



Update on crystalline oxides coatings

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AGENTSCHAP
INNOVEREN &
ONDERNEMEN

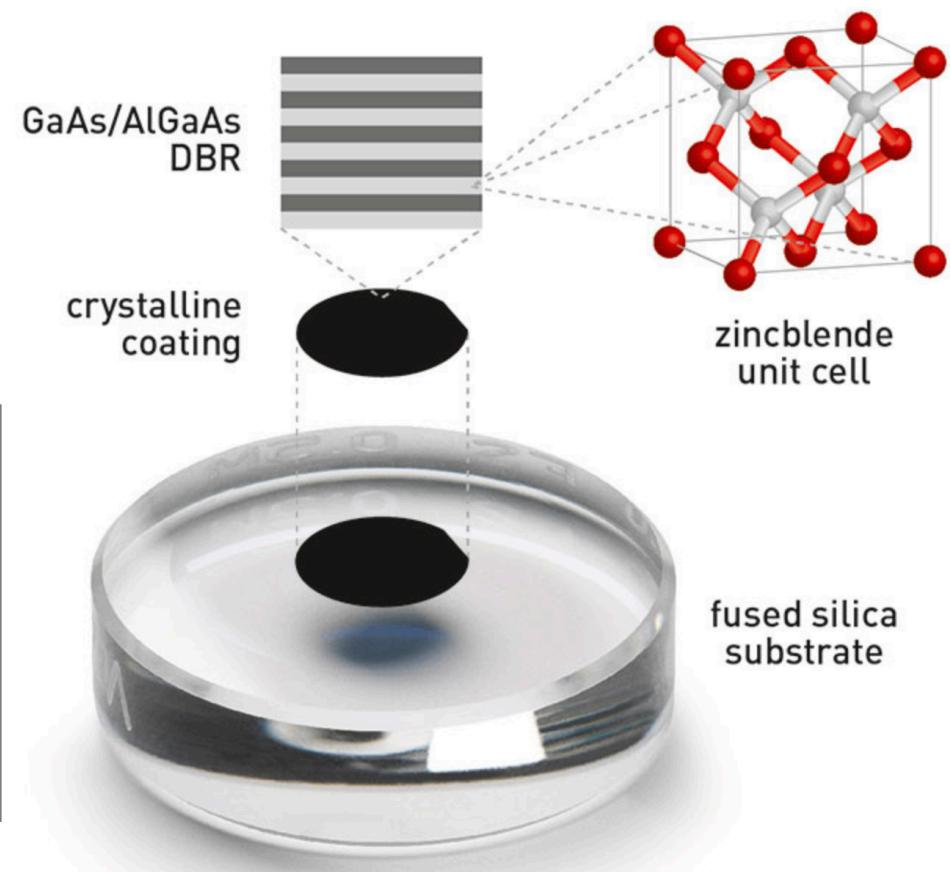


Crystalline materials

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

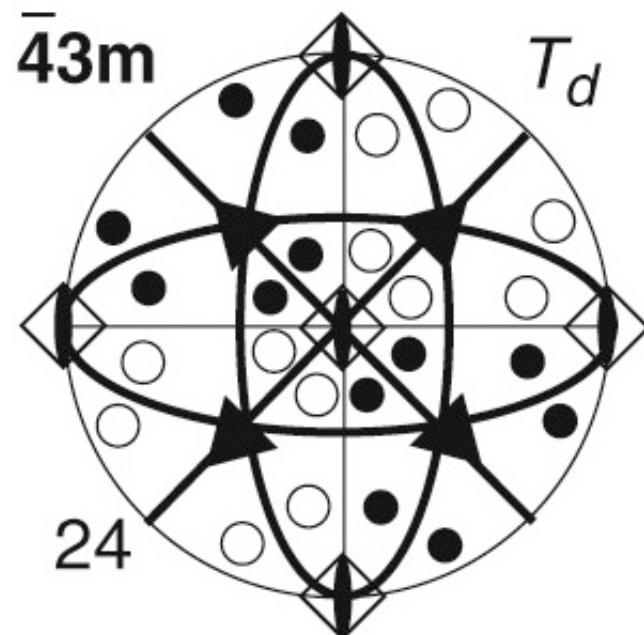
THORLABS
Supermirrors

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

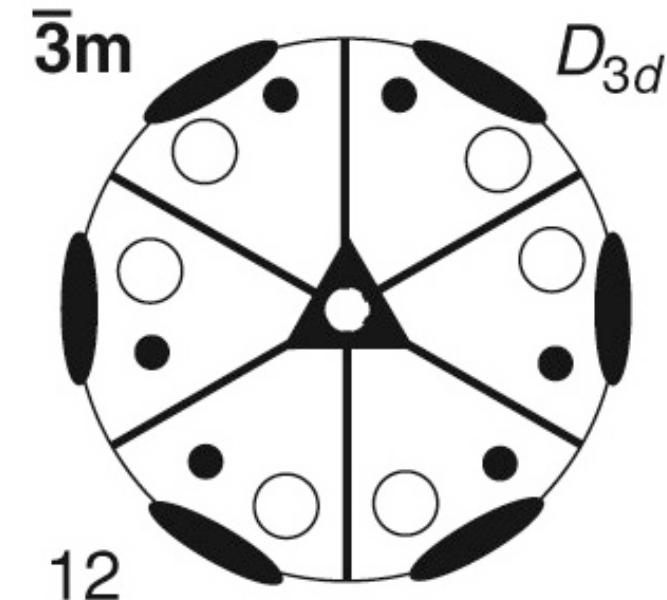


Point symmetries

GaAs



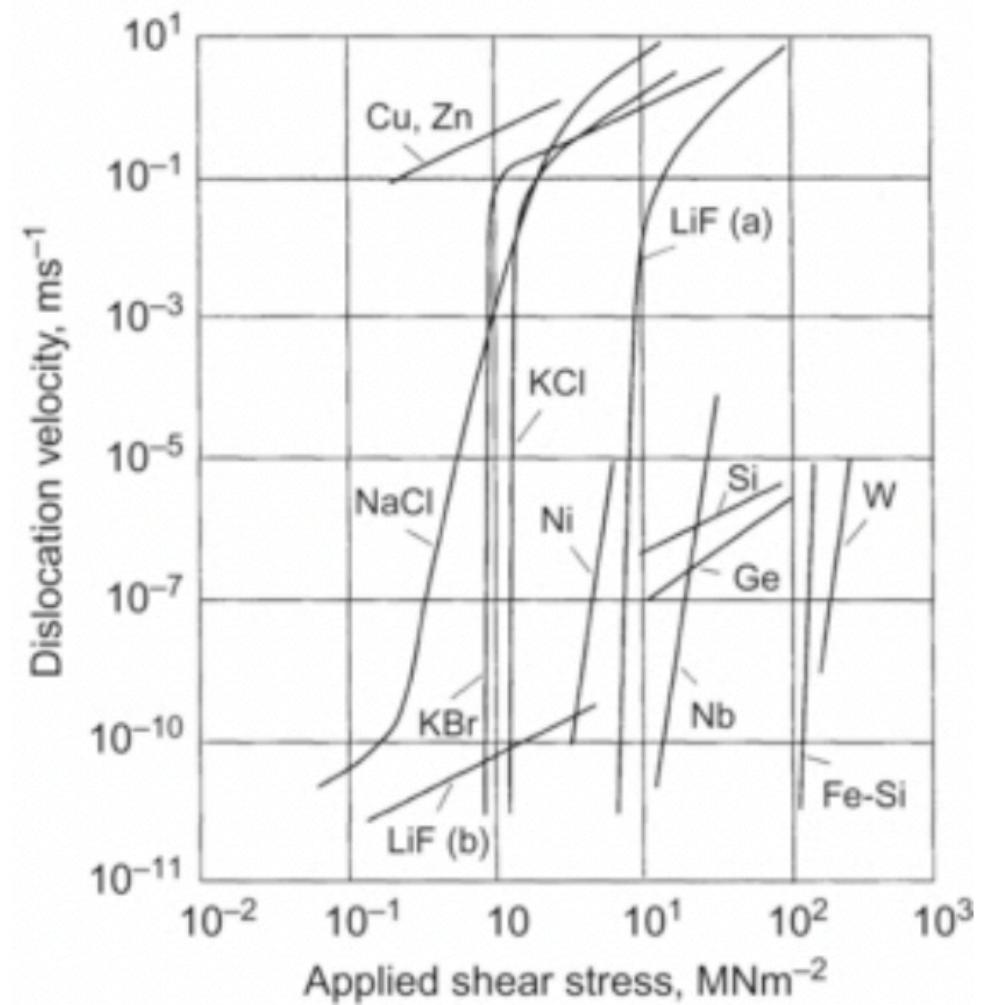
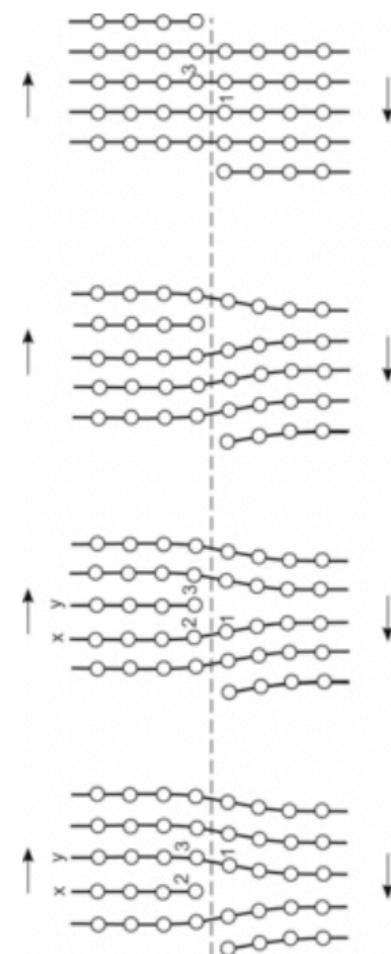
Ga₂O₃



Different symmetries => origin of losses

Point symmetries

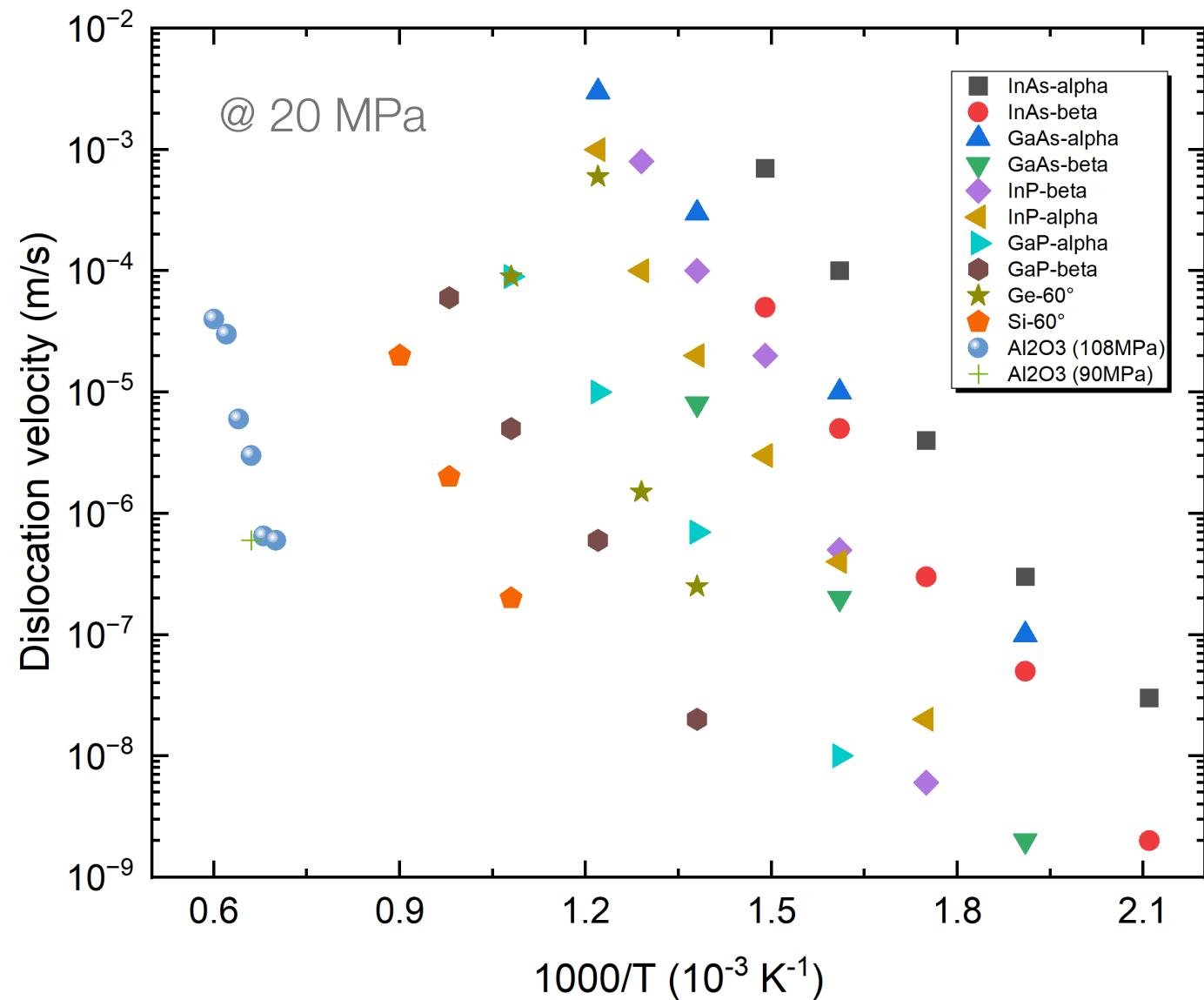
- Dislocations



Introduction to dislocations, Hull

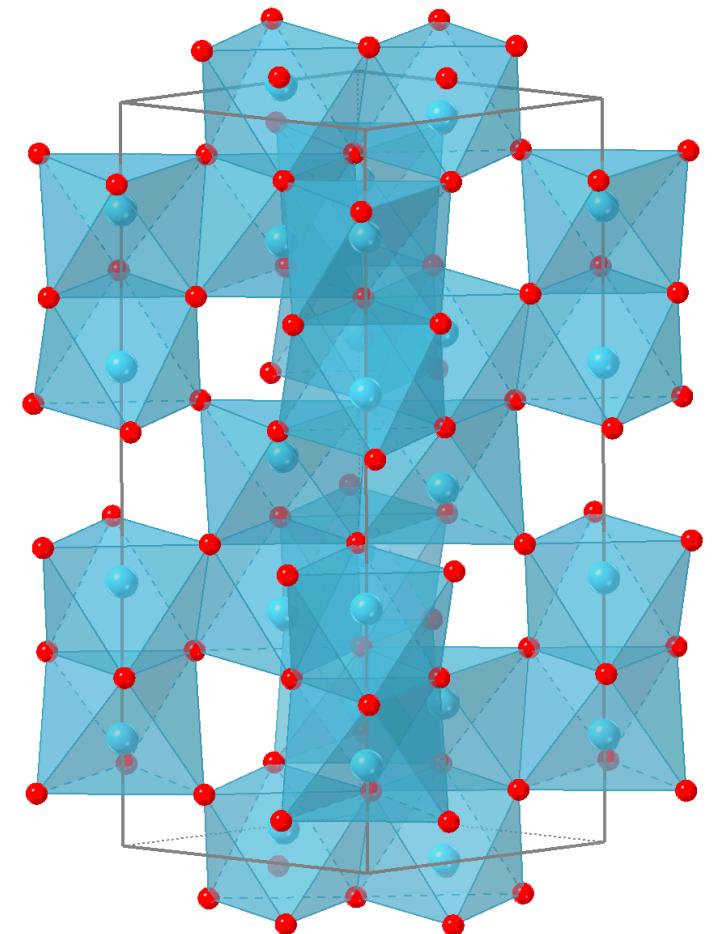
Point symmetries

- Dislocations

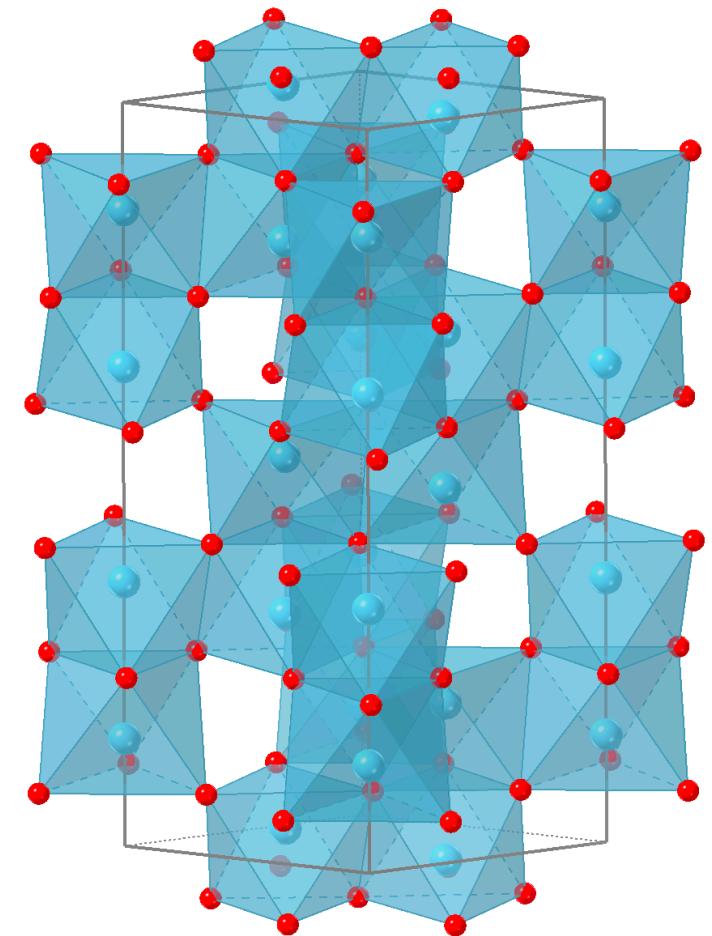
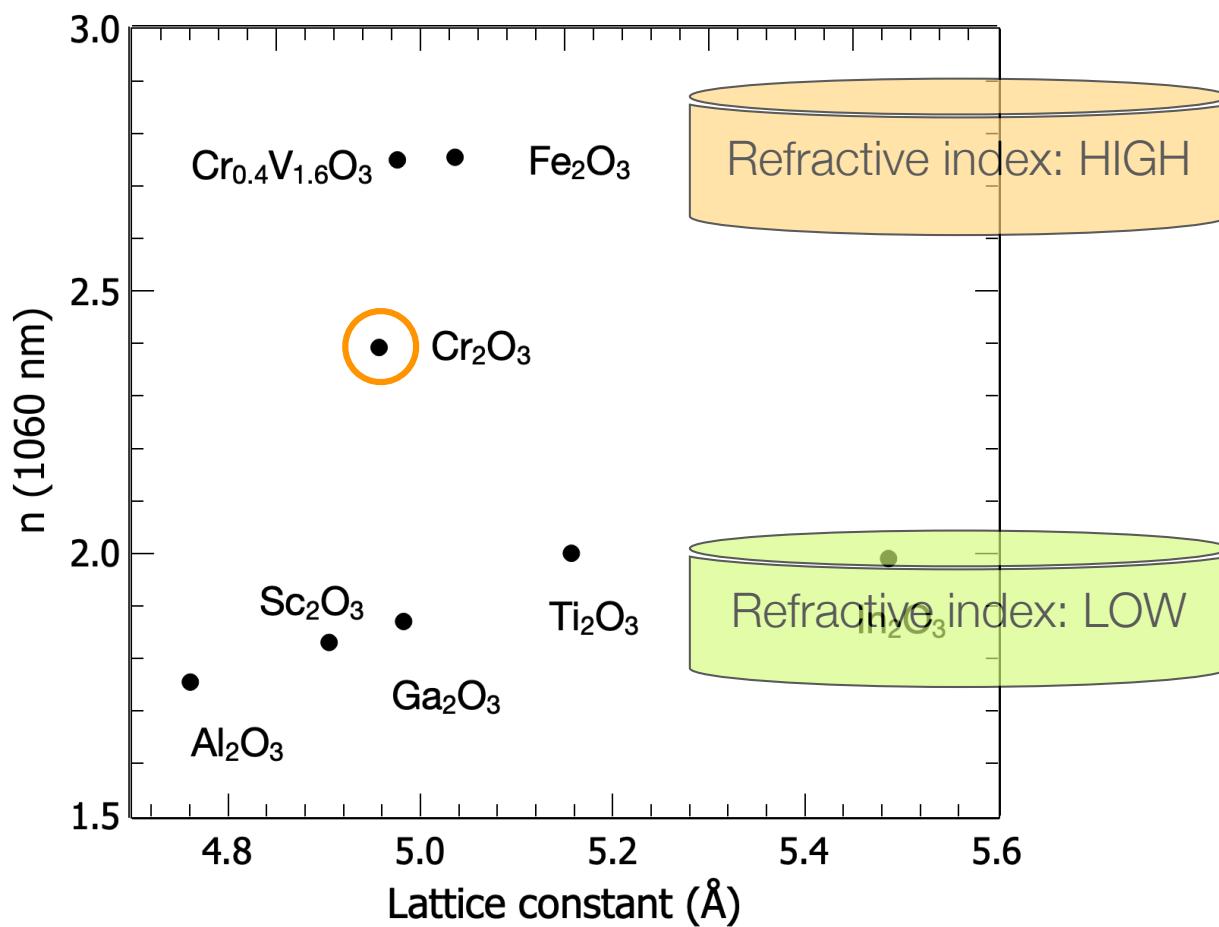


Corundum structures

- Why study these ?
 - Al_2O_3
 - Same structure as sapphire
 - Spacegroup 167 $R\bar{3}c$
 - Mechanical loss angle of sapphire **crystals** $\sim 10^{-9}$
 - 6 layers of rotated MO_6 octahedra
 - Solid solutions

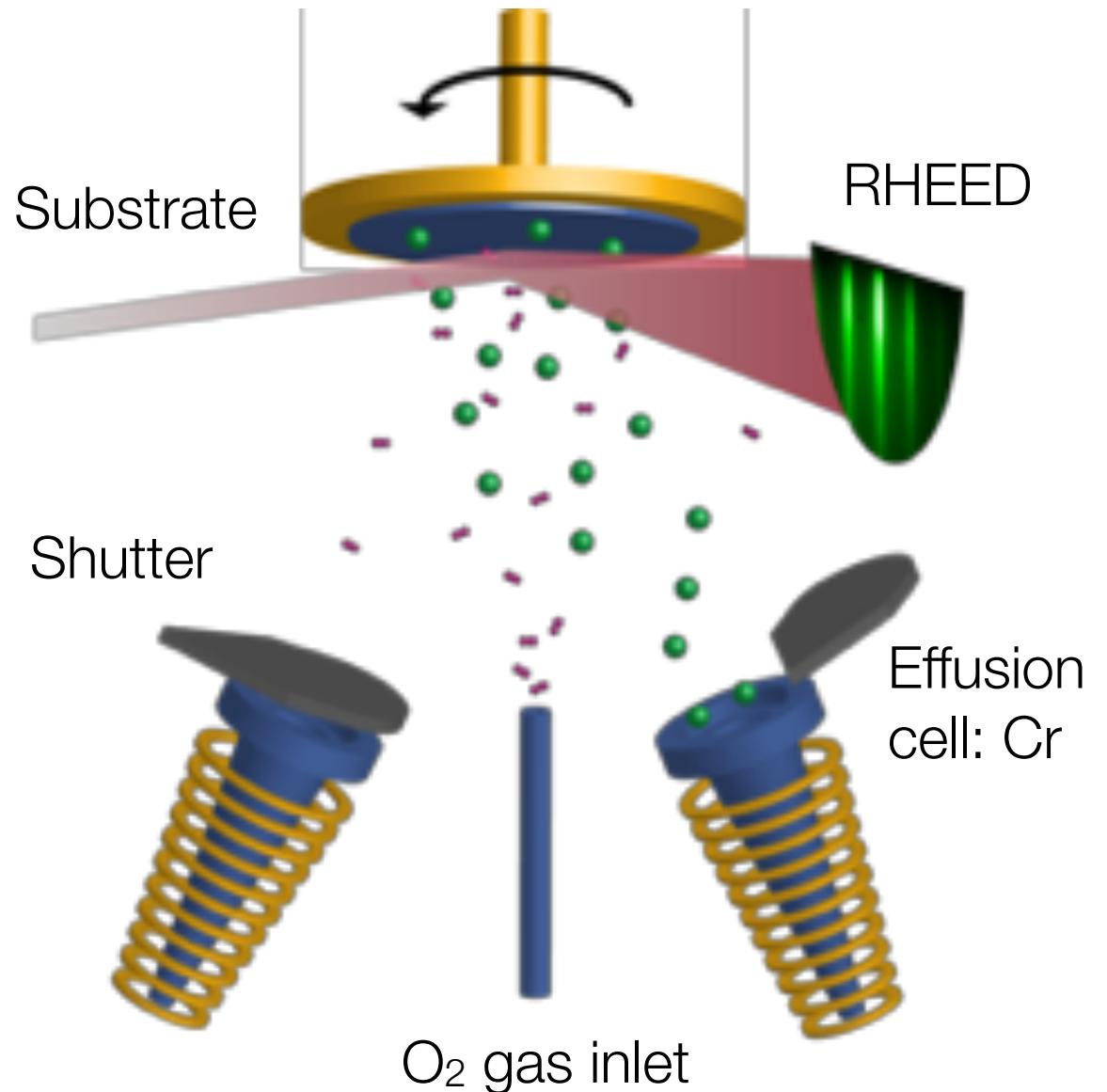


Corundum structures



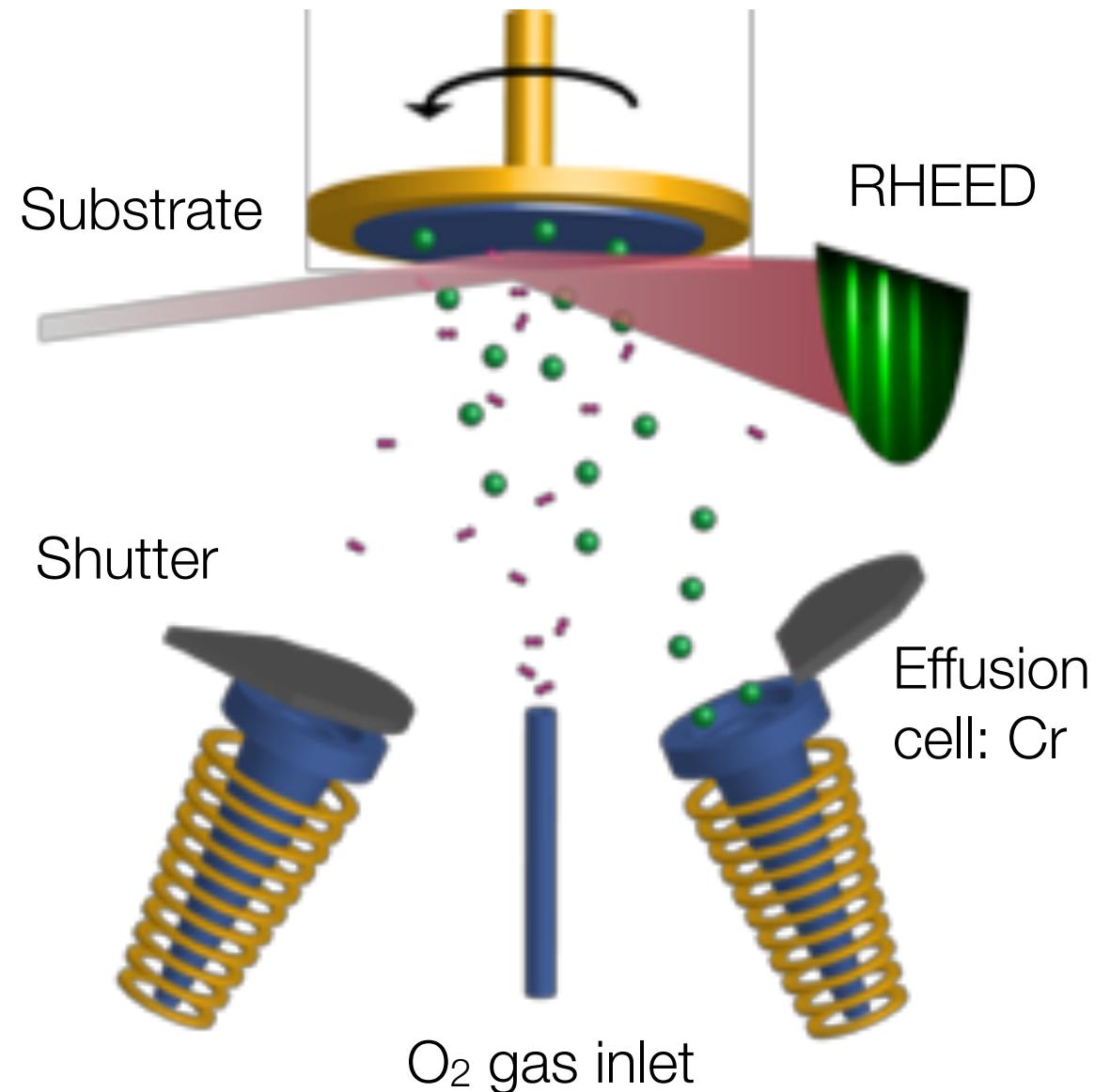
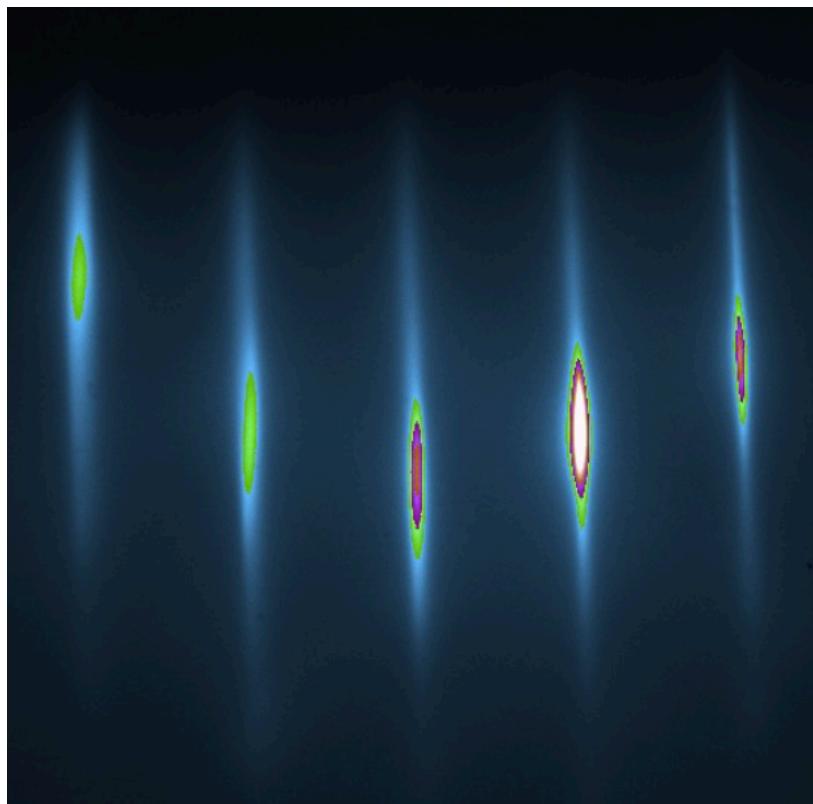
Molecular Beam Epitaxy

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



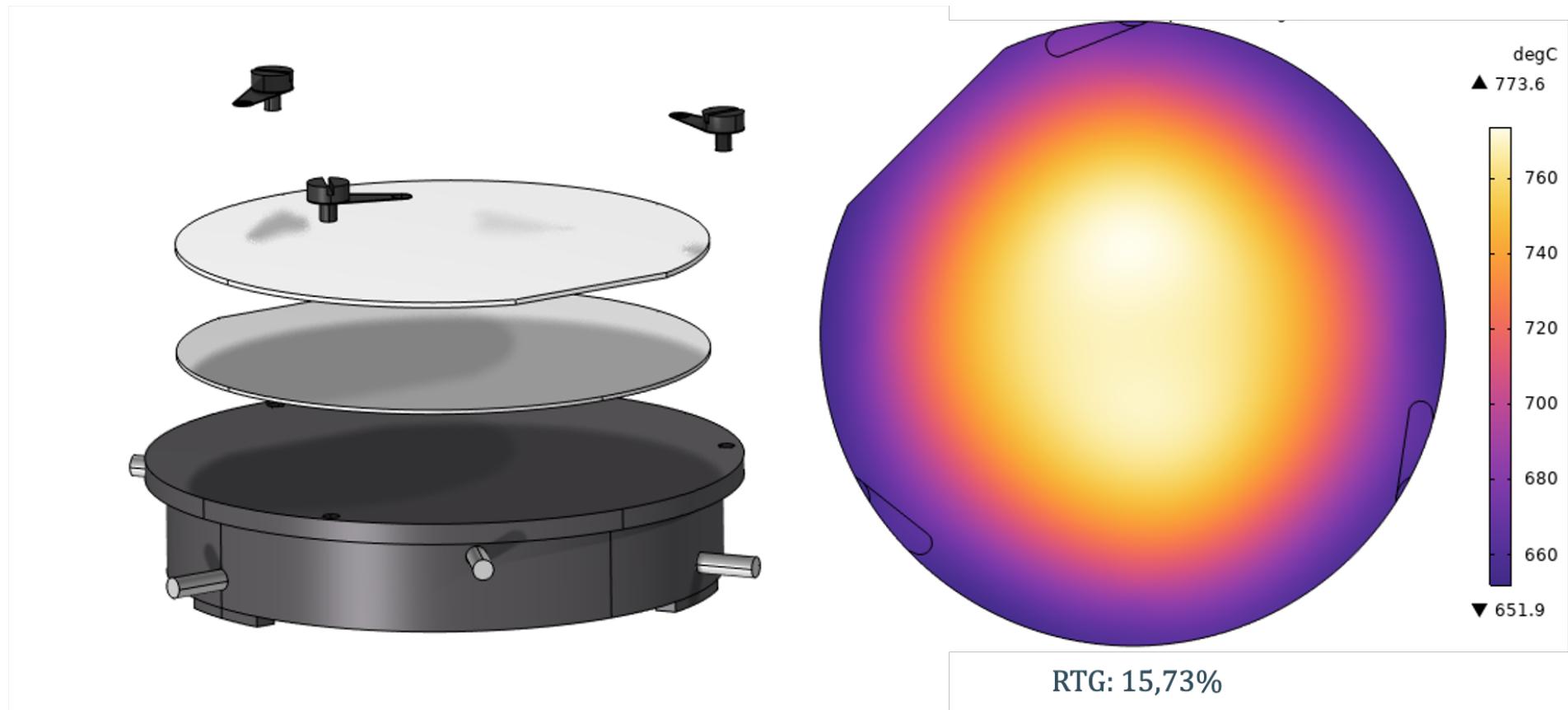
Molecular Beam Epitaxy

- 500 nm Cr_2O_3 / Al_2O_3



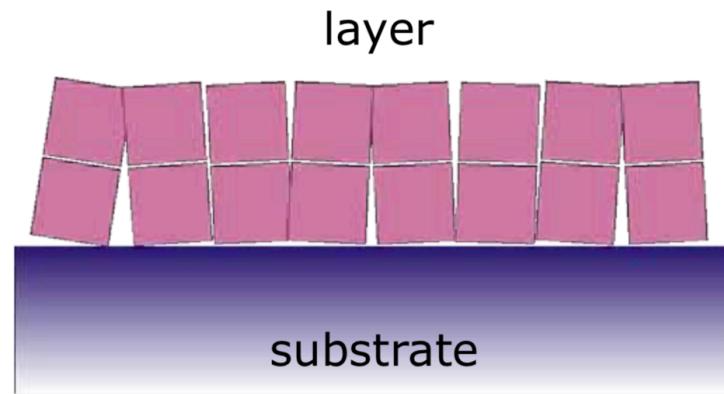
Temperature uniformity

- Original design

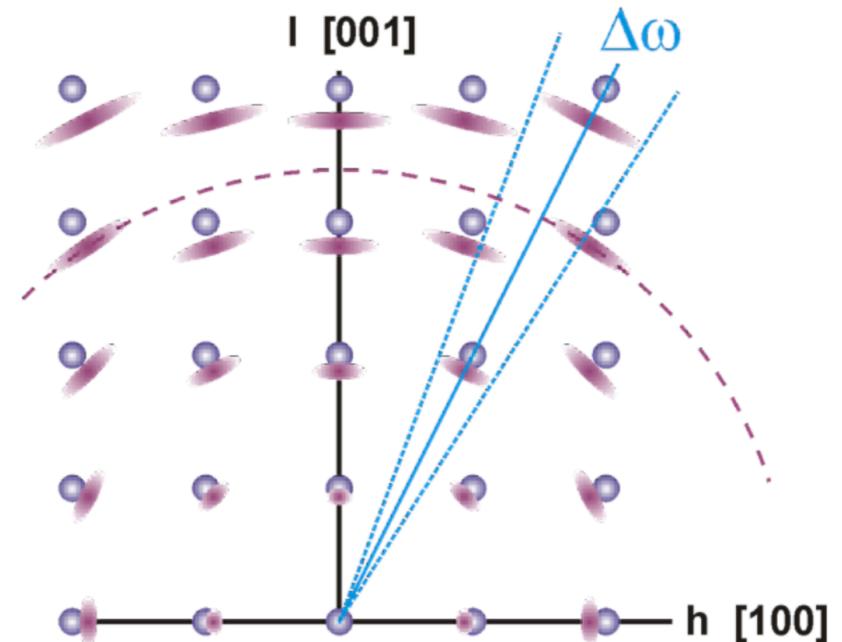


Crystalline films

- Quality criterium: X-ray diffraction rocking curve



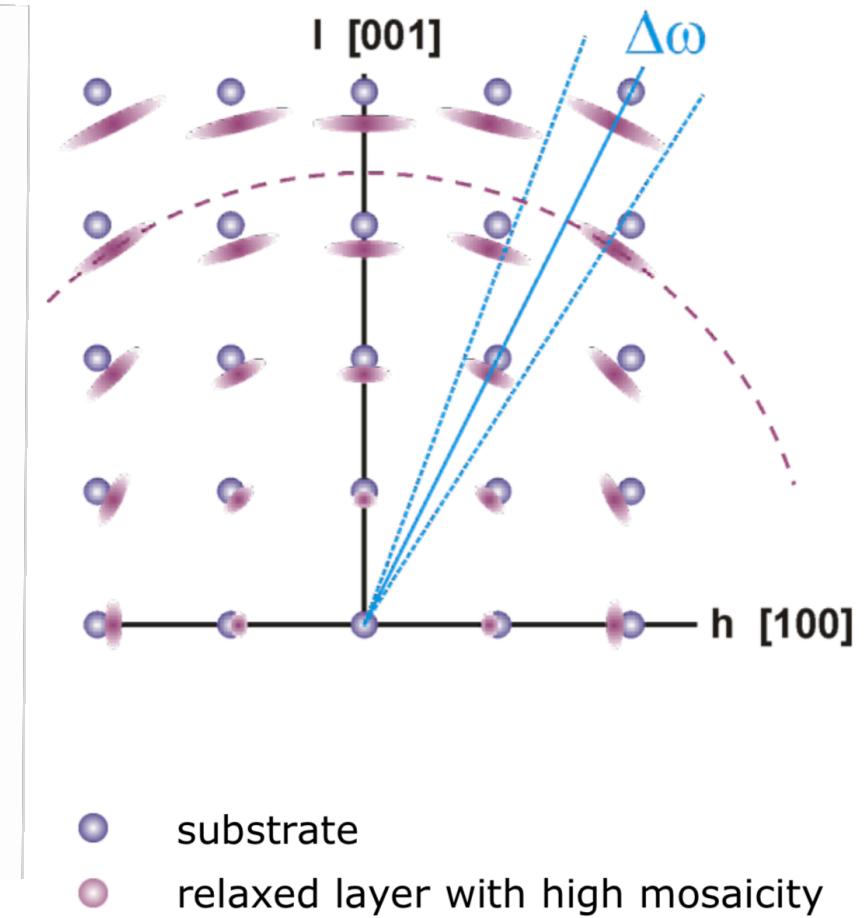
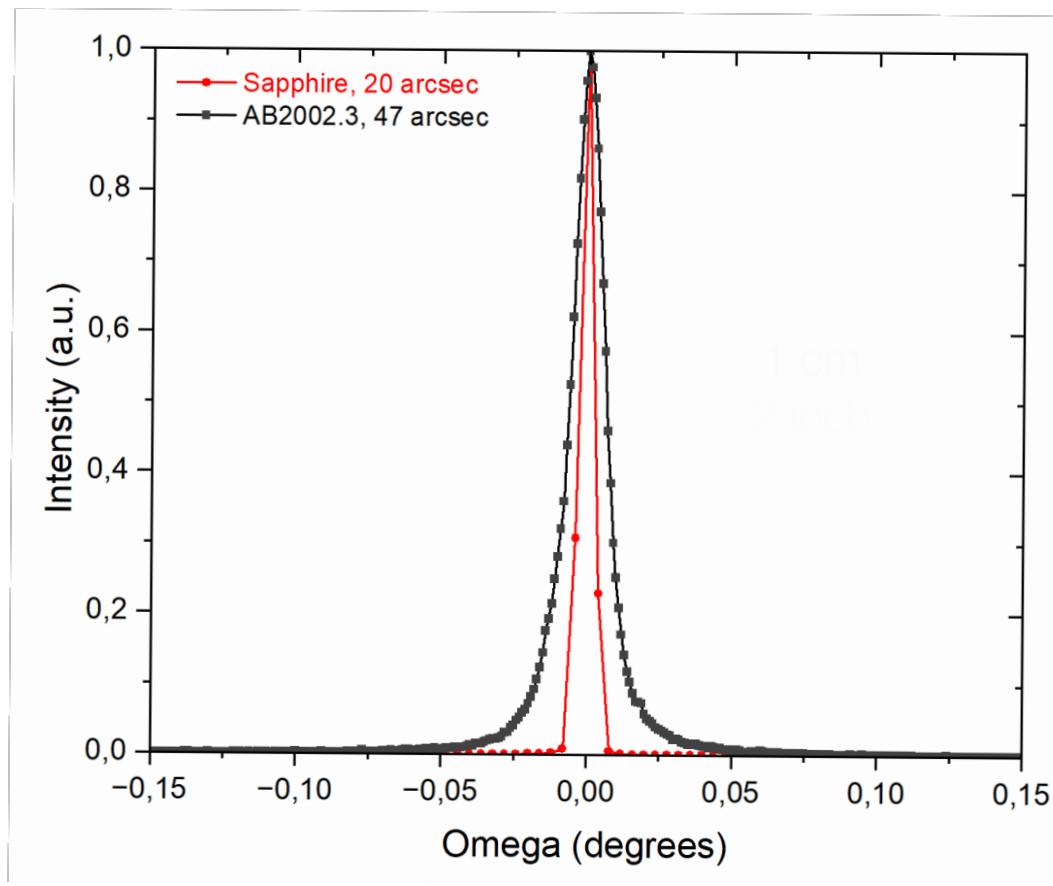
Mosaicity causes a smearing of the reflection on a circle around (000).



- substrate
- relaxed layer with high mosaicity

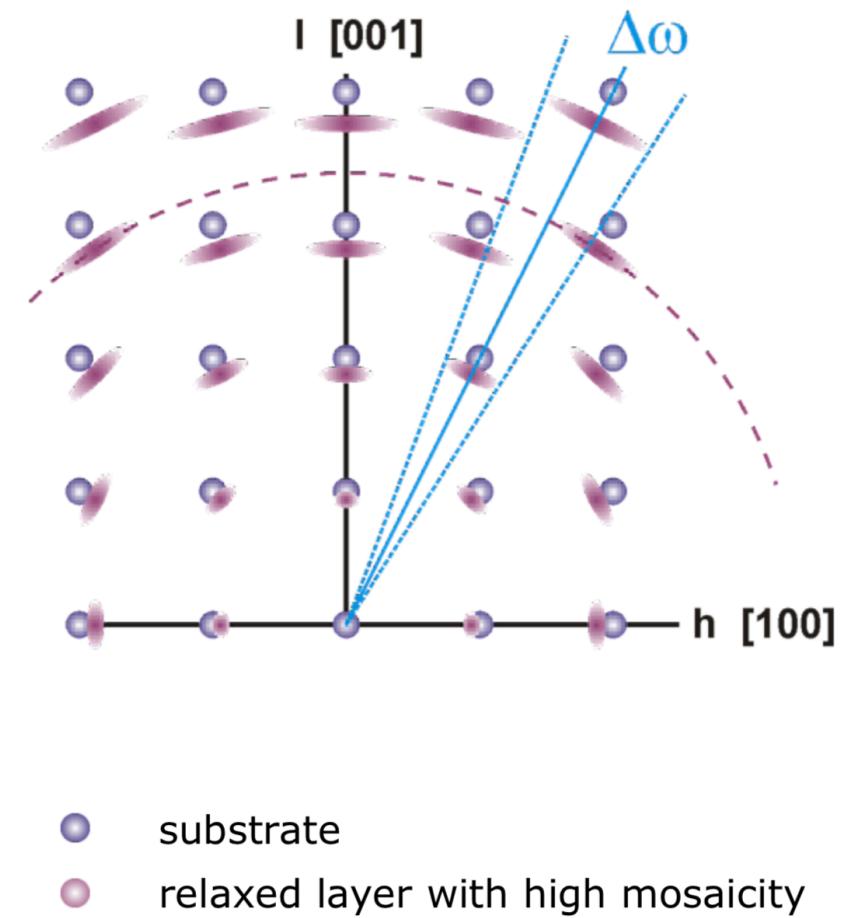
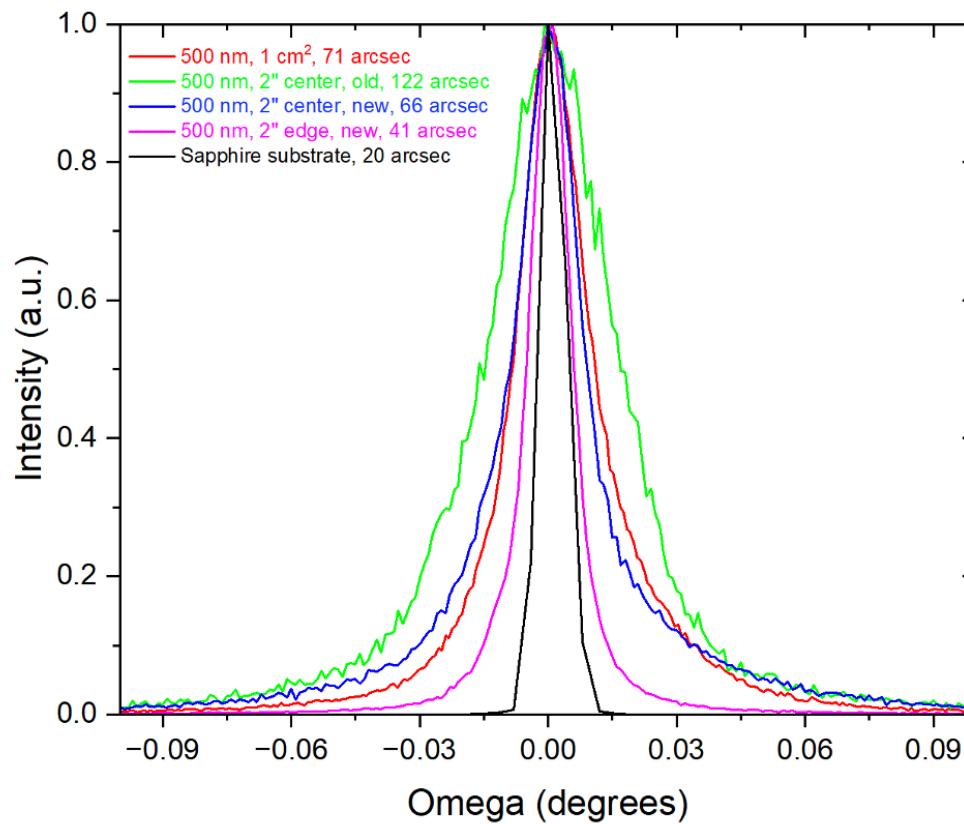
Crystalline films

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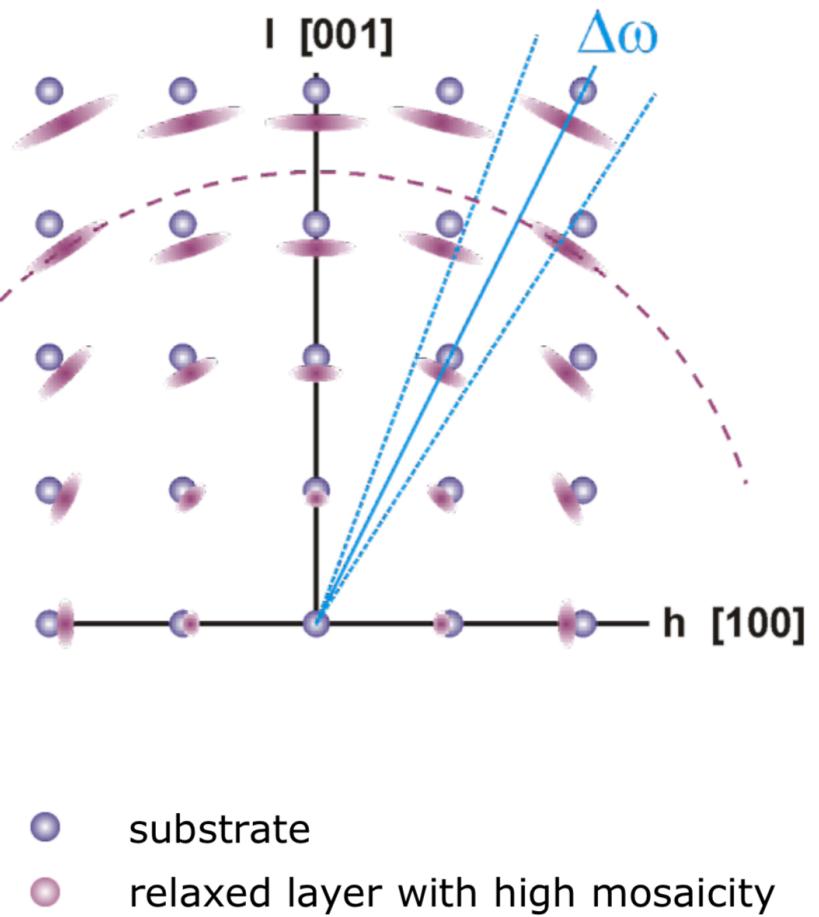
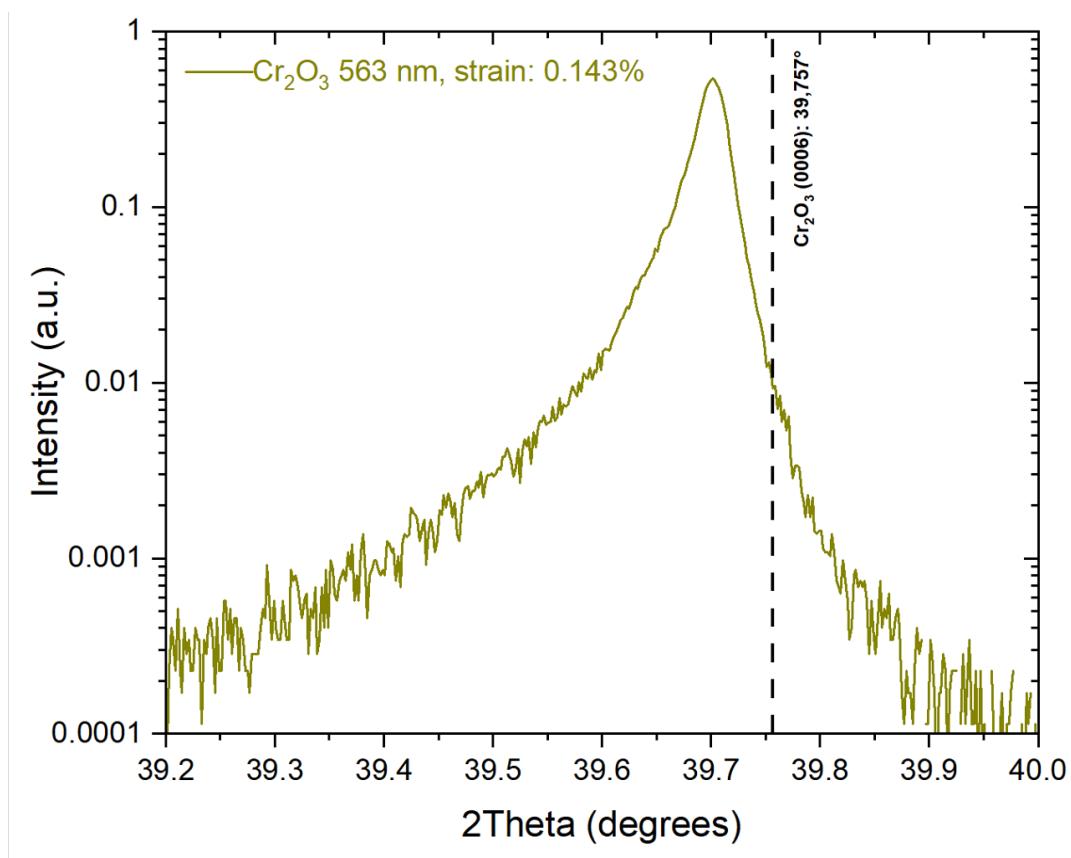
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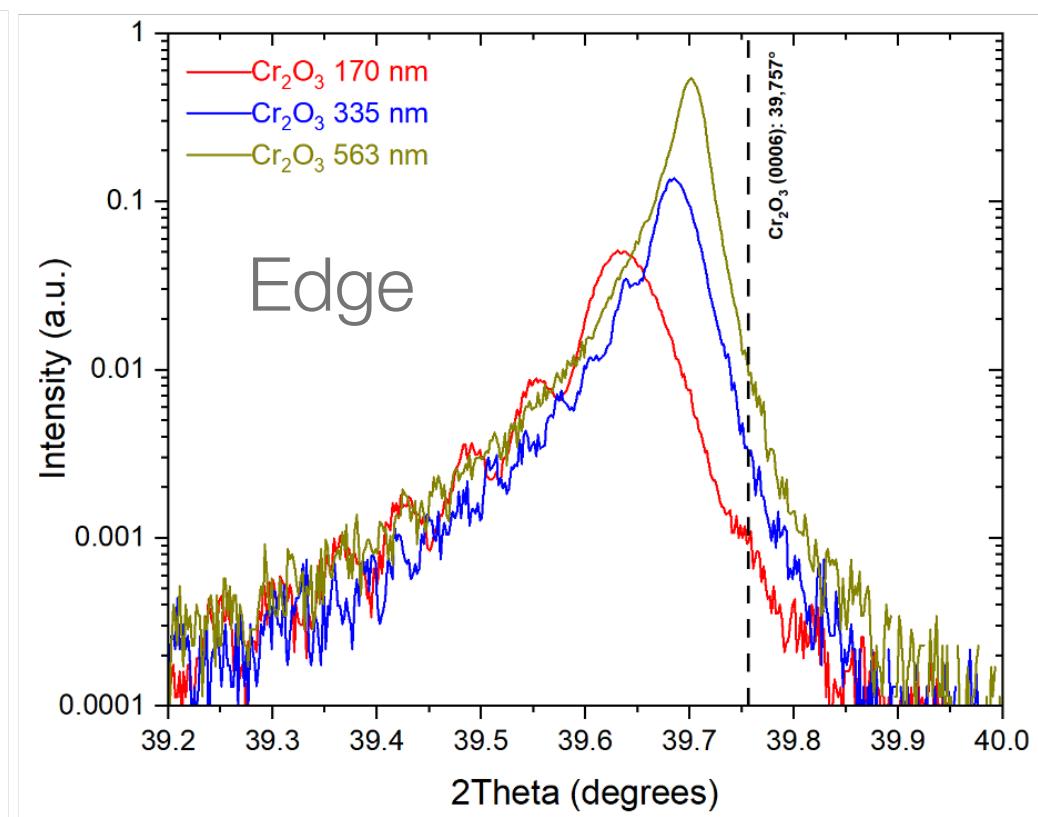
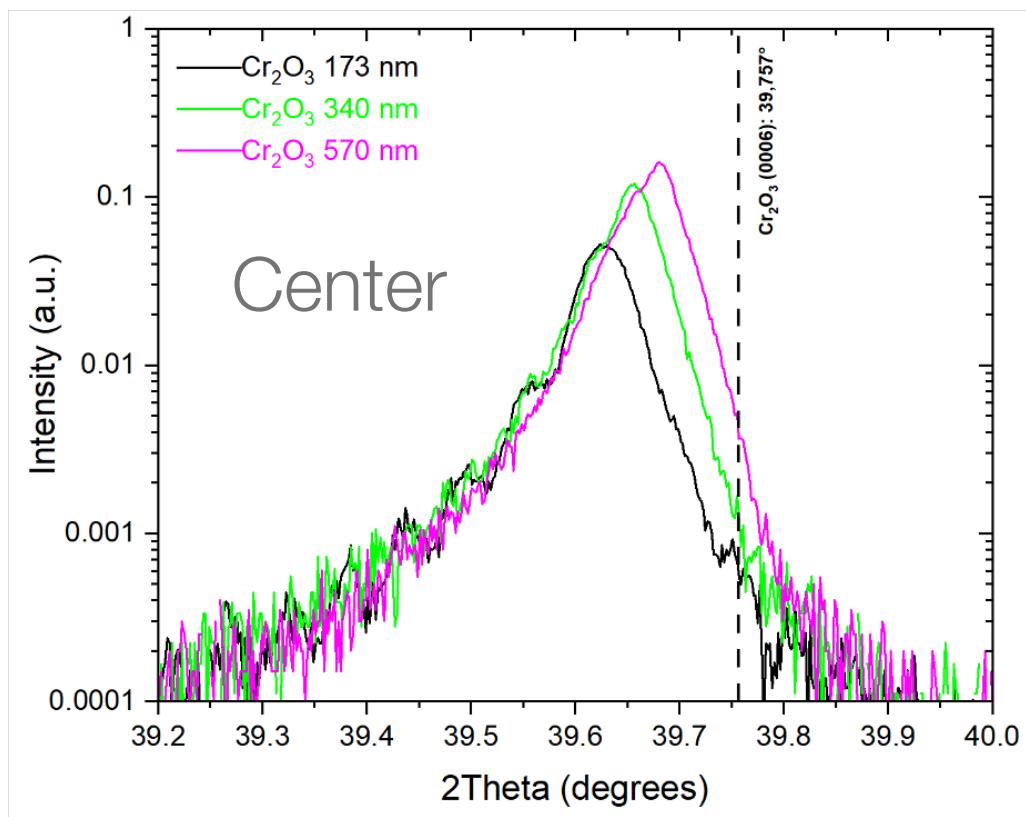
Crystalline films

- X-ray diffraction T-2T: strain



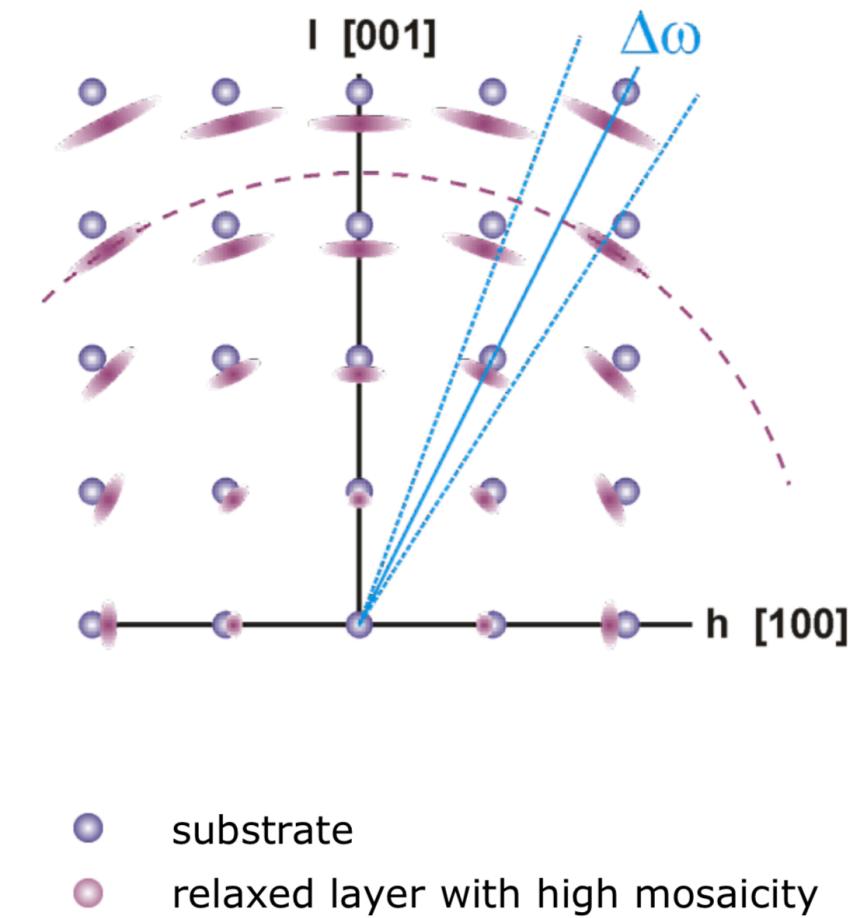
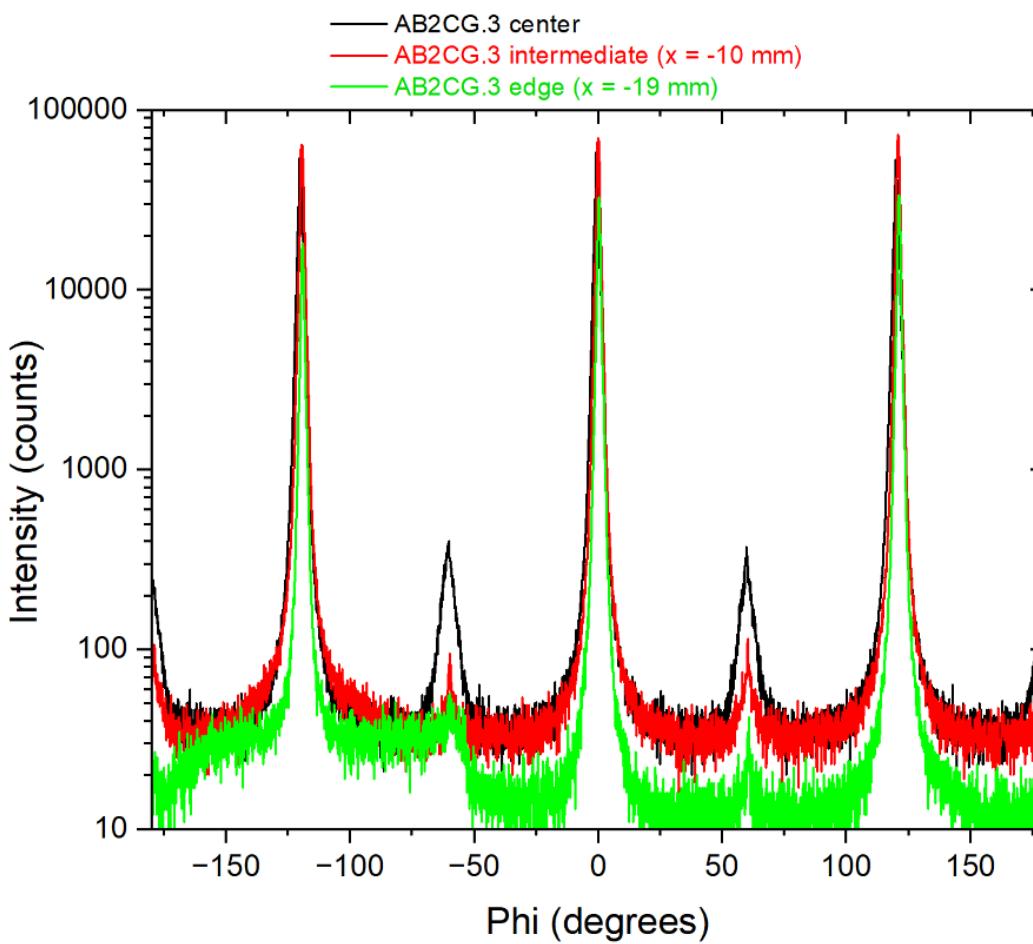
Crystalline films

- X-ray diffraction : strain



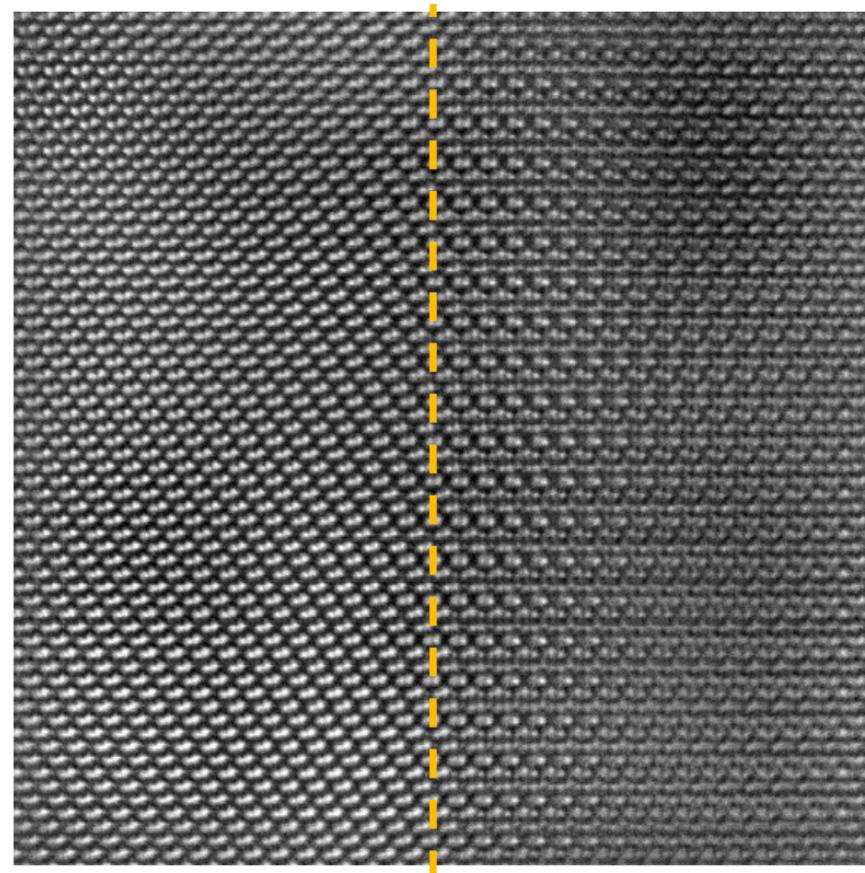
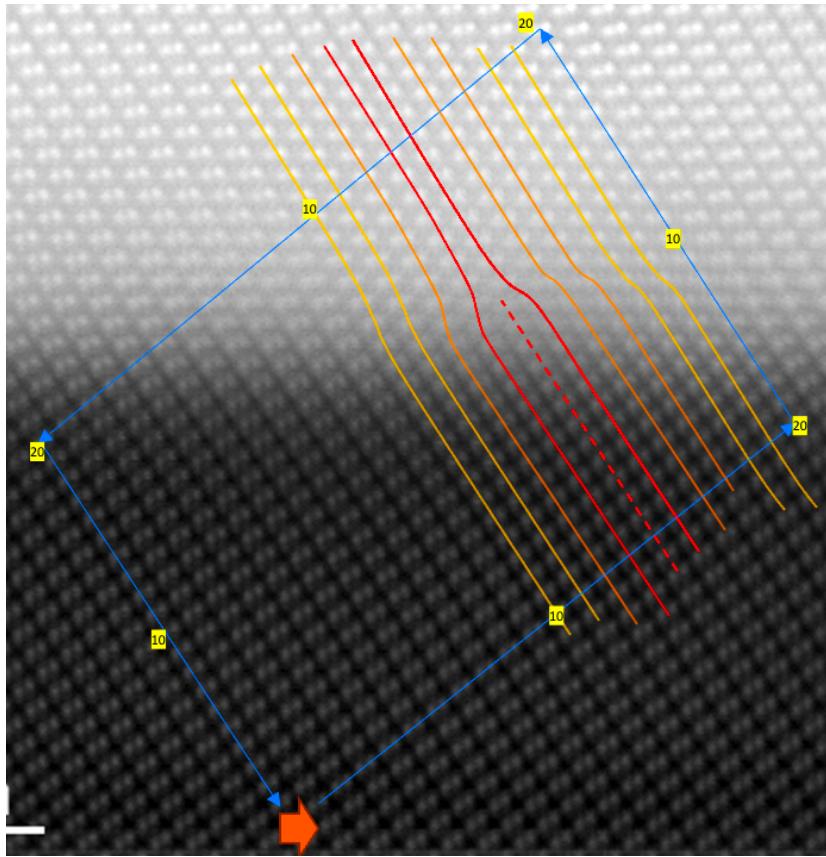
Crystalline films

- X-ray diffraction pole figures: twin domains



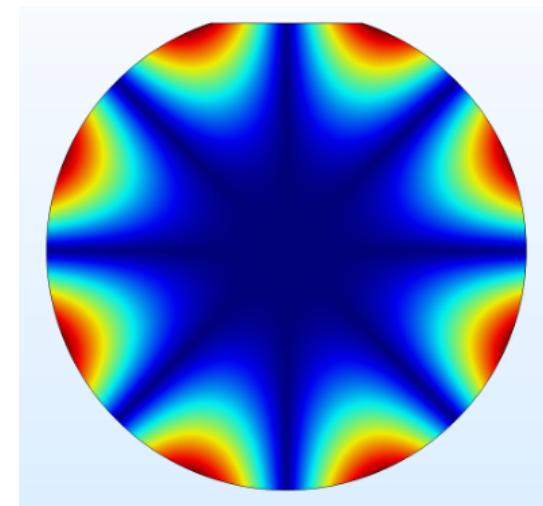
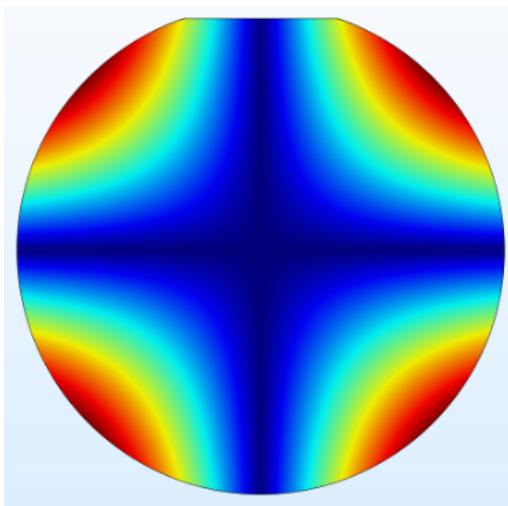
Crystalline films

- Dislocations, twinning



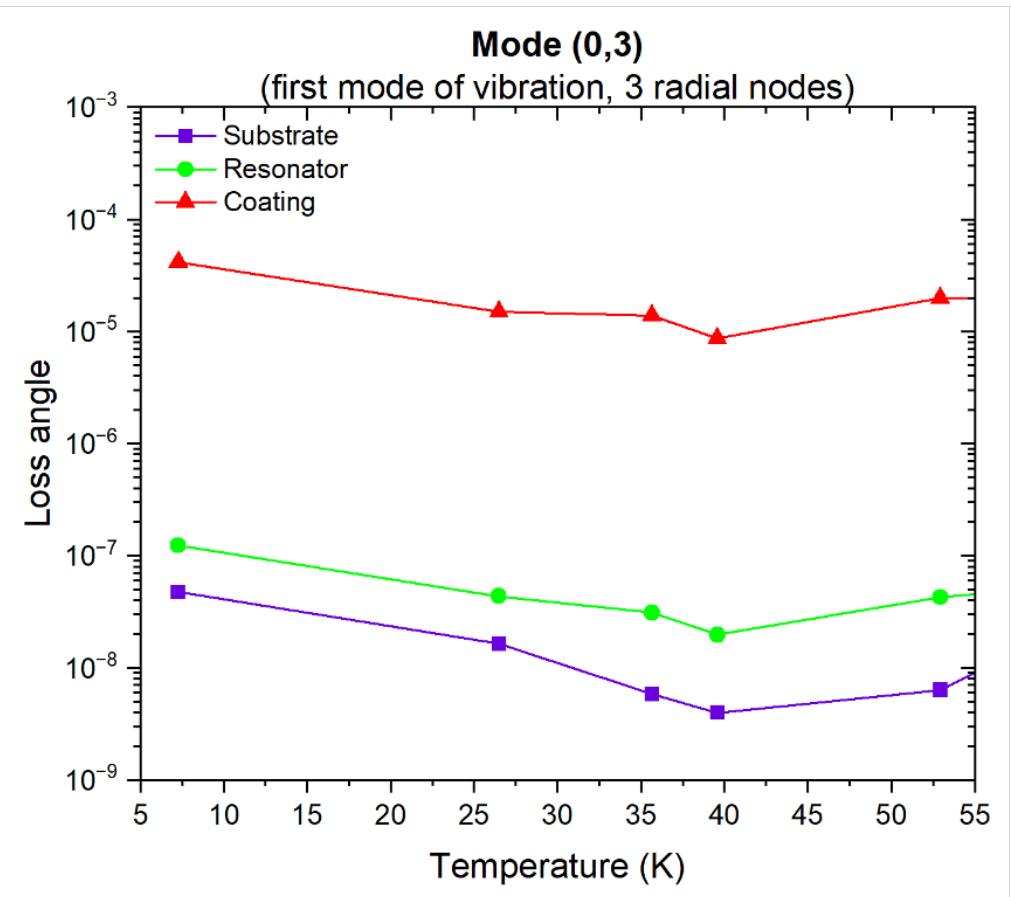
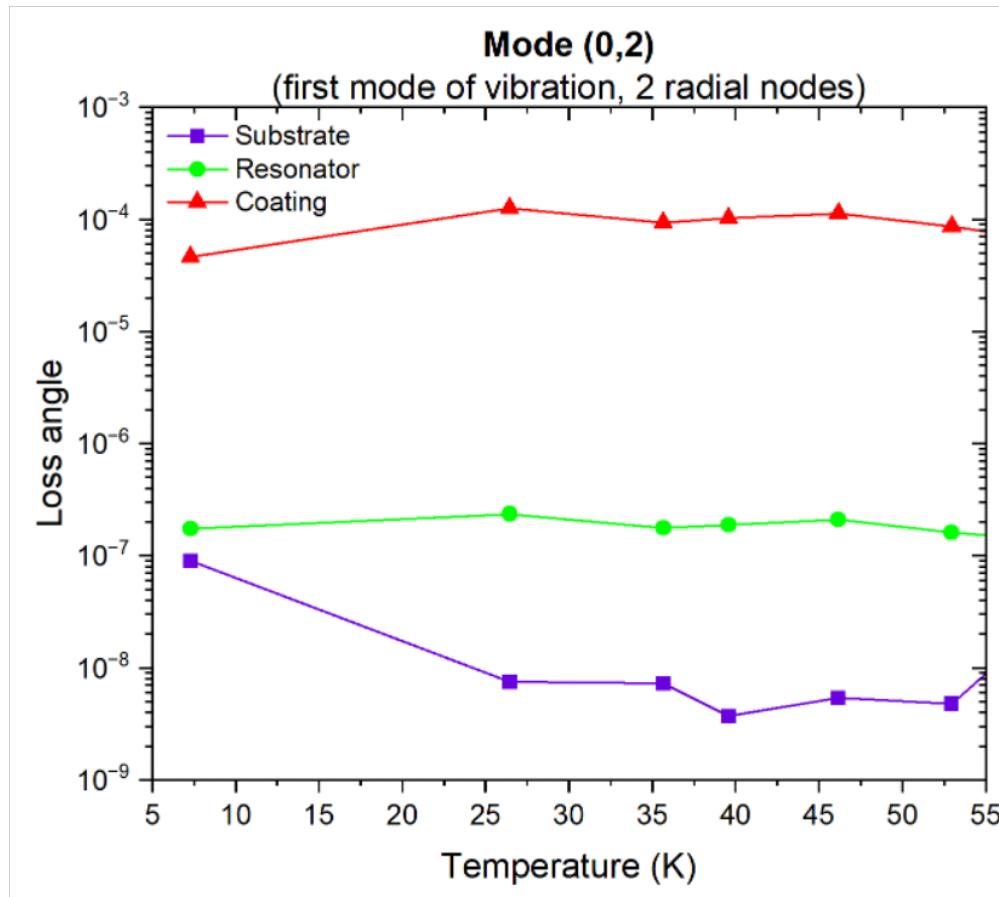
Mechanical losses

- Method: Gentle Nodal Suspension



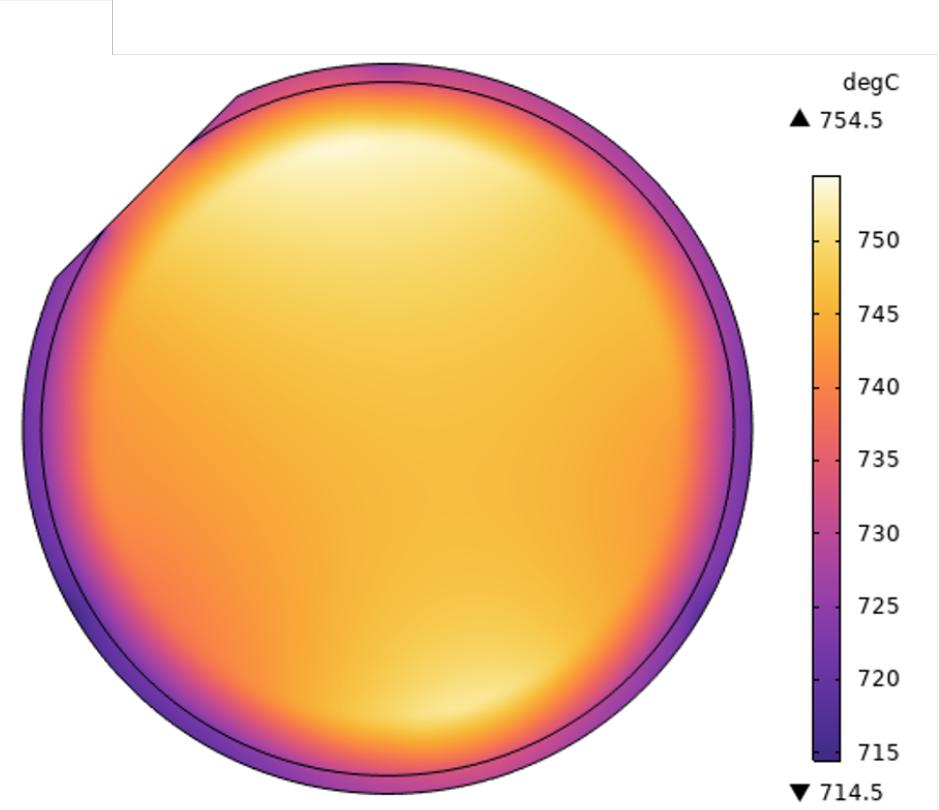
Mechanical losses

- Cr₂O₃/Al₂O₃ (old configuration)



Temperature uniformity

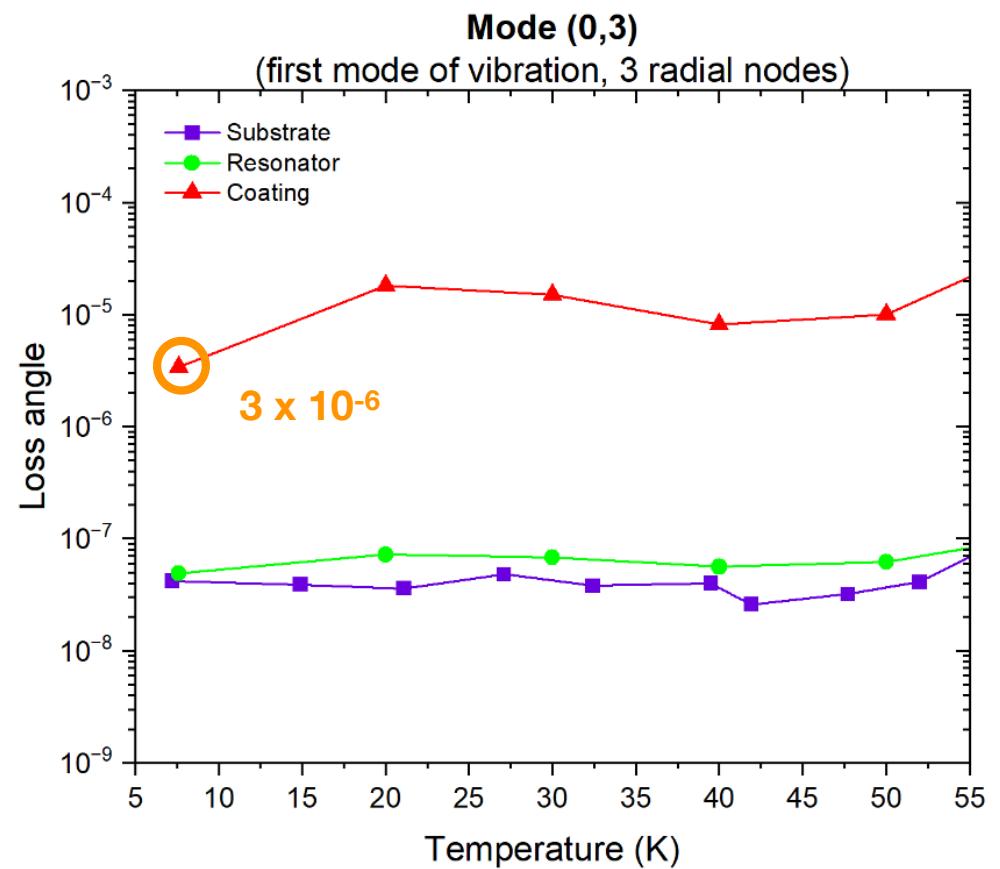
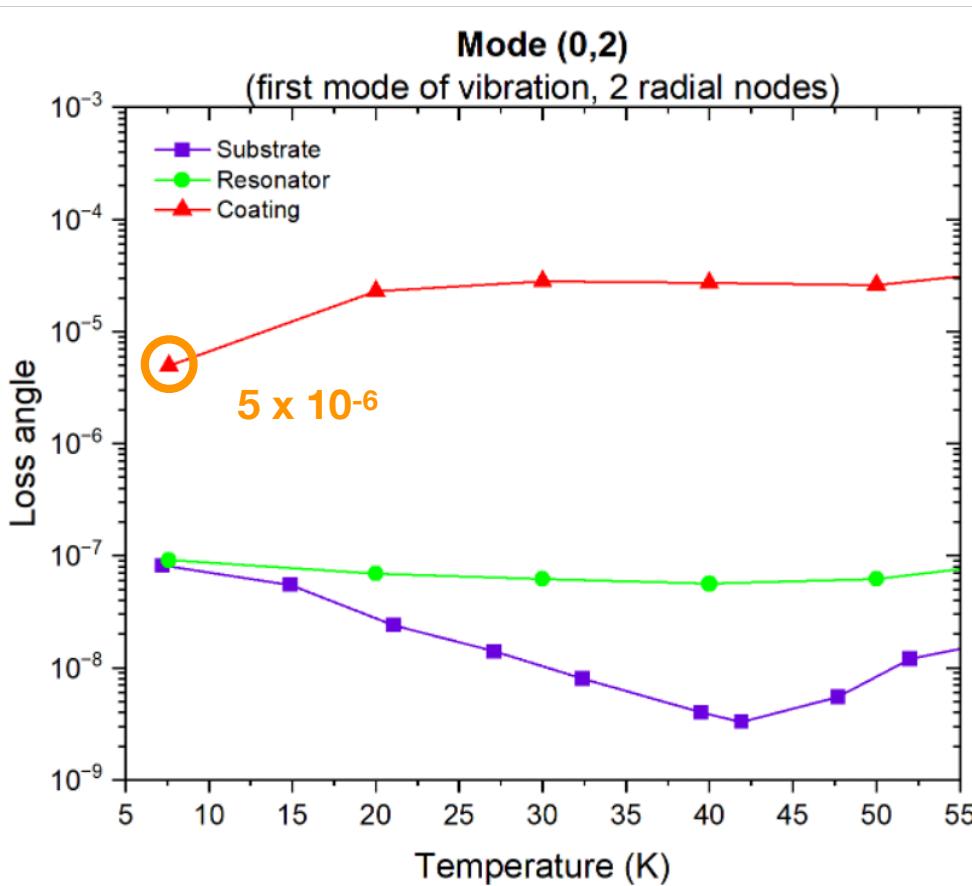
- New design



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

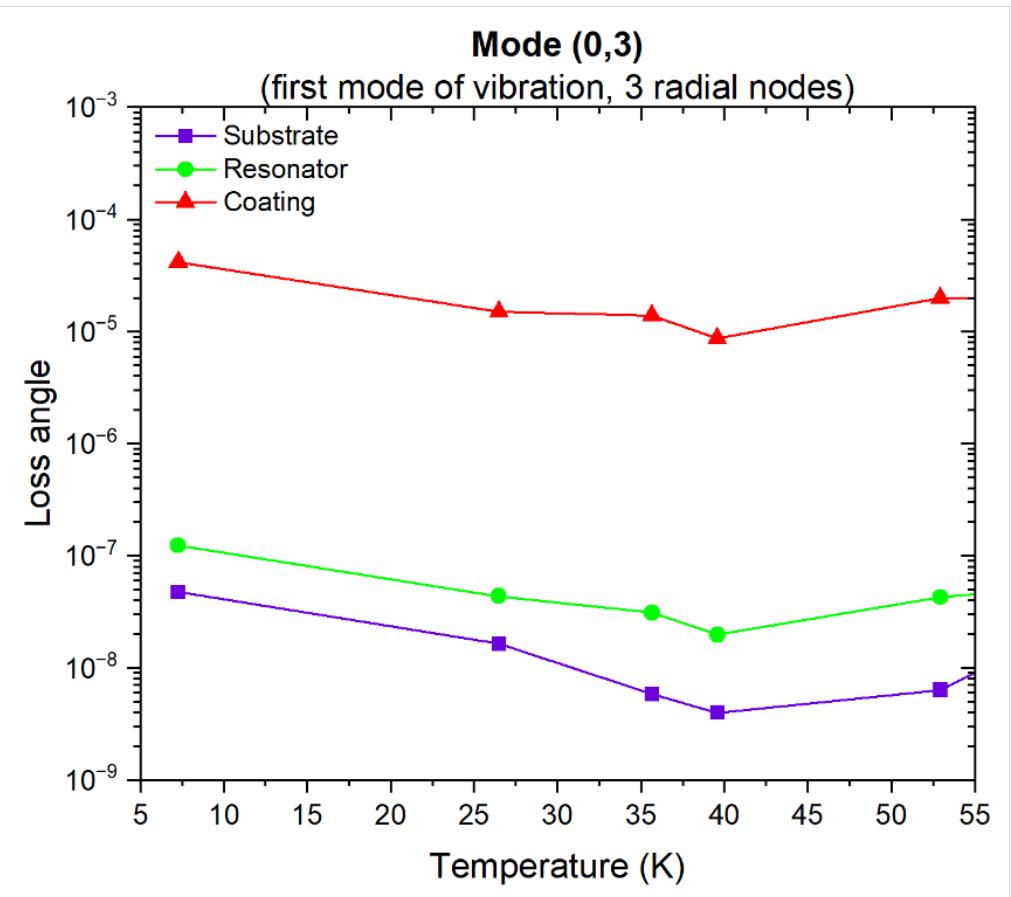
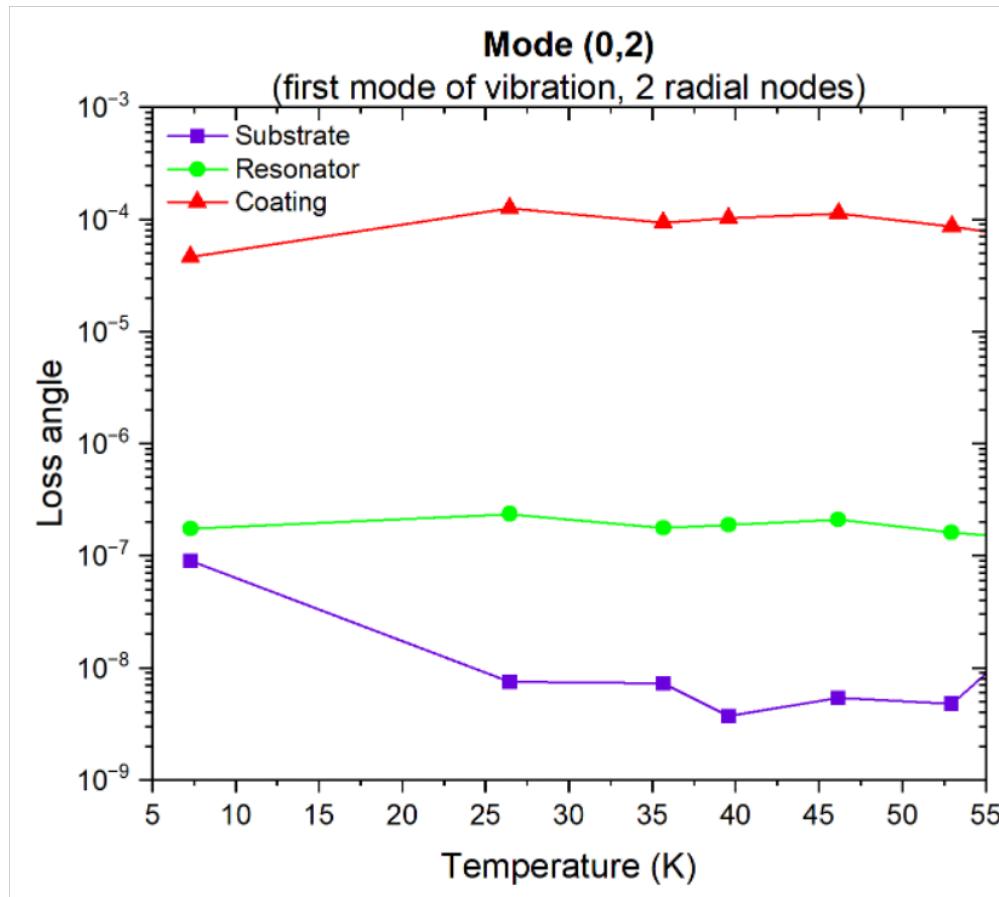
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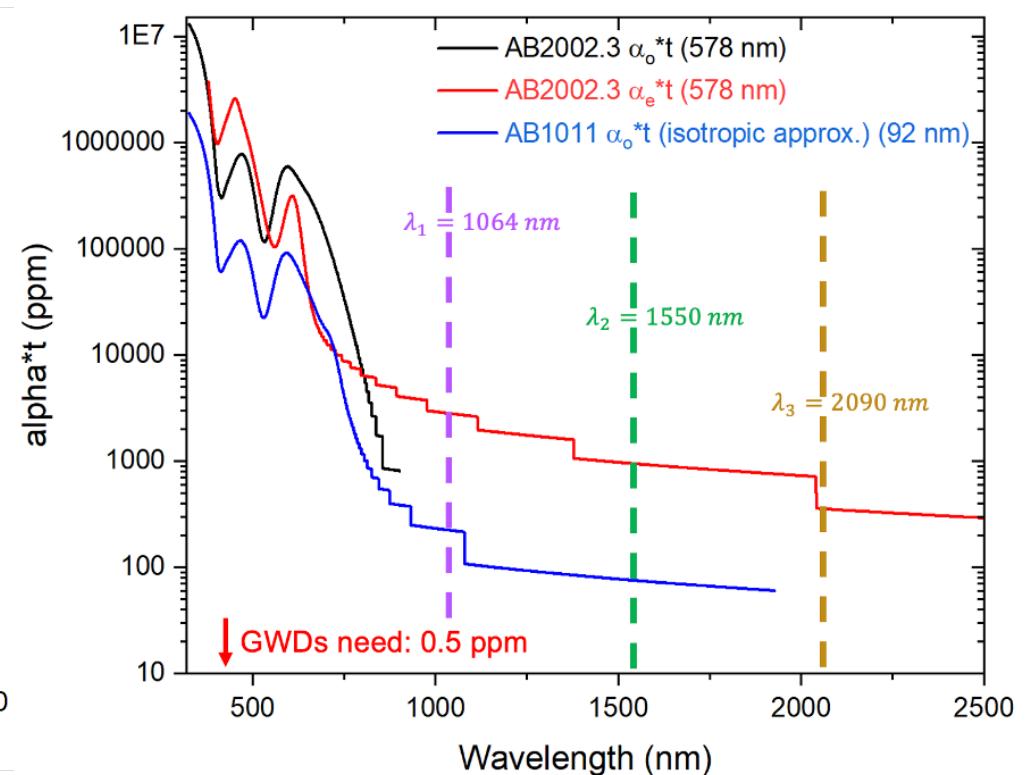
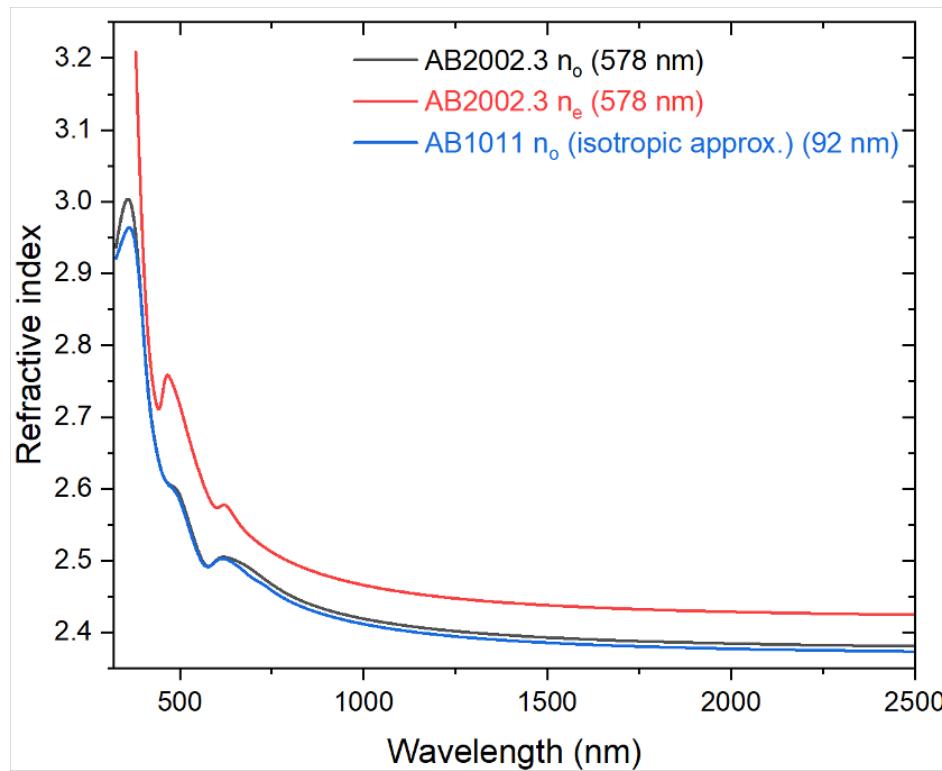
Mechanical losses

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Spectroscopic Ellipsometry

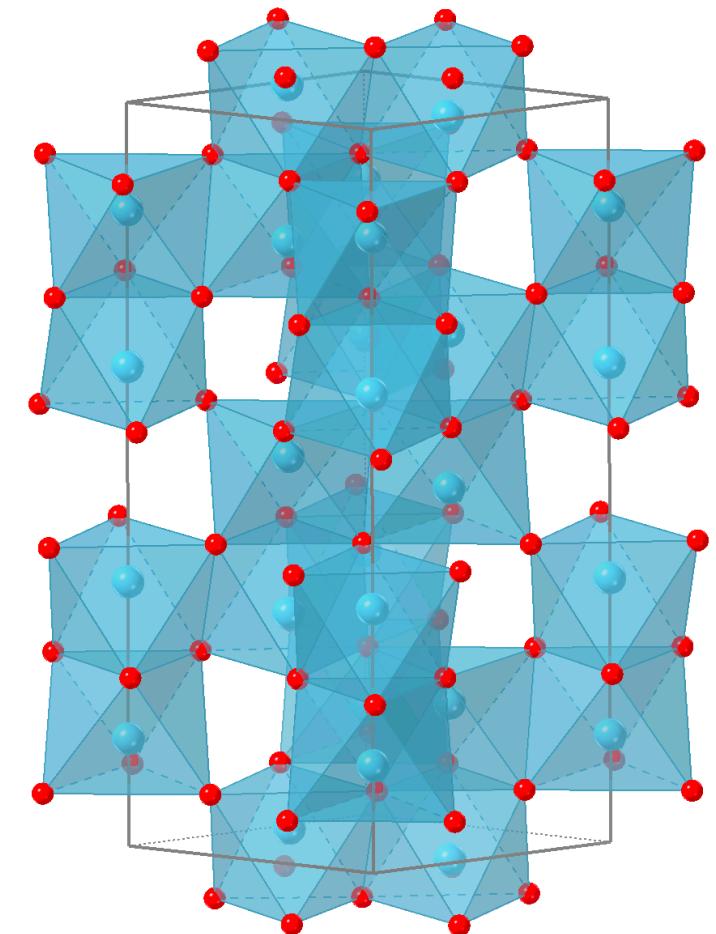
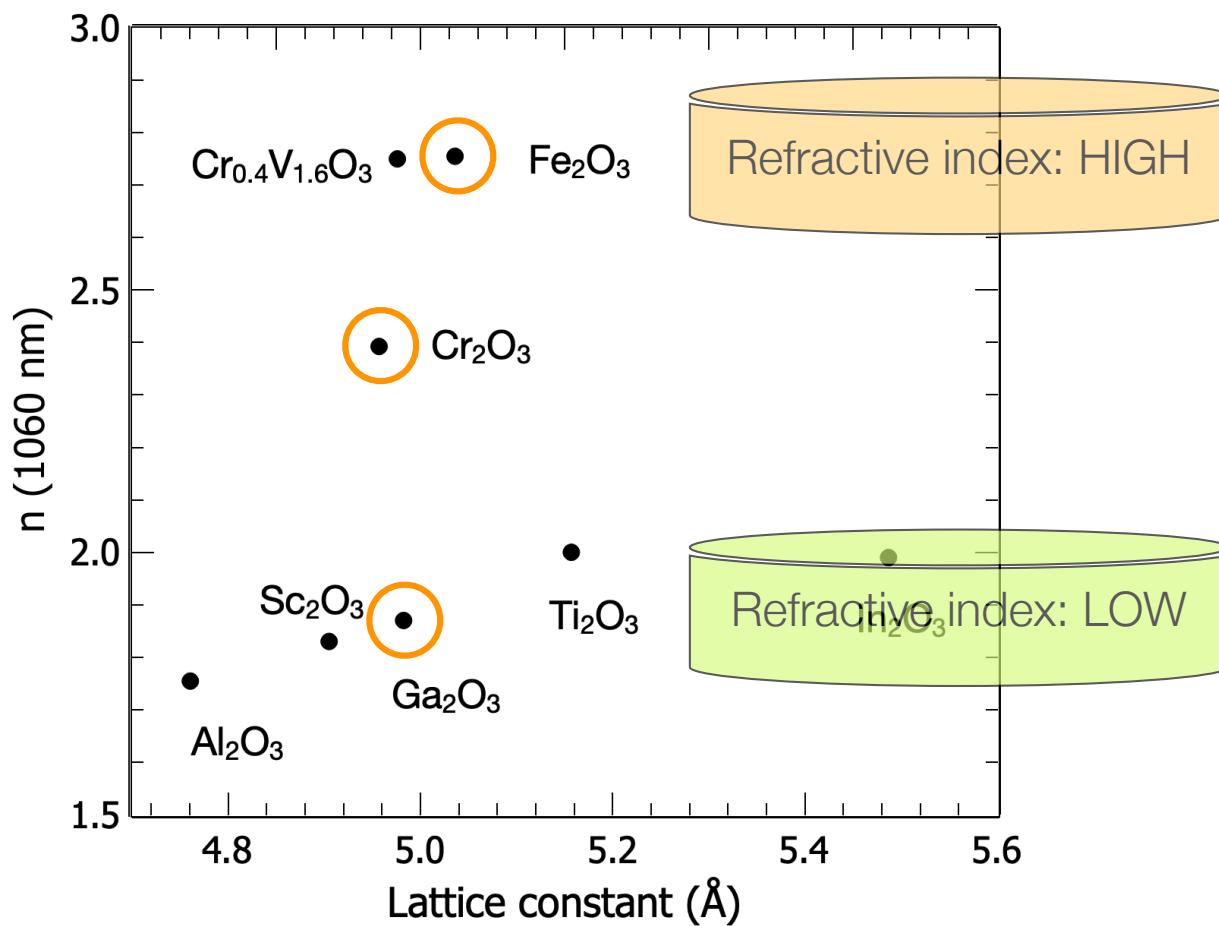
- Cr₂O₃/Al₂O₃



by Sven Peeters

Outlook

Corundum structures



300 mm MBE system



Crystalline Oxide Coatings: tools & process flow

Grow
Anneal

MBE



Strain
Defects
Crystallinity

HR-XRD



Clean
Etch



Defects
Roughness

AFM / FFM



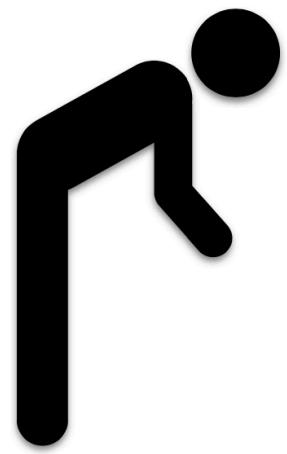
Thickness
Uniformity
Optical
constants



Ellipsometry

Summary

- First experiments on crystalline oxides: Cr₂O₃
- Demonstration of high quality epitaxial growth on 2"
- Low mechanical losses ($3 \cdot 10^{-6}$ @ 7K) despite large amount of dislocations and twin domains
- Optical characterisation (absorption & birefringence)
- Starting work with the 300 mm system



Thank you !