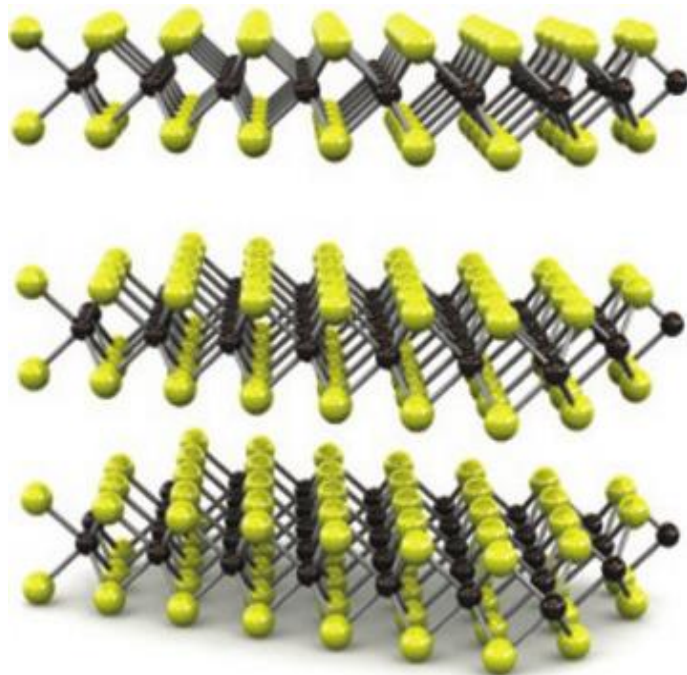


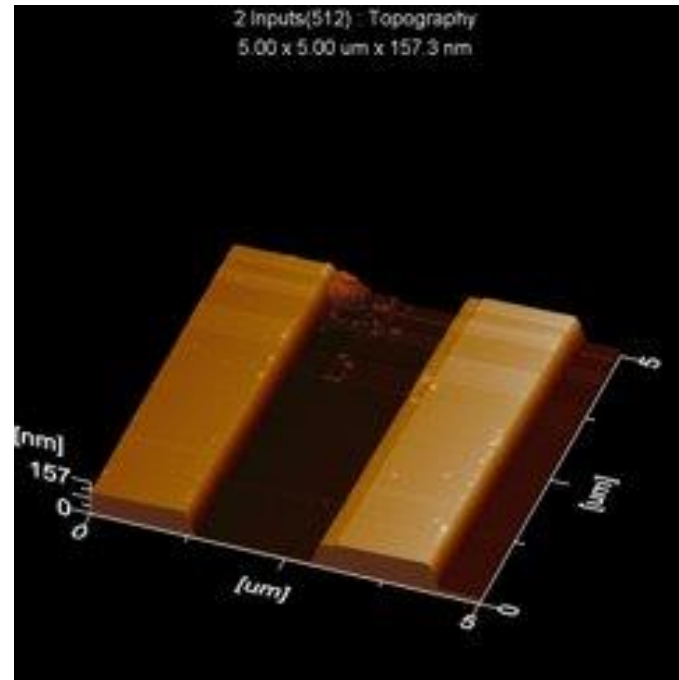
With Molybdenum Disulfide into the World of 2D-Materials

Björn Schäfer

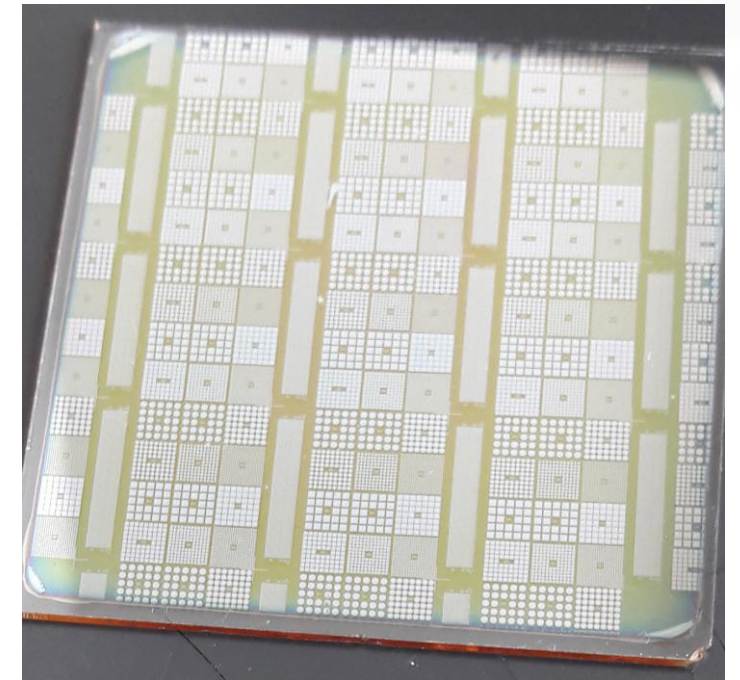
MoS₂



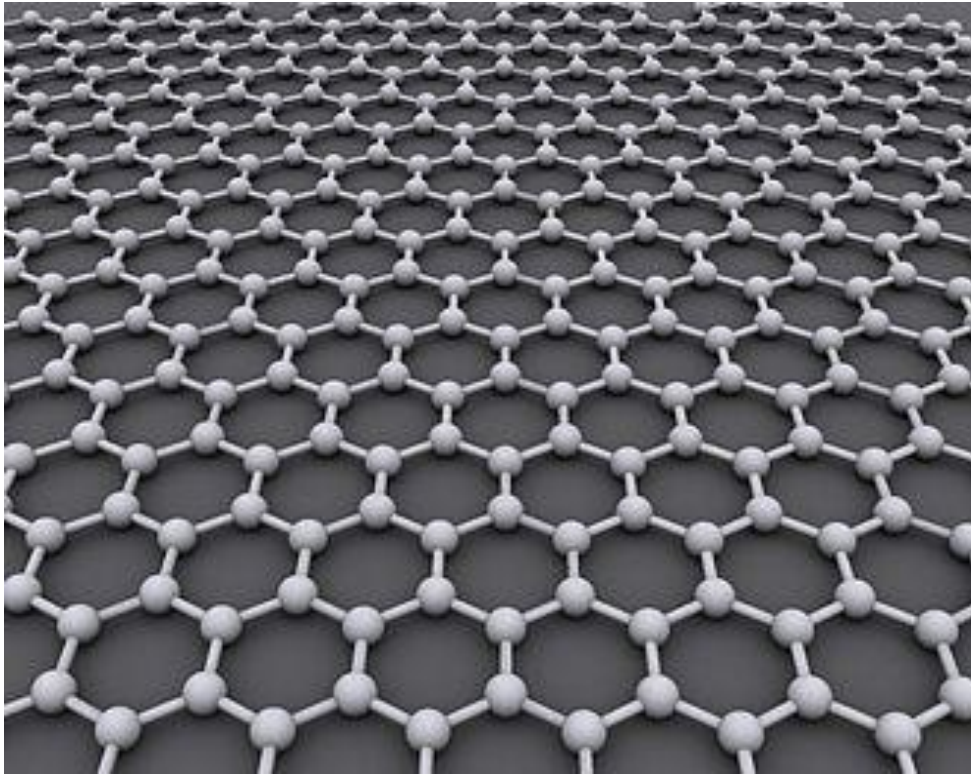
Thickness determination



Device integration

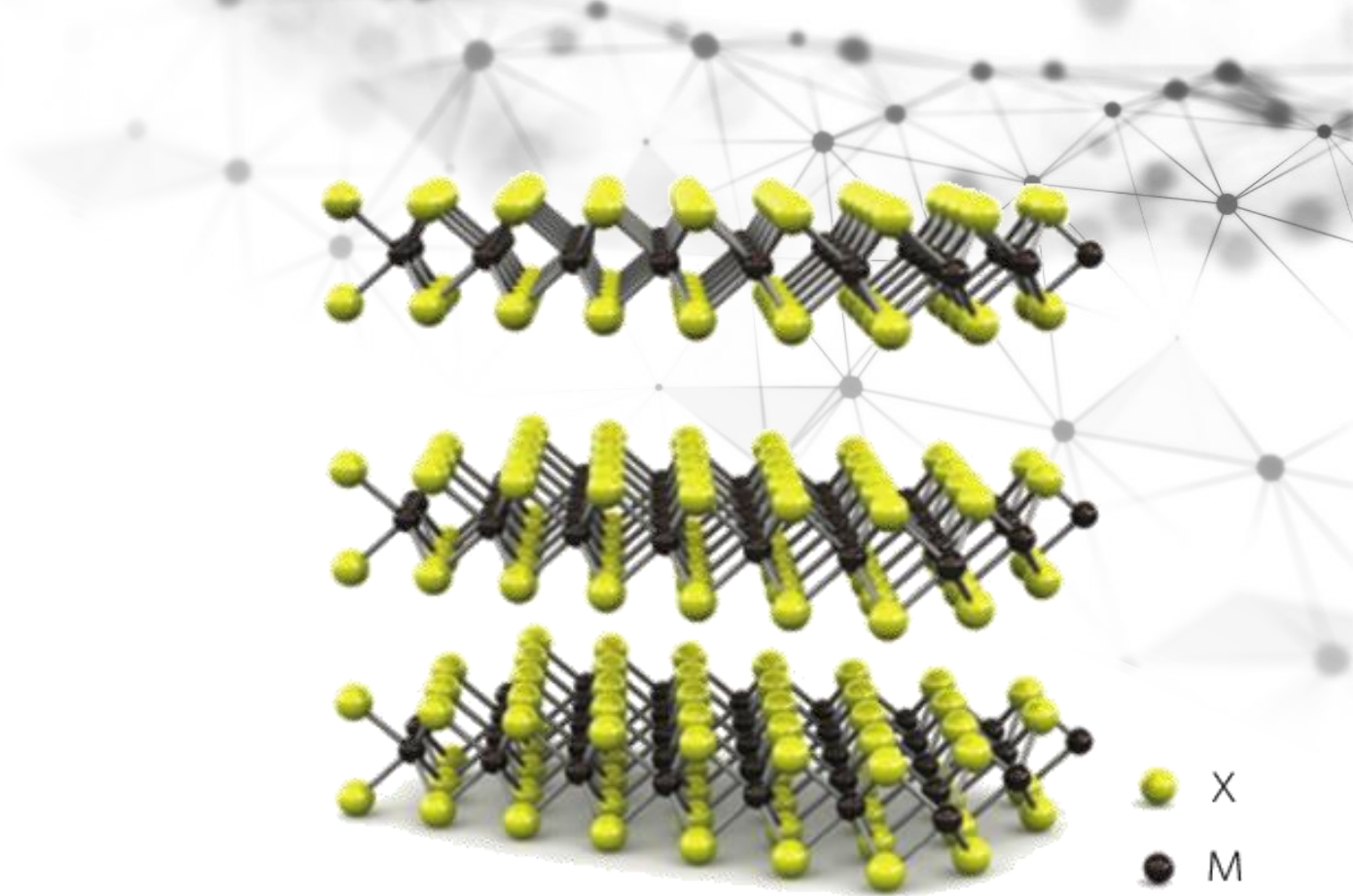


What is a 2D-Material?



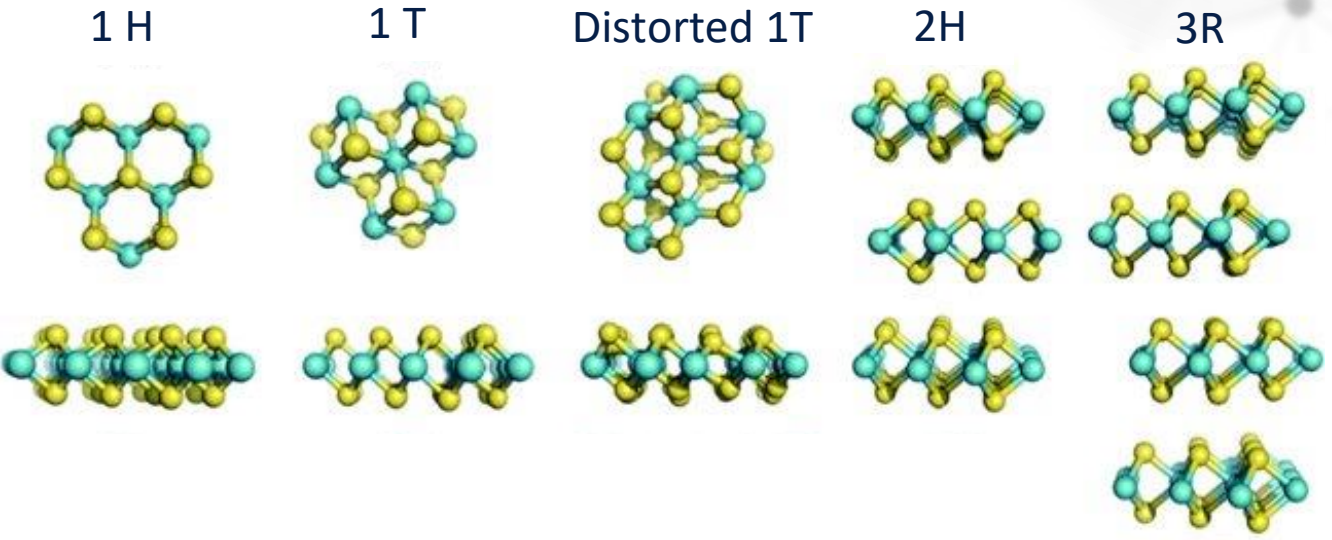
wikipedia.de

- Strict definition
 - One layer with thickness of one atom
- Graphene



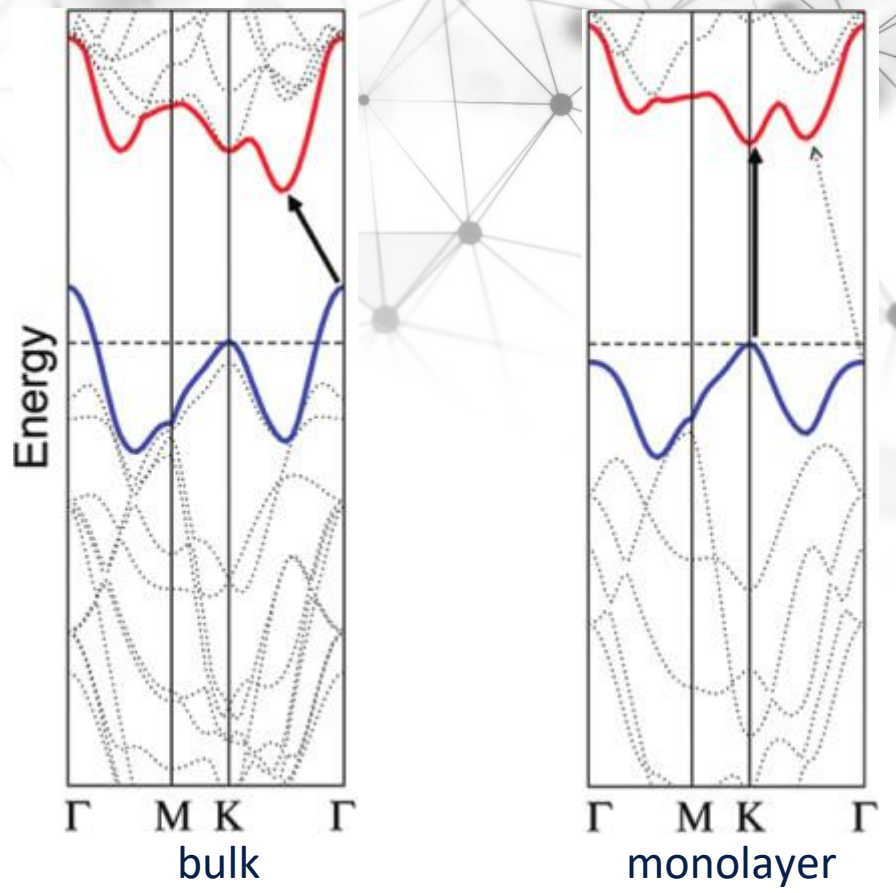
- ISO/TS 80004-13:2017
 - Layered with strong bonds in each layer
 - Thickness in the nanoscale
 - Properties different from bulk material
- Transition metal dichalcogenides

Molybdenum Disulfide (MoS₂)



- Semiconducting 1H-phase most common
- 1T-phase metallic
- One S-Mo-S-layer 0.65 nm thick
- Stacking of 1H-phase
 - AB sequence (2H)
 - ABC sequence (3R)

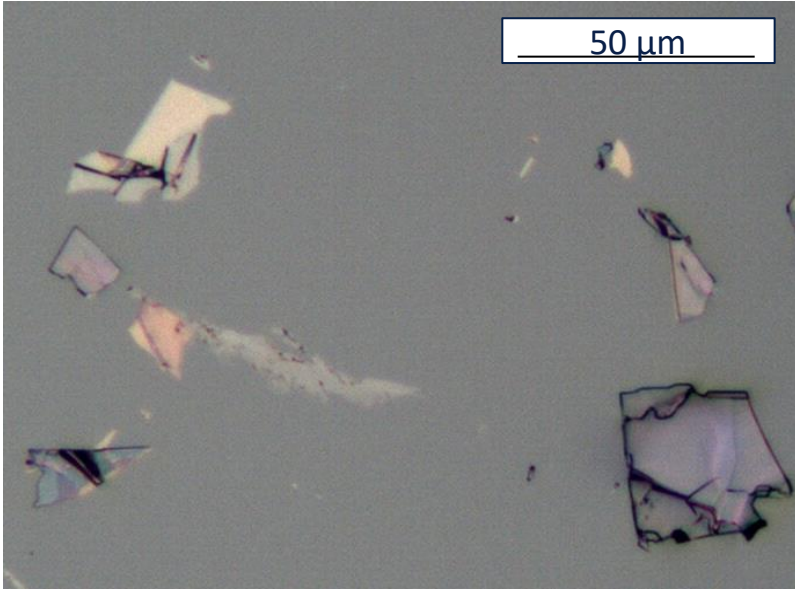
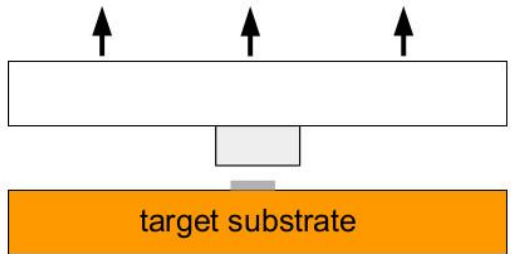
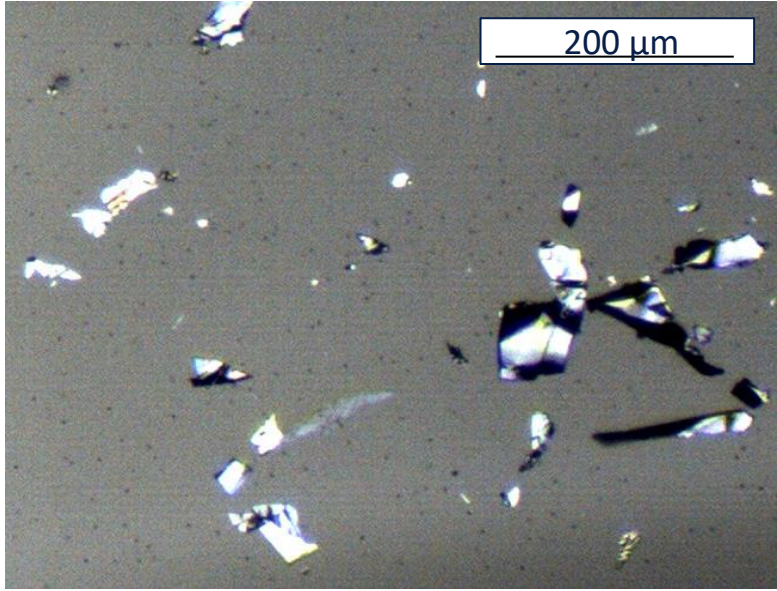
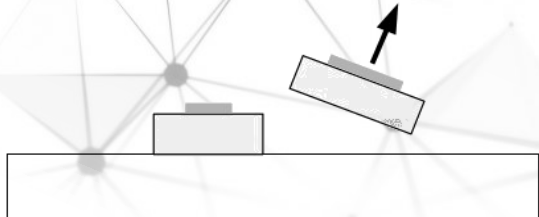
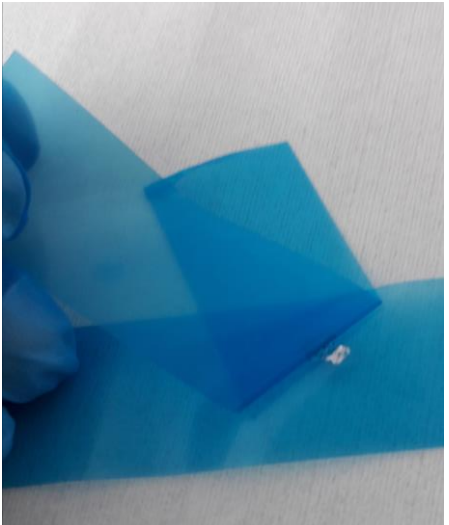
Calculated bandstructure



- Bulk: indirect band gap of ~ 1 eV
- Monolayer: direct band gap of ~ 1.9 eV

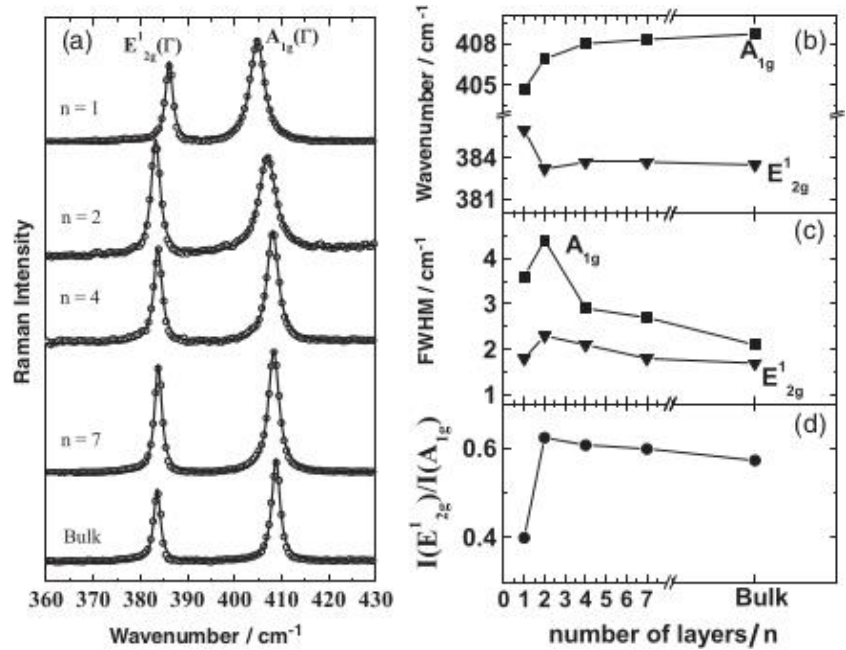
Voiry *et al*, Chemical Society Reviews 44.9 (2015) 2702
 Wang *et al*, Nature nanotechnology 7.11 (2012) 699
 Splendiani *et al*, Nano Lett. 10 (2010) 1271

Preparation Procedure

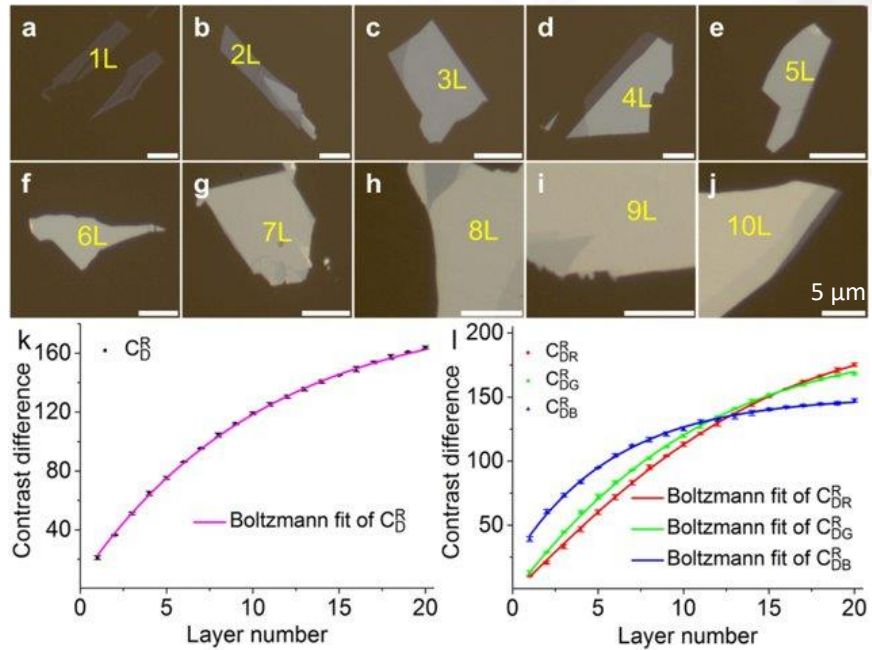


Thickness Determination

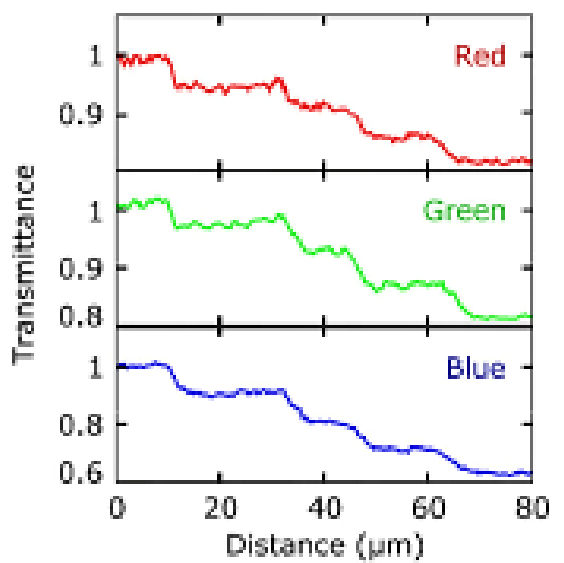
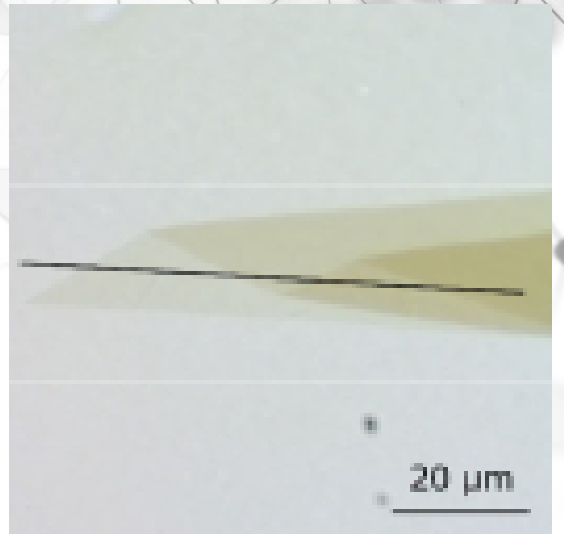
Raman spectroscopy



Reflection of light



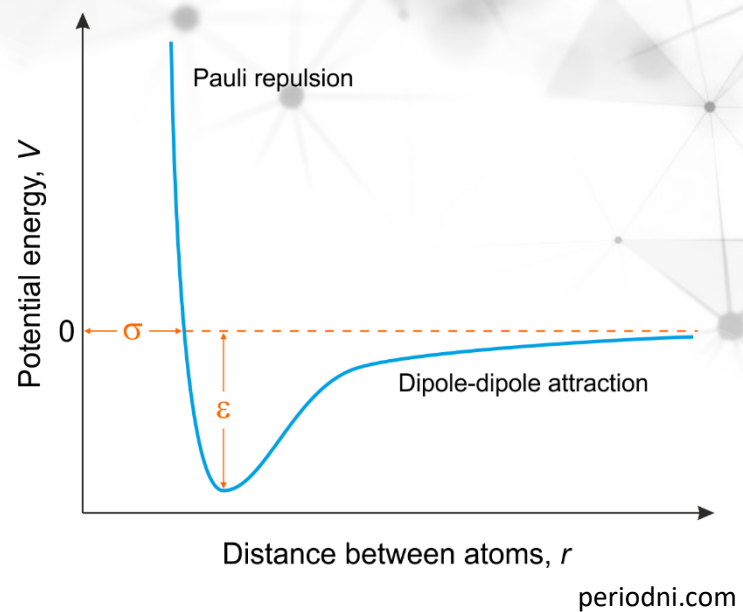
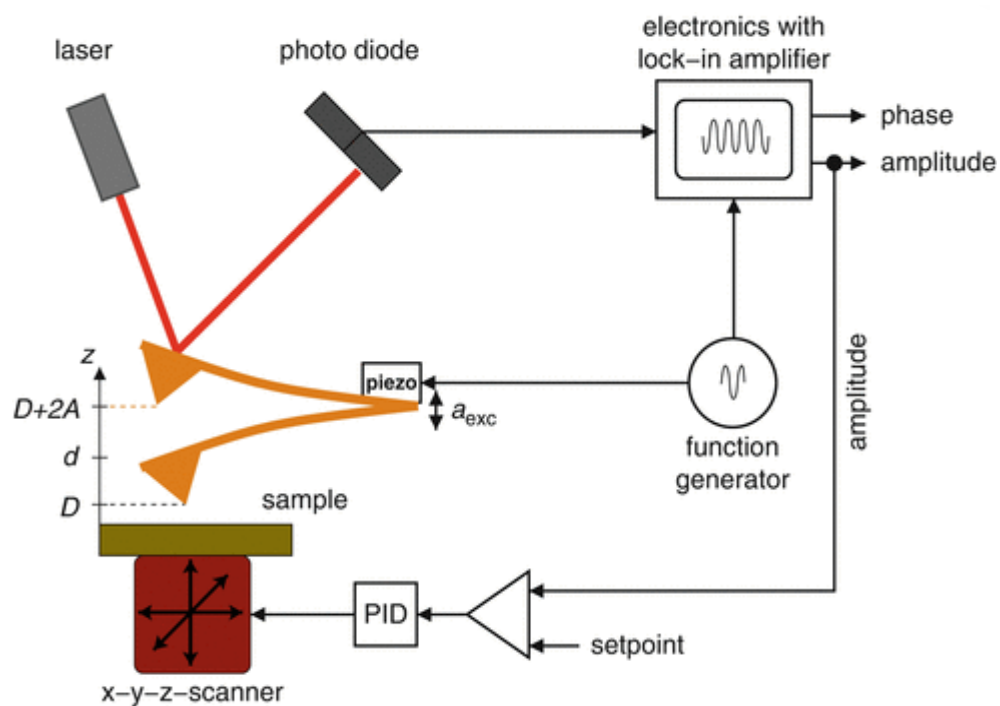
Transmission of light



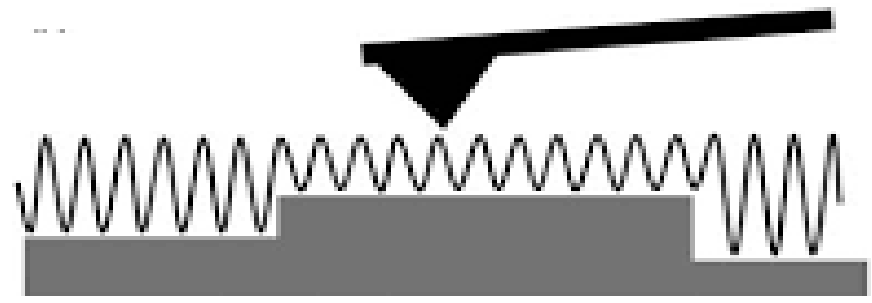
- Determination via optical microscopy before transfer process most practical method
 → Reference measurements with AFM

Chakraborty *et al*, J. Raman Spectroscopy 44 (2013) 92
 Zhang *et al*, Nanotechnology 28 (2017) 164001
 Taghavi *et al*, Nano Research 12.7 (2019) 1691

Atomic Force Microscopy

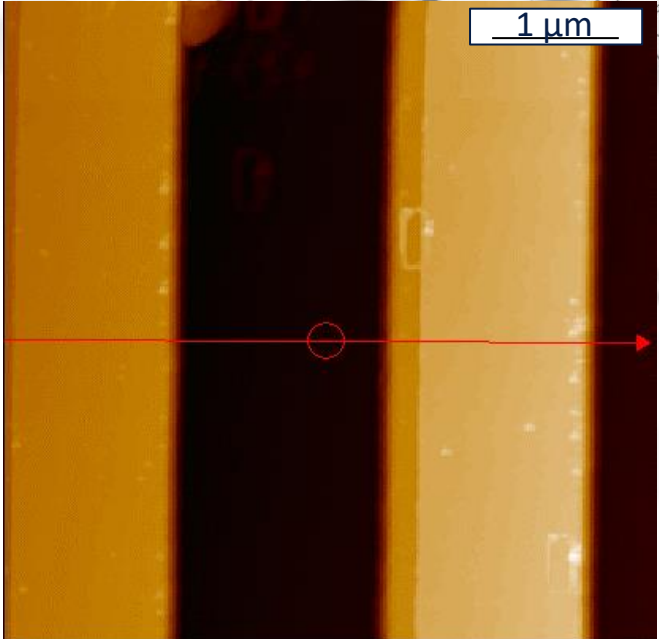
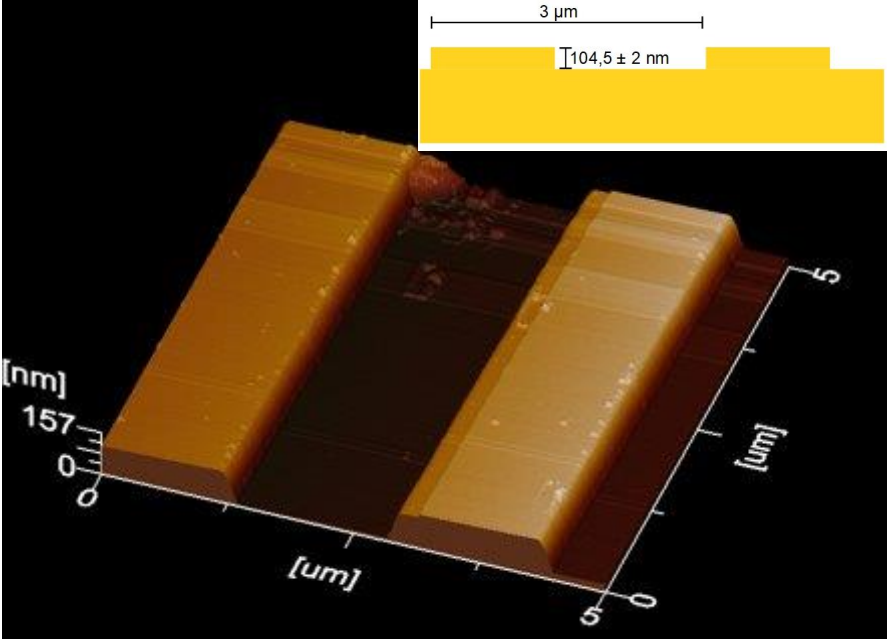
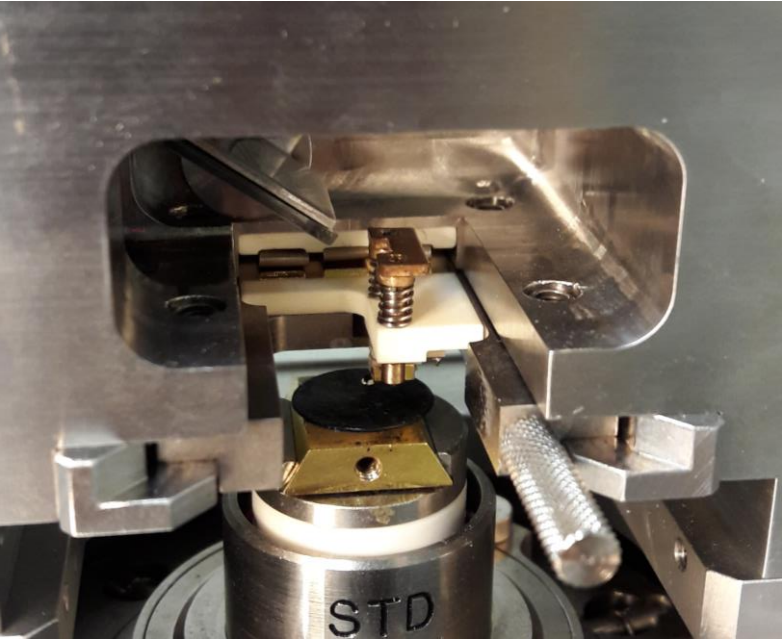


- Cantilever with tip scans the sample
- Tapping mode
 - Oscillating cantilever
 - Change of amplitude due to interaction with sample
 - Feedback loop adjusts height to keep amplitude constant
 - Height adjustments contains topographic information

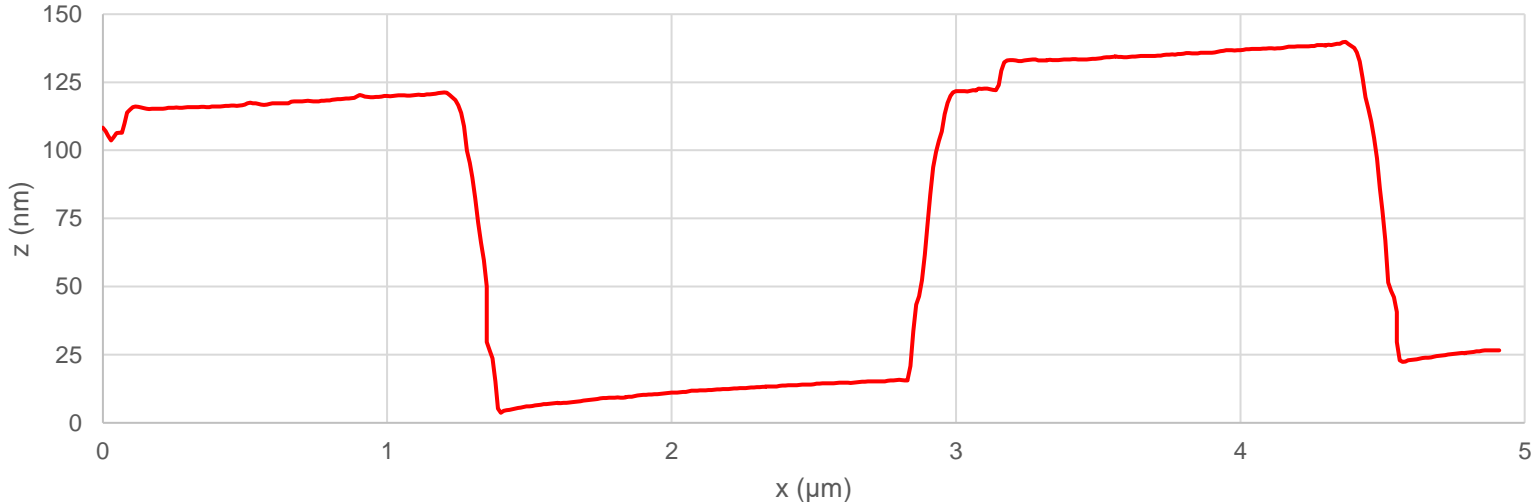


Hölscher, Encyclopedia of Nanotechnology (2012)
 Averett and Schoenfish, Analyst 135 (2010) 1201

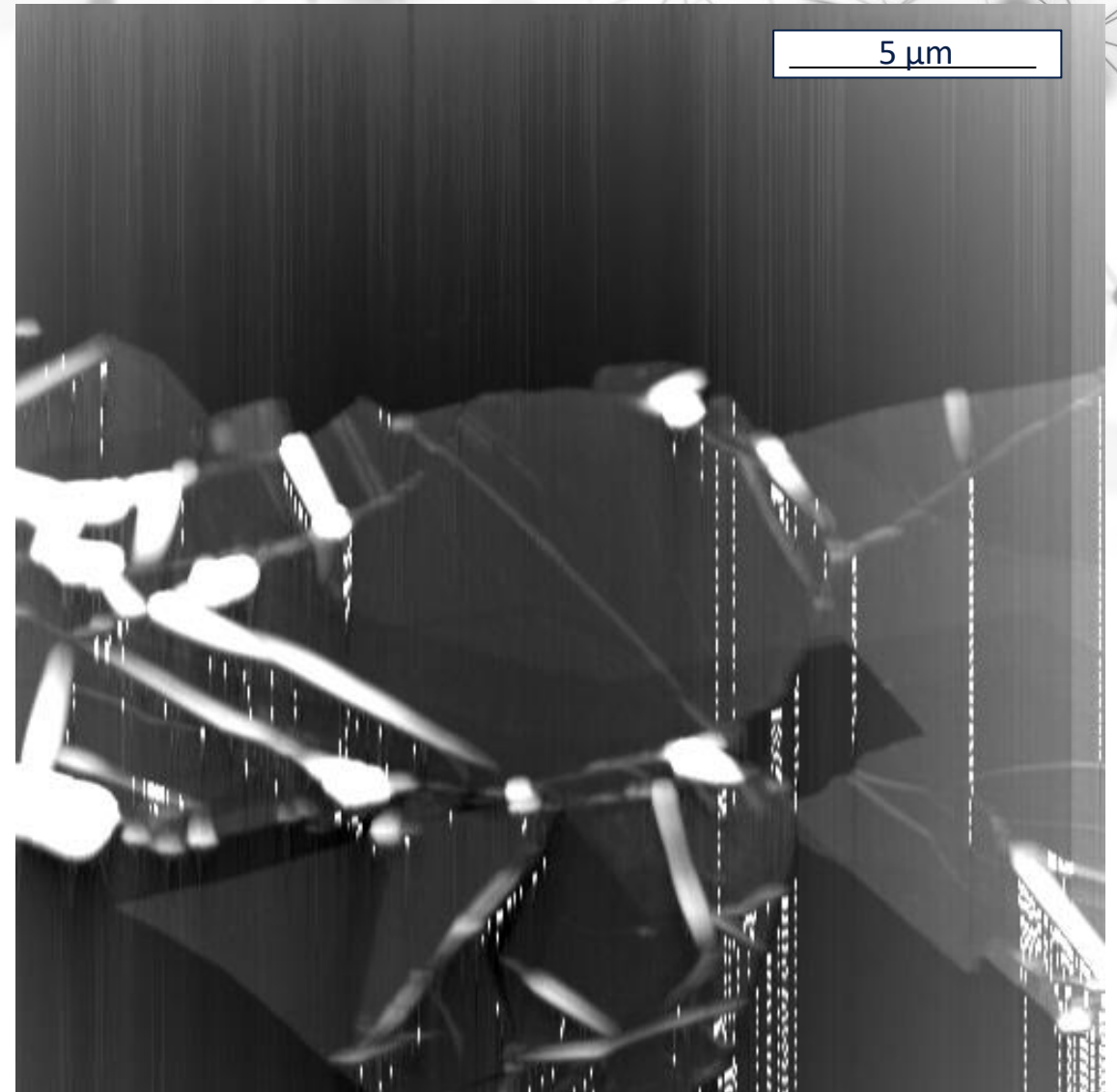
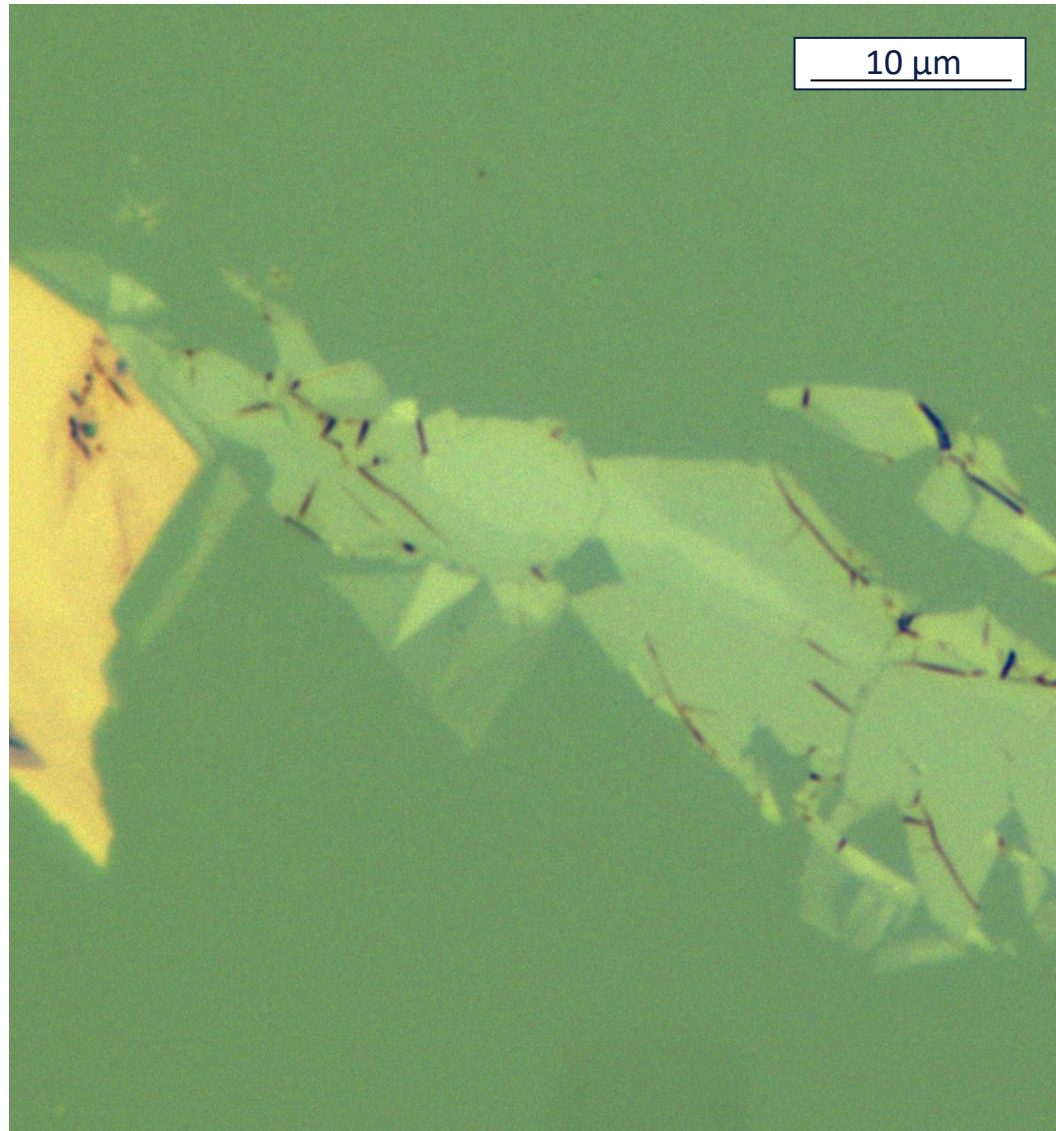
AFM Reference Sample



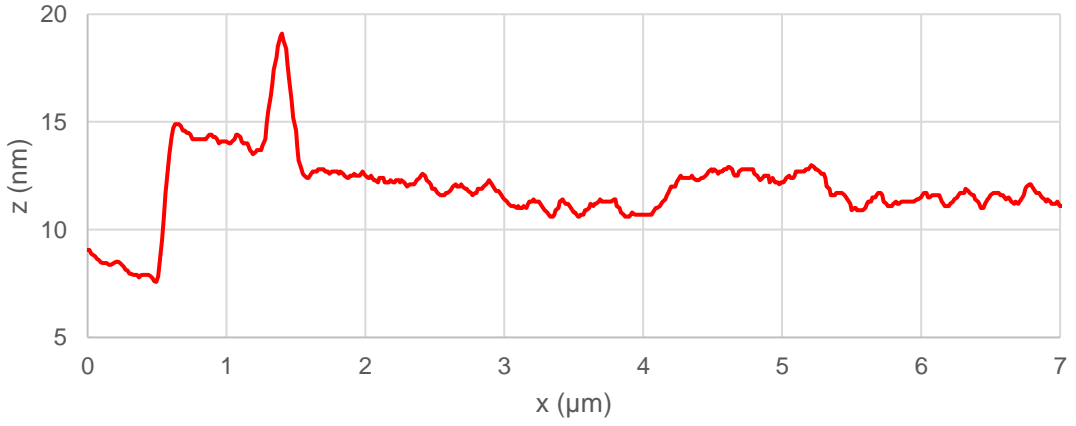
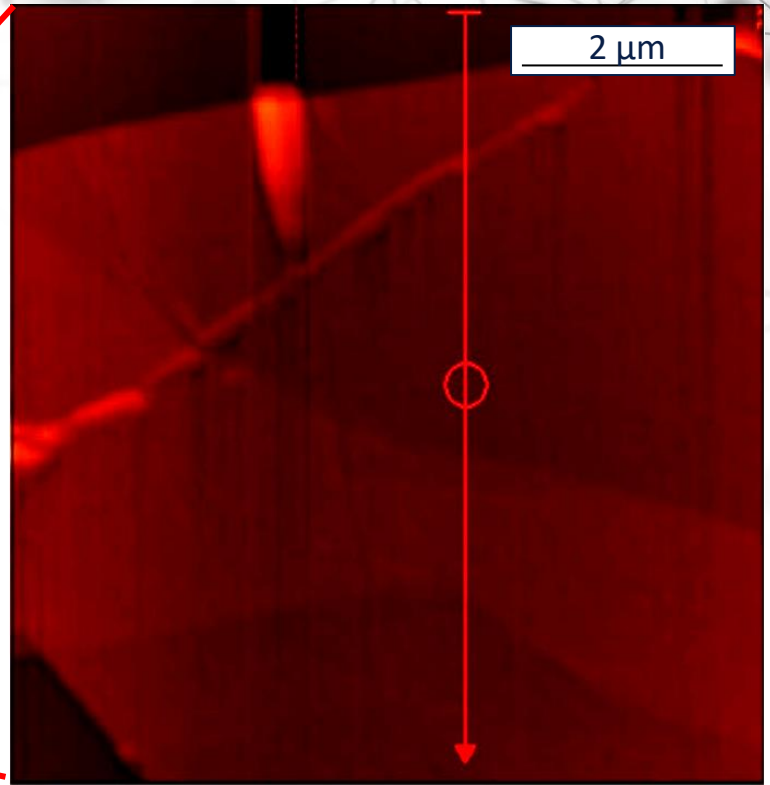
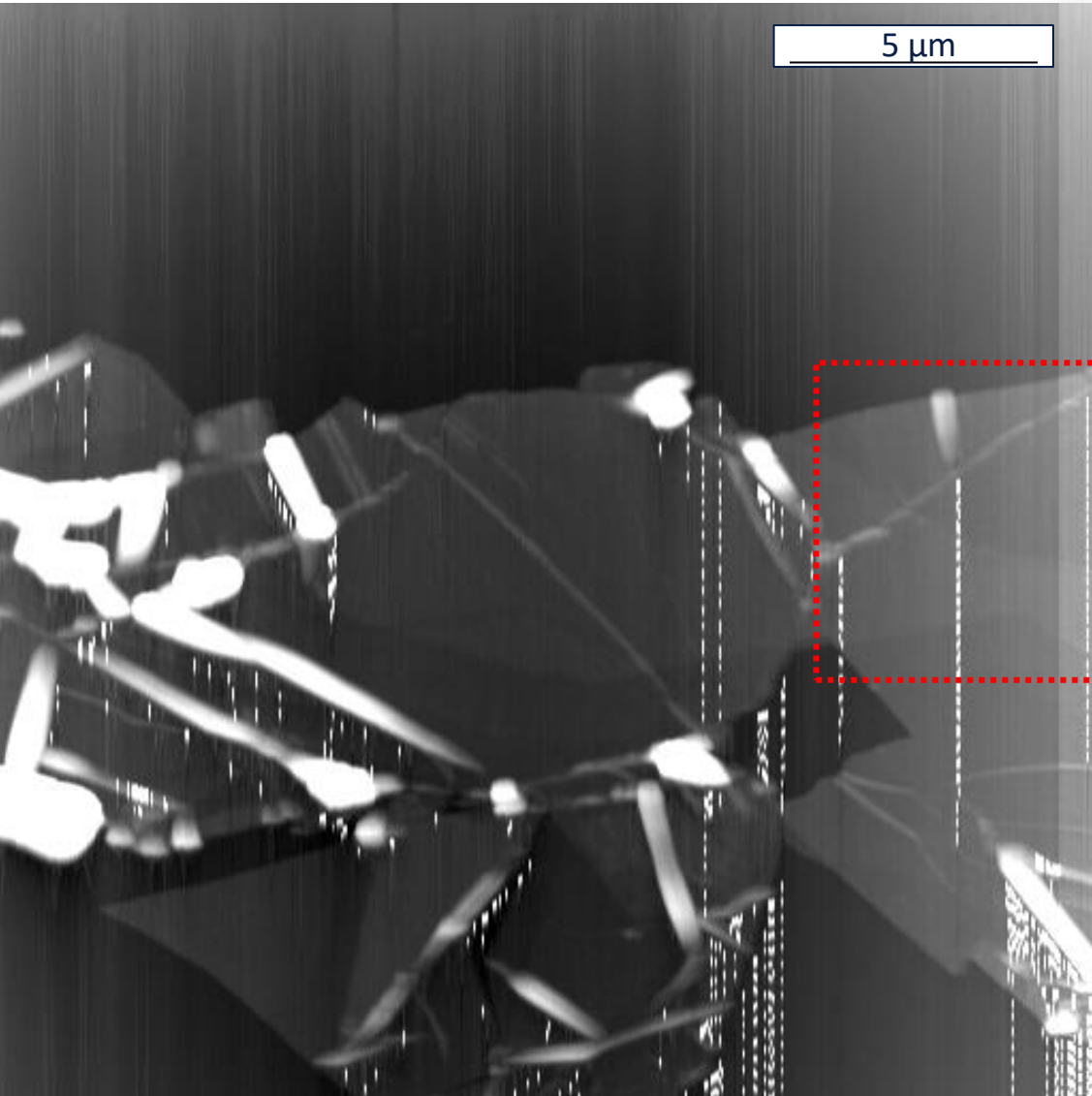
→ Deviation in z - measurement



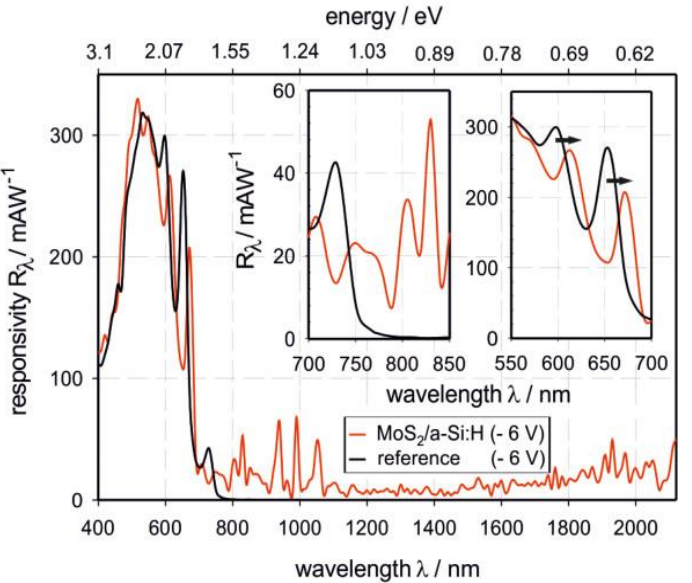
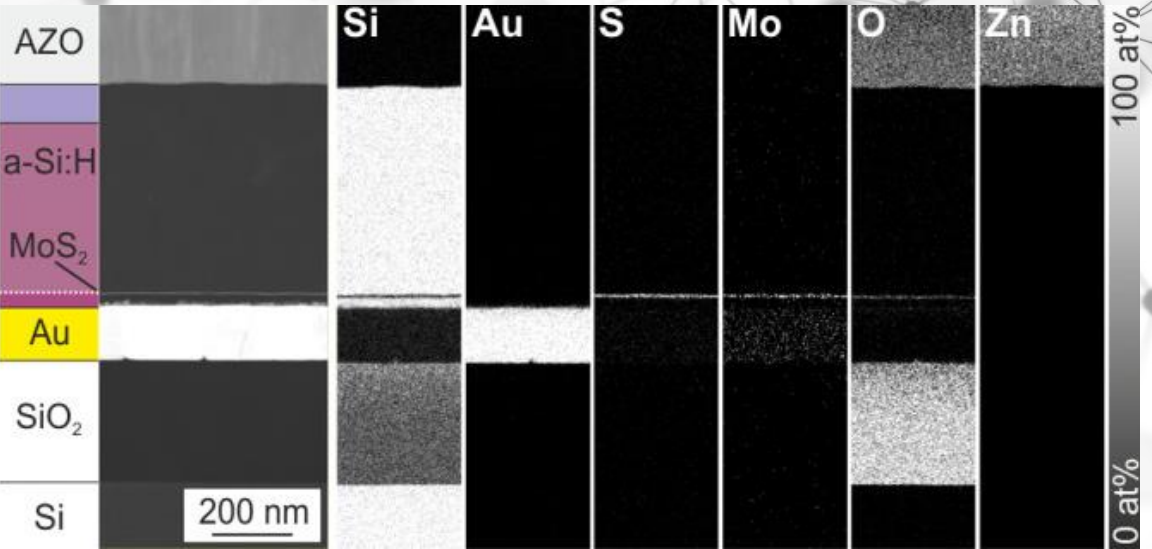
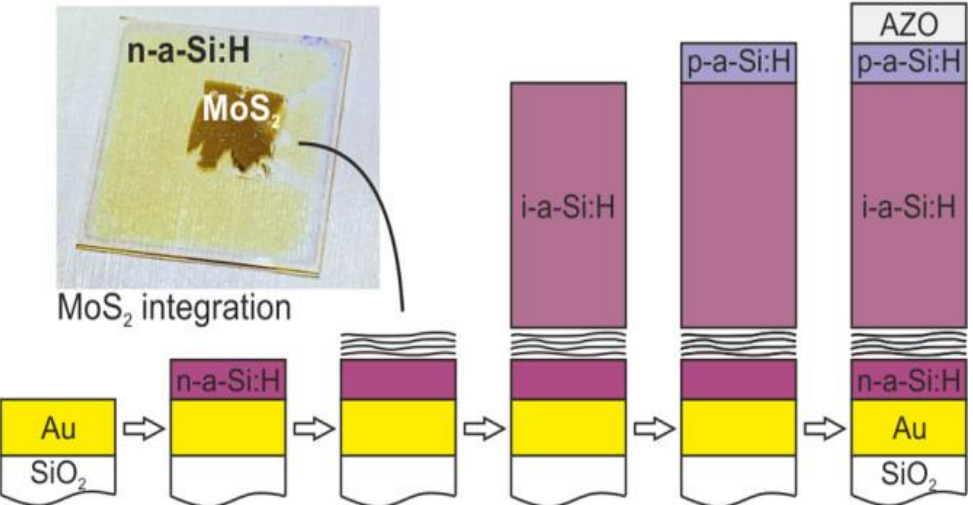
First AFM Measurements



First AFM Measurements



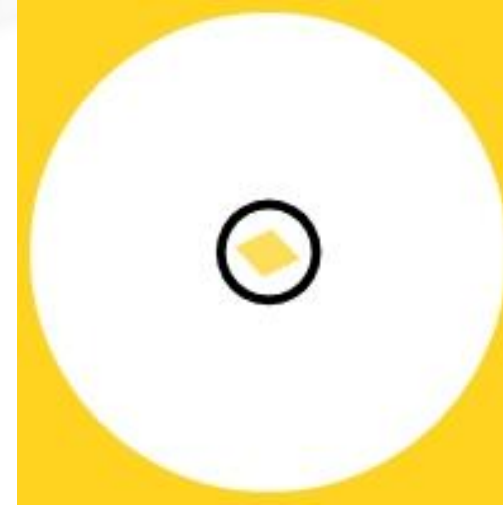
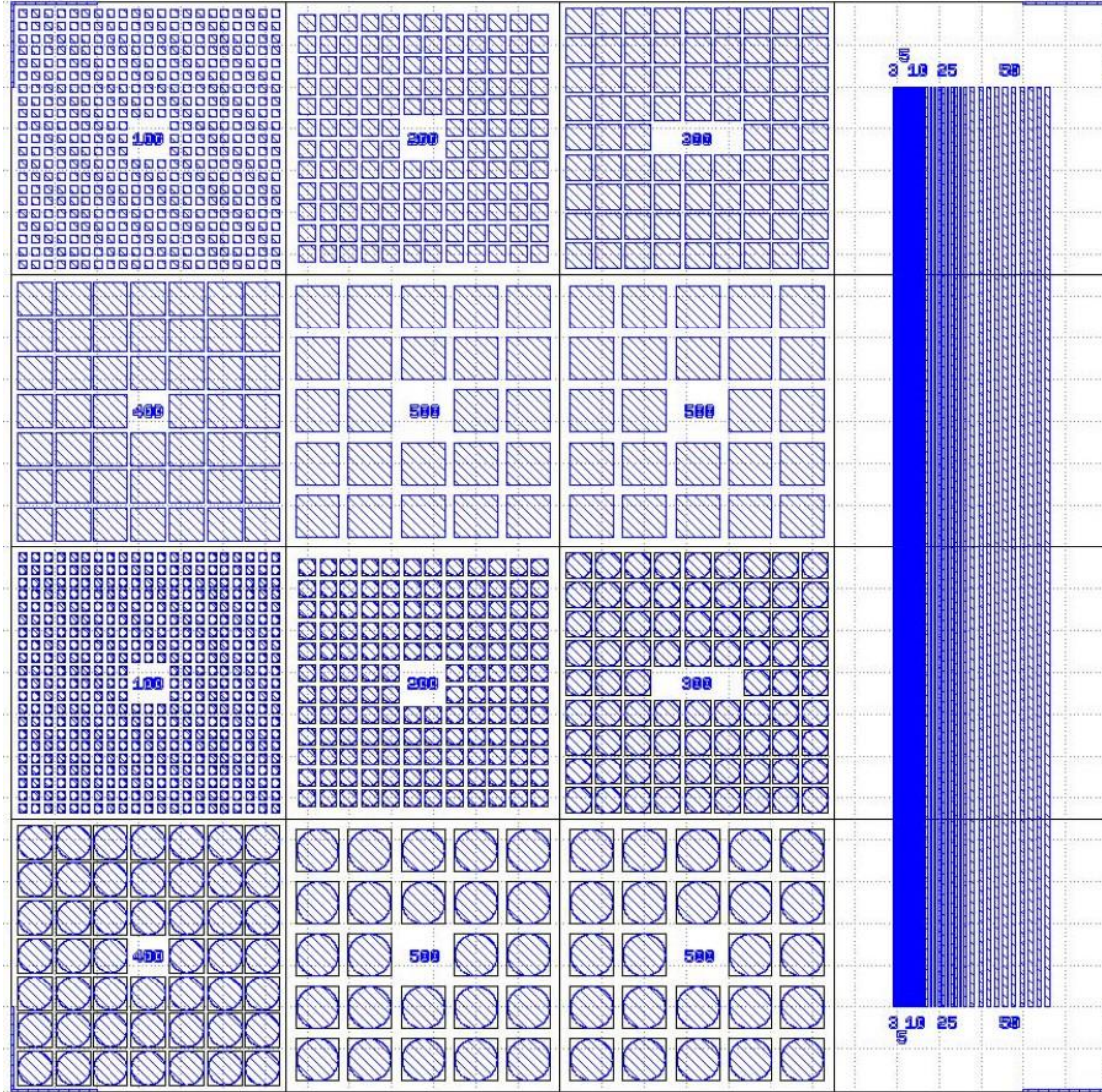
Device Integration - MoS₂/a-Si:H Photodiode



- Responsivity in infrared range by adding a layer of MoS₂
- 4 nm thick thermally assisted converted MoS₂
- Unknown structure of the MoS₂ layer
 → Replacing deposited MoS₂ by exfoliated MoS₂ flakes

Bablich *et al*, ACS Photonics 6.6 (2019) 1372.

Transfer of MoS₂-Flakes

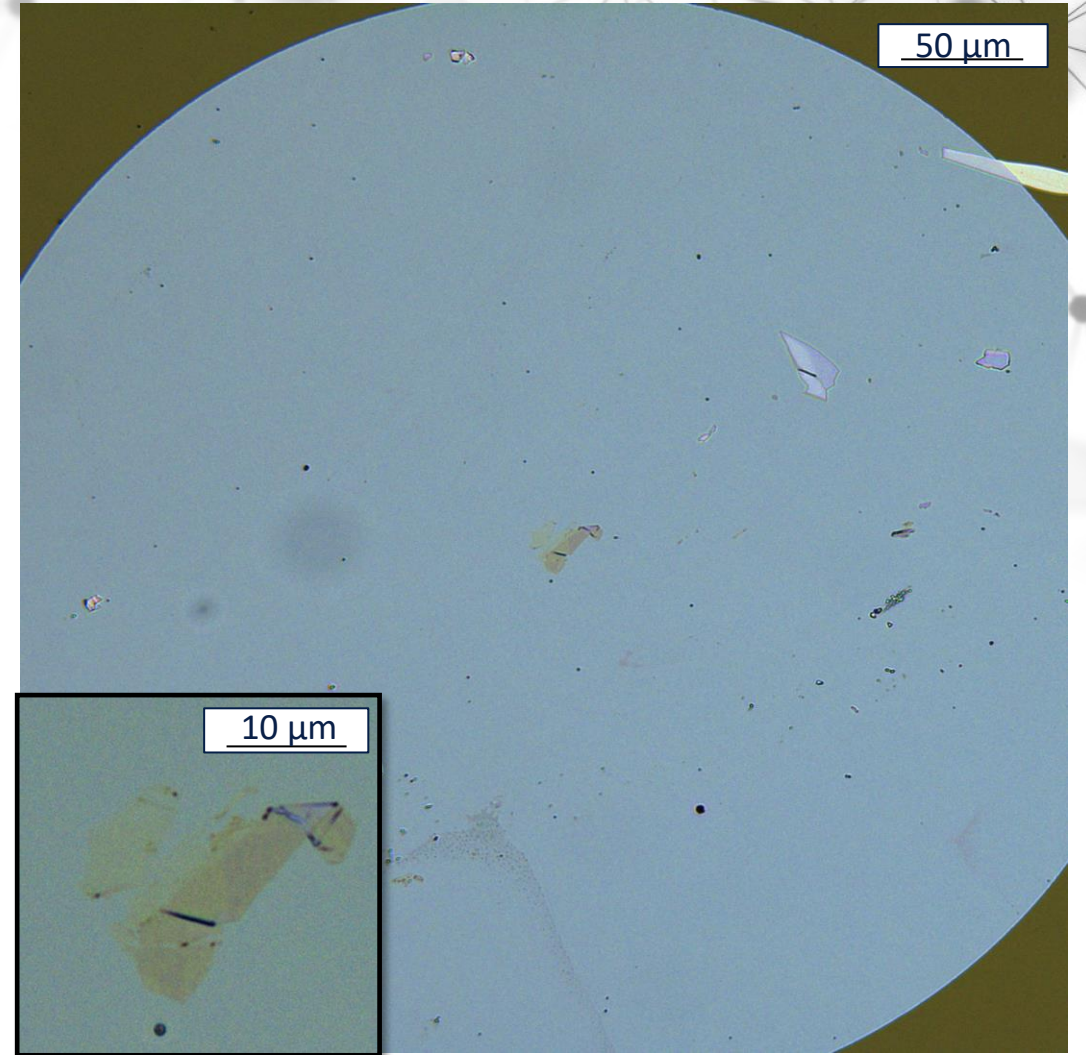
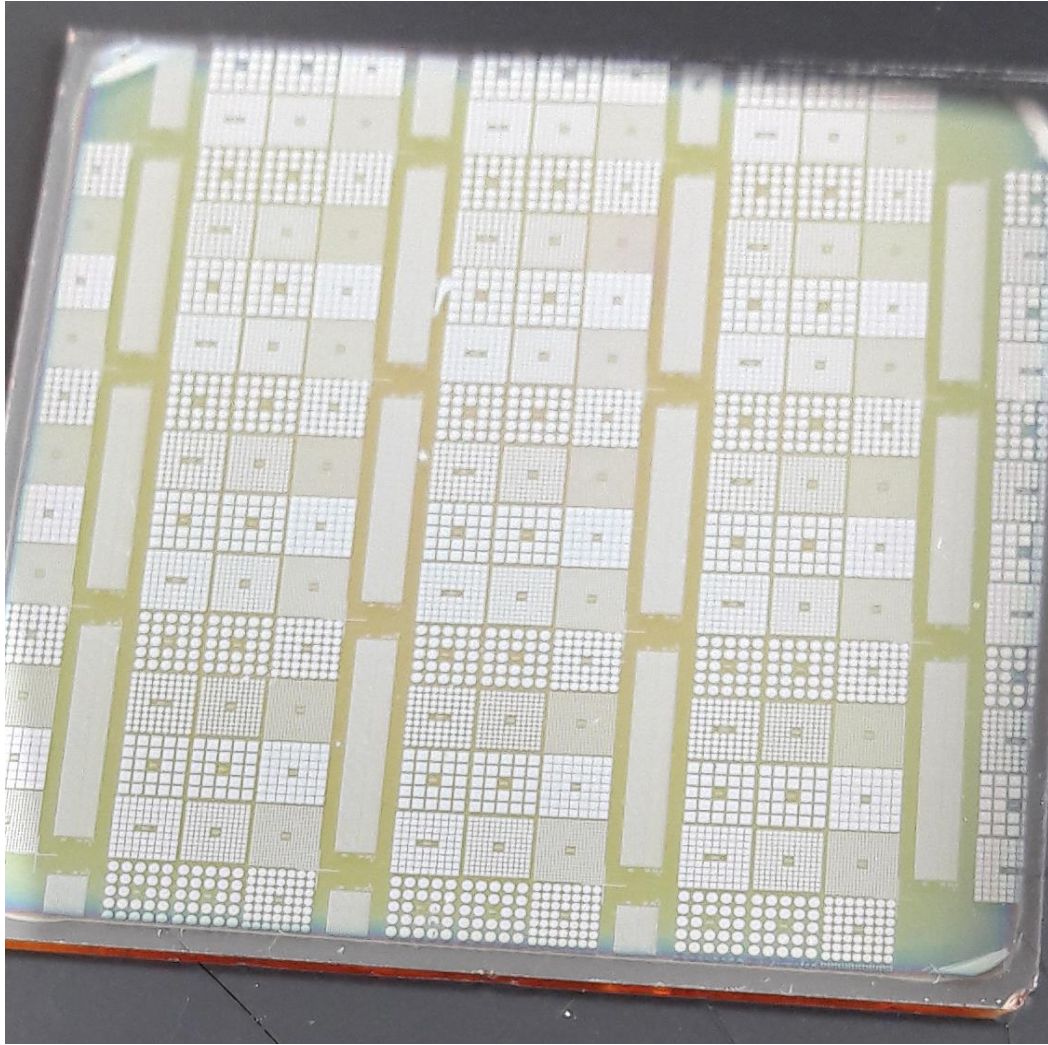


	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4			X							
5						X	X			
6		X						X		X
7				X						X
8	X	X						X		
9										
10										

wikipedia.de

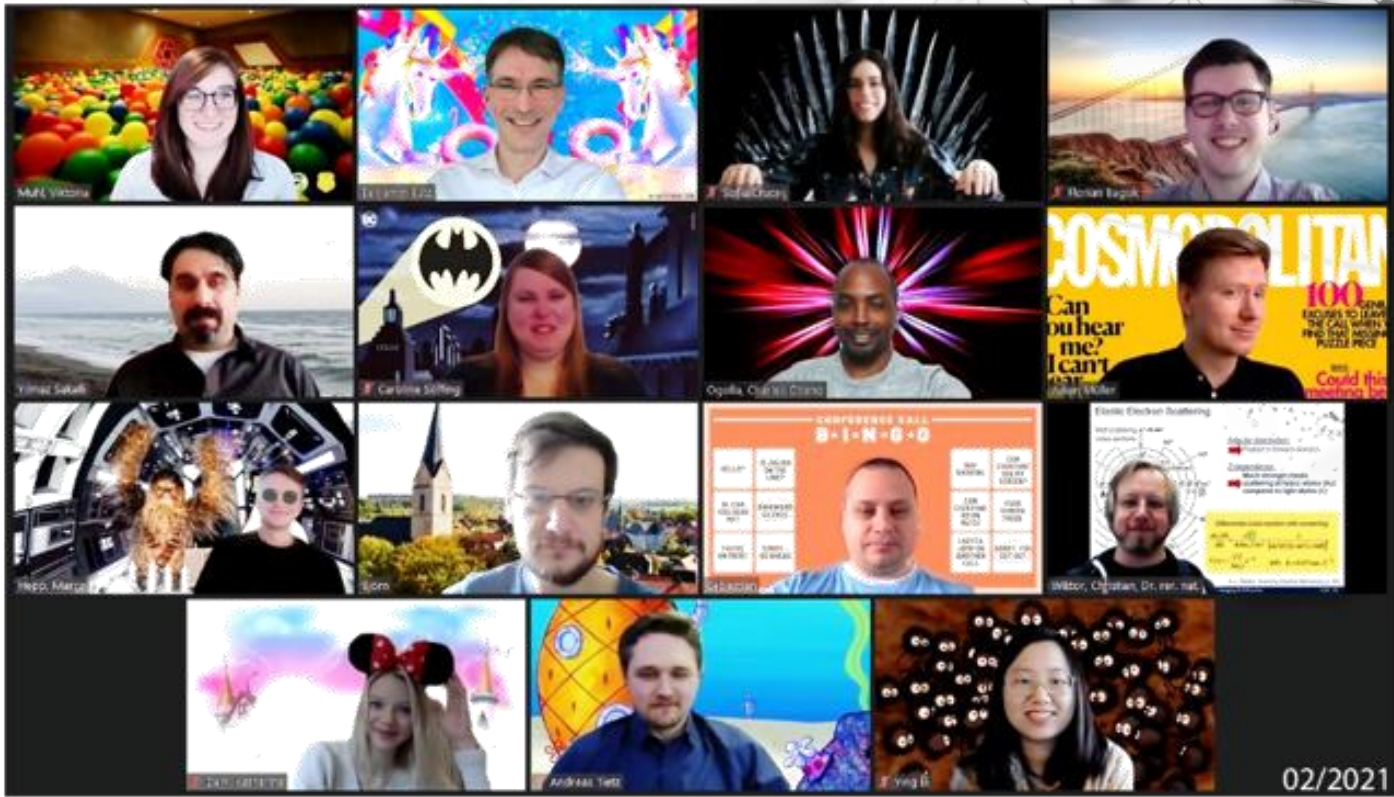
- Flakes with thickness of few layers
- Notation of target location
 - Shape and size of structure
 - In each block by number and letter (like "Schiffe versenken")
- Further processing requires transfer in the middle of one structure

First Test Transfers



Acknowledgment

Prof. Benjamin Butz
Charles Otieno Ogolla
Sofia Cruces
Dr.-Ing. Julian Müller
Dr. Andreas Bablich
Patrick Hartwich
... and many more!

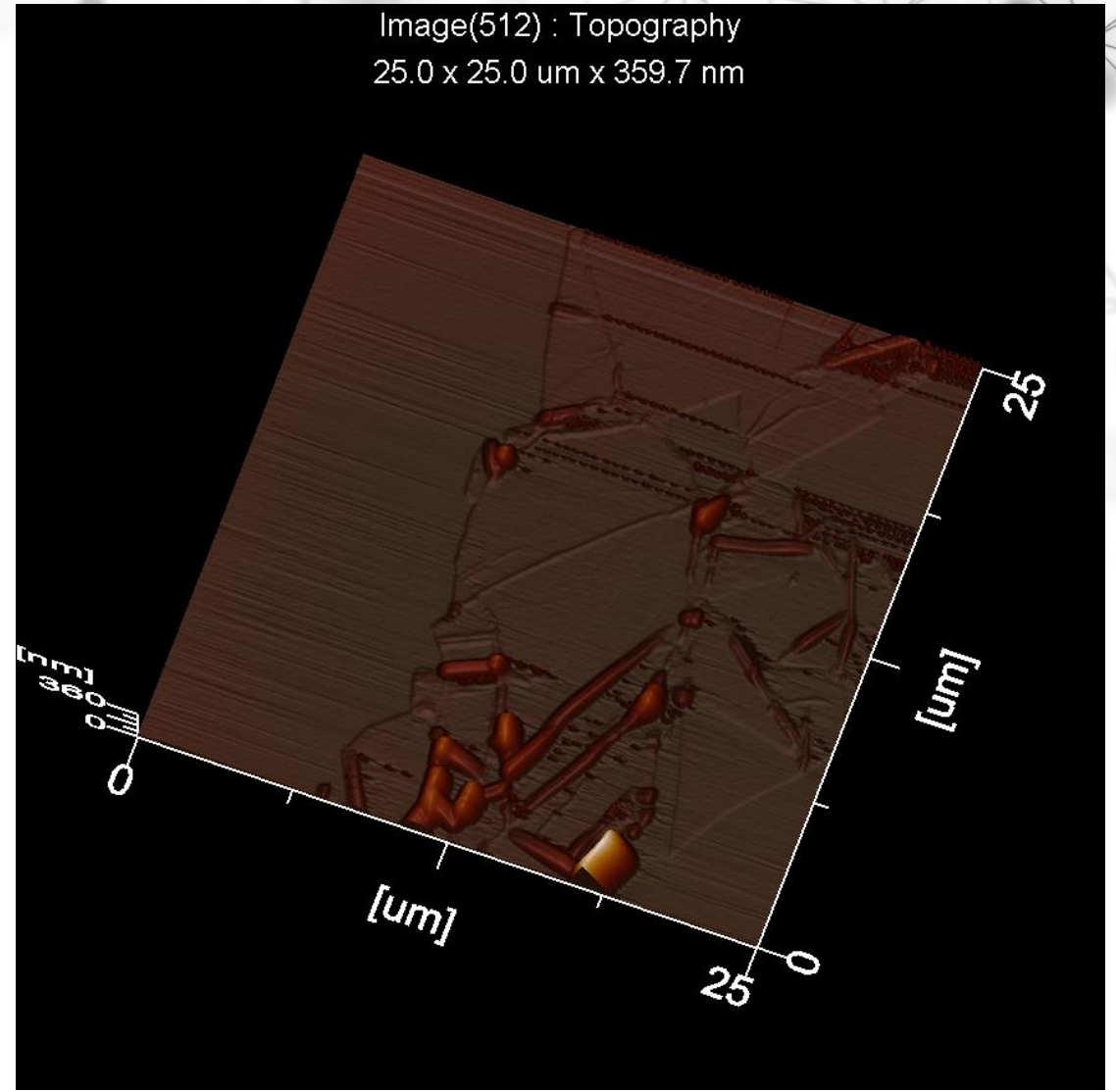
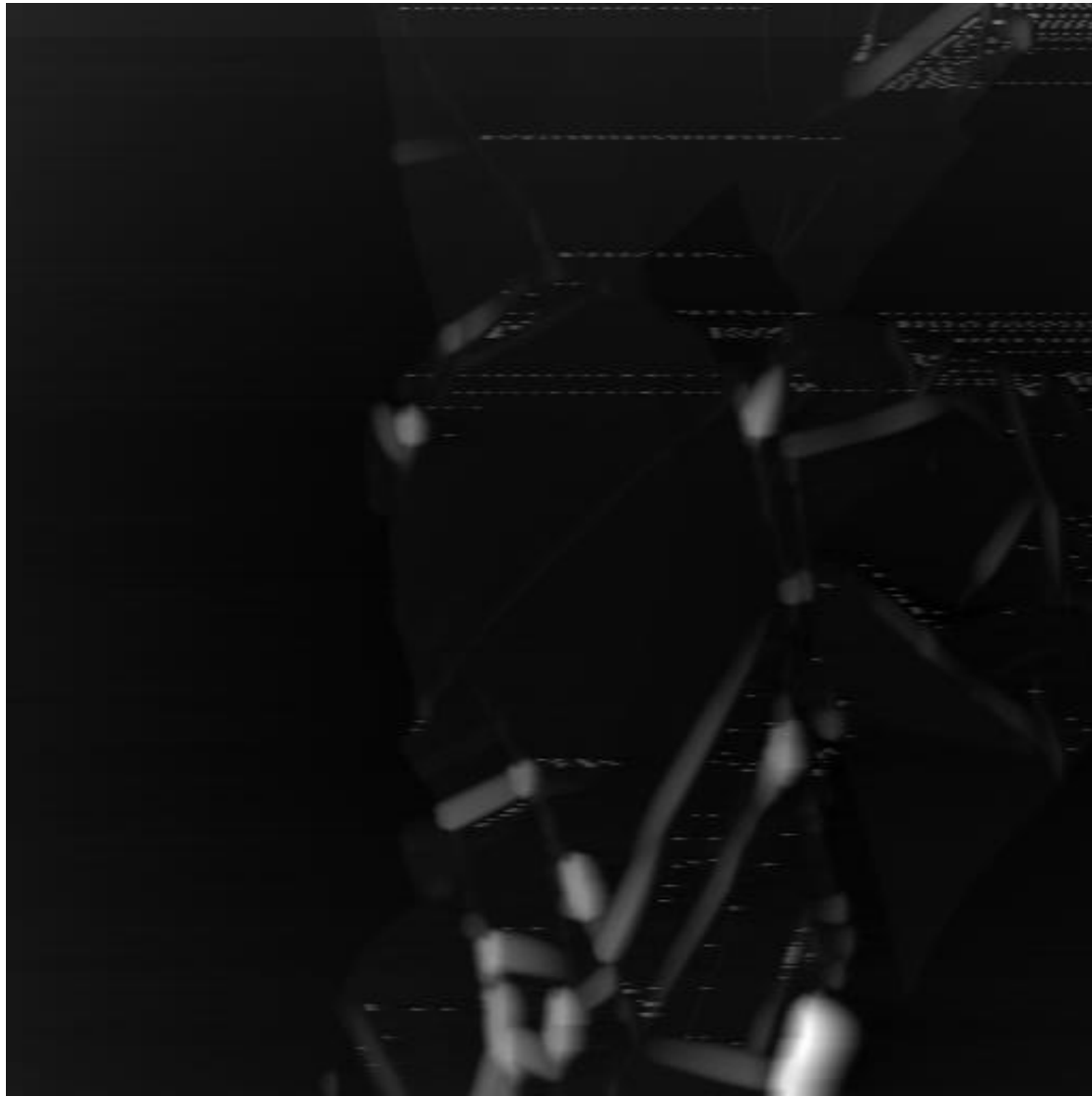


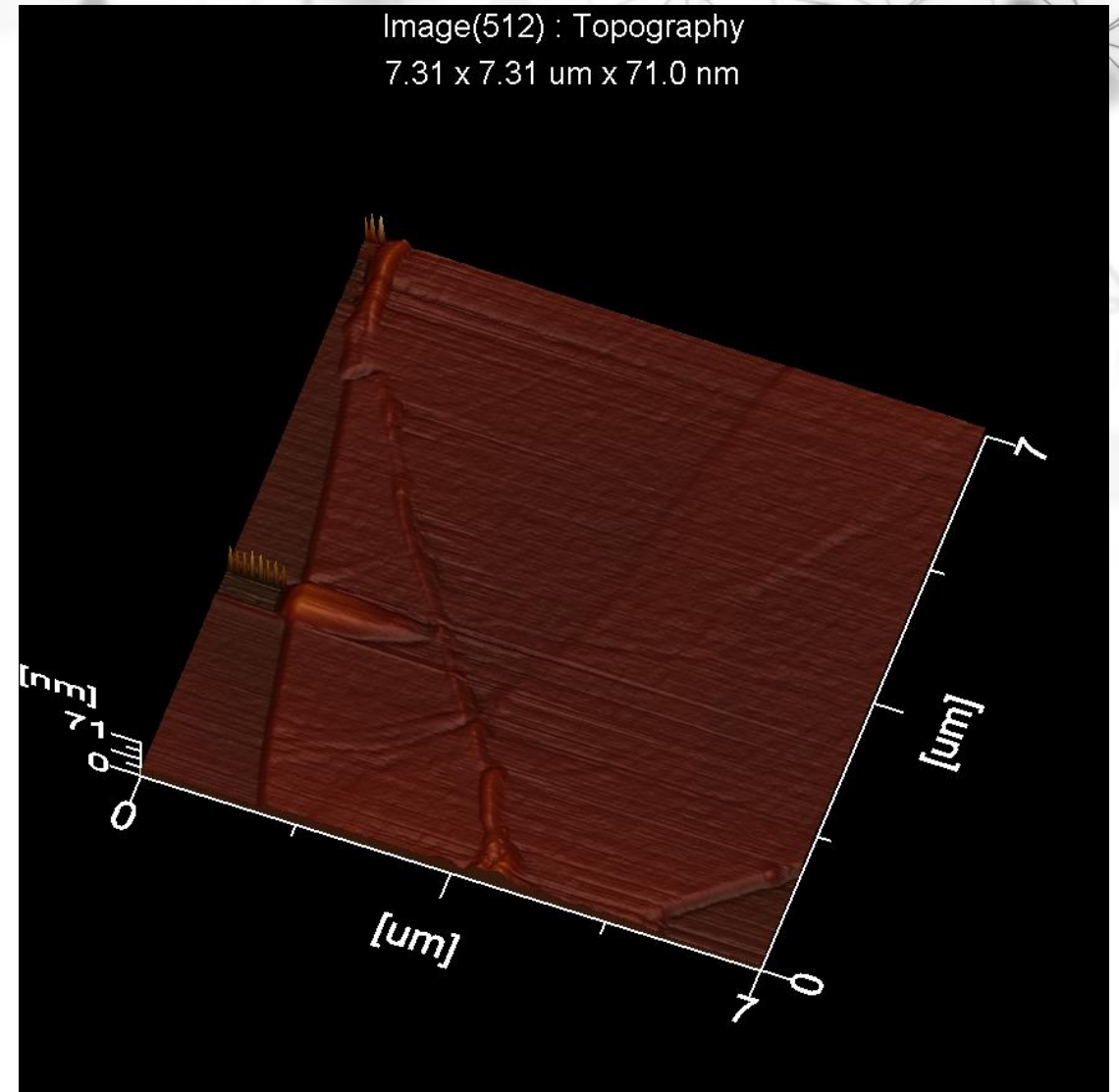
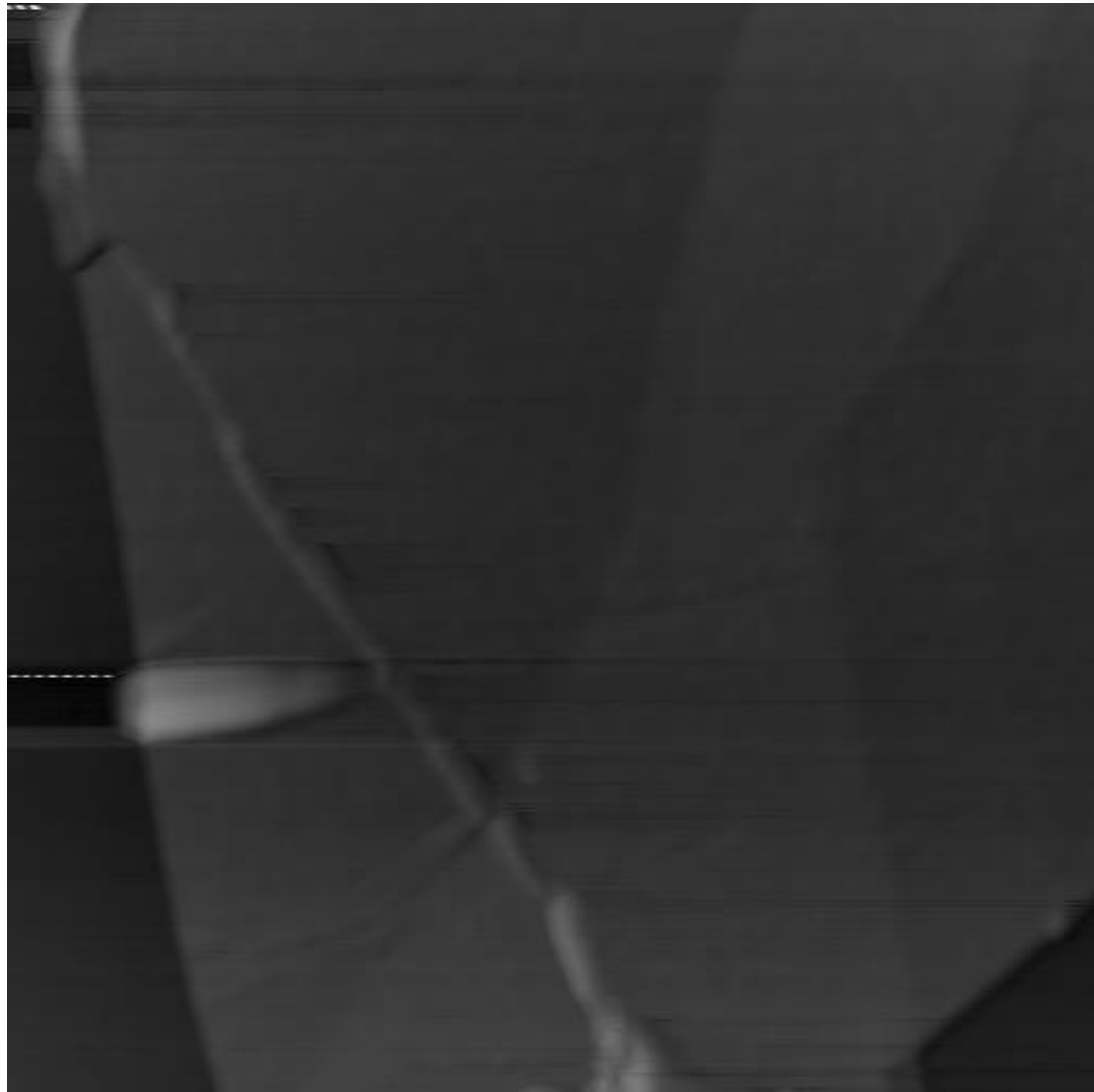
An abstract graphic in the top right corner consisting of a network of interconnected nodes and lines, with some nodes highlighted in a light gray color.

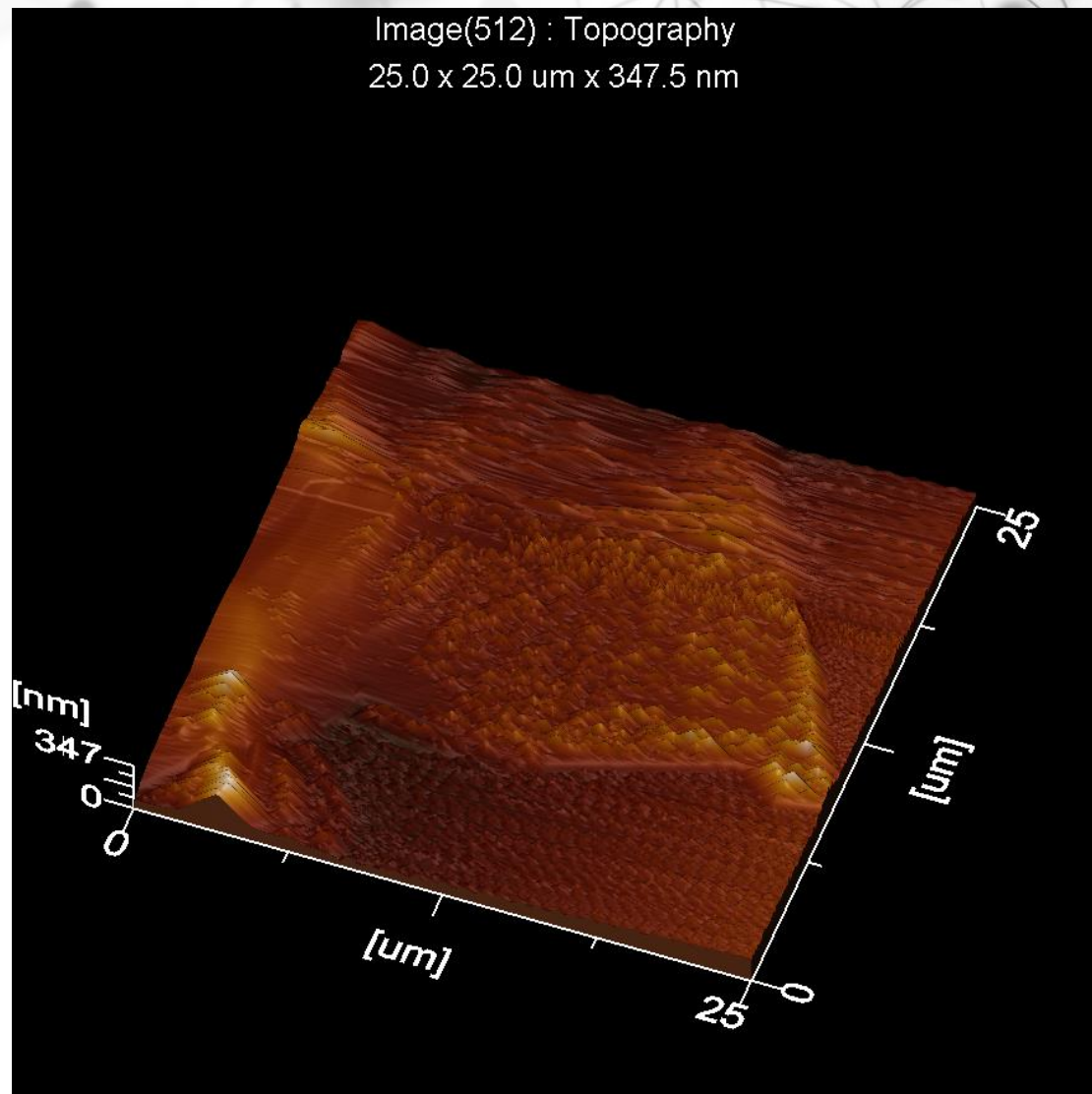
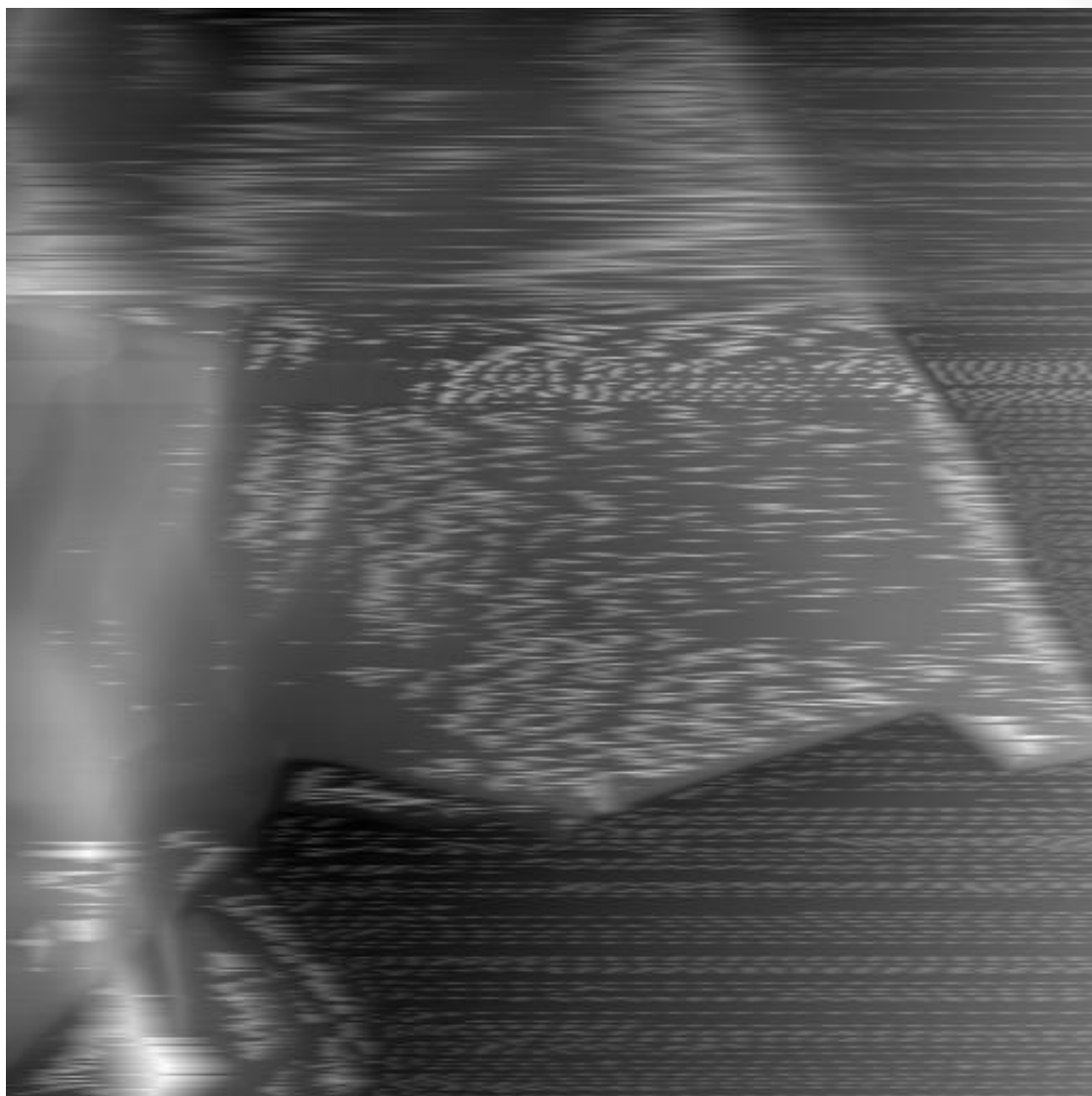
THANK YOU FOR YOUR ATTENTION !

An abstract graphic in the top right corner consisting of a network of interconnected nodes and lines, with some nodes highlighted in a light gray color.

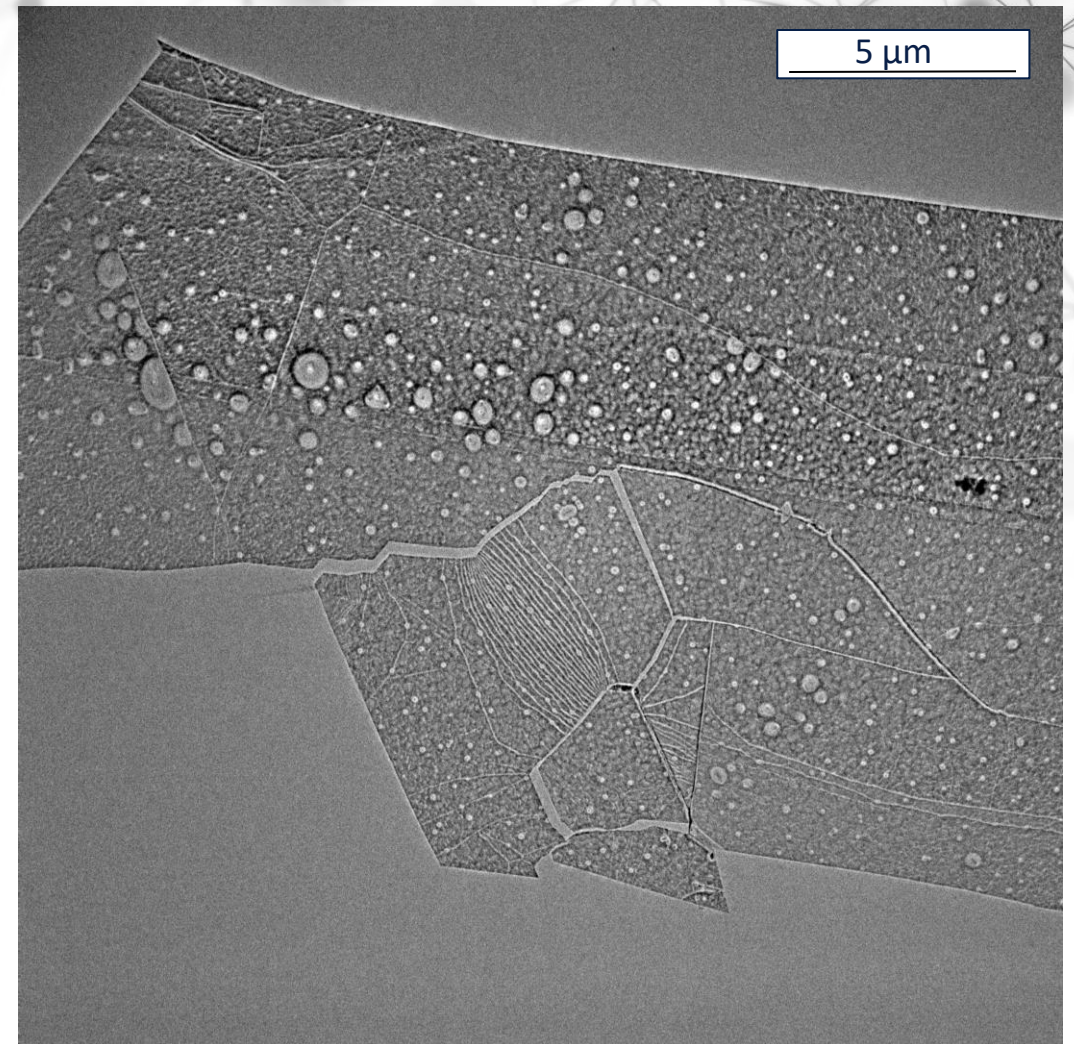
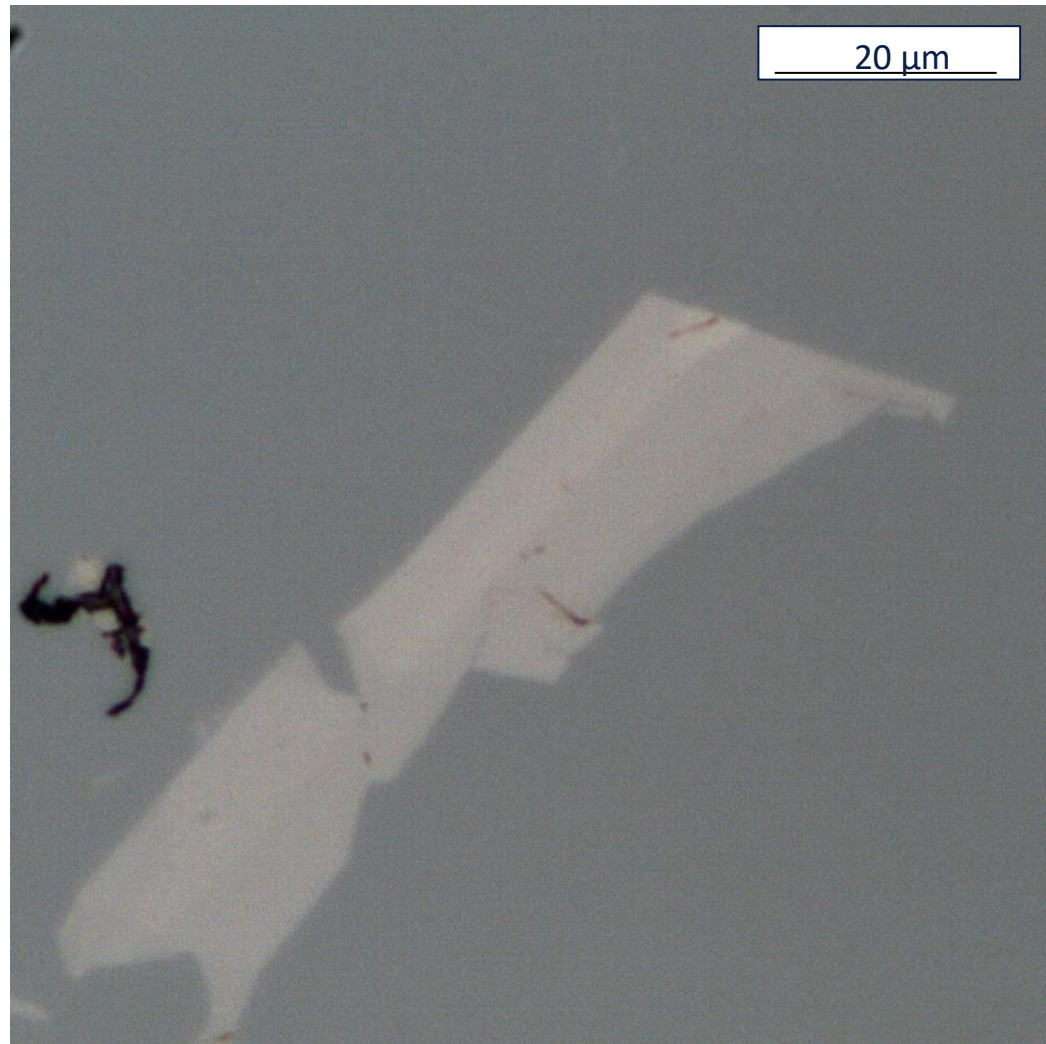
Extra slides



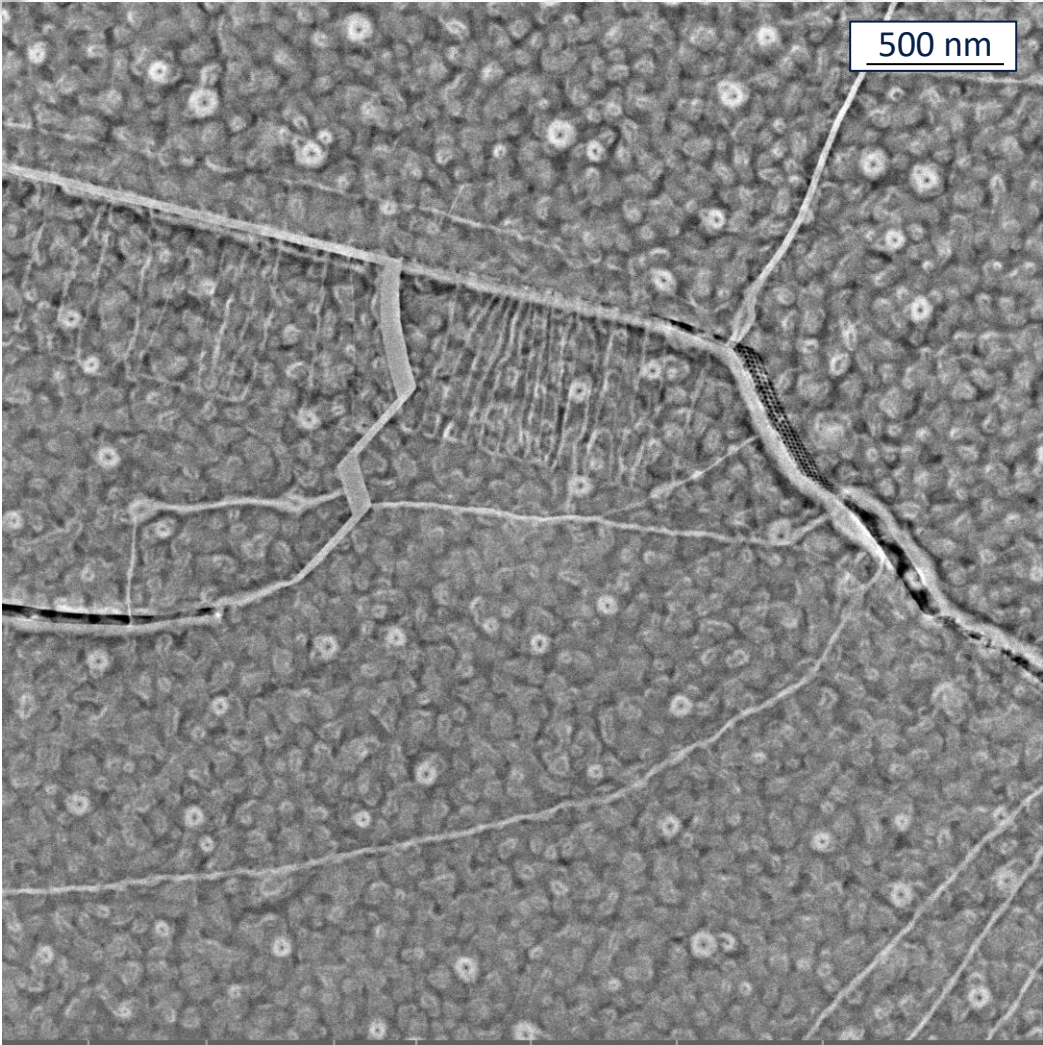
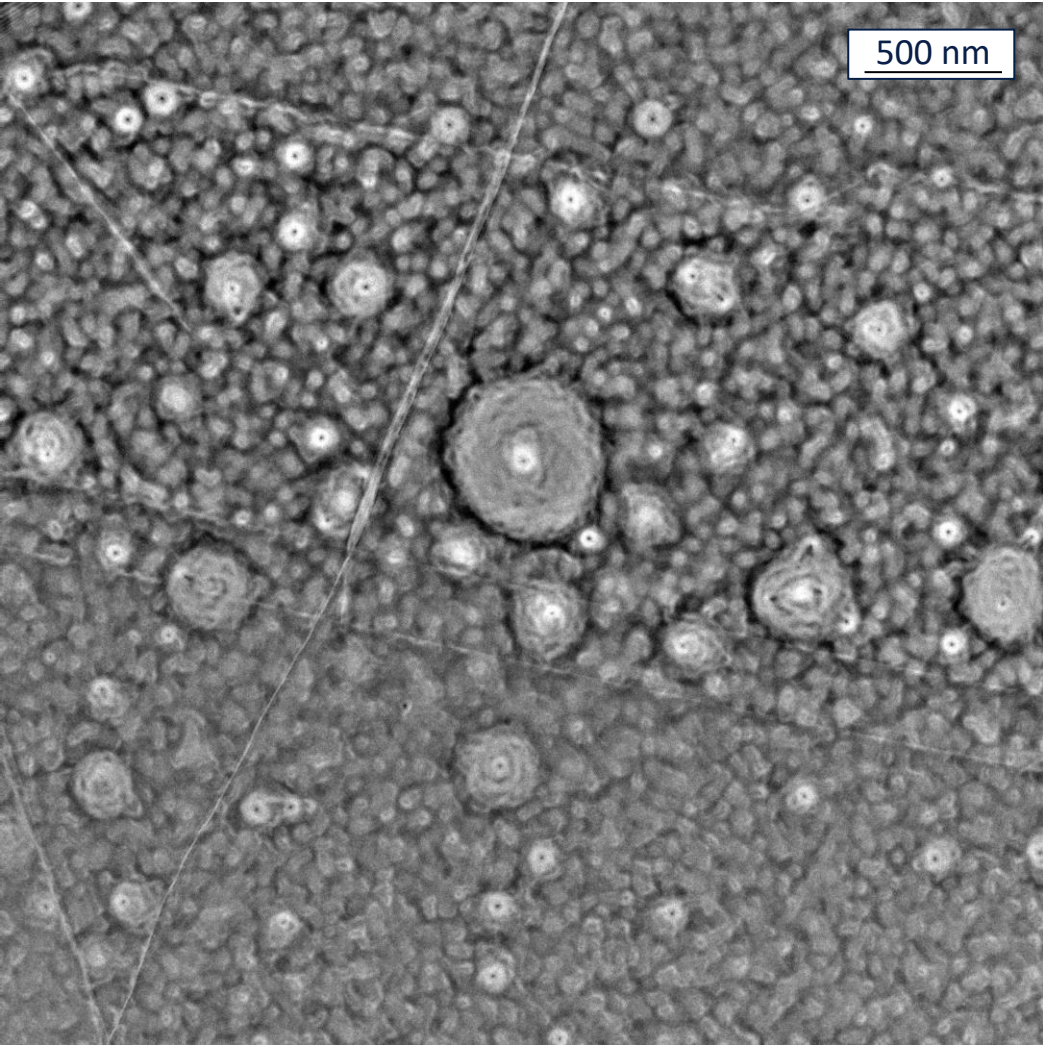




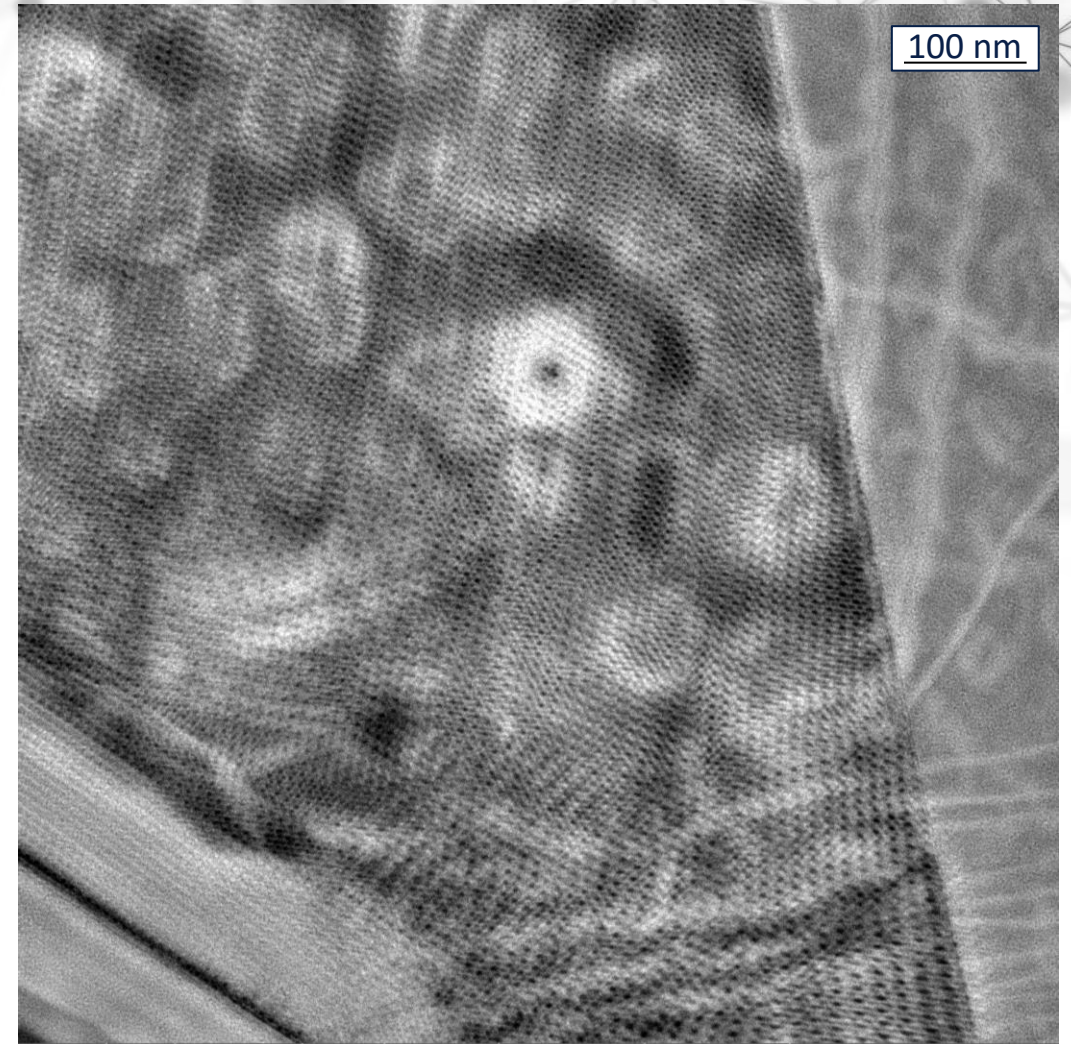
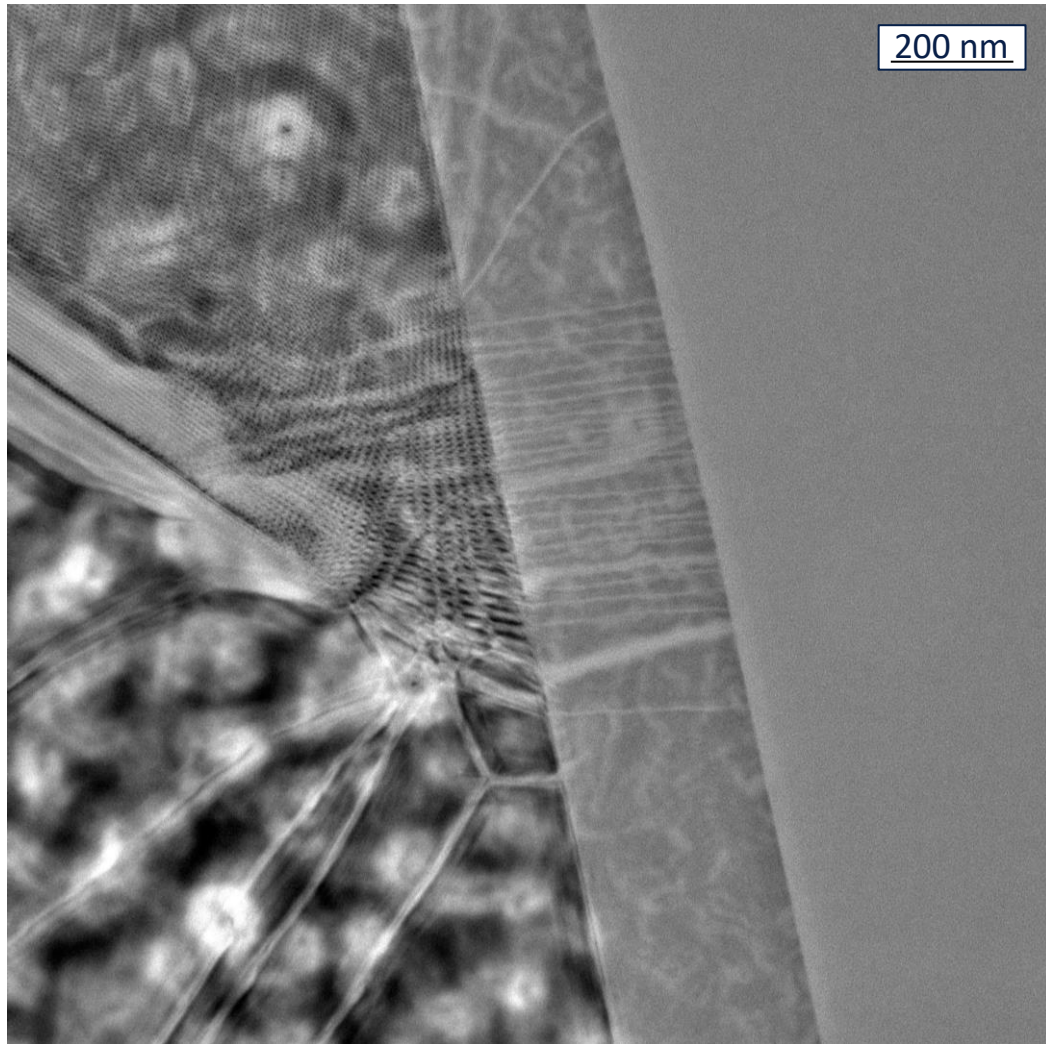
Defect Characterisation



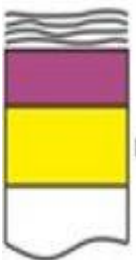
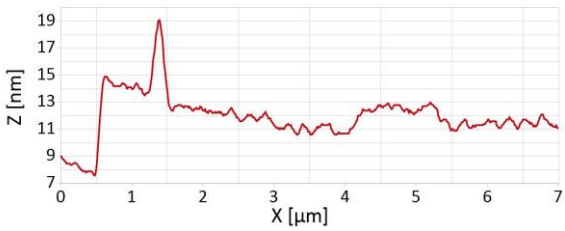
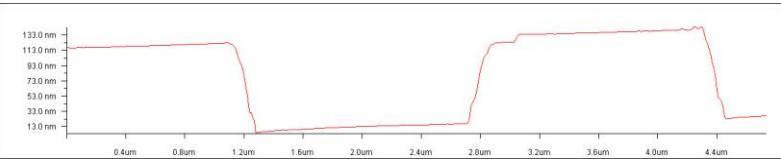
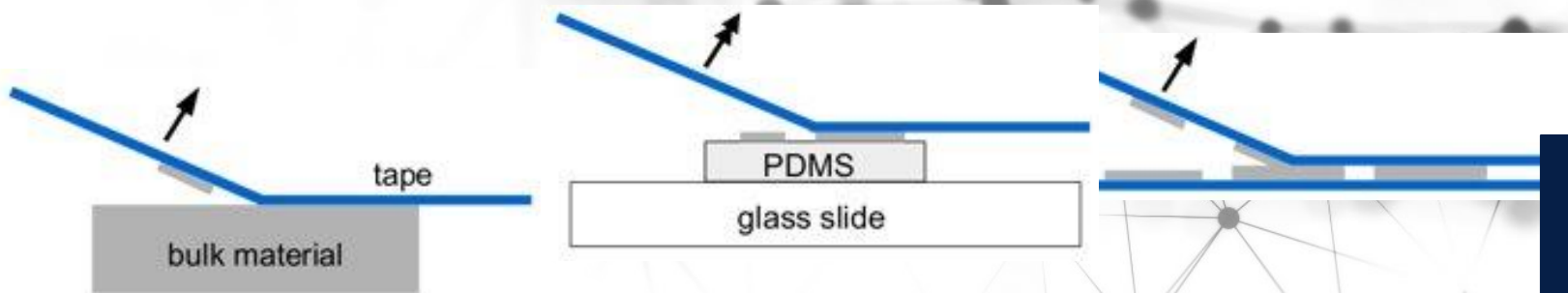
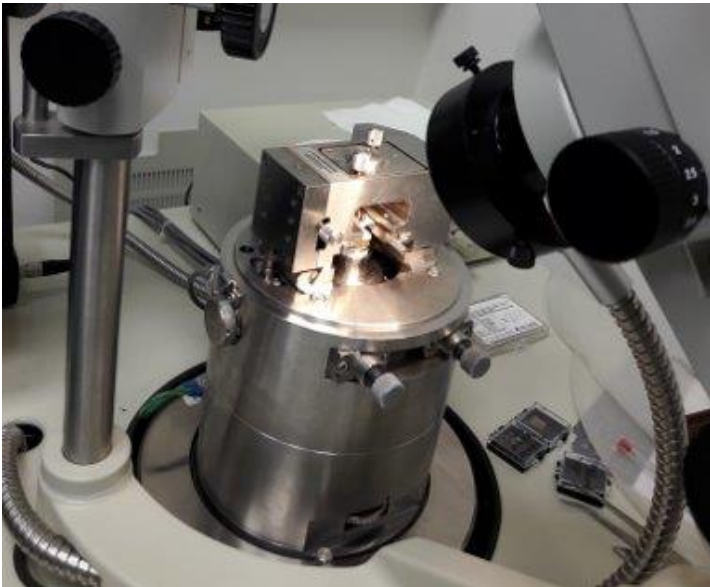
Defect Characterisation



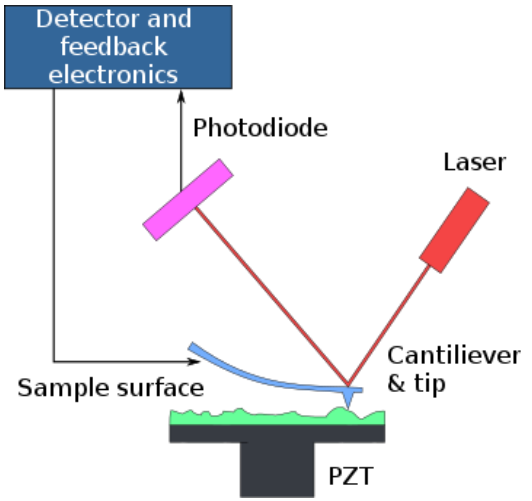
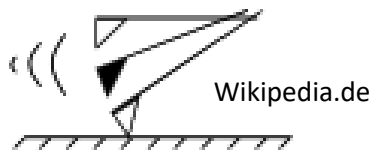
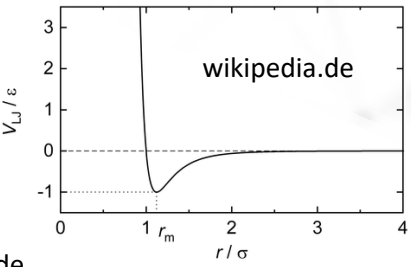
Defect Characterisation



Rumpelkammer



200 μm



Wikipedia.de

