Update on crystalline oxides coatings

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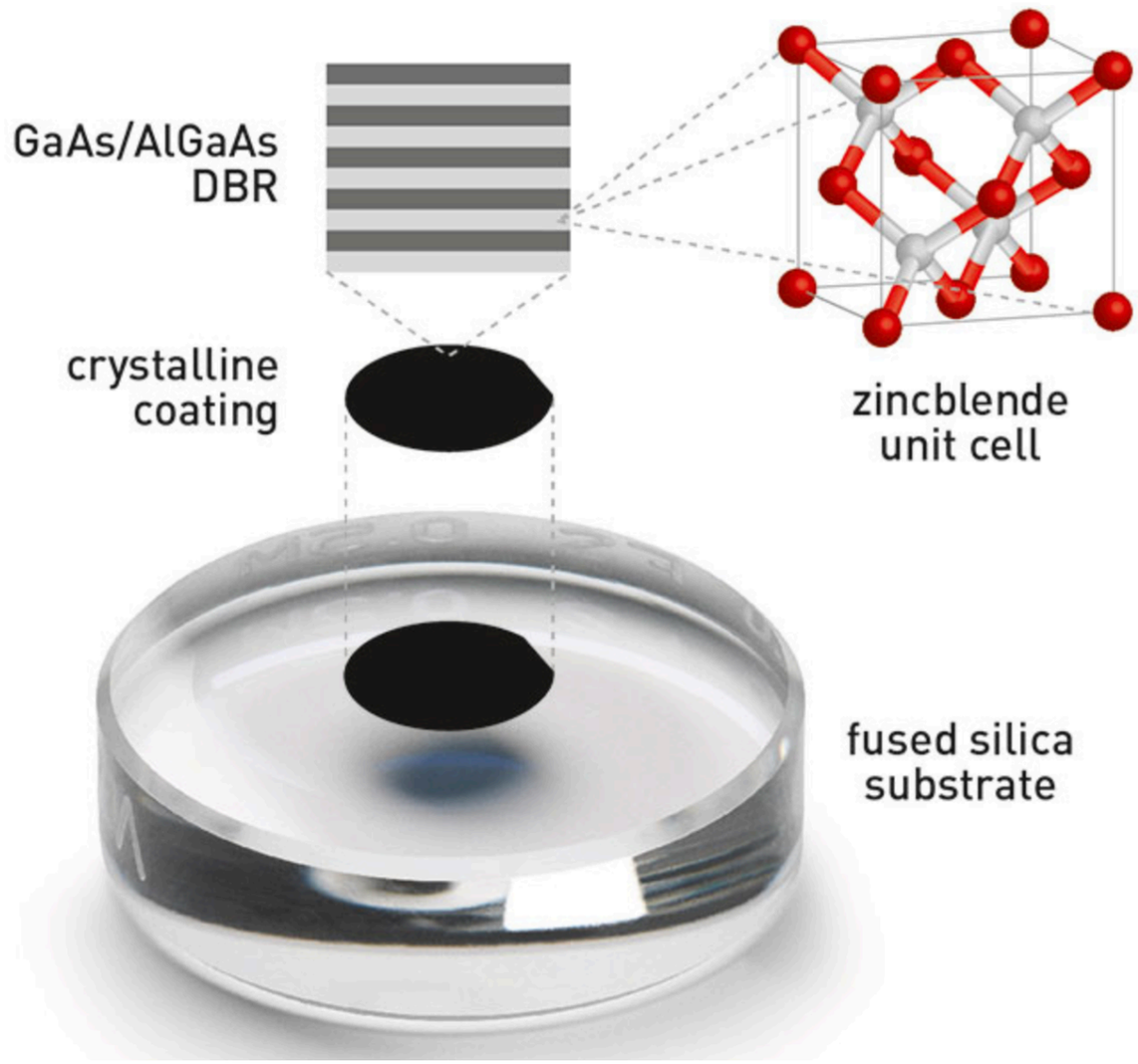
Crystalline materials

- GaAs based mirror coatings: G. Cole, S. Penn et al.

THORLABS

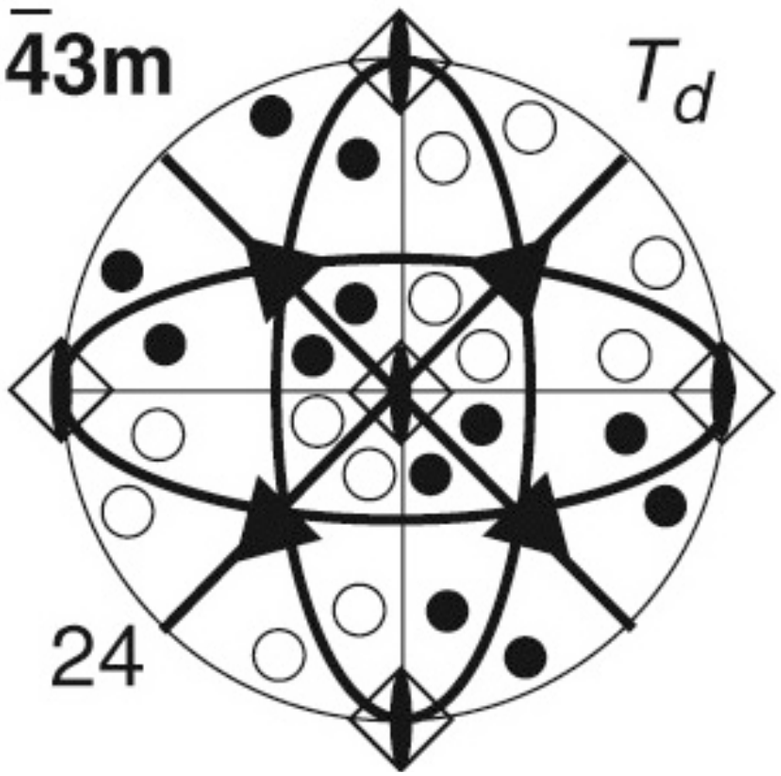
Supermirrors

Key Specifications	
Center Wavelength	Between 900 nm and 2.0 µm
Reflectance	>99.99% (Typical) >99.999% (Max)
Substrate Material	Typically Fused Silica (Other Materials Possible)
Loss Angle[a]	$<4 \times 10^{-5}$ at 300 K $<5 \times 10^{-6}$ at 10 K

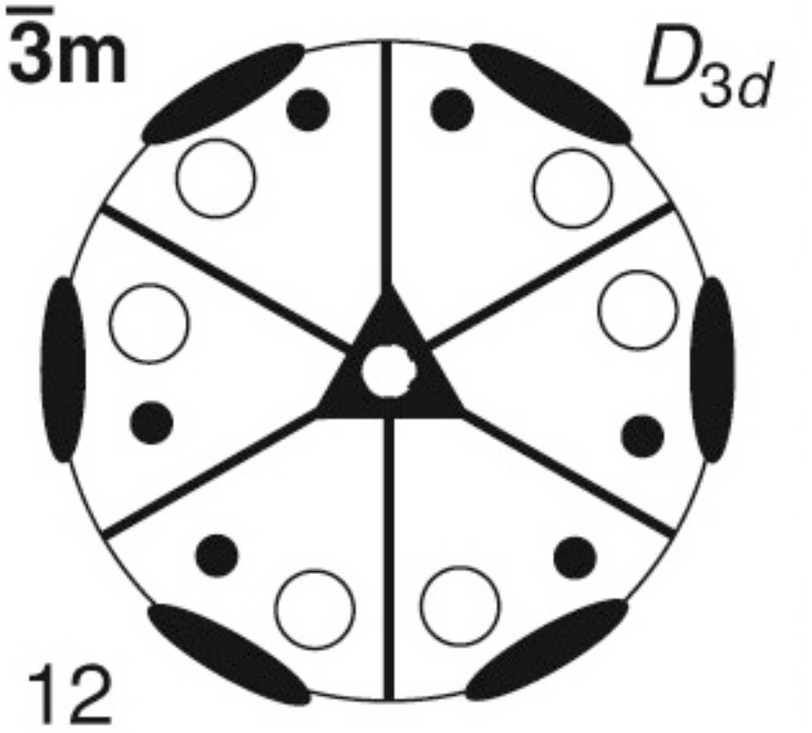


Point symmetries

GaAs



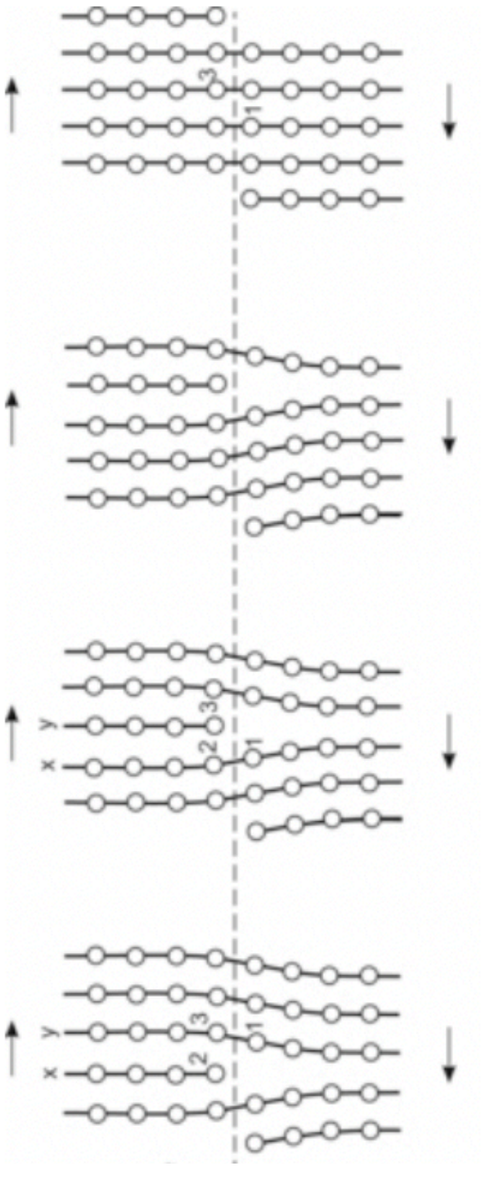
Ga_2O_3

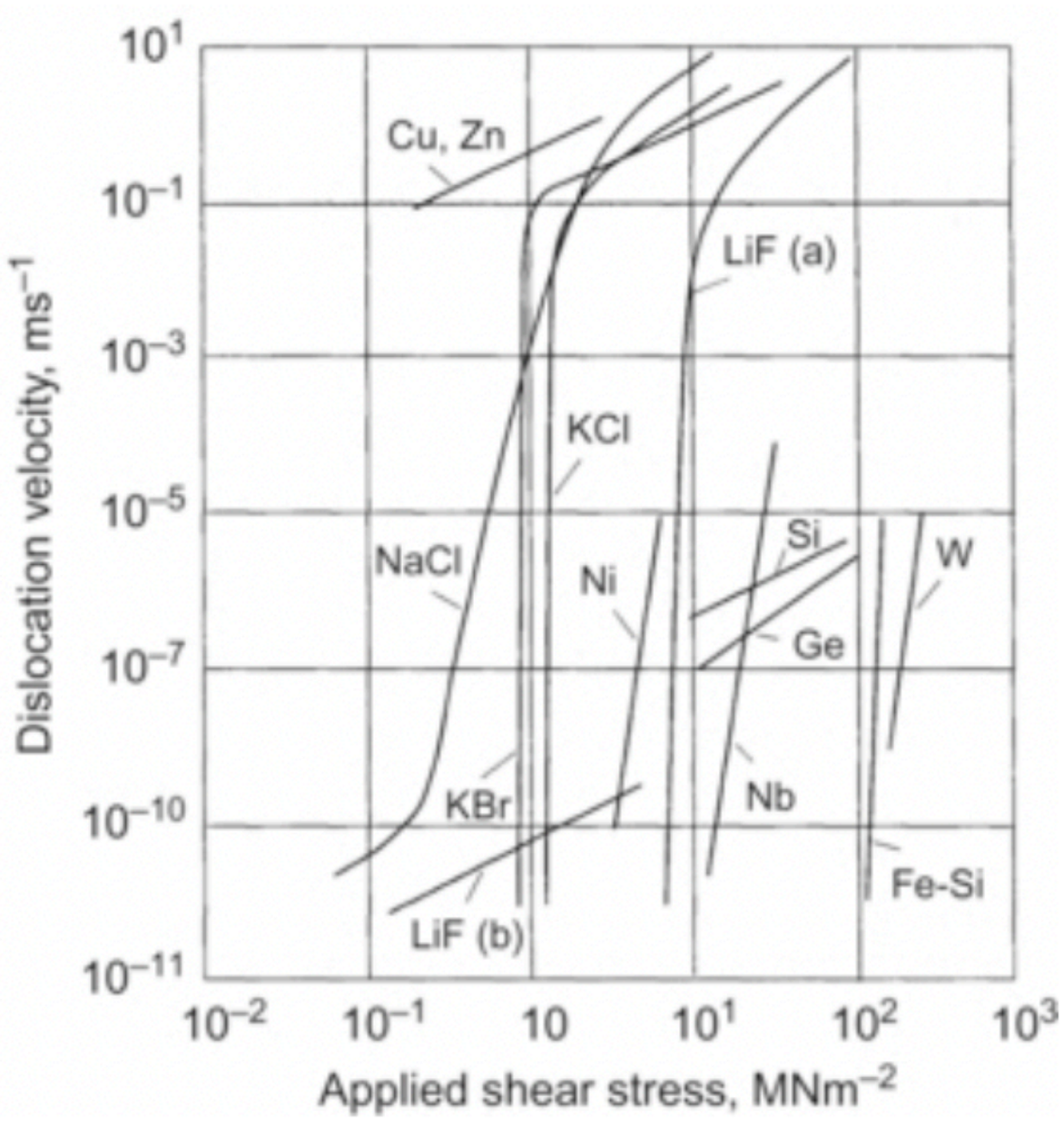


Different symmetries => origin of losses

Point symmetries

- Dislocations

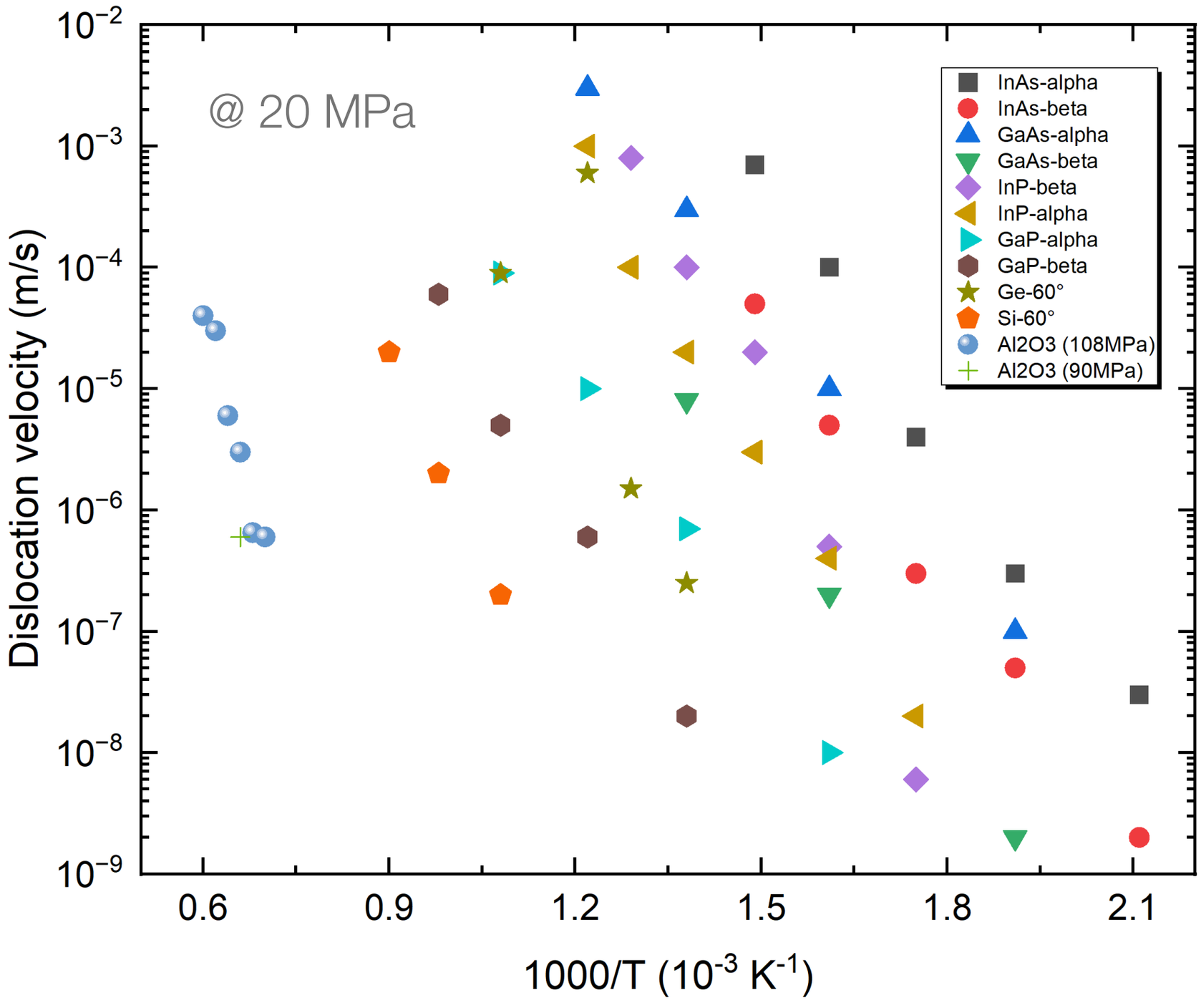




Introduction to dislocations, Hull

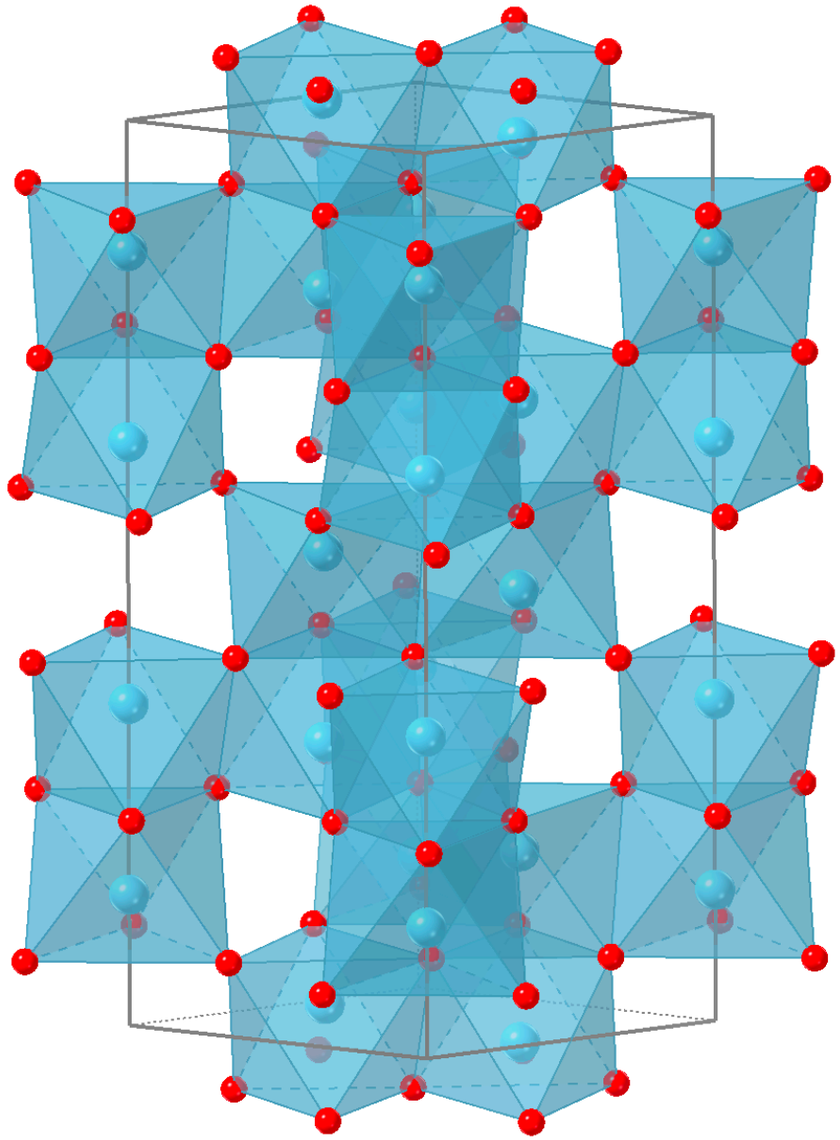
Point symmetries

- Dislocations

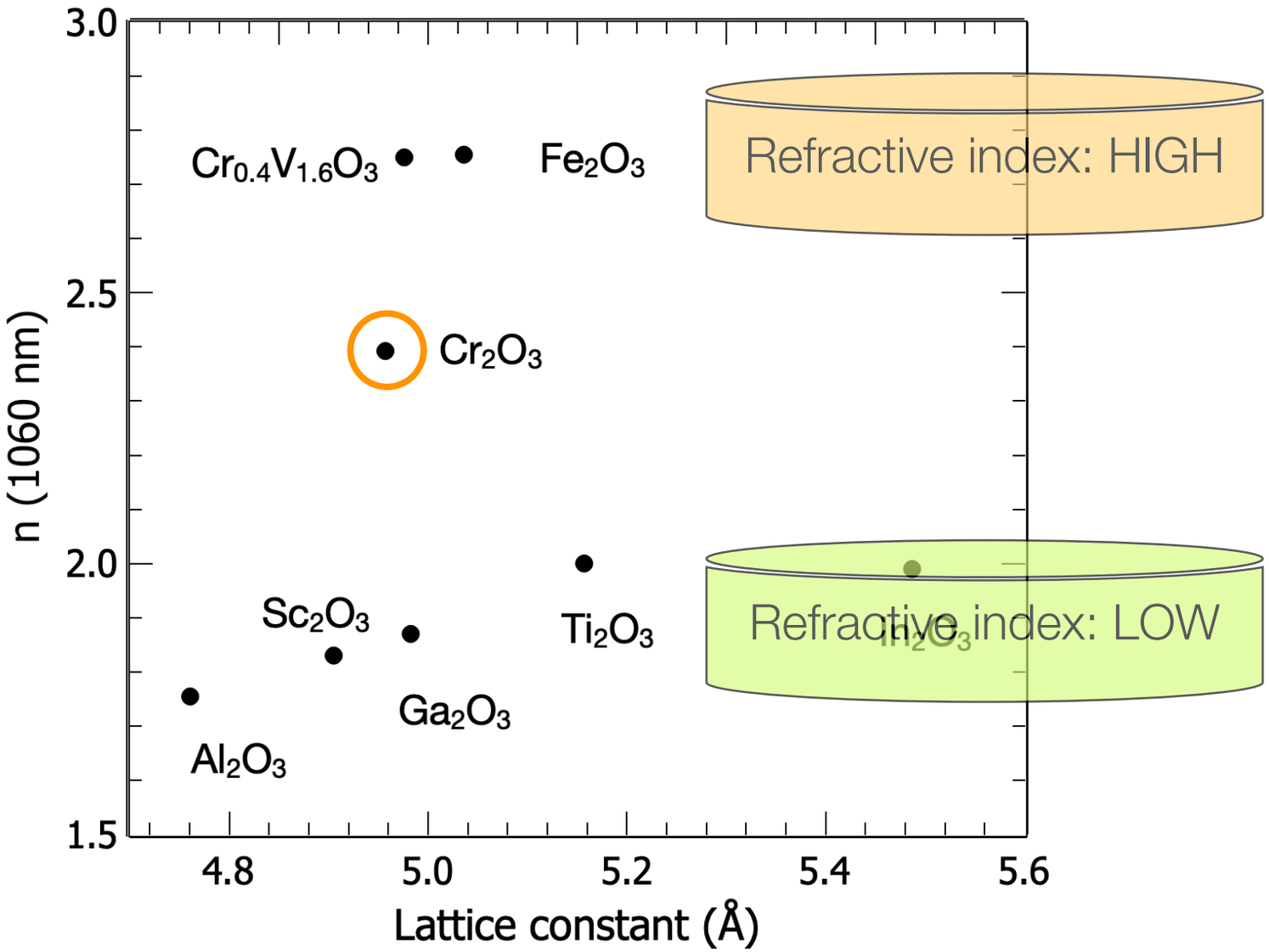


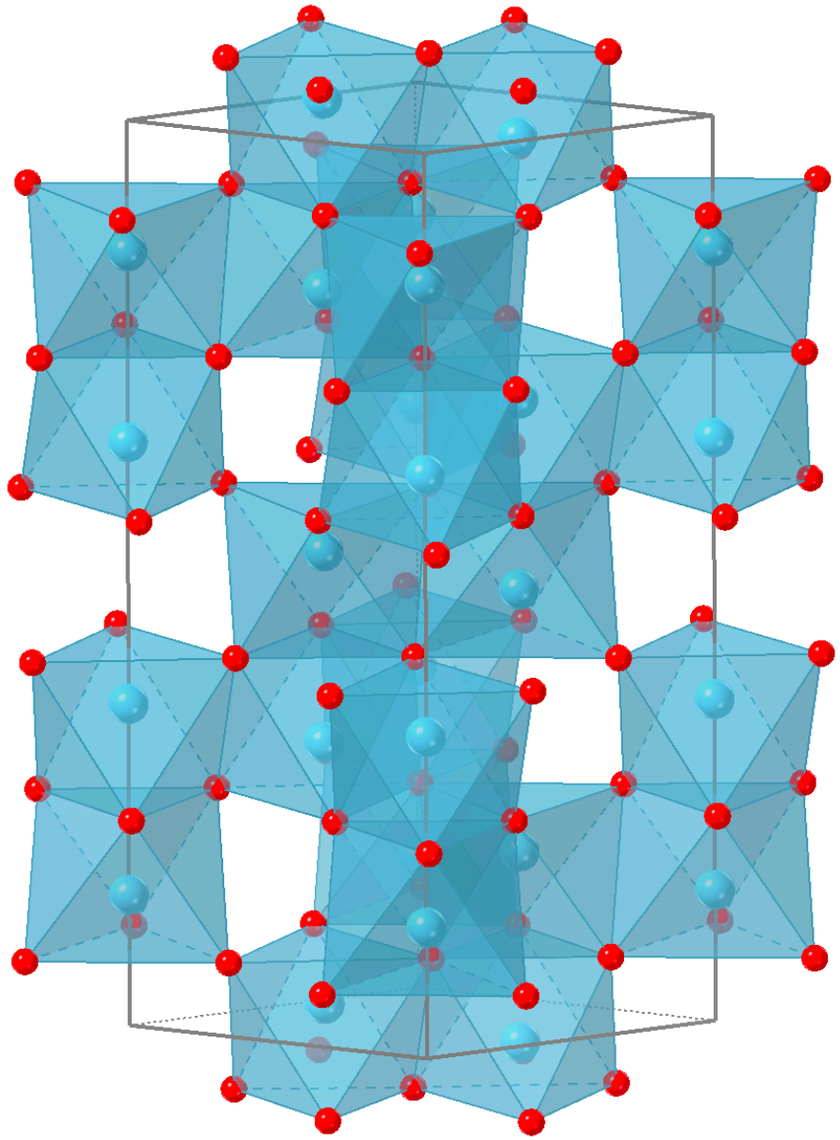
Corundum structures

- Why study these ?
  - AAO_3
  - Same structure as sapphire
  - Spacegroup 167 $R\bar{3}c$
  - Mechanical loss angle of sapphire **crystals** ~ 10^{-9}
  - 6 layers of rotated MO_6 octahedra
  - Solid solutions



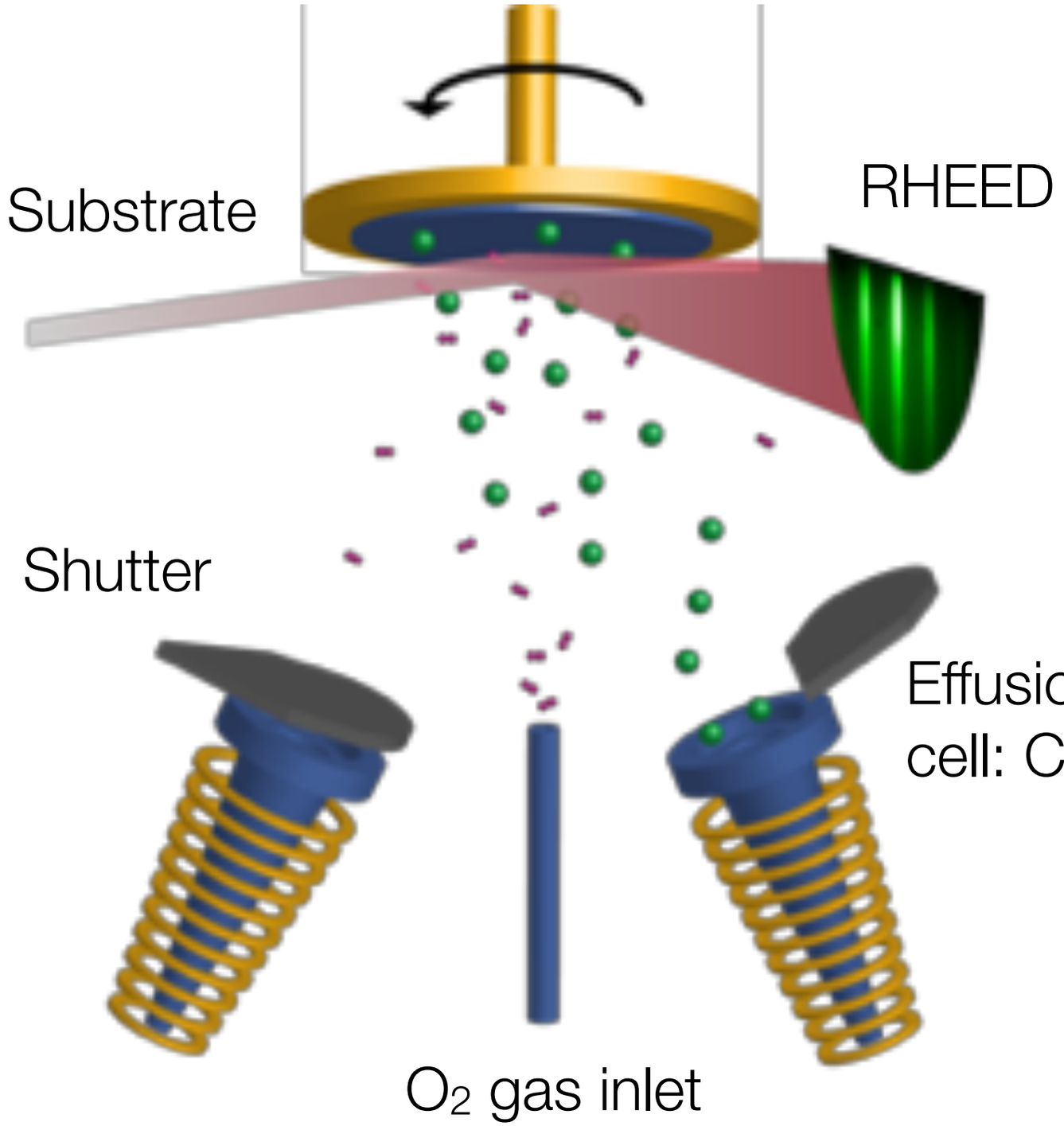
Corundum structures





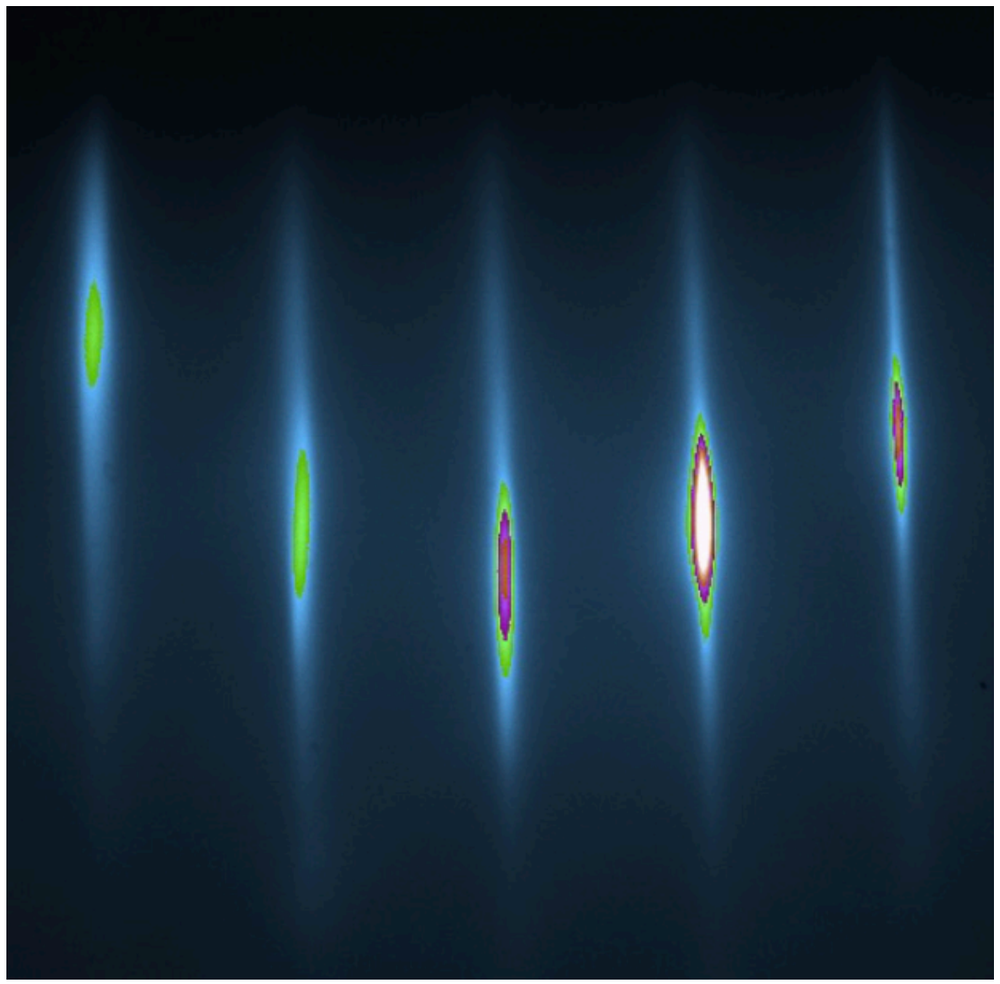
Molecular Beam Epitaxy

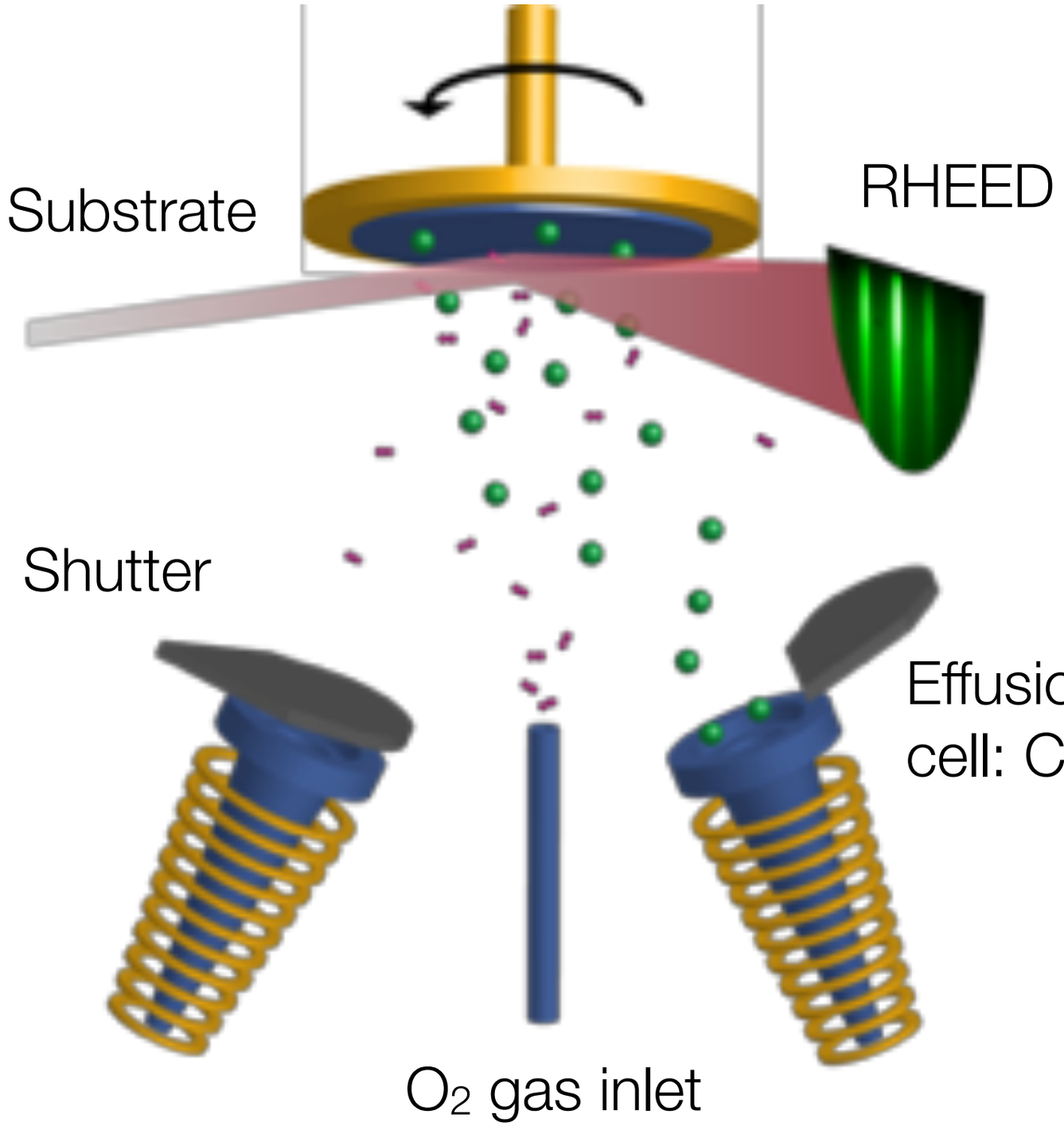
- Ultrahigh vacuum
- In-situ monitoring
- Shutter control
- Highest purity
- Highest quality



RHEED

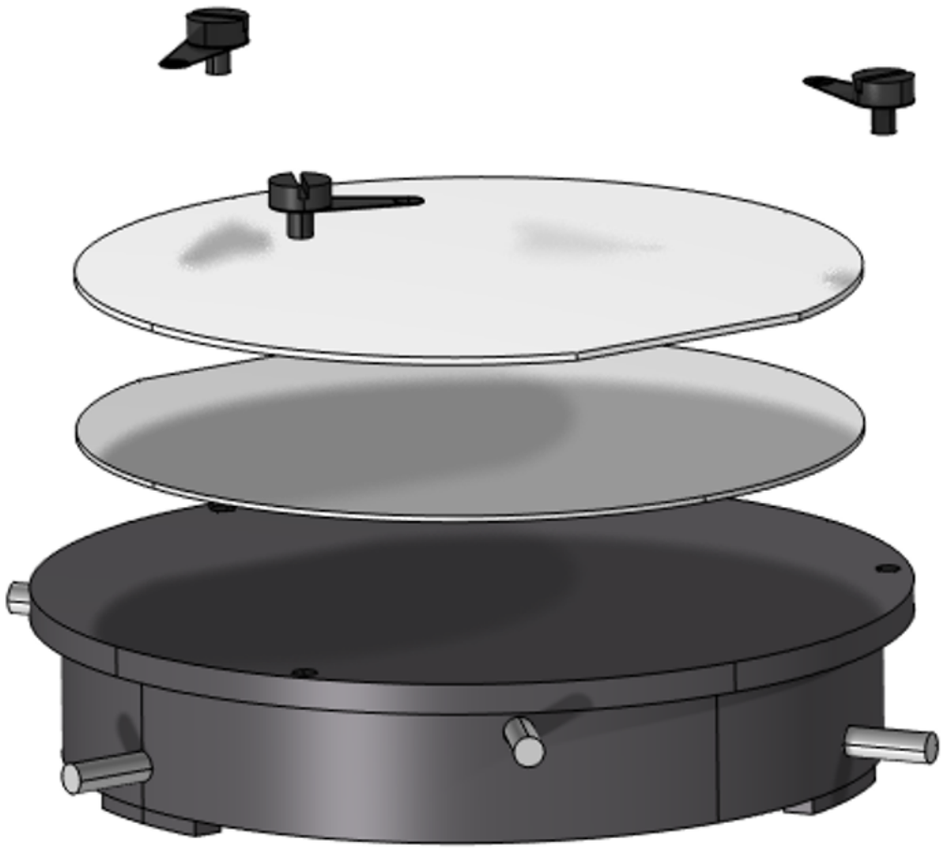
- 500 nm Cr_2O_3 / Al_2O_3

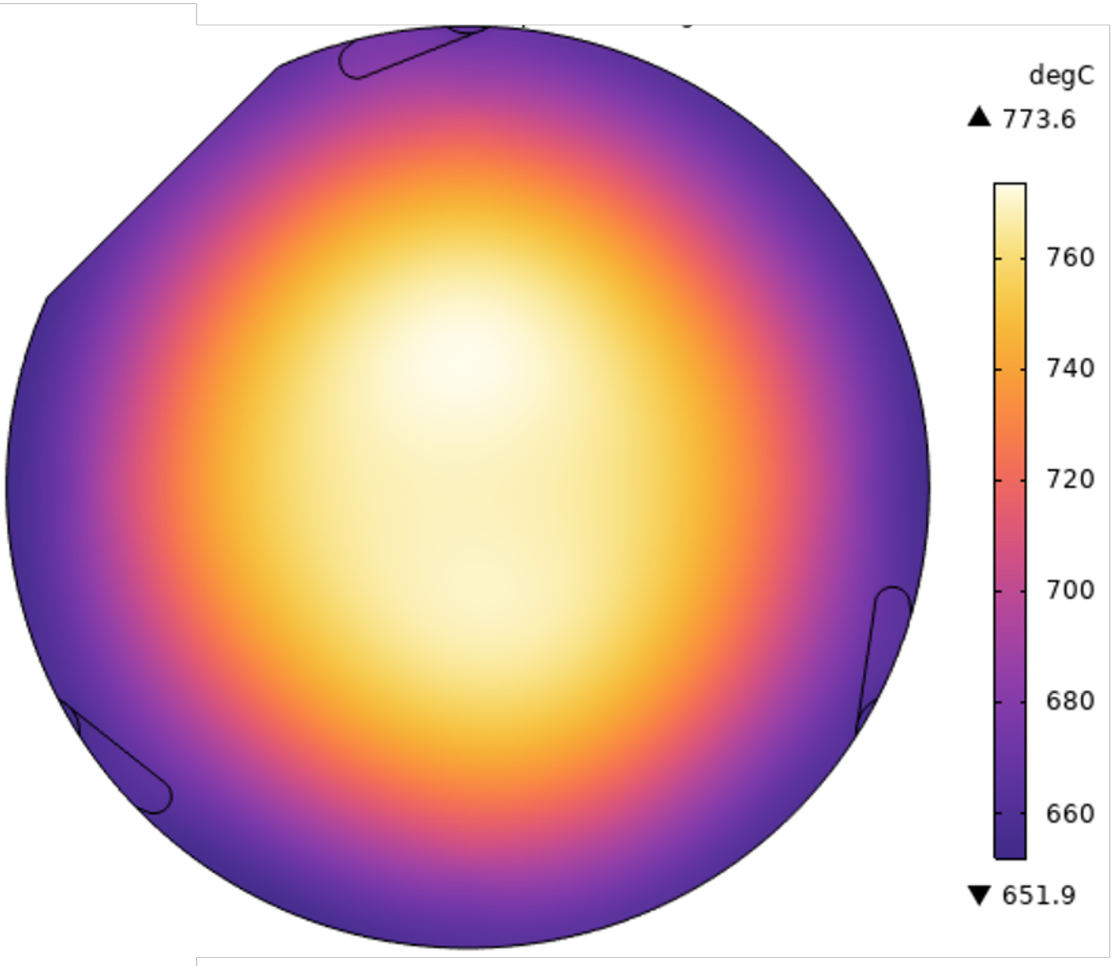




Temperature uniformity

- Original design



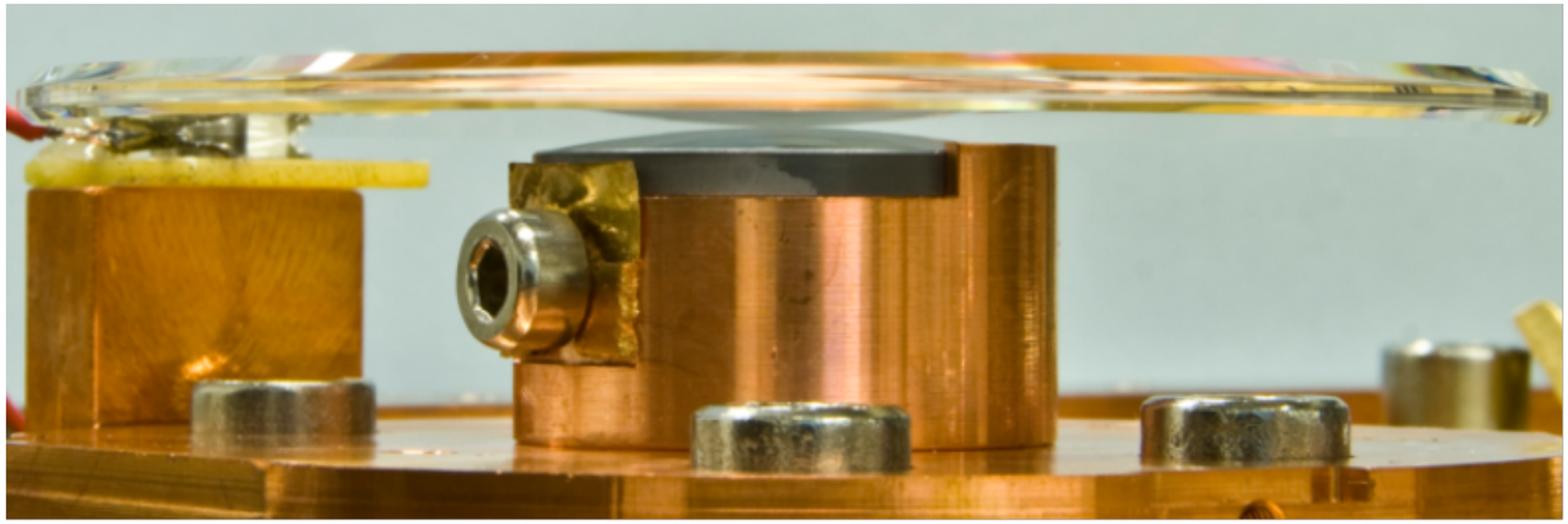


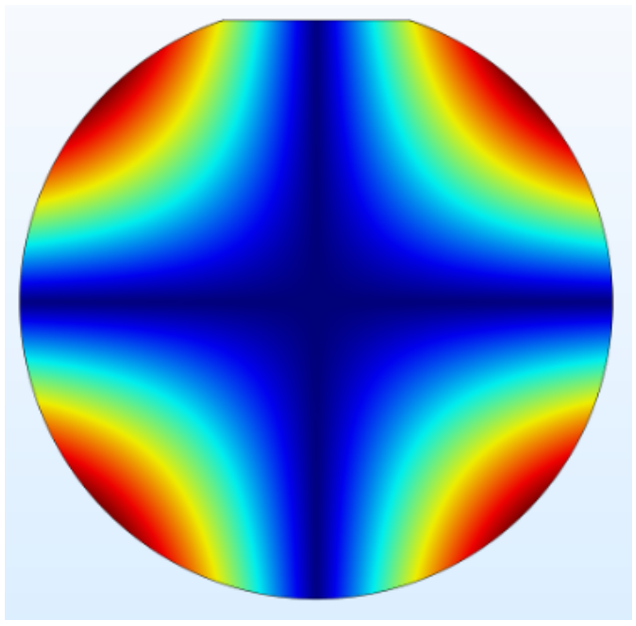
RTG: 15,73%

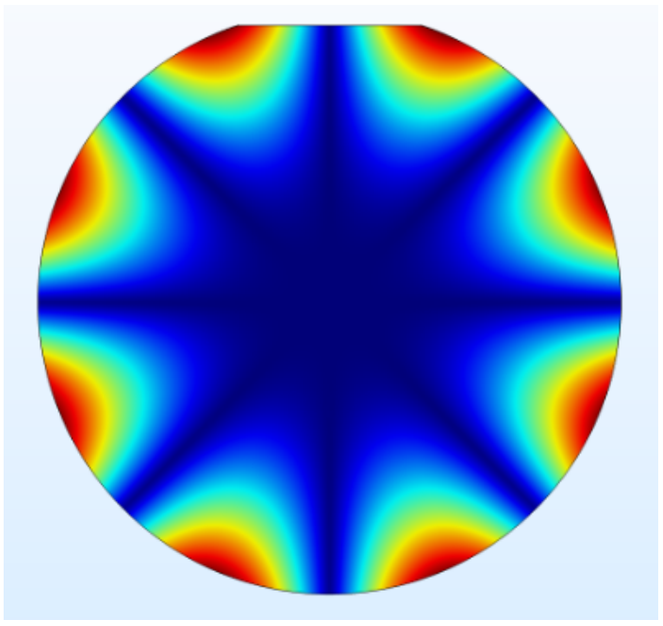
RTG is the relative temperature gradient, namely $^{\Delta T}/_{T_{max}} \cdot 100$

Mechanical losses

- Method: Gentle Nodal Suspension

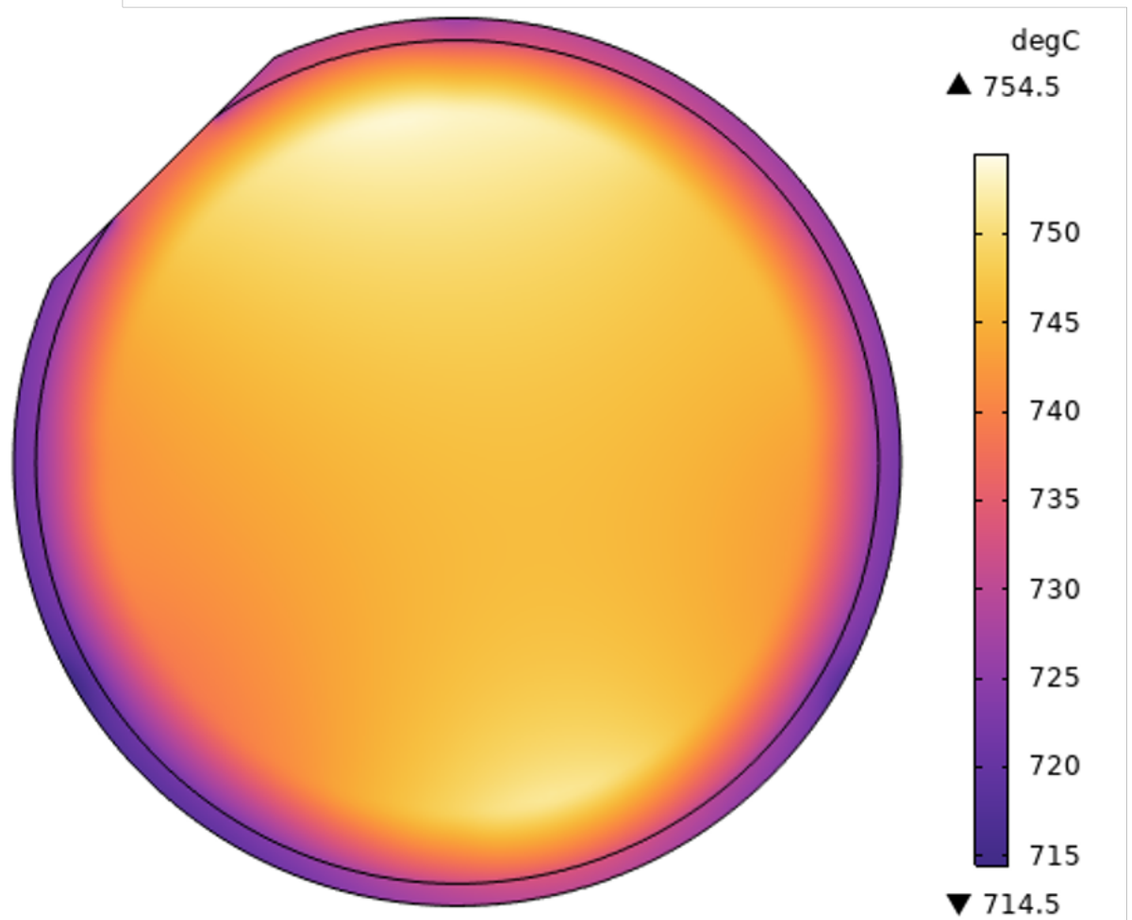






Temperature uniformity

- New design

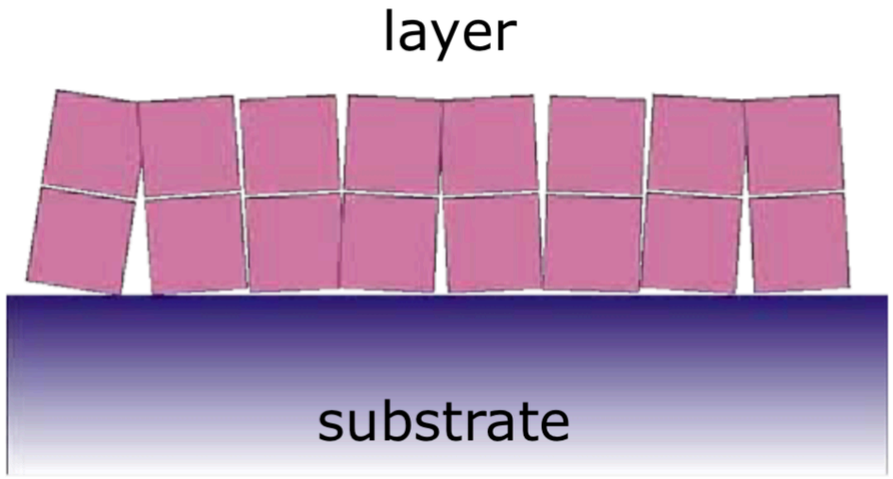


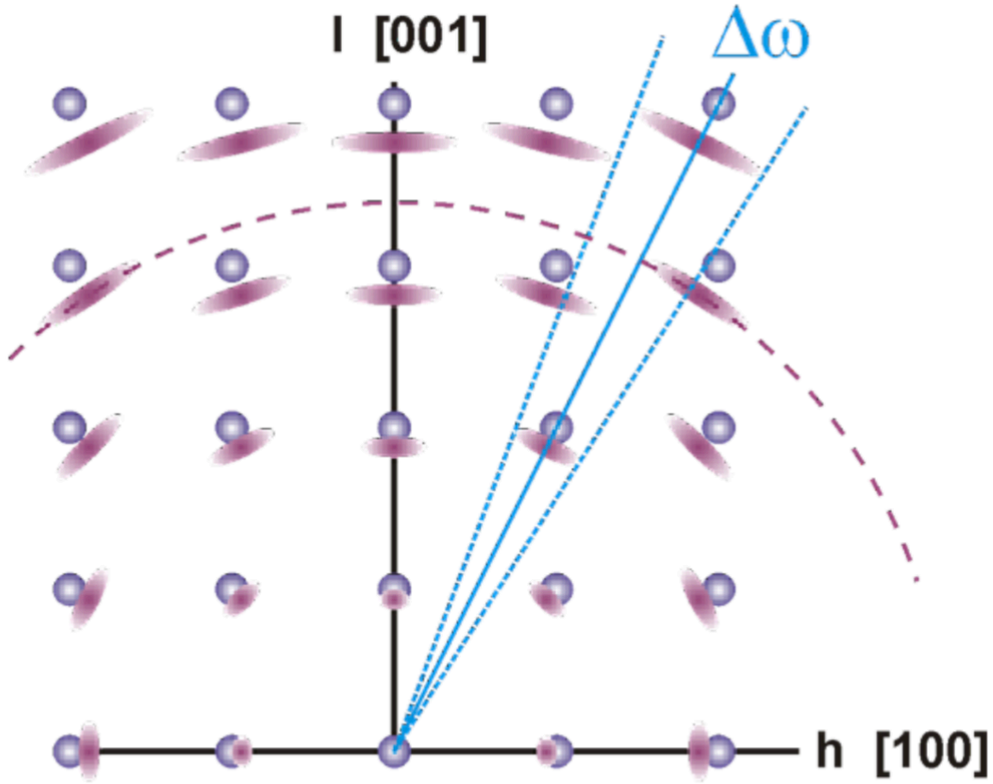
RTG: 5,30%

RTG is the relative temperature gradient, namely $^{\Delta T}/_{T_{max}} \cdot 100$

Crystalline films

- Quality criterium: X-ray diffraction rocking curve





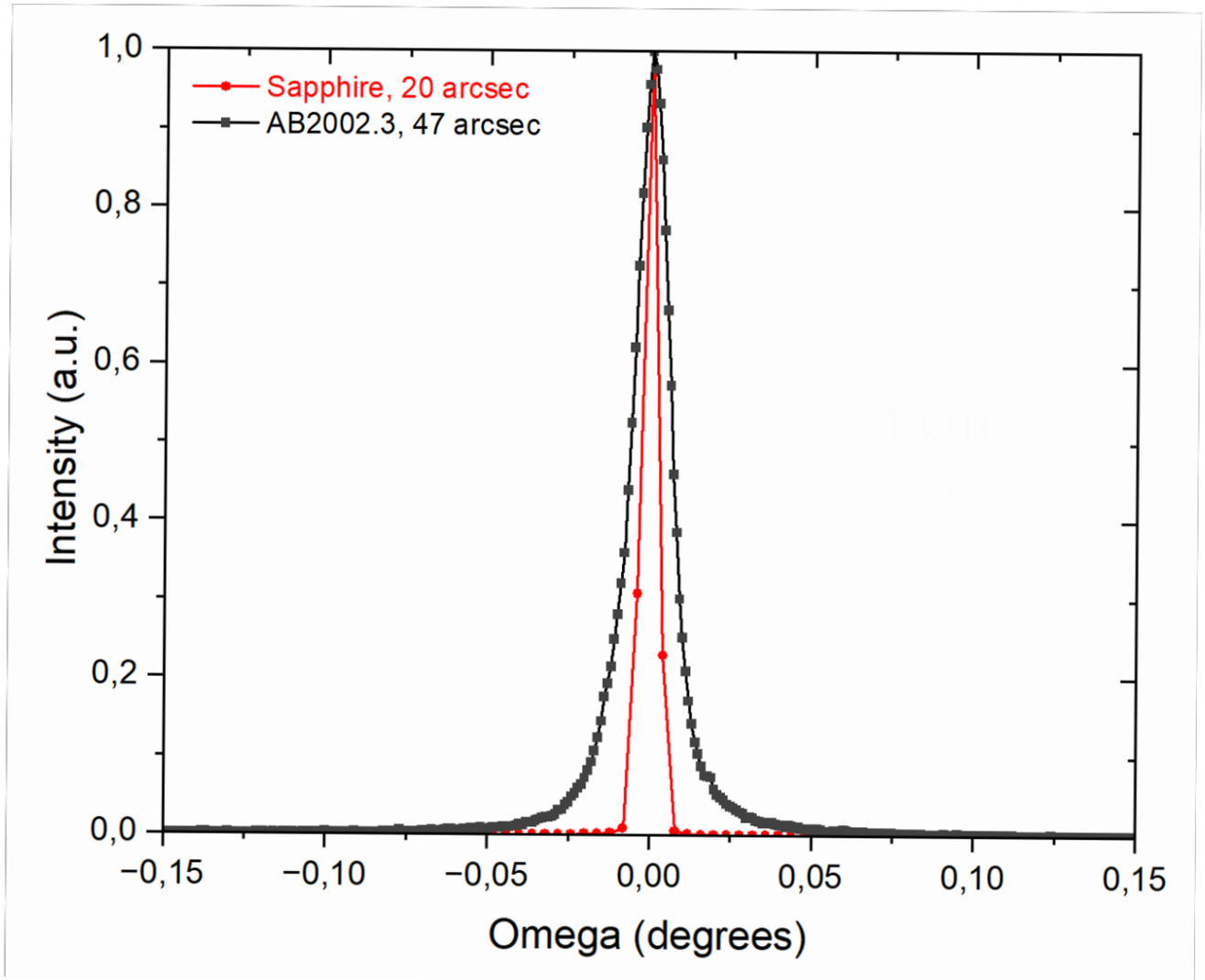
Mosaicity causes a smearing of the reflection on a circle around (000).

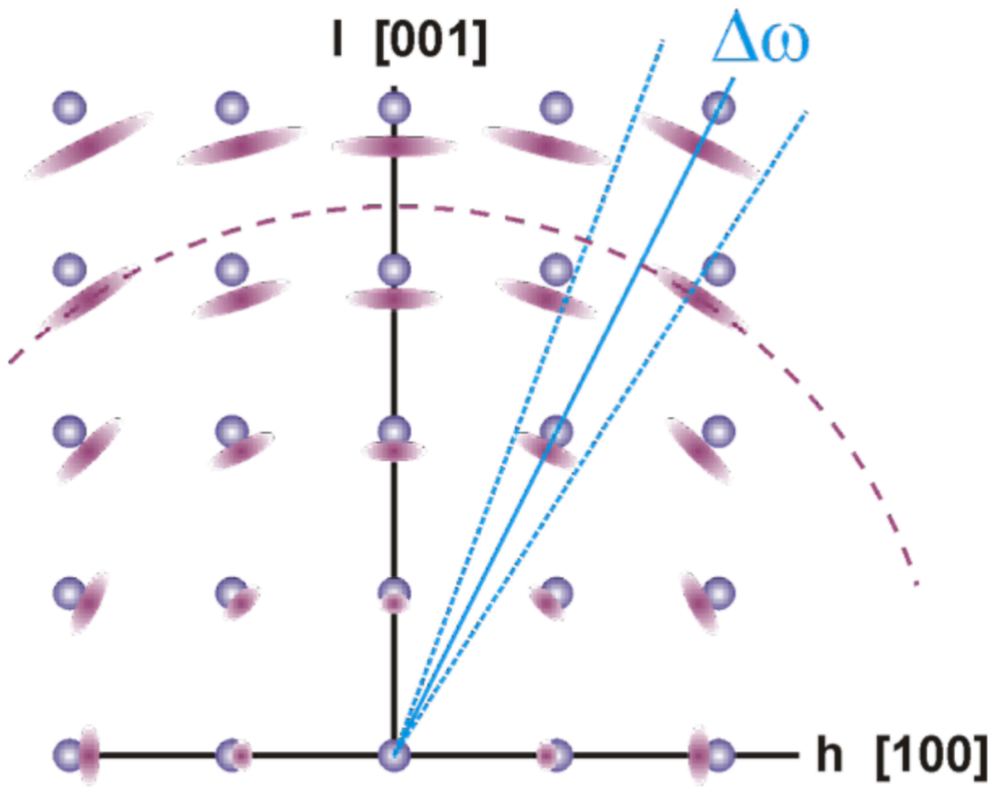
substrate

relaxed layer with high mosaicity

Crystalline films

- Quality criterium: X-ray diffraction rocking curve



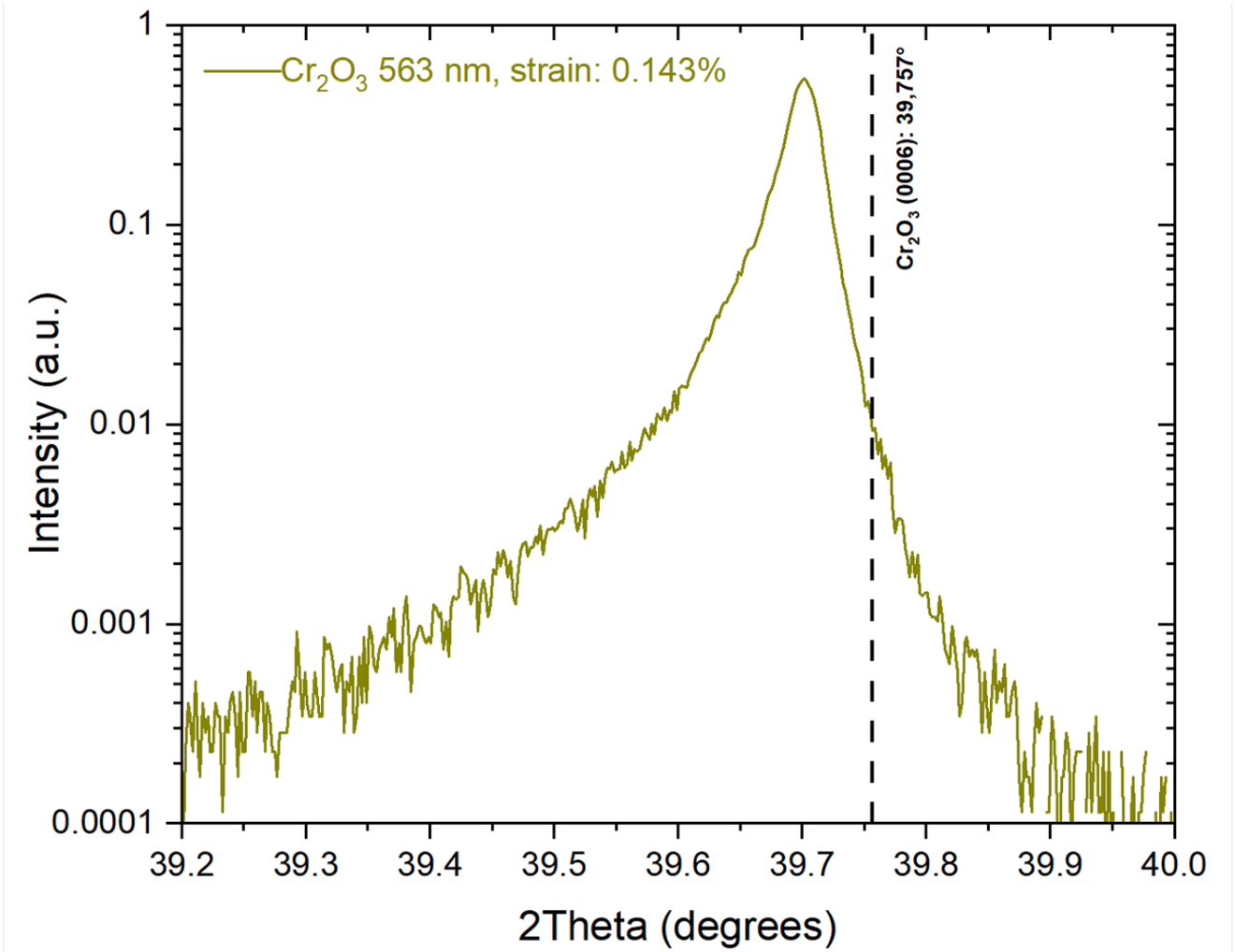


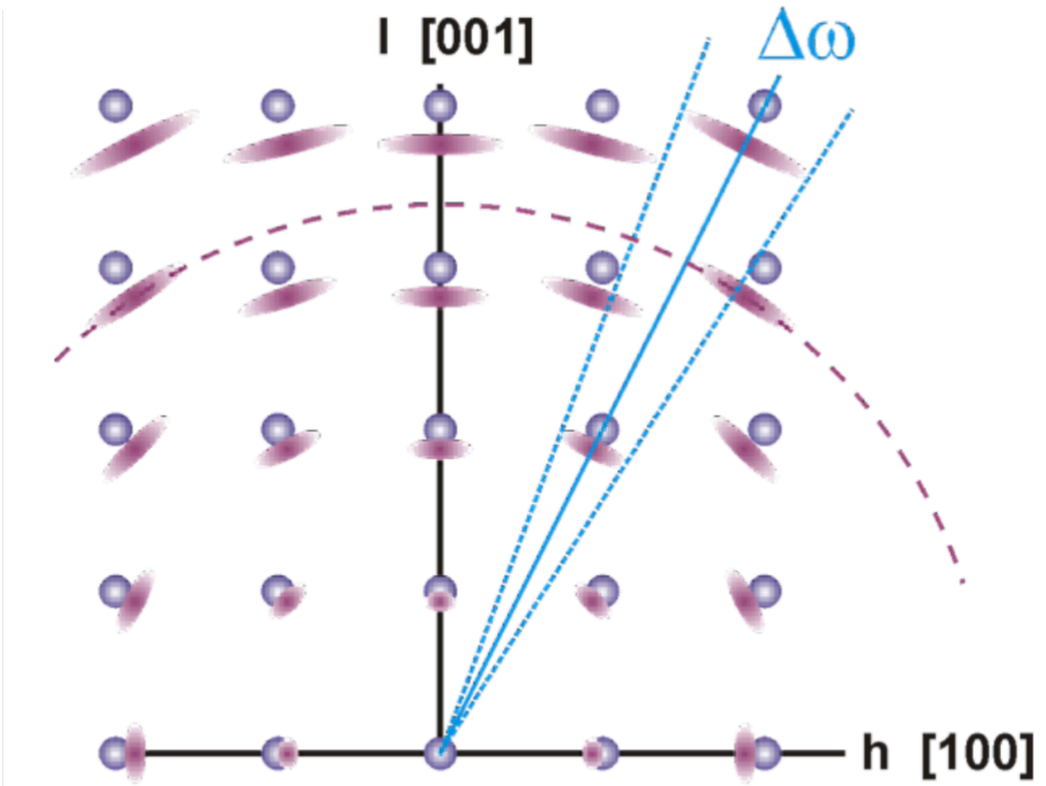
substrate

relaxed layer with high mosaicity

Crystalline films

- X-ray diffraction : strain



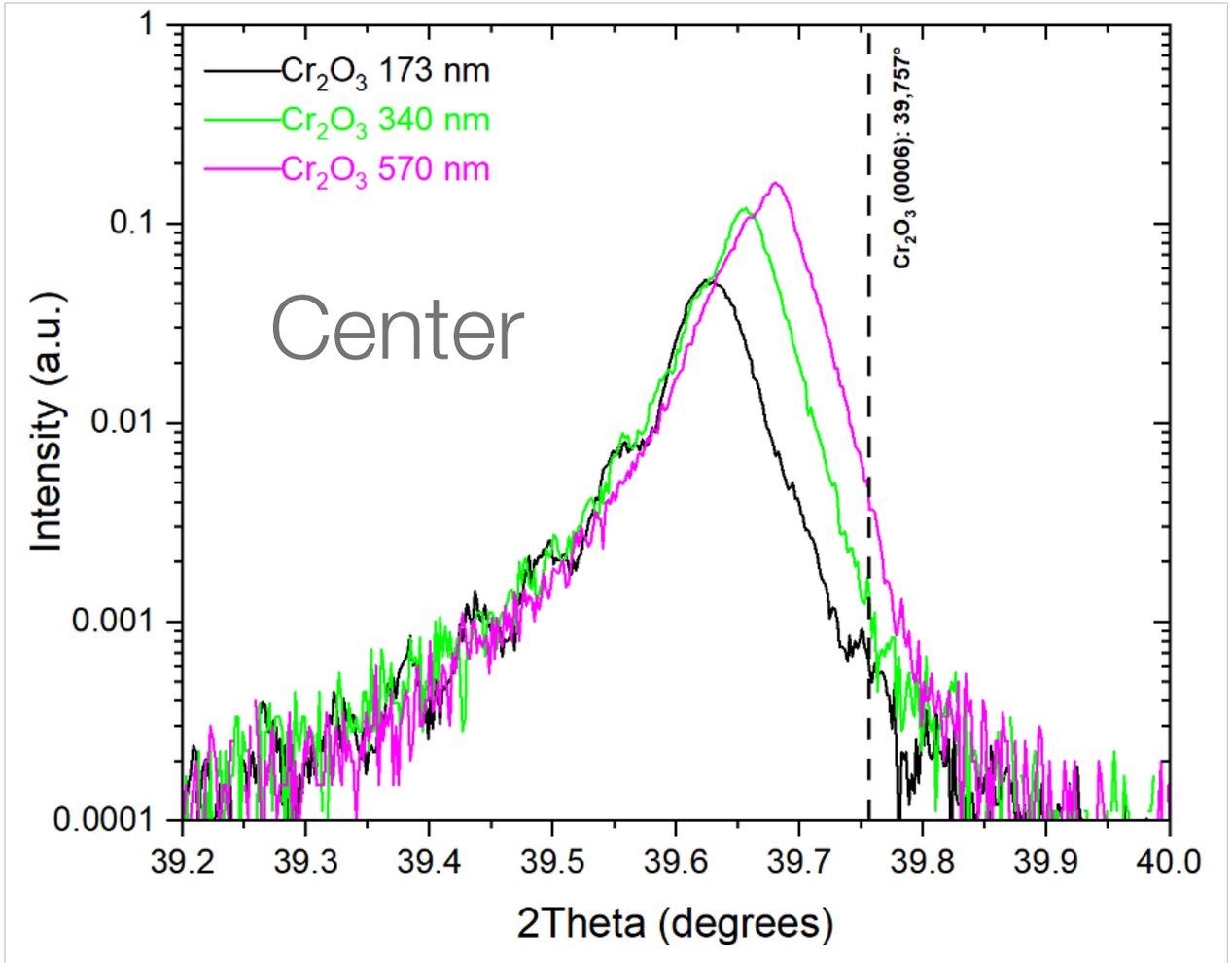


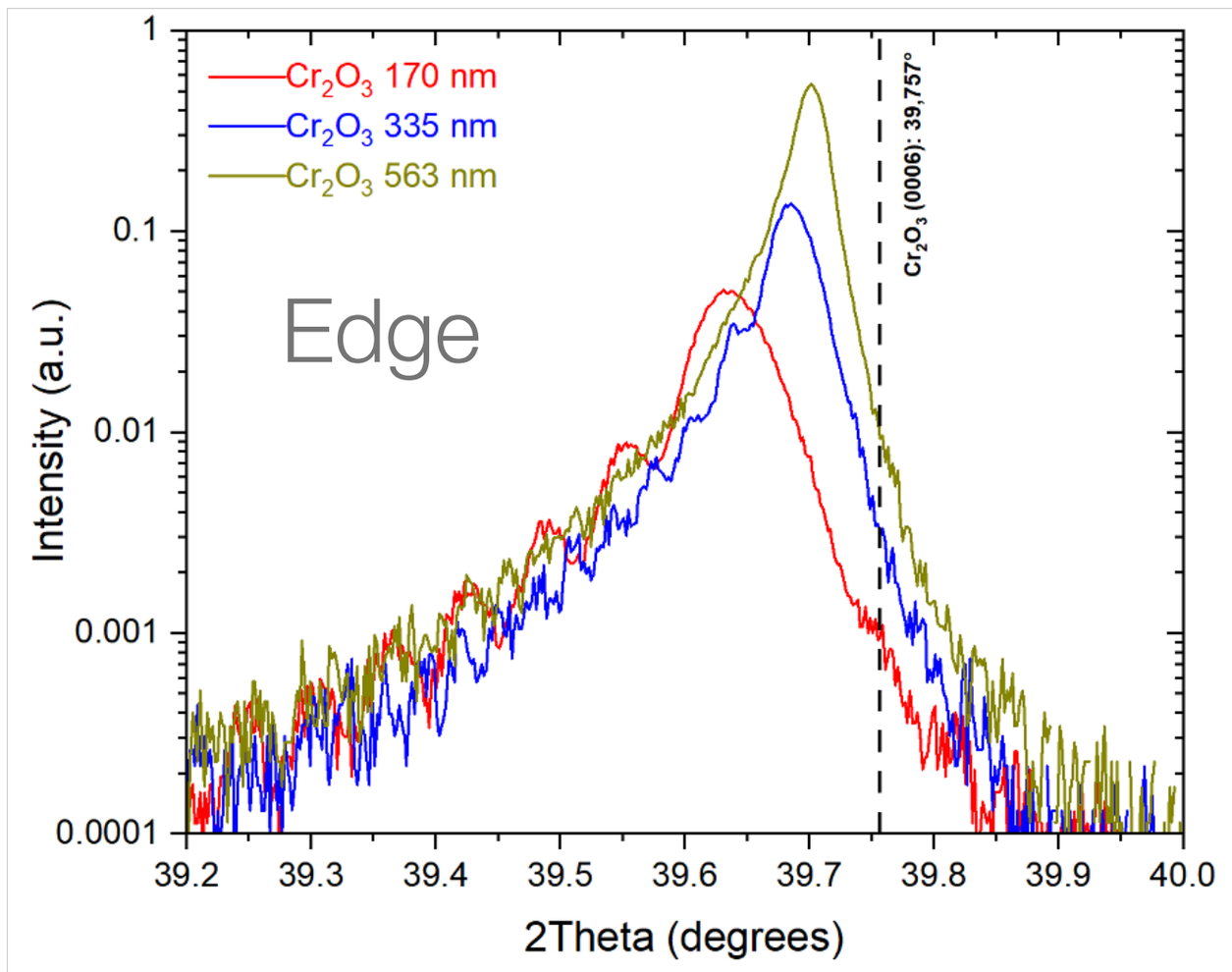
substrate

relaxed layer with high mosaicity

Crystalline films

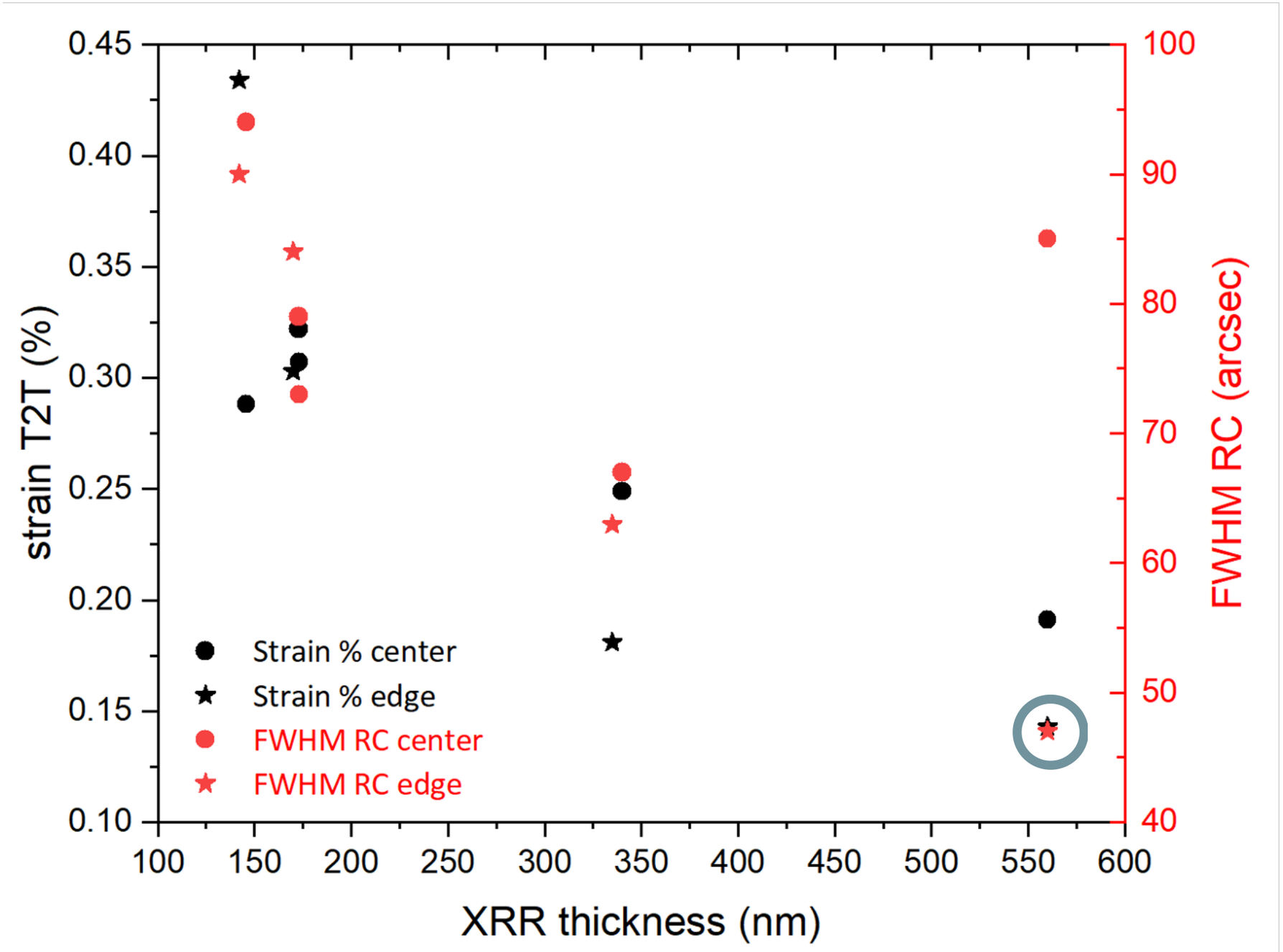
- X-ray diffraction : strain





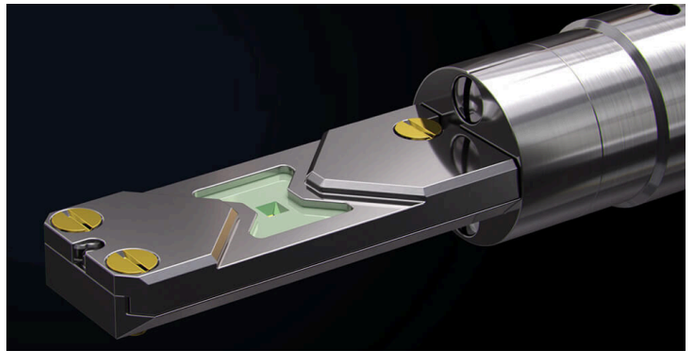
Crystalline films

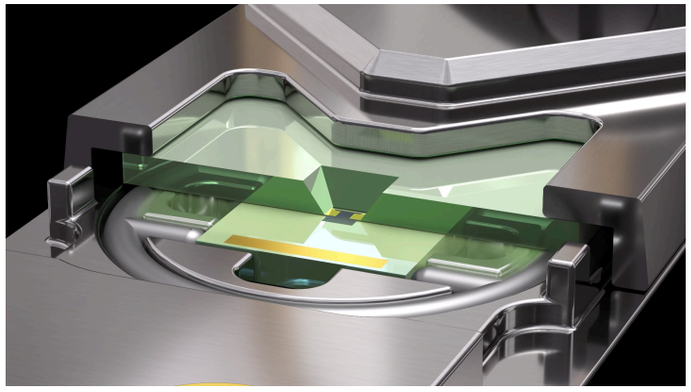
- Strain and rocking curve

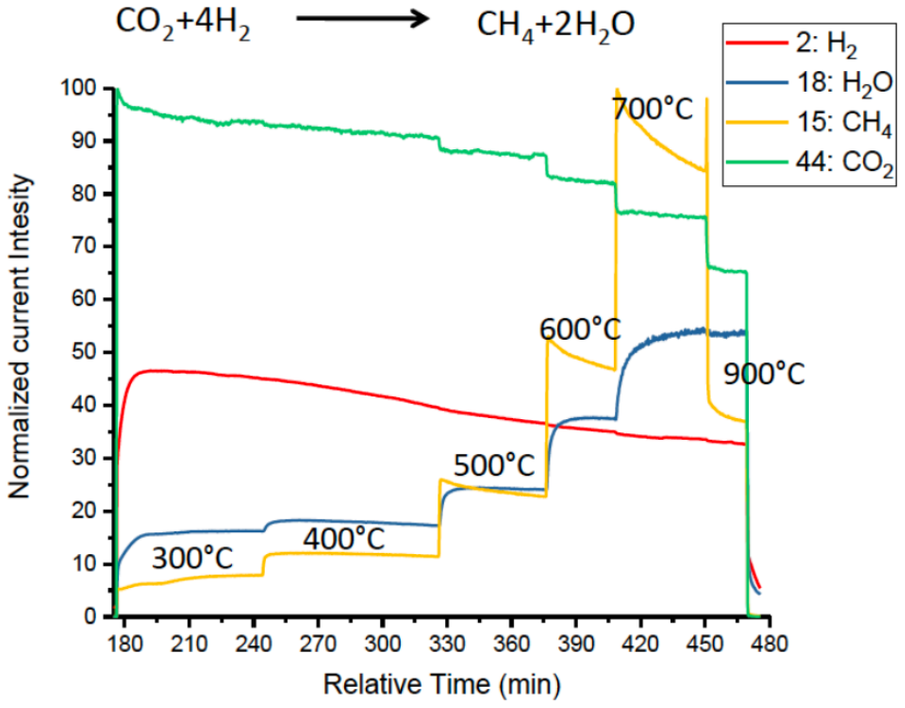


Oxide Characterization

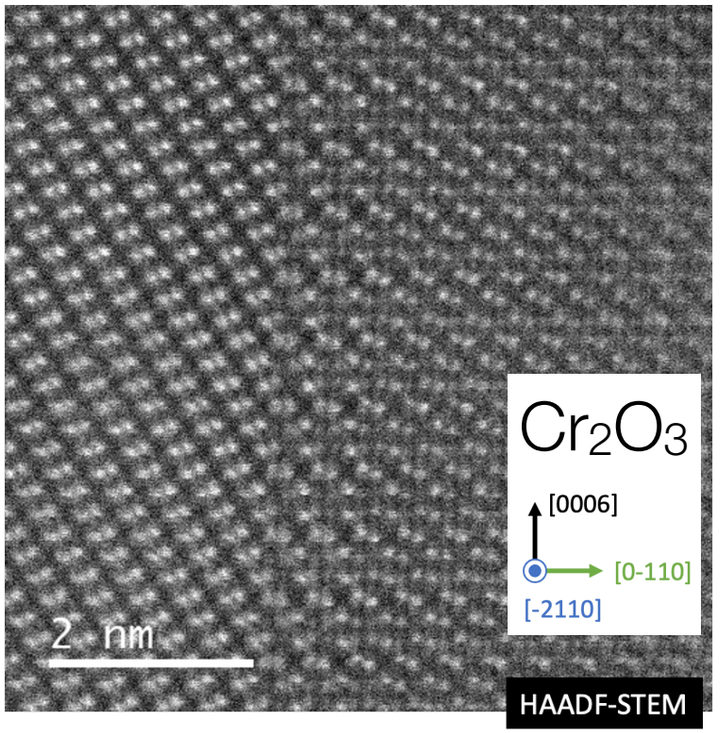
- (S)TEM, EDX, EELS
- In-situ heating + cooling with reactive gases







CO_2 methanation using a nickel-based catalyst



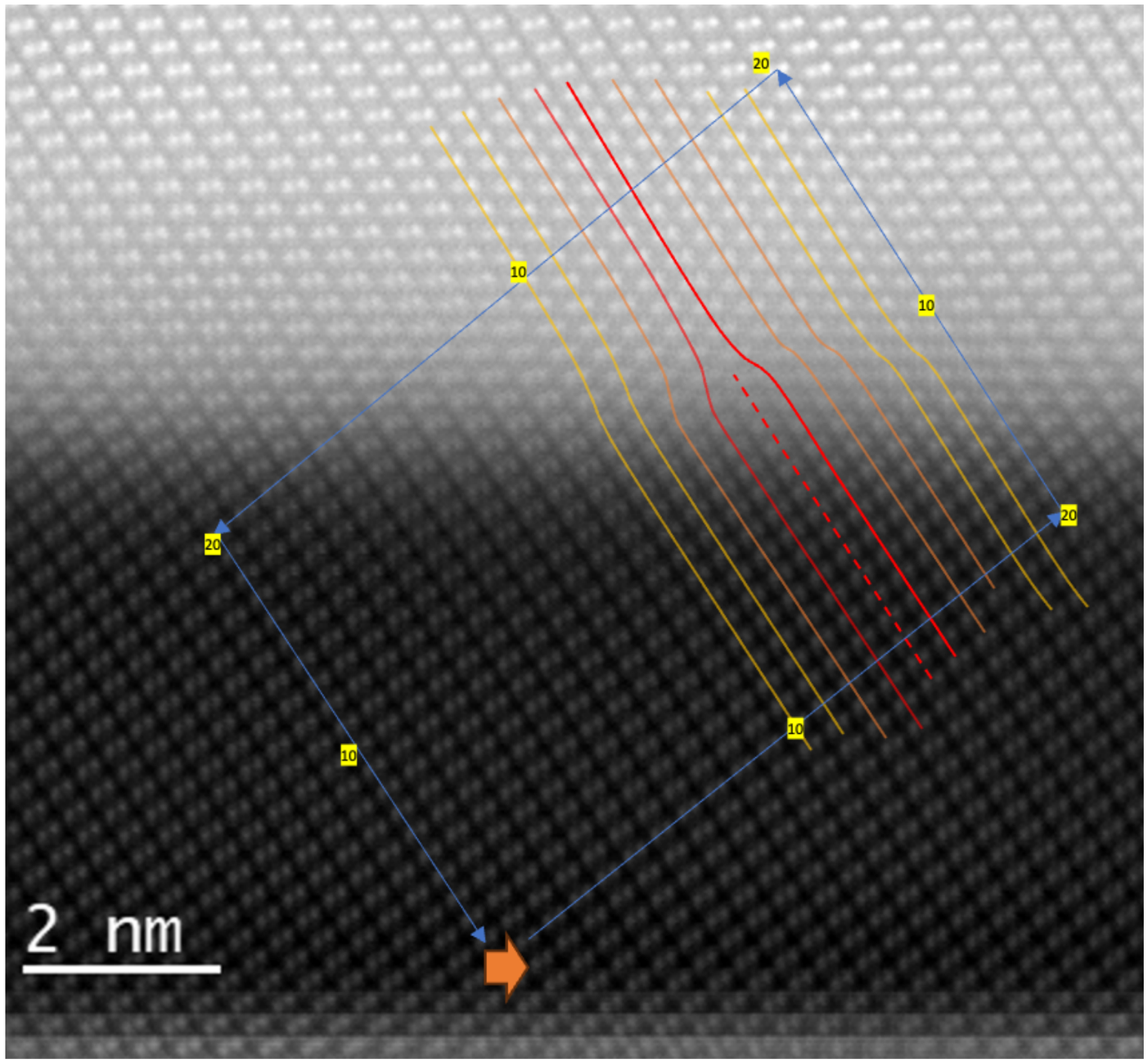
Crystalline films

- Dislocations

|b| = 4.14 Å
Measured averaging 10 peak-to-peak distances.

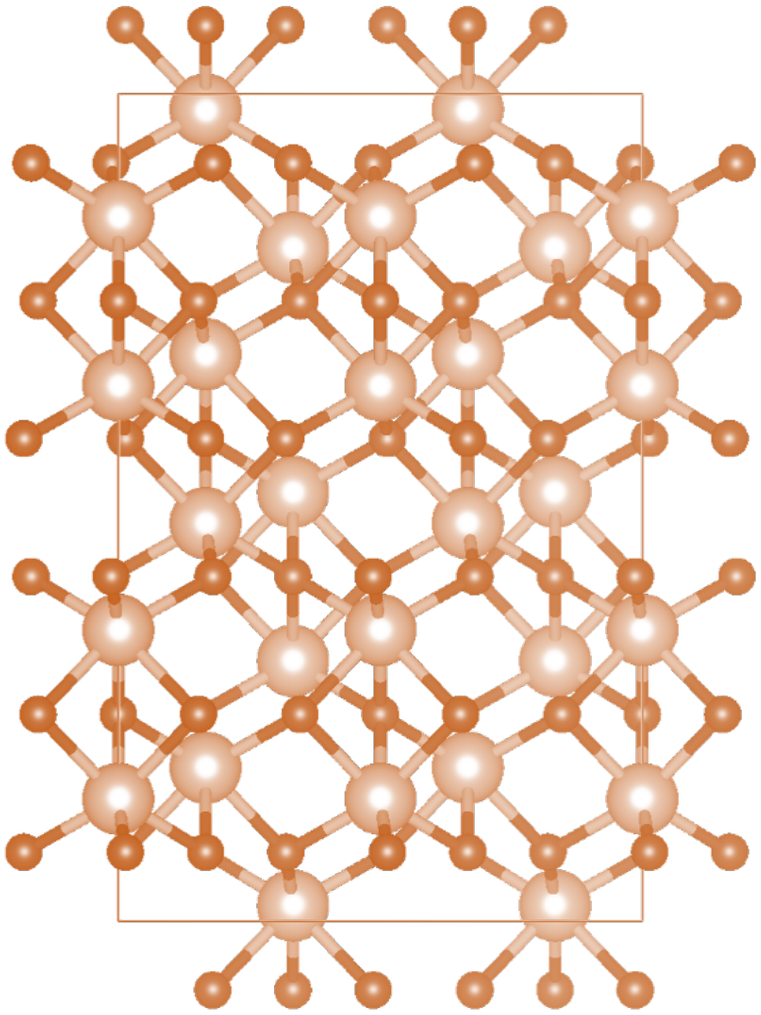
$$|b| = 4.14\ \text{Å} = \left|\frac{1}{2}\times[0\bar{1}10]\right|$$

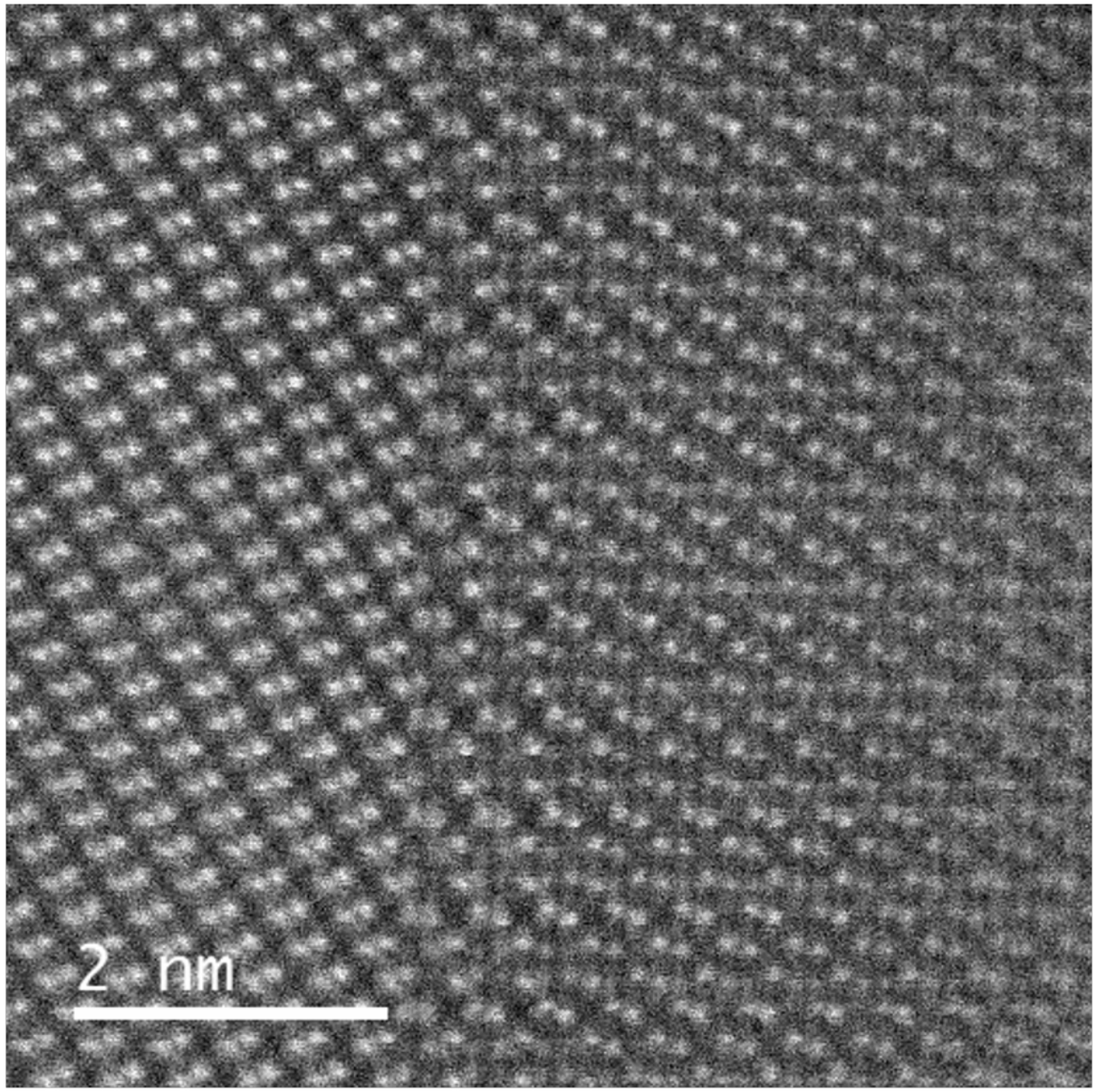
$$|b| = 4.14\ \text{Å} = \frac{\sqrt{3}}{2}a_{sapphire}$$



Crystalline films

- Twin boundaries ?

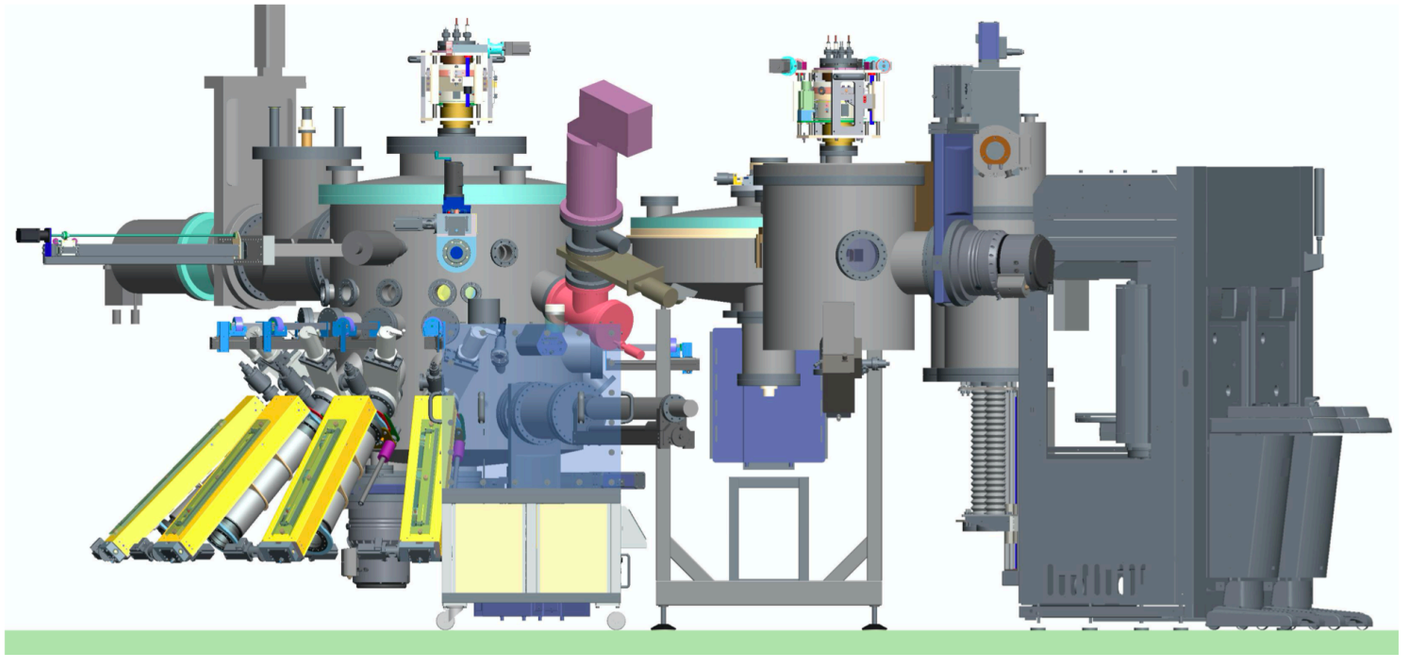




Laboratory

300 mm Oxide MBE (4th generation)

- FOUP compatible
- faster process
- better composition accuracy
- degassing & annealing chamber
- uniformity control



300 mm XRD system

- FOUP compatible
- 9kW rotating anode
- Goal: uniformity of crystallinity
- Delivery September 2024

Summary

- Crystalline oxides offer unique possibilities for mirror coatings
- Gradually improving the quality
- Building up 300 mm growth and characterisation facility