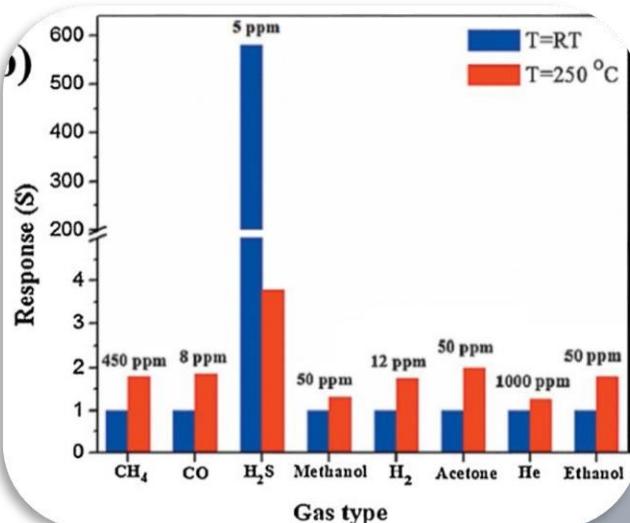


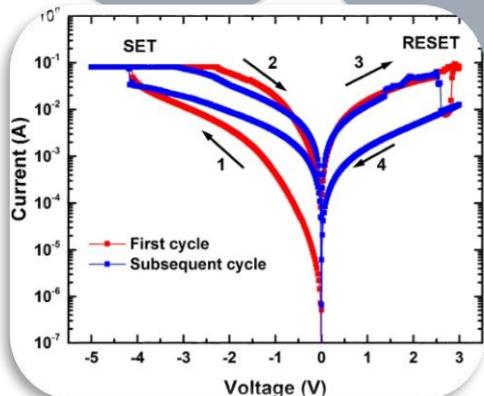
ZnO thin films grown by plasma-enhanced ALD: material properties in and outside the ALD window

Julian Pilz, Alberto Perrotta, Günther Leising, and Anna Maria Coclite
Graz University of Technology
Institute of Solid State Physics

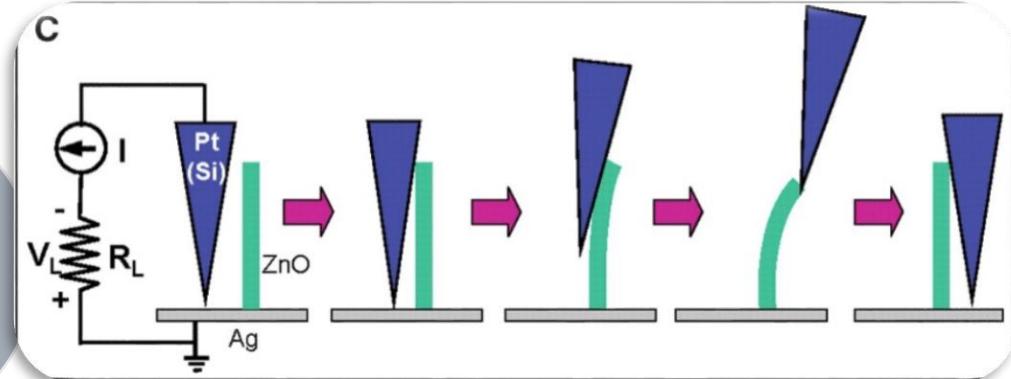
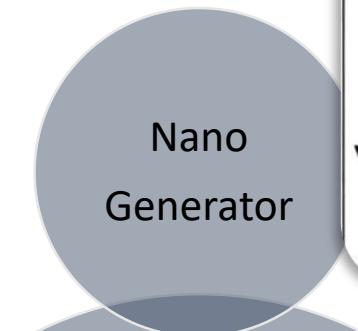
Motivation



Zhu et al., Sensors Actuators A Phys. 267, 242 (2017)



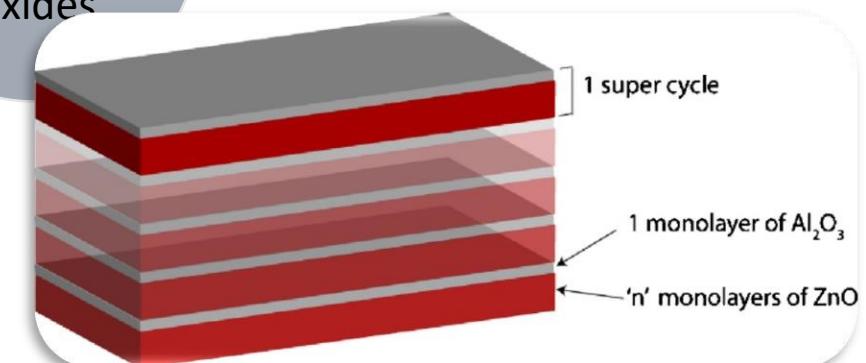
Huang et al., Microelectron. Eng. 161, 7 (2016).



Z.L. Wang, Science. 312, 242 (2006)

ZnO

Memory

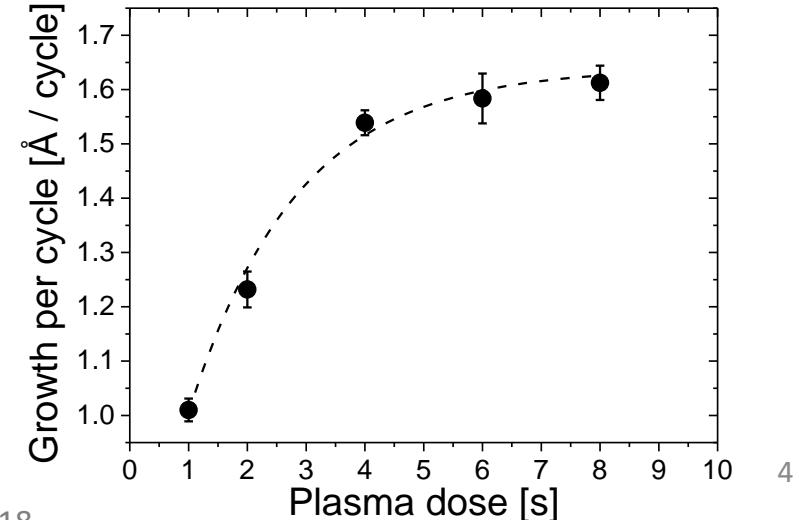
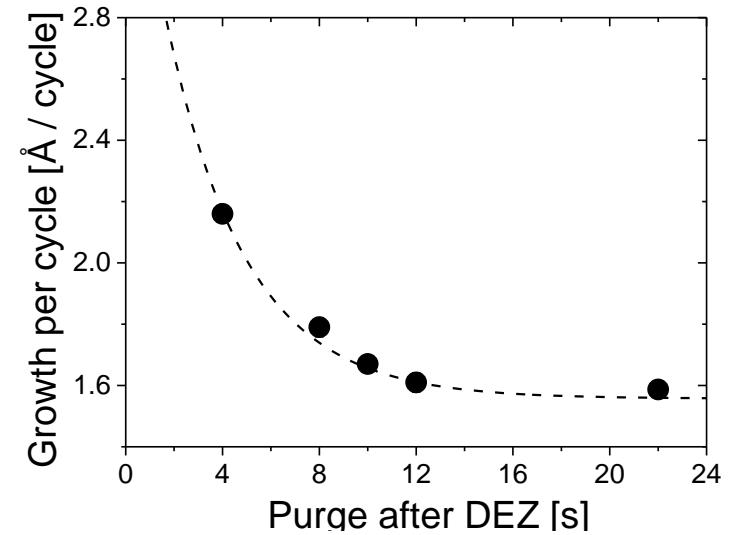
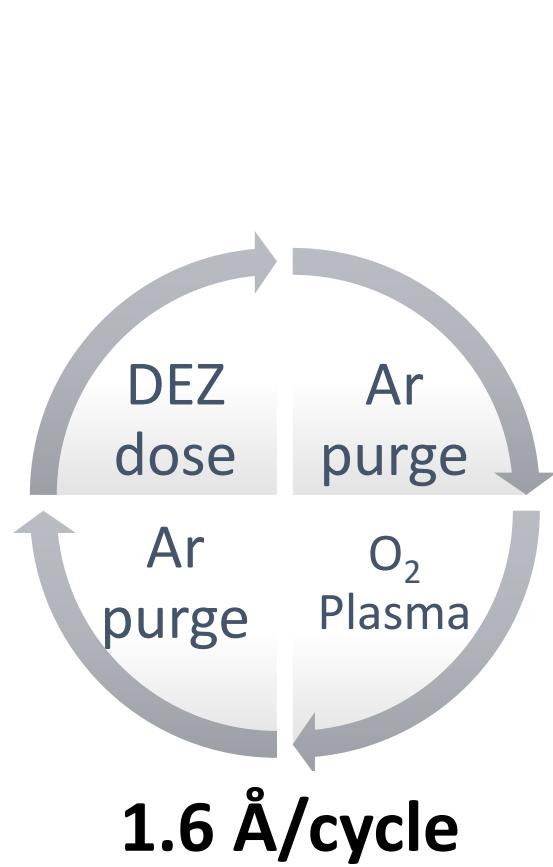
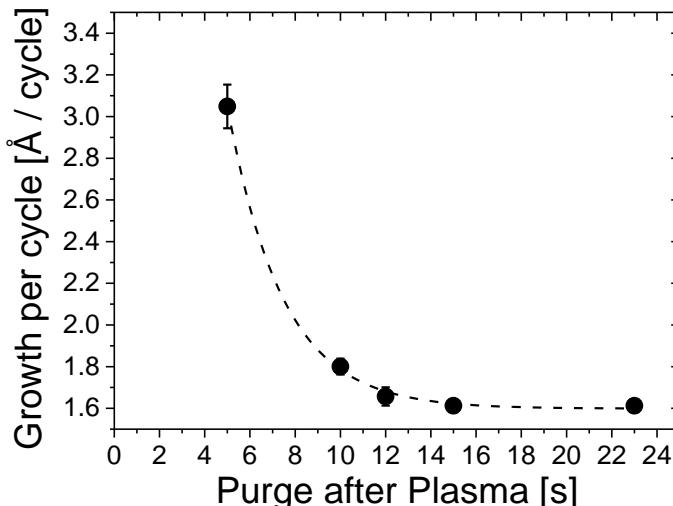
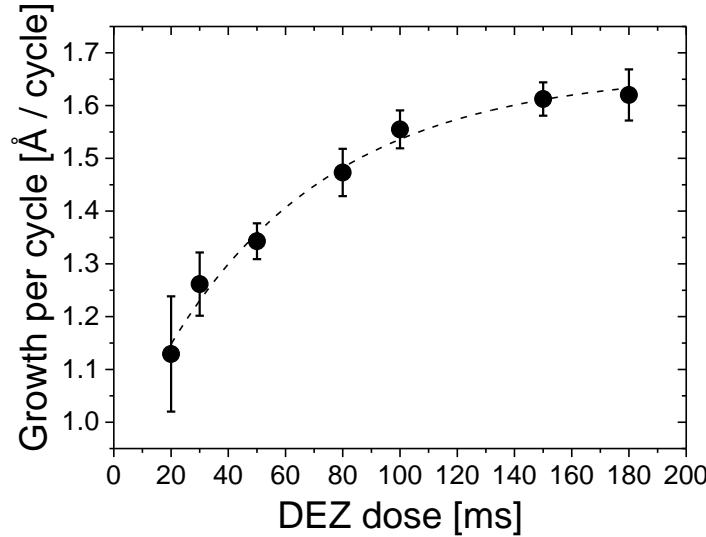


Banerjee et al., J. Appl. Phys. 108, 43504 (2010)

Outlook

- Plasma-enhanced atomic layer deposition
- Effect of substrate temperature on
 - Growth per cycle
 - Crystalline properties
 - Optical properties
 - Sheet resistivity
- Conclusions

Saturation at room temperature



Experiment

- Thickness around 30 nm
- Recipe: 8 s O₂ Plasma / 15 s Ar Purge / 0.15 s DEZ dose / 22 s Ar Purge

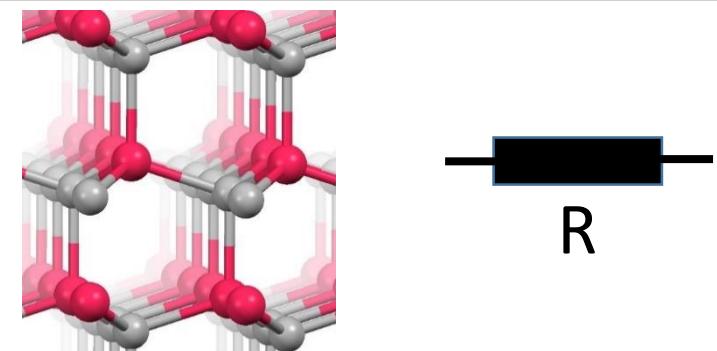
Si(100) with
native oxide

Spectroscopic
ellipsometry



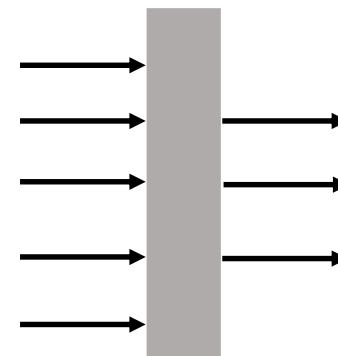
Cover glass

X-ray diffraction
4-point probing

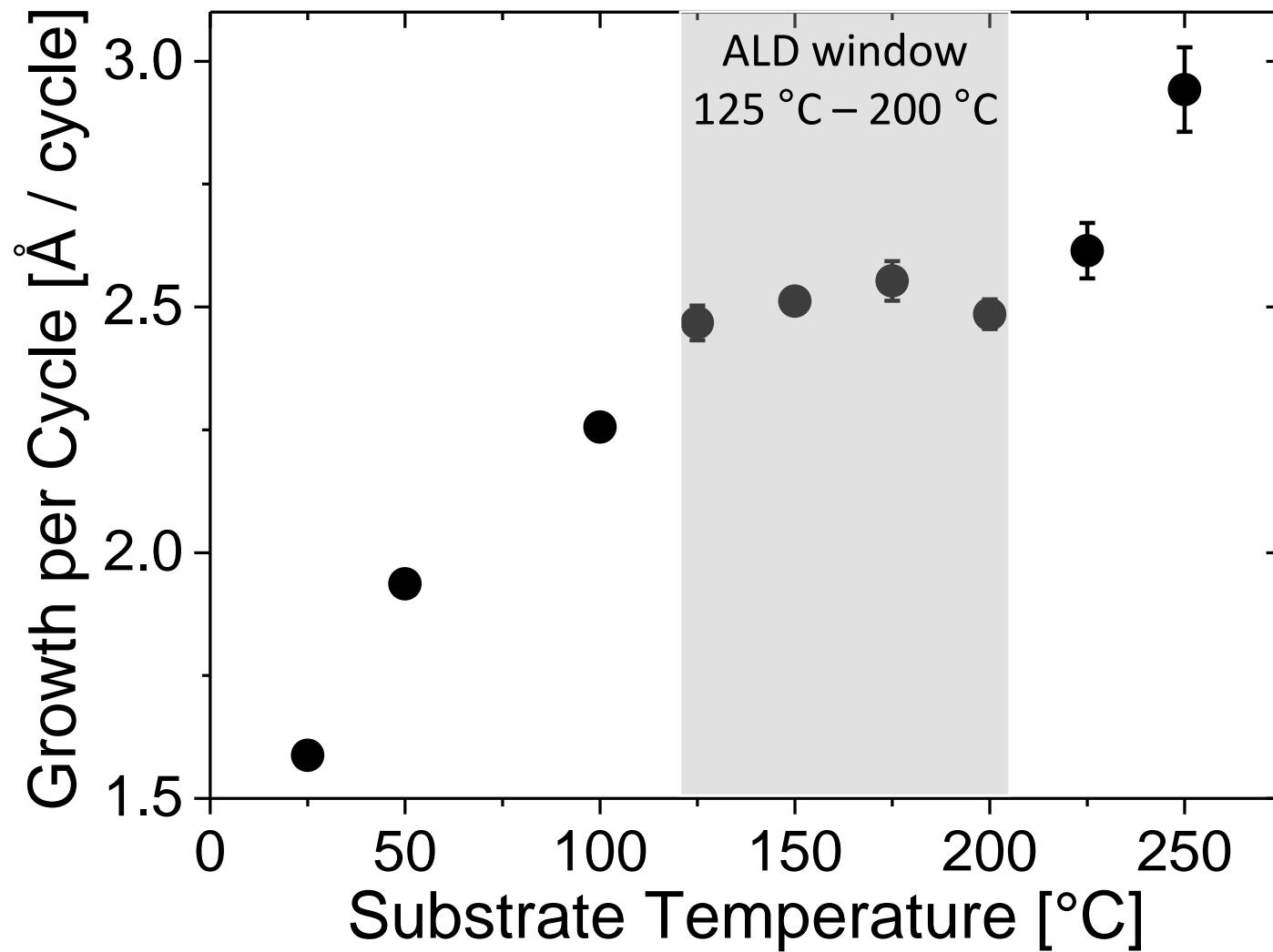


Quartz

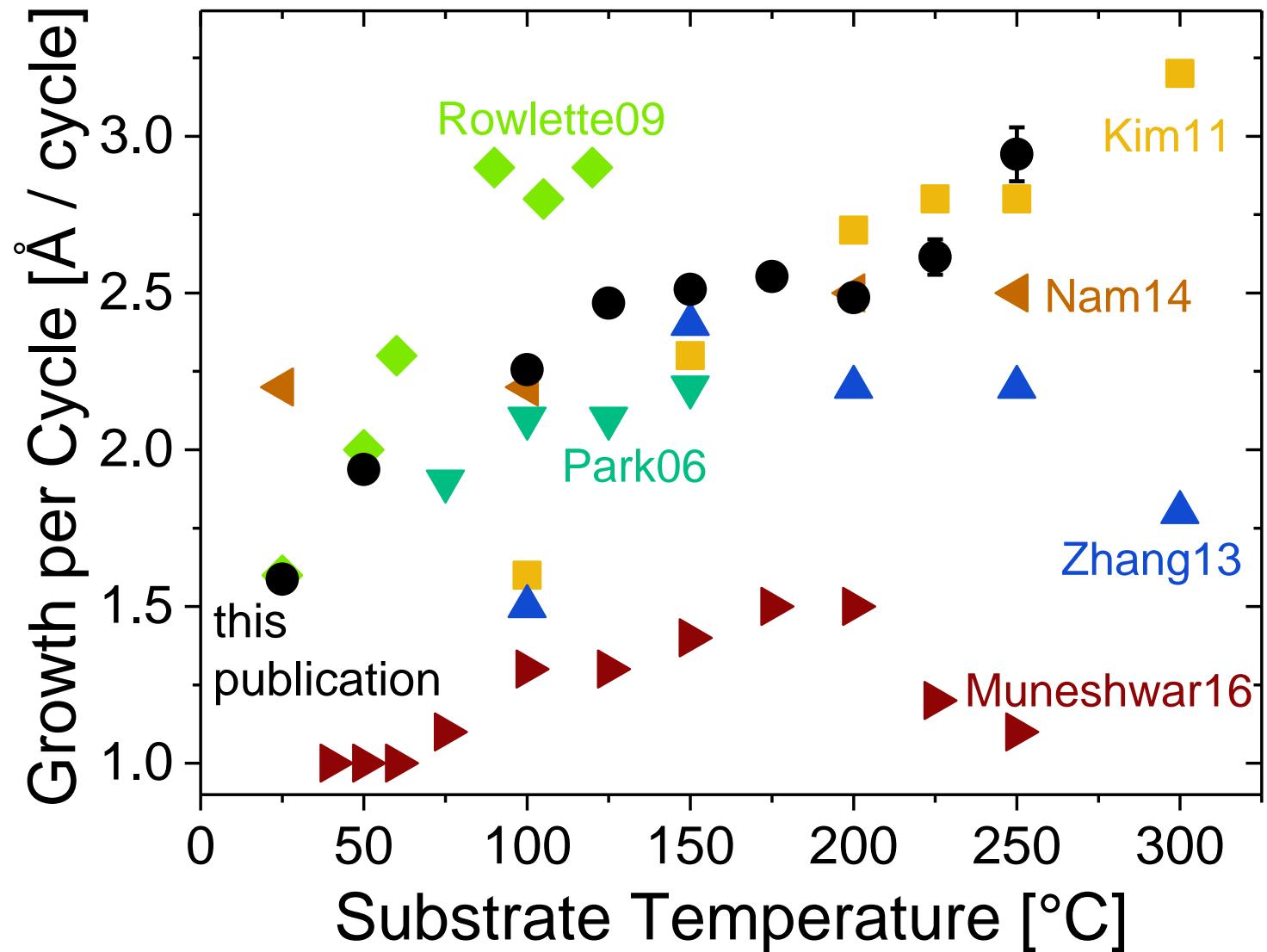
UV-Vis spectroscopy



Growth per cycle

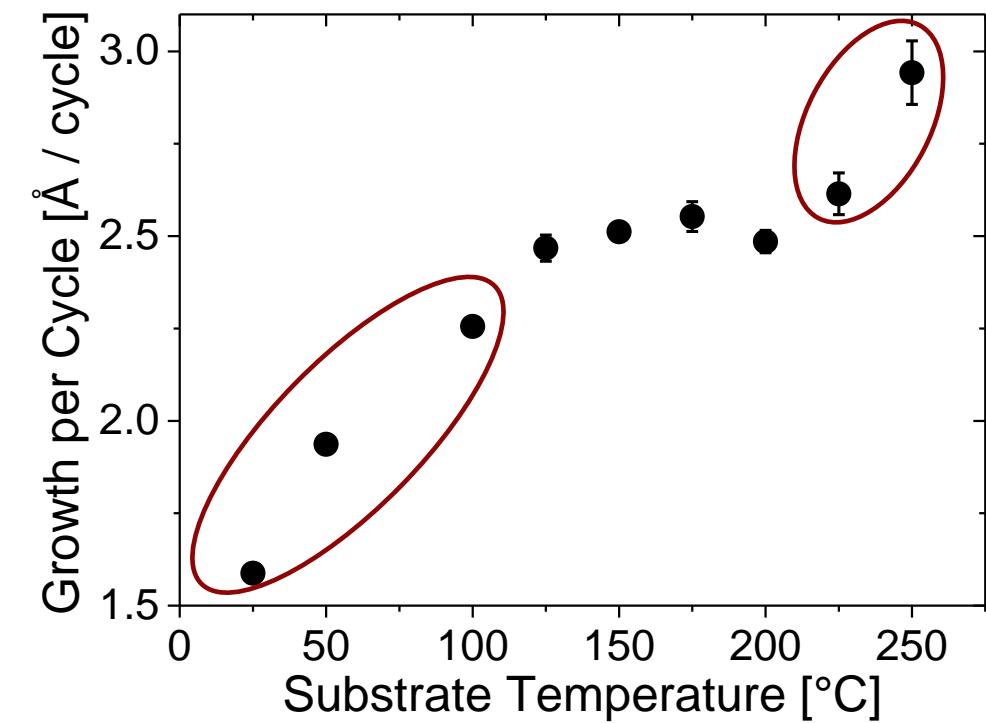
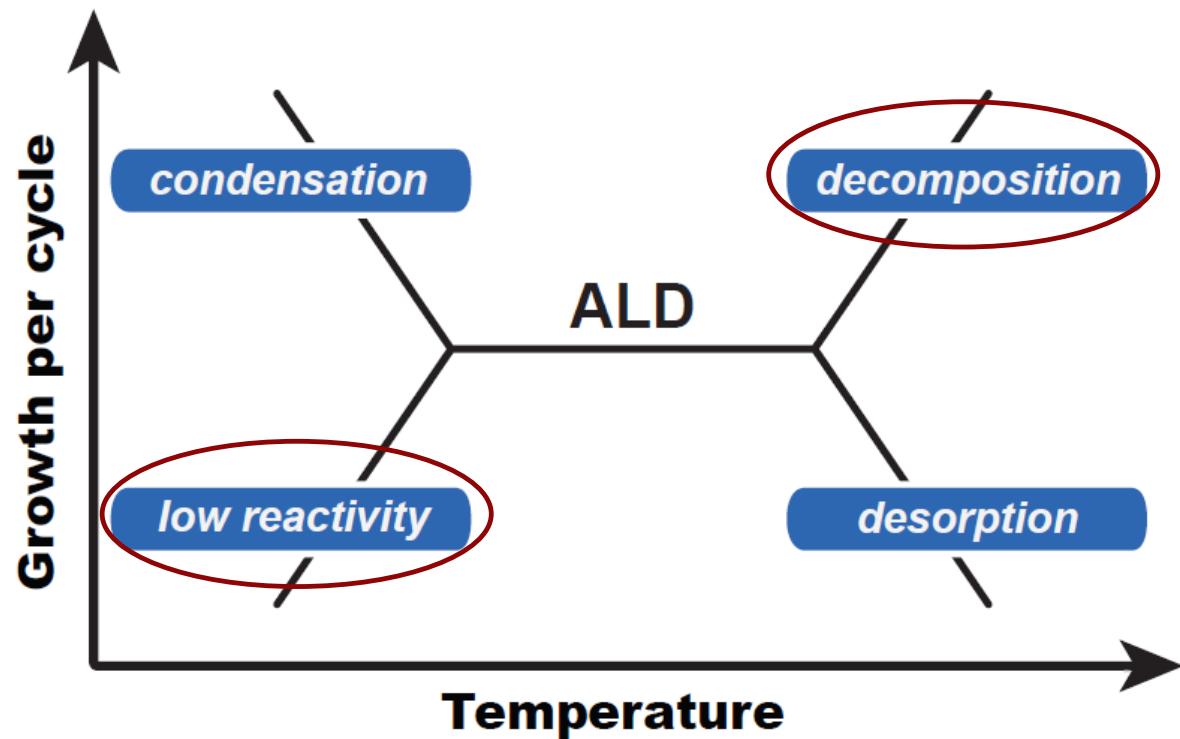


GPC in literature



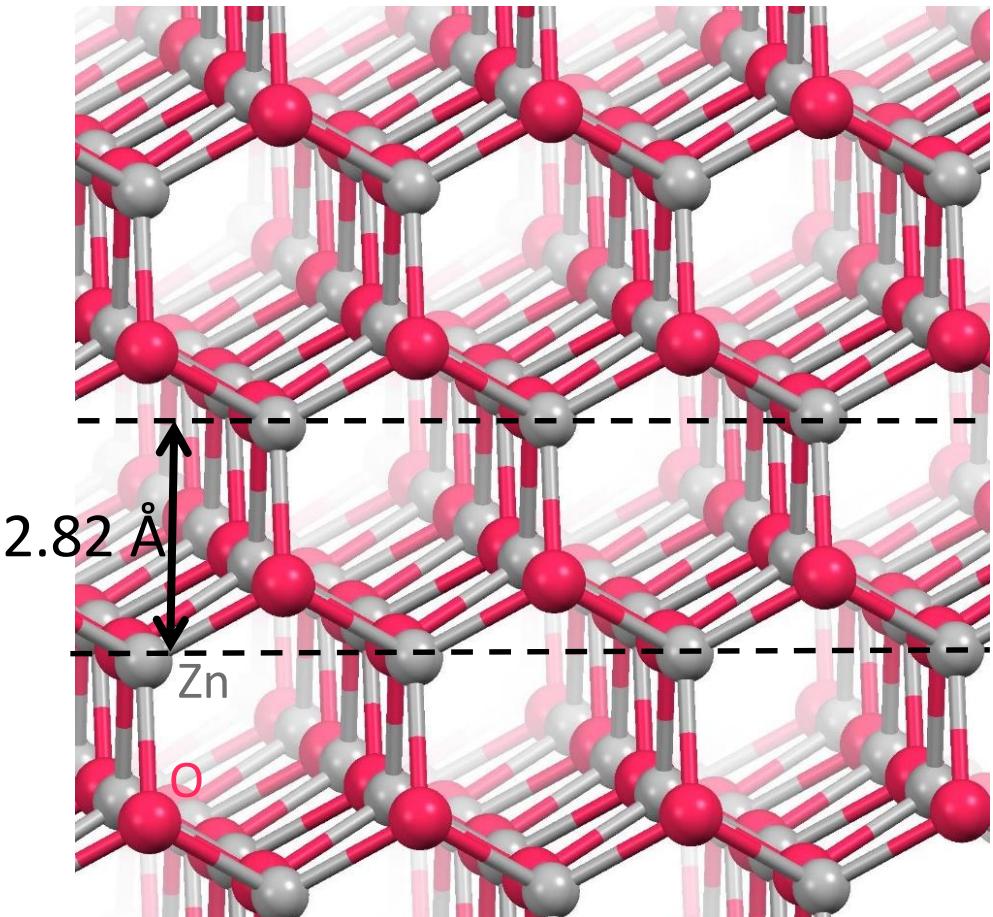
- What is the reason behind the temperature dependence?
 - How do ZnO properties change?

GPC model

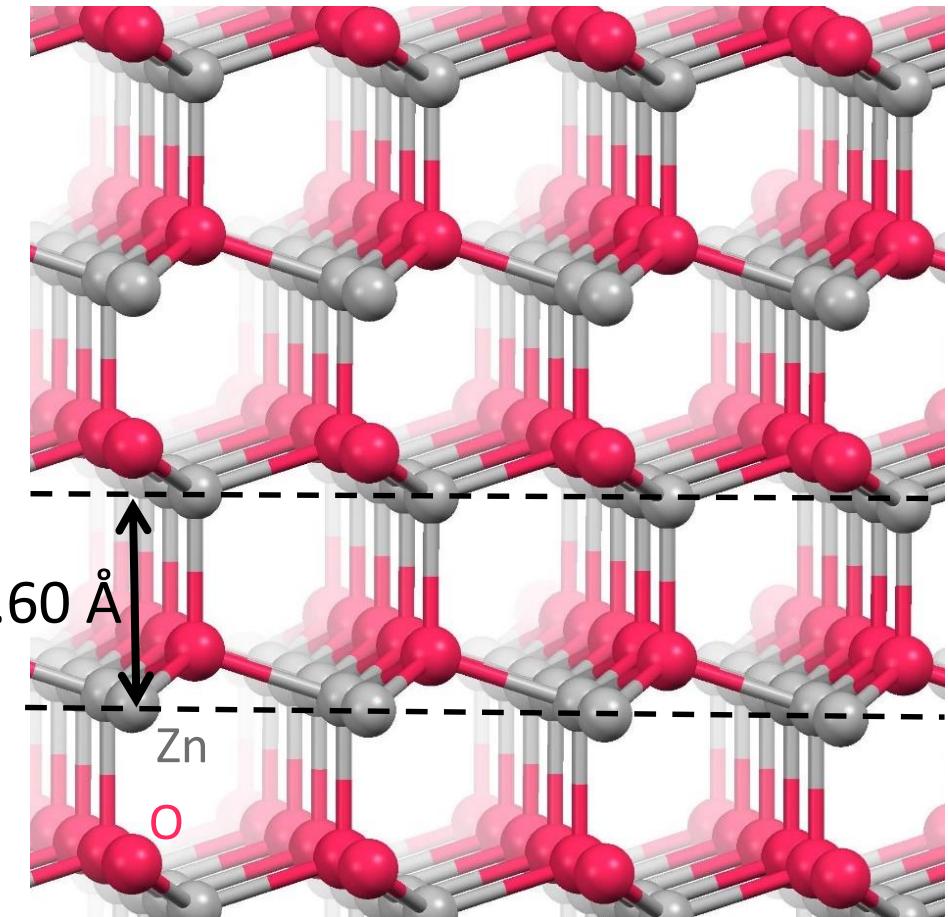


Monolayer

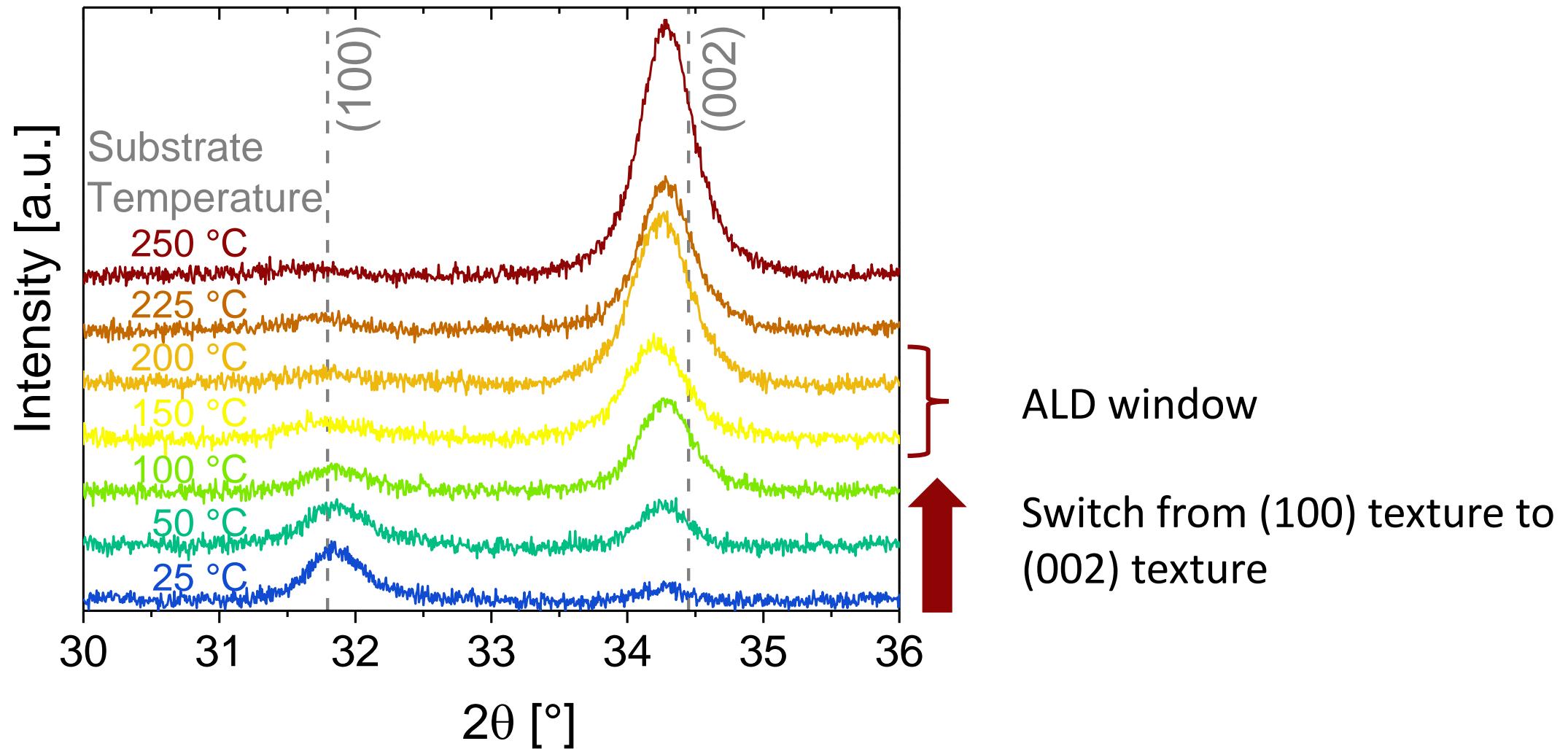
(100)



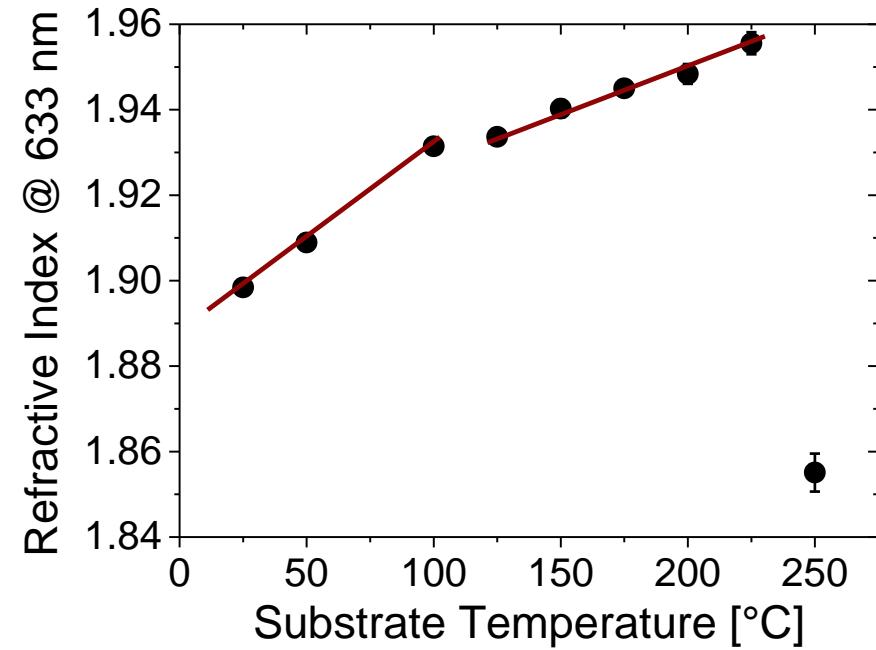
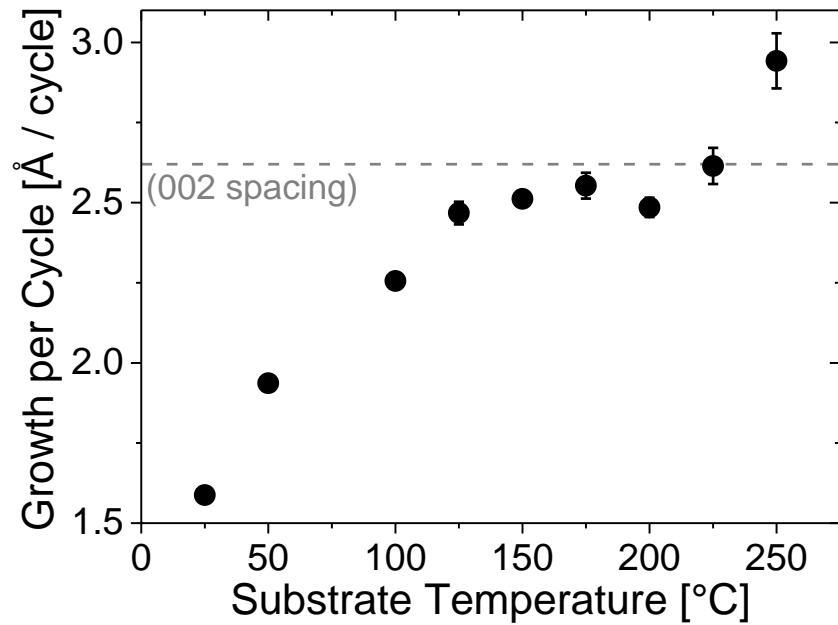
(002)



Crystalline properties

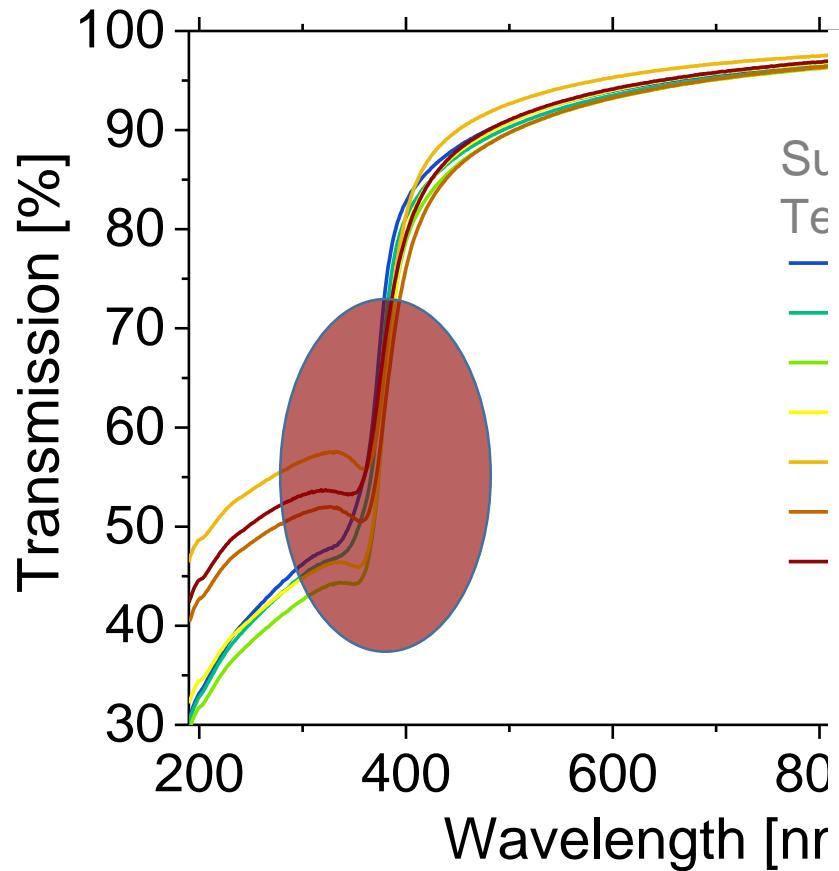


Temperature dependent growth

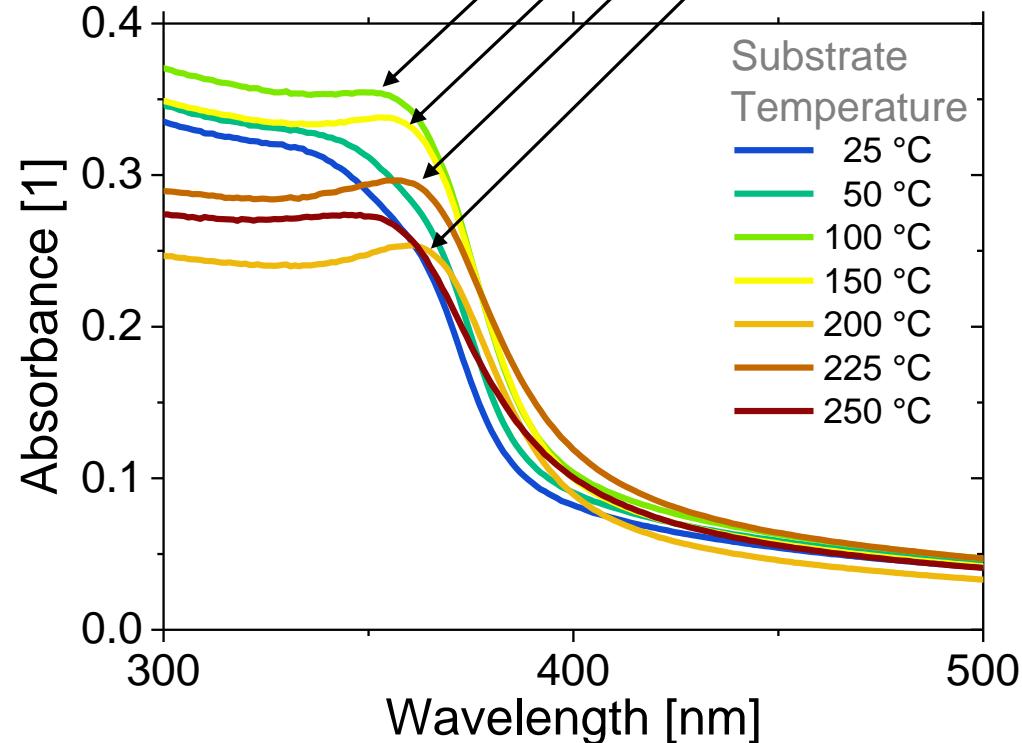


- GPC
 - Saturates within ALD window close to (002) spacing
 - Increases rapidly above ALD window
- Refractive index
 - Two slopes before and within ALD window
 - Rapid drop above ALD window

Transmission

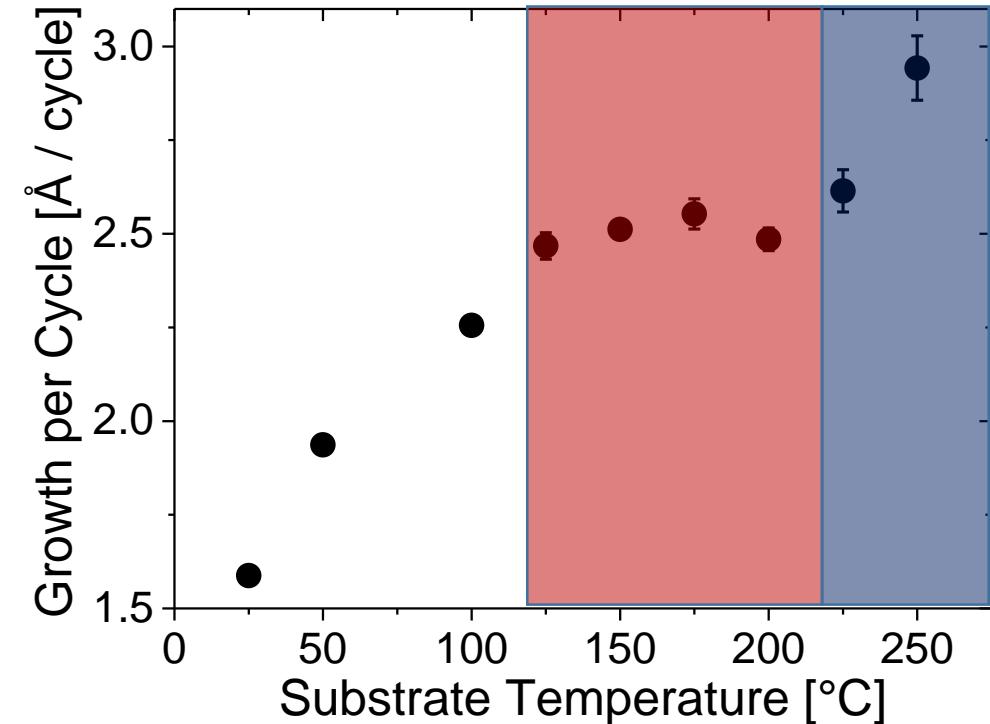
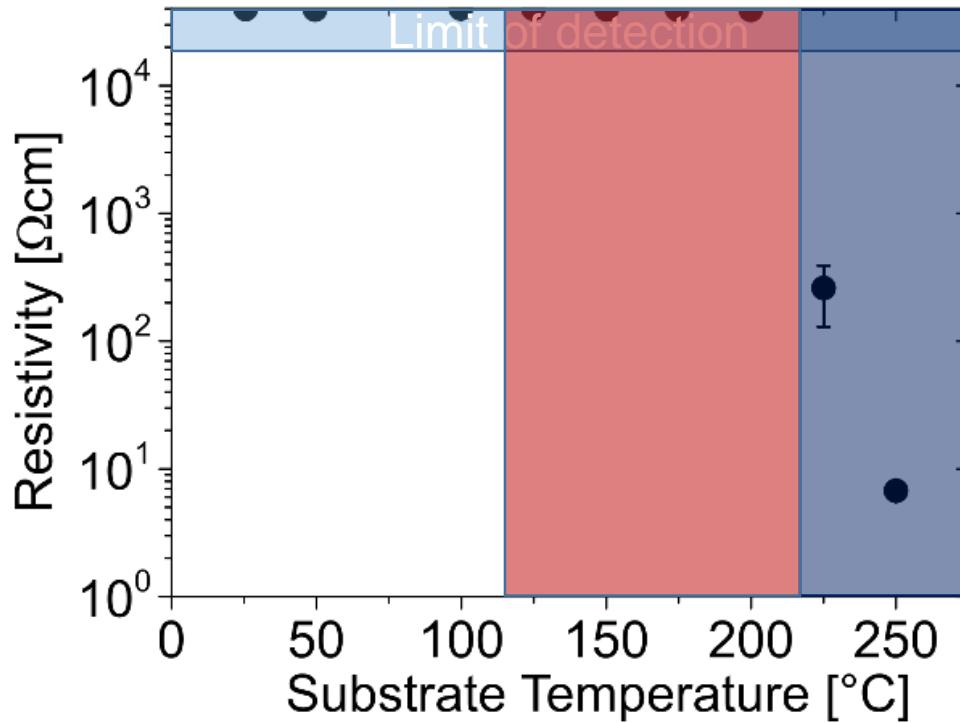


Excitonic absorption:
Basis for Laser applications



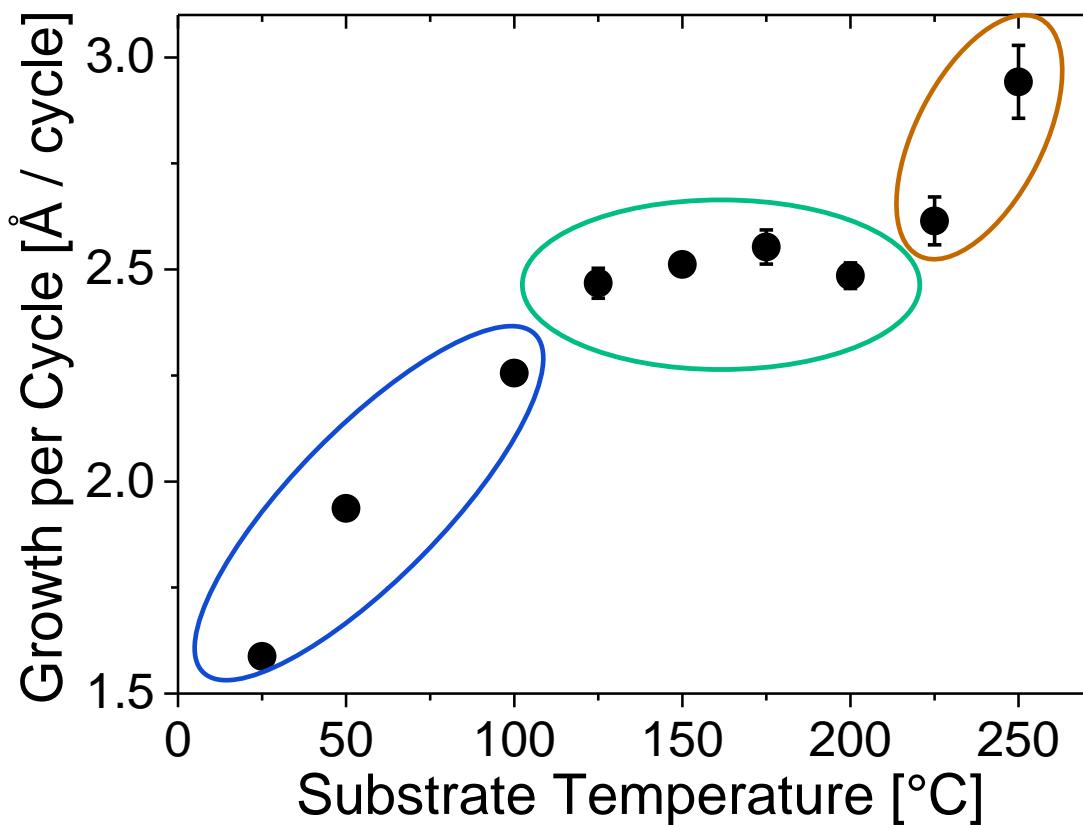
- High transparency over most of visible light range
- Excitonic absorption for samples prepared within ALD window

Sheet resistivity



- (002) texture + high resistivity: piezoelectric devices
- Lower resistivity: potential for transparent conductive films

Conclusions



- **XRD:** first (100) then (002)
- **SE:** n increases
- **4PP:** High resistivity

- **XRD:** (002)
- **SE:** n slowly increases
- **UV-Vis:** excitonic absorption
- **4PP:** High resistivity

Pilz et al.,
Physica Status
Solidi (a),
under review

- **XRD:** (002)
- **SE:** CVD component in GPC, rapid drop of n
- **4PP:** Rapid drop of resistivity



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Alberto Perrotta
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