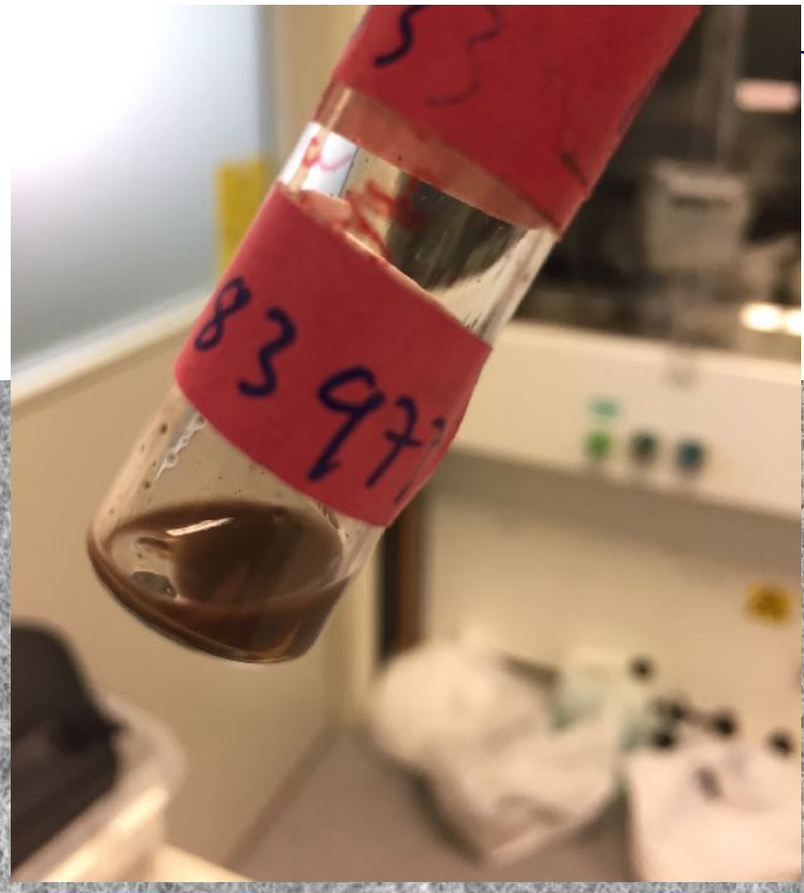
Length 2.8 µm ± 15 %

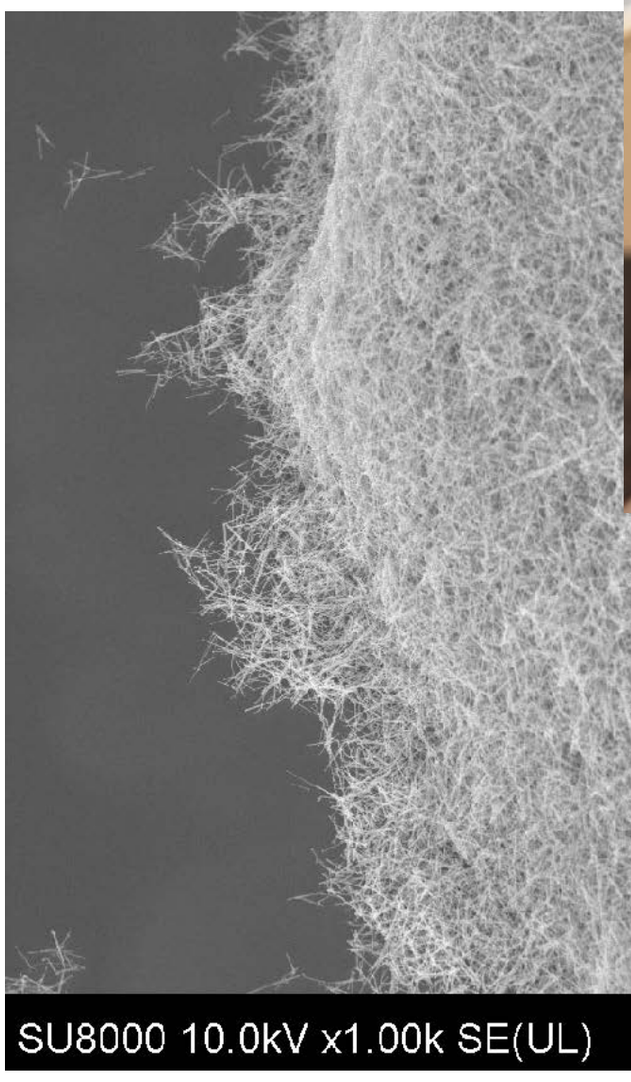


GaAsP	W. Metaferia *et al.*, Nano Lett. **16**, (2016), 5701
GaAs:Zn	F.F. Yang *et al.*, J Crystal Growth **414**, 161 (2015)
GaAs:Sn	W. Metaferia *et al.*, Nanotechnology **29**, 285601 (2018) A. Persson *et al.*, Small, **14**, 1801285 (2018)
GaAs *pn*	E. Barrigón *et al.,* Nano Lett **18**, 1088 (2017)

“Mass production”

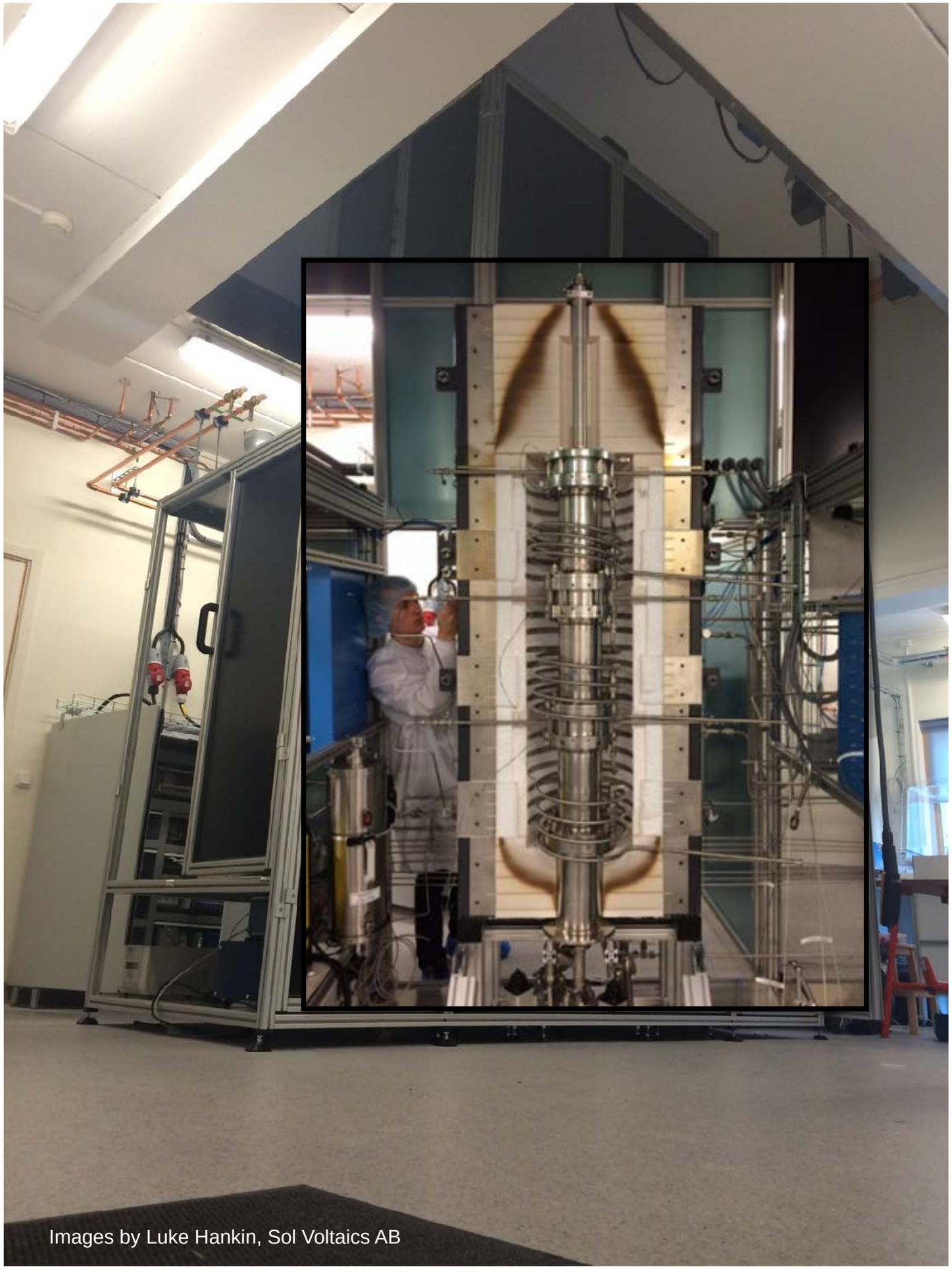
- 1 hour of collecting GaAs wires on a filter
  - –Measured: 1.6 mg
  - –Calculated: 1.85 mg (80 nm x 2 µm)
- MOVPE comparison:
  - –100 mm wafer with 4 wires/µm²
  - –Aerotaxy needs no lithography to define size selected seeds
  - –Scalable!





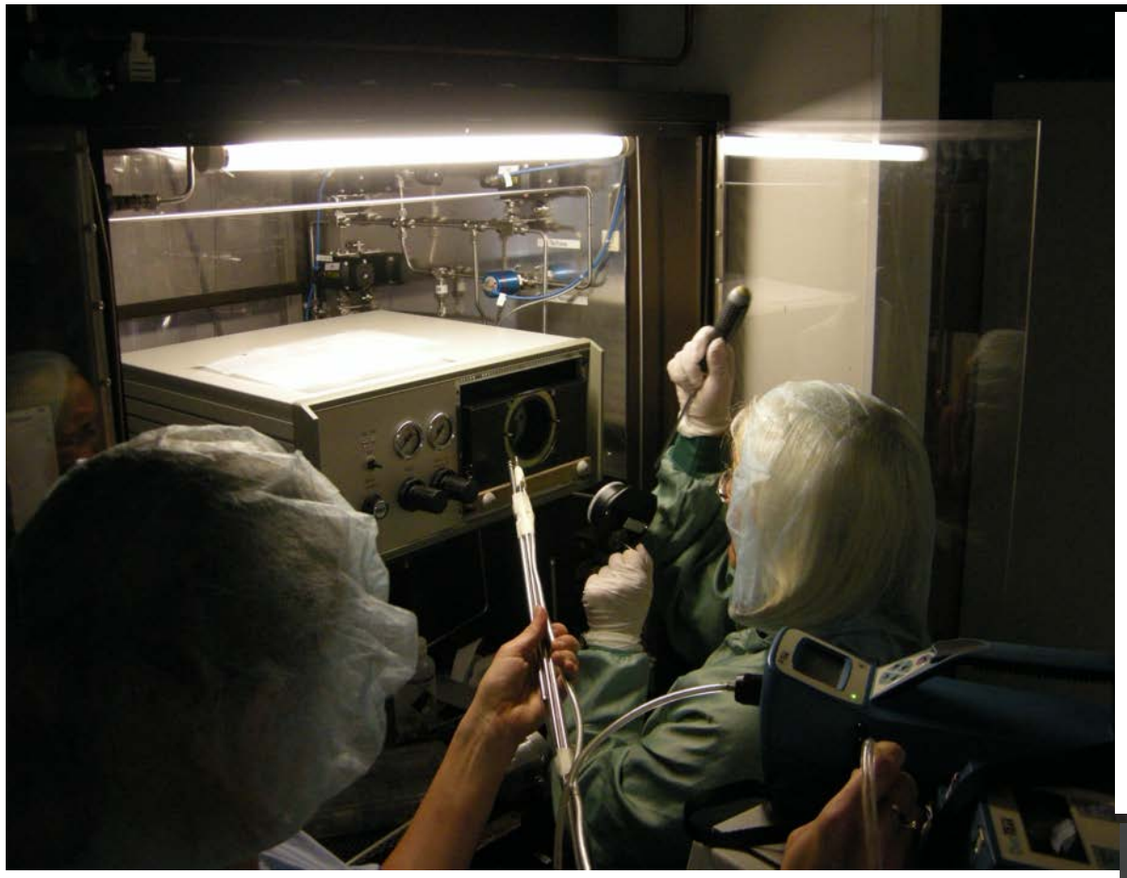
Aerotaxy Gen 4

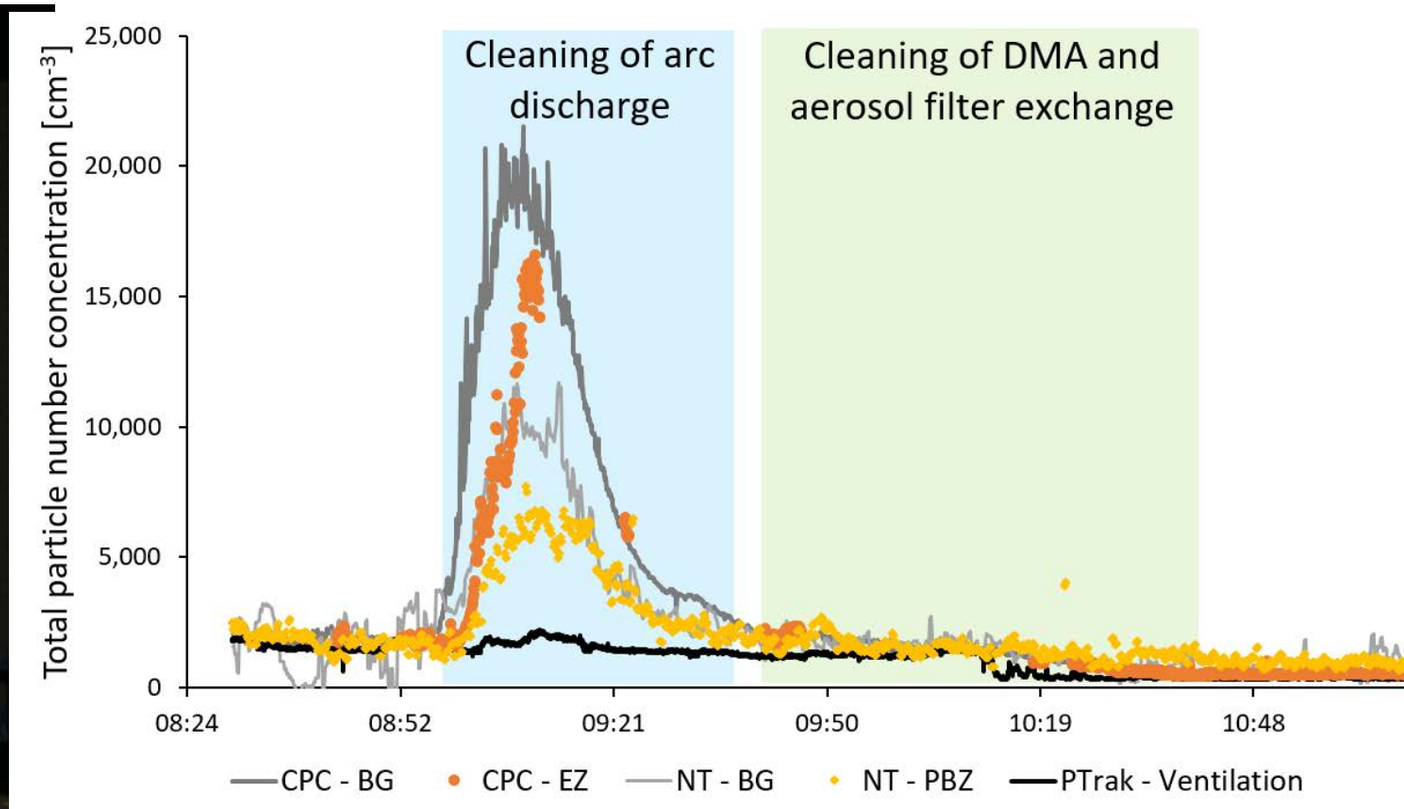
- Sol Voltaics' lab in Lund
- Pre-pilot production
- Up to six growth stages
- Demonstrated upscaled production capability



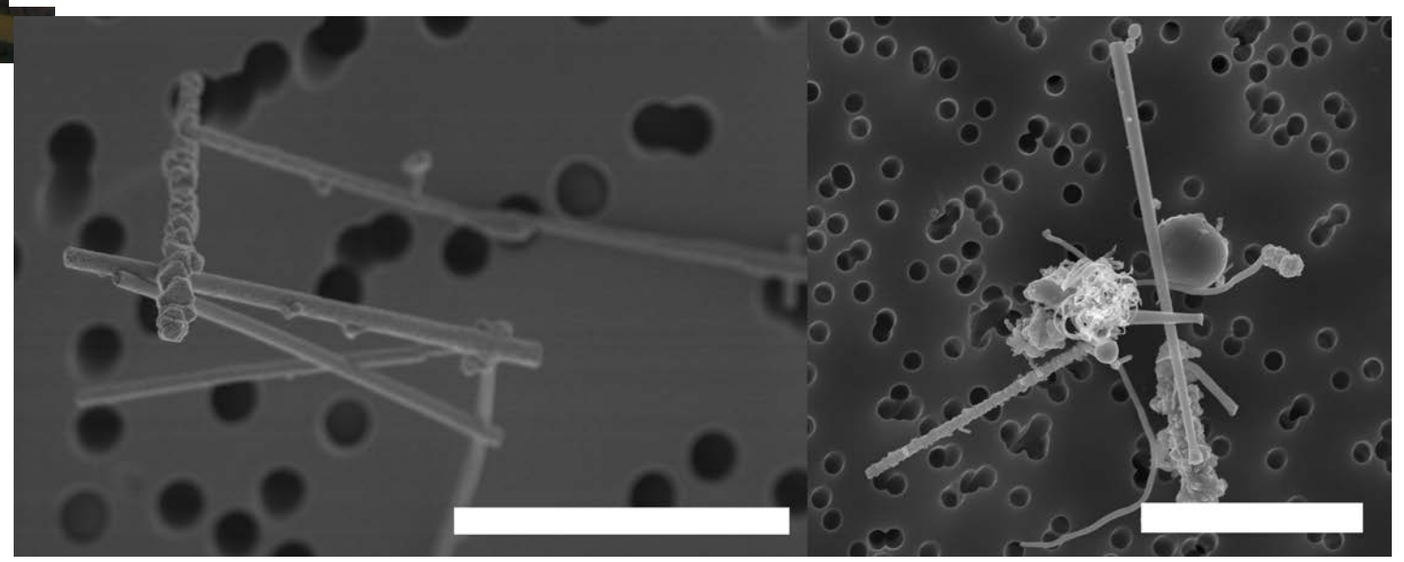
Images by Luke Hankin, Sol Voltaics AB

Aerosol safety studies





Conclusion: some particles can be measured during maintenance, but our safety arrangements are adequate



The Aerotaxy team

@ Lund University

PhD students

- Sudhakar Sivakumar
- Axel R. Persson
- Irene Geijselaers
- *Fangfang Yang*
- *Dr. Robert Hallberg*
- *Dr. Olof Hultin*
- *Dr. Kilian Mergenthaler*

Post-docs

- Yang Chen
- *Enrique Barrigón*
- *Wondwosen Metaferia*
- *Nicklas Anttu (Aalto U)*

Faculty

- Bengt Meuller
- Jonas Johansson
- Mats-Erik Pistol
- L. Reine Wallenberg
- Knut Deppert
- Lars Samuelson

@ Sol Voltaics

- Linda Johansson
- Dr. Magnus Heurlin
- Dr. David Lindgren
- Farnaz Yadegari
- Sung Youn Ju
- Dr. Greg Alcott
- Dr. Mikael Björk
- Dr. Luke Hankin

Knut och Alice Wallenbergs Stiftelse
Vetenskapsrådet
Energimyndigheten
Crafoordska stiftelsen
GRUNDAD AV HOLGER CRAFOORD 1980
H2020: Nano-Tandem 641023

martin.magnusson@ftf.lth.se