In situ X-ray studies of the early stage of ZnO Atomic Layer Deposition on InGaAs

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Grenoble INP

Collaborators

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Leti, technology research institute, Grenoble (France)

Funders:

MINOS Labex

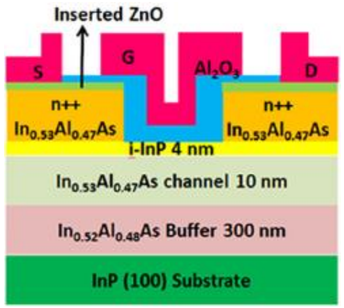
ANR

nanoSCIENCES FONDATION

Communauté UNIVERSITÉ Grenoble Alpes

Talk outline

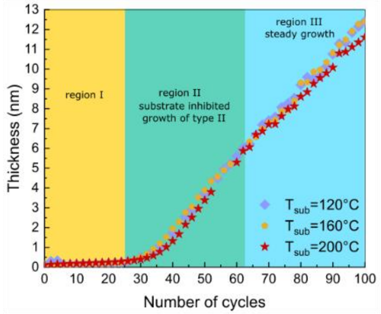
Motivation: ZnO for MIS junctions, IPL



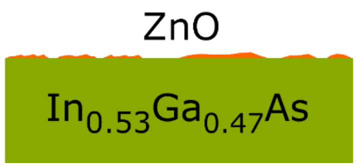
MOON reactor for *in situ* ZnO ALD analysis

ZnO ALD early stages on $In_{0.53}Ga_{0.47}As$

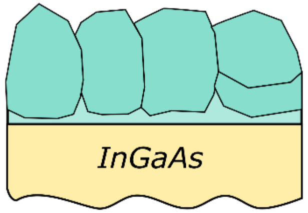
Substrate temperature effect



Transient region

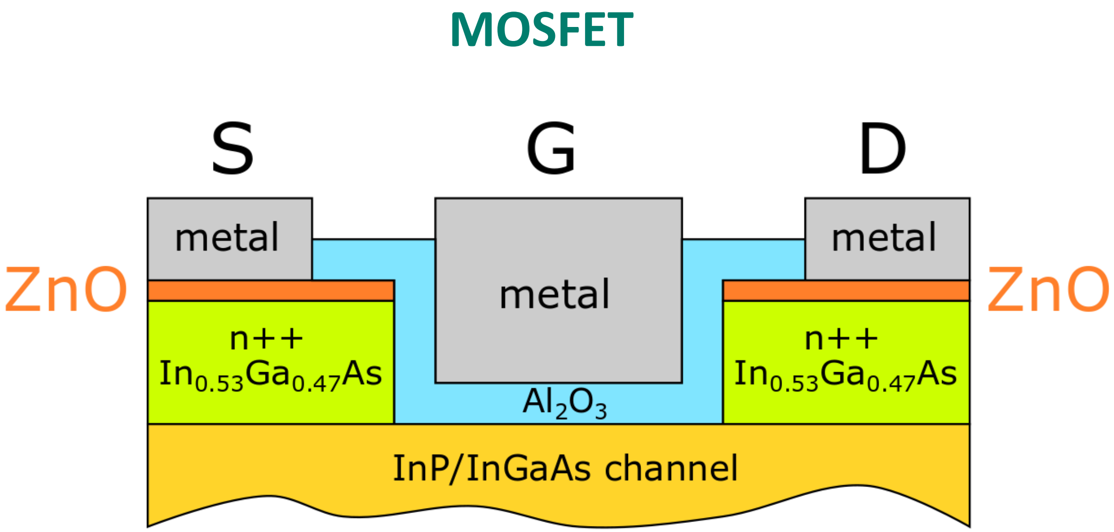


ZnO cristallisation

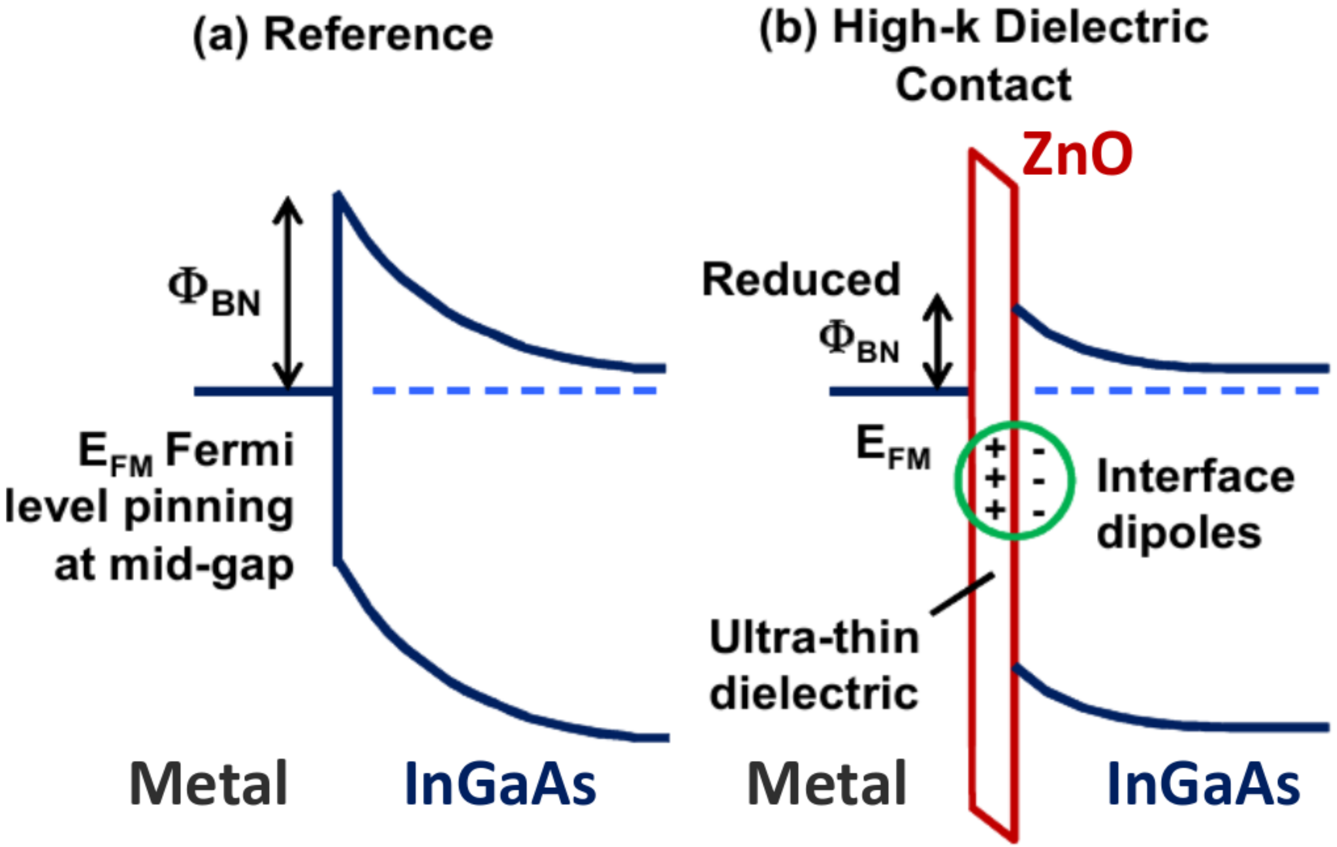


Conclusion

Source/Drain specific contact resistivity



ZnO to reduce source/drain specific contact resistivity

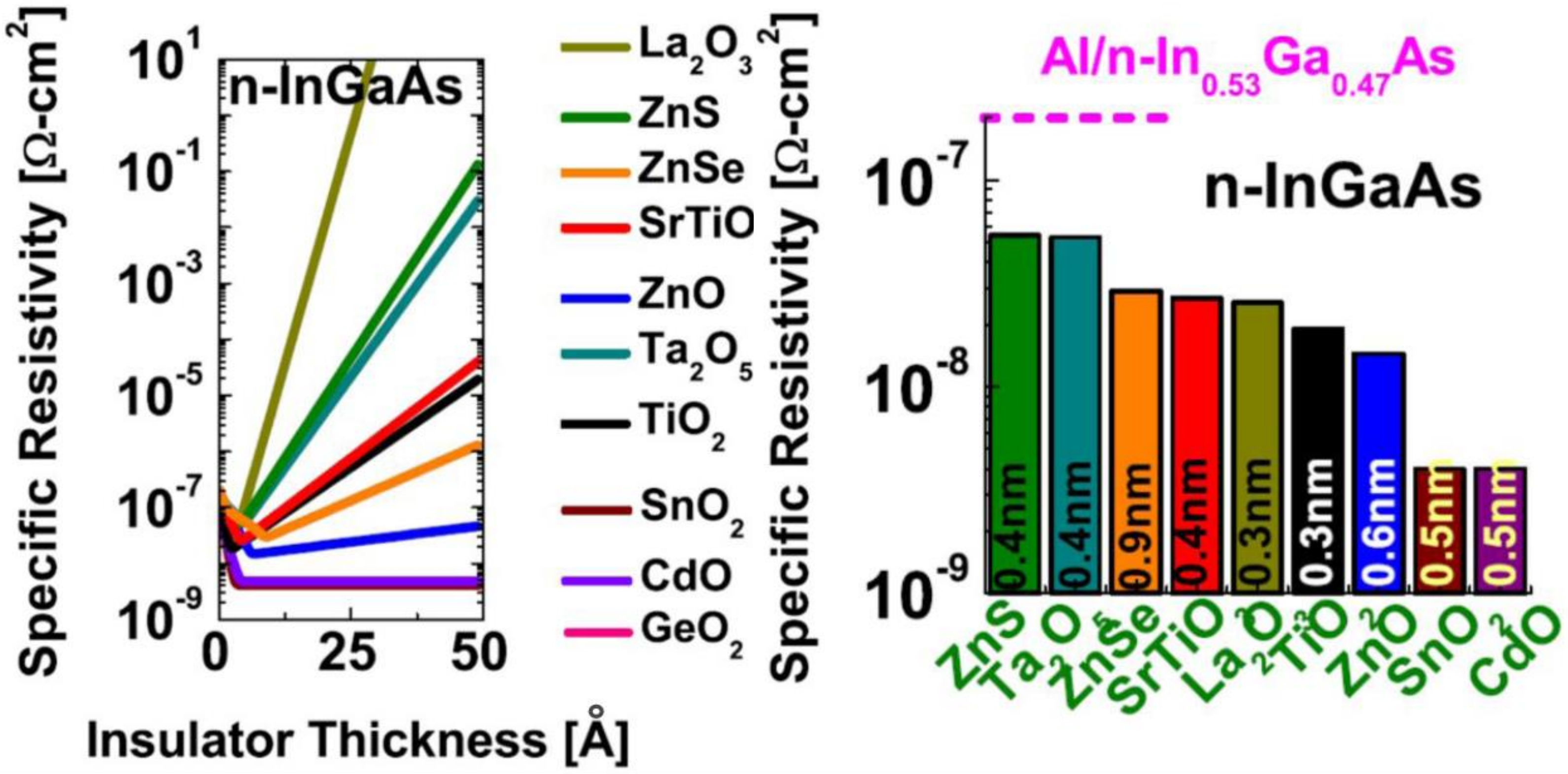


Liao et al., Appl. Phys. Lett. 103, 072102 (2013)
Ang et al., IEDM (2012) 18.6.1

Optimal ZnO thickness

Al/Insulator/n-InGaAs

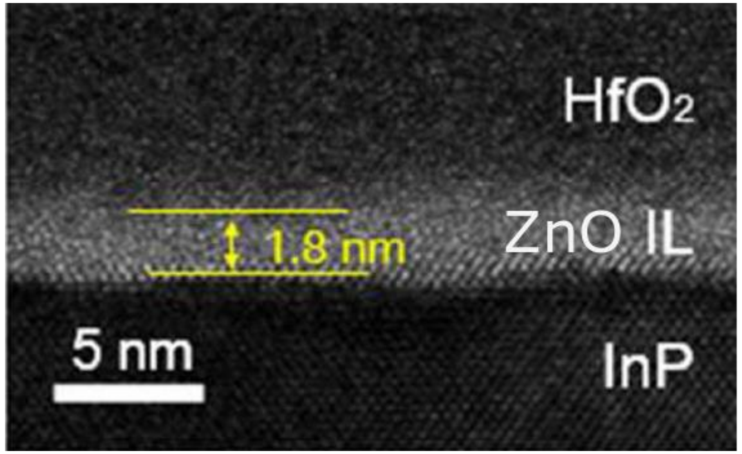
Optimal thickness



calculations

A. Agrawal et al. APL 101 042108 (2012)

ZnO interfacial passivation layer (IPL)



- ✓ suppresses film crystallization
- ✓ reduces interface state density

S.H. Kim et al. ACS App. Mat. & Int. 8.32 (2016)

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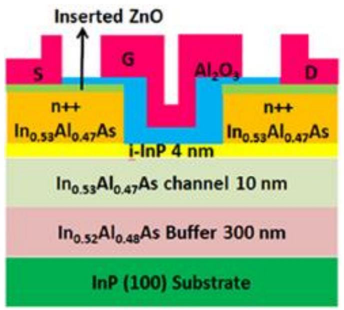

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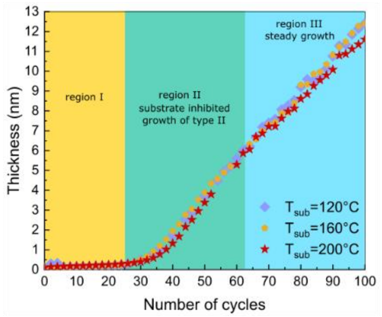

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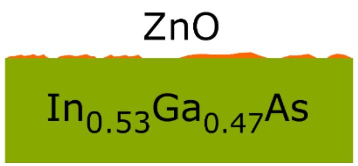

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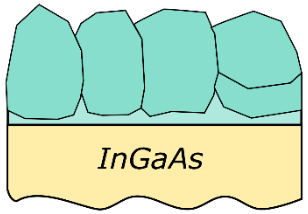


Conclusion

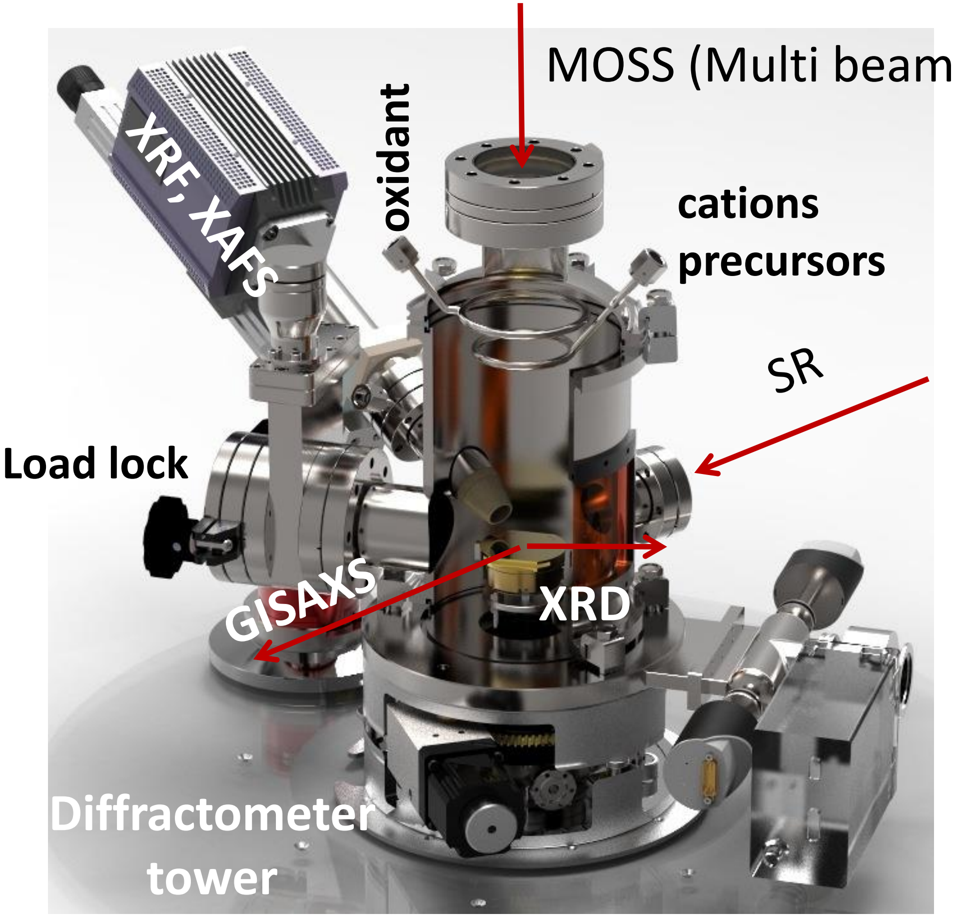
In situ growth study of ZnO ALD

Thermal ALD

Allows:

✓pressures from atmosphere to vacuum
✓ Thermal ALD: temperatures from room to 800°C

✓ Counter-rotating flange



Designed and built under the guidance of D. De Barros

Synchrotron probes

- ✓ **Fluorescence, spectroscopy (XAFS)**
- ✓ **Reflectivity *vs* angle, energy, thickness**
- ✓ **Grazing Incidence XRD**
- ✓ Surface diffraction
- ✓ Anomalous diffraction, DAFS spectroscopy

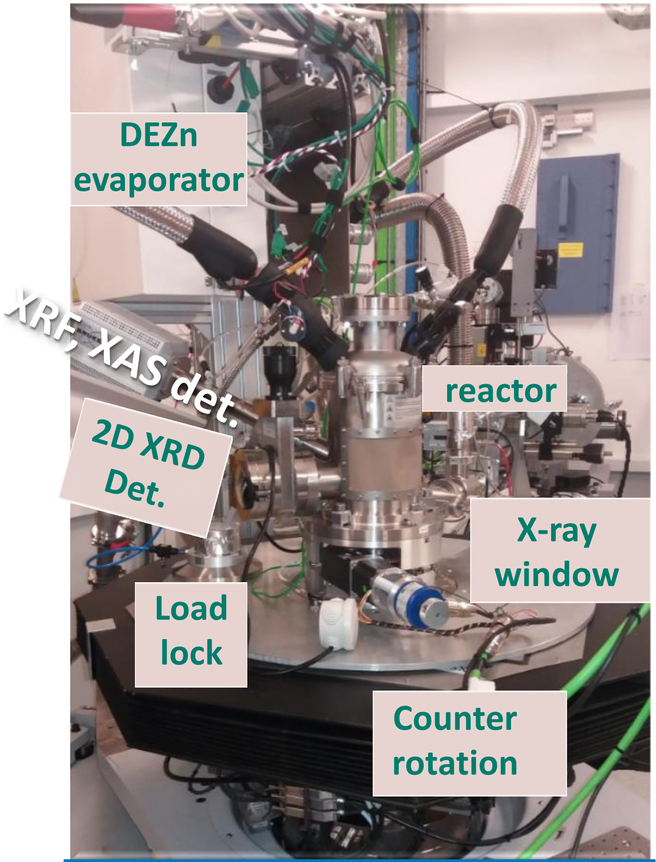
In house probes

- ✓ Substrate curvature (MOSS)
- ✓ PL
- ✓ Ellipsometry (ready to start)
- ✓ Residual Gaz Analyzer (near future)

Chem. Mat. 28 592 (2016)
Cryst. Growth Des.16 5339 (2016)

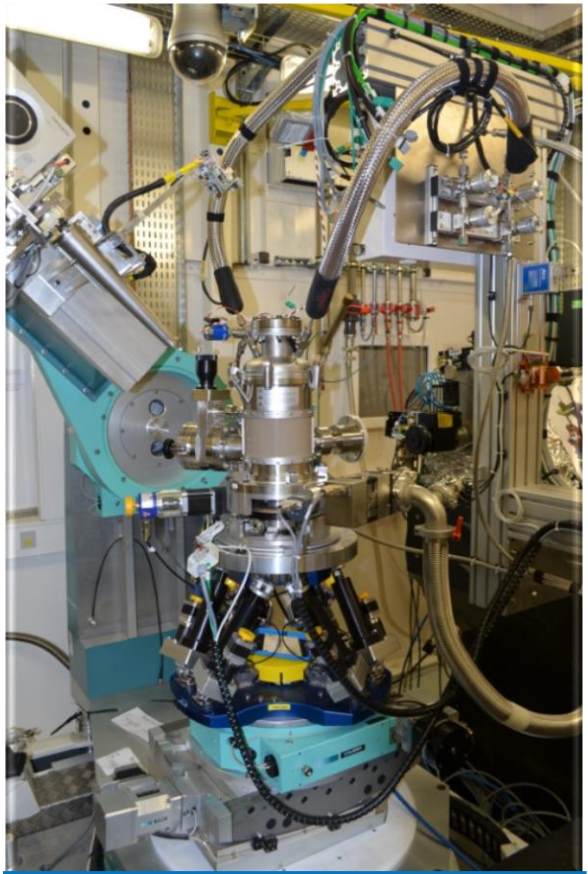
In situ growth study of ZnO ALD

ALD setup @ SOLEIL
SIRIUS beamline



X-ray absorption

ALD setup @ ESRF
ID3 beamline



Fast in-plane x-ray diffraction

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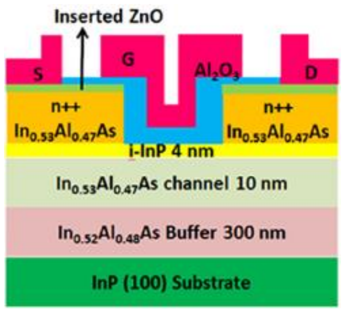

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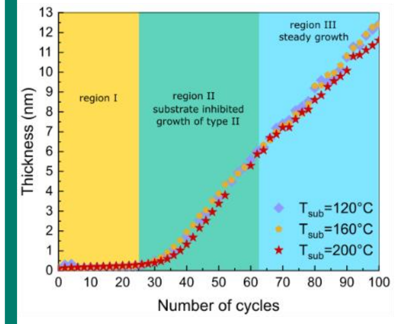

ZnO ALD early stages on $In_{0.53}Ga_{0.47}As$

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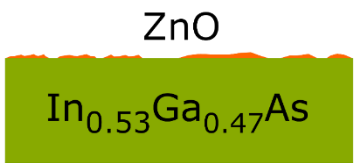

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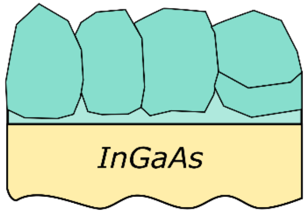
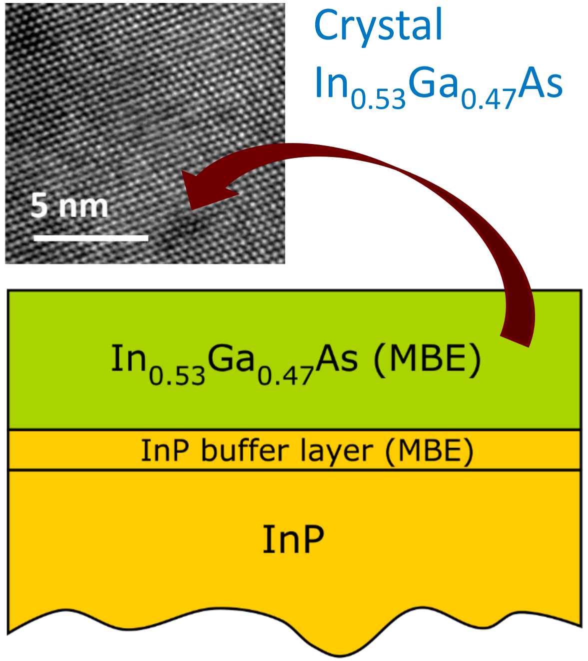


Conclusion

ZnO ALD on $In_{0.53}Ga_{0.47}As$ substrate

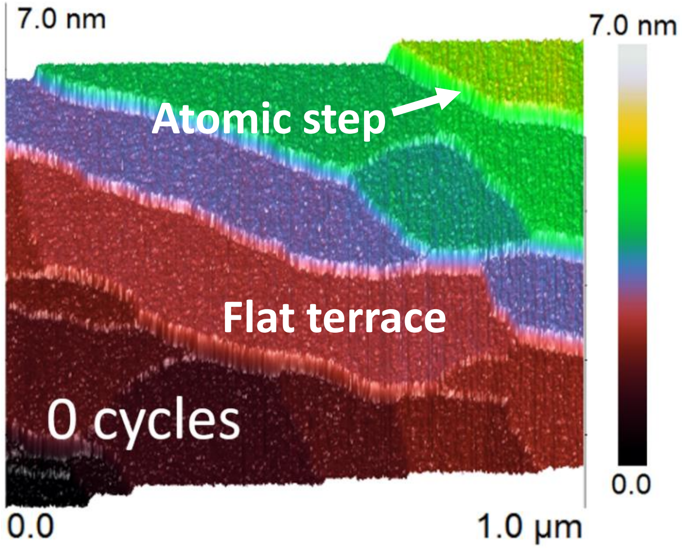
Crystal $In_{0.53}Ga_{0.47}As$

270 nm
10 nm



n-InGaAs & p-InGaAs provider : III-V Lab™

$In_{0.53}Ga_{0.47}As$ terraces



3D AFM image

ZnO ALD Precursors:

DEZn ($Zn(C_2H_5)_2$)

H_2O

$DEZn/N_2/H_2O/N_2$

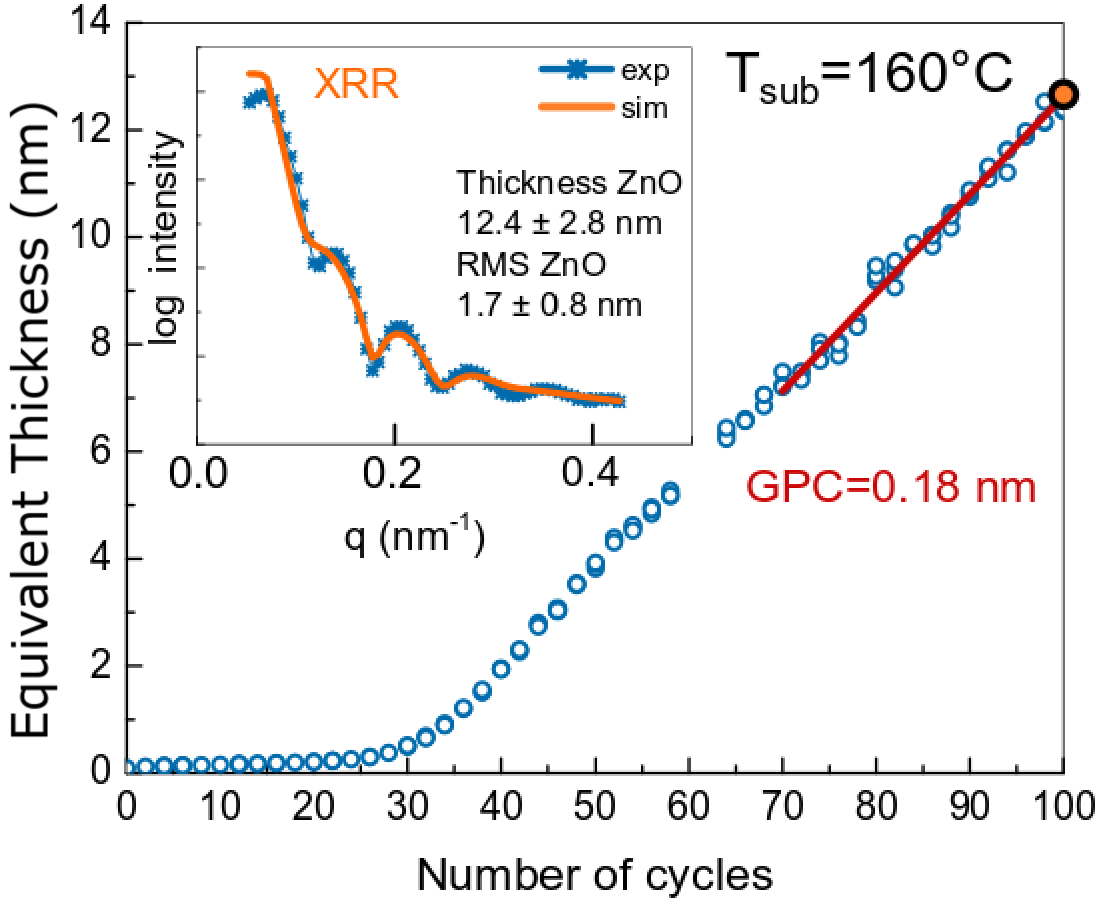
Etched 5 min in a 4M HCl solution

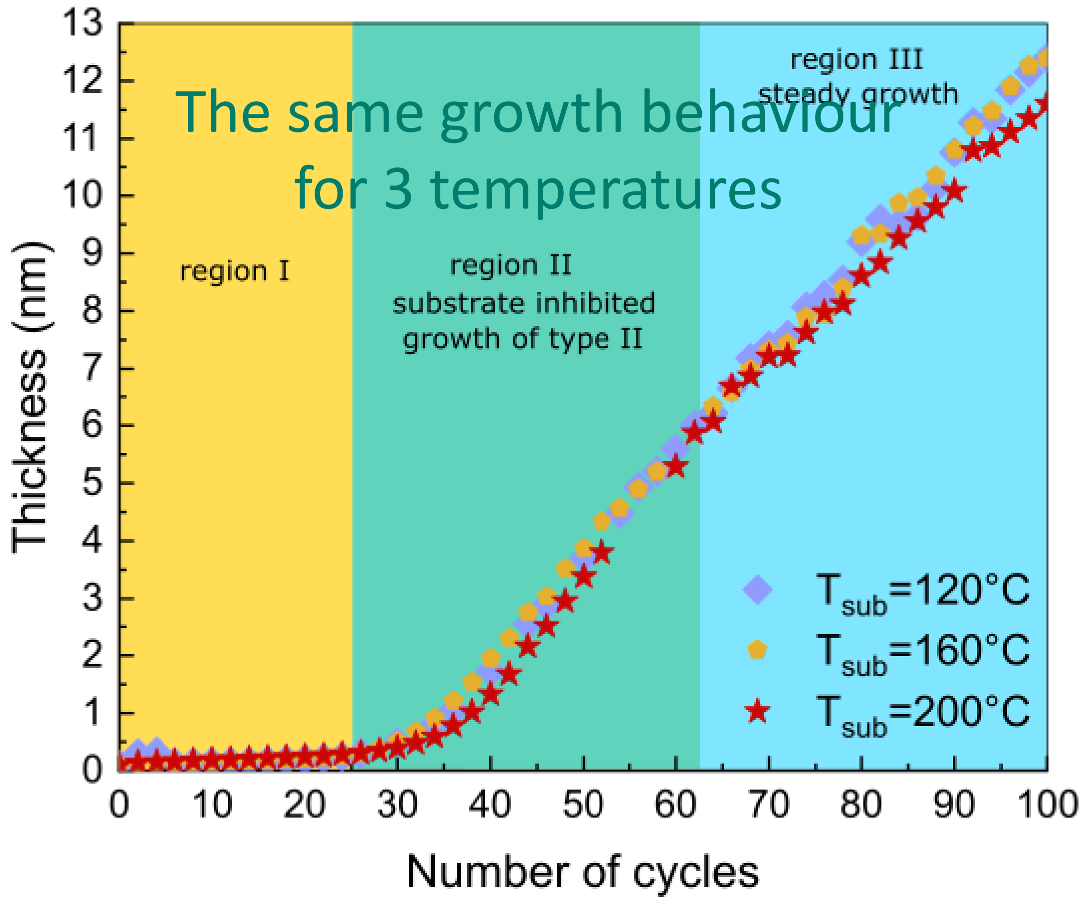
APL 93, 194103 (2008)

Substrate temperature effect

- Substrate temperature = 120°C, 160°C, 200°C
- Number of cycles = 100
- DEZn/ H_2O/ N_2 flow = 5sccm/2.6sccm/1000sccm
- DEZn/ H_2O/ N_2 inj. or purge time = 5s/40s/45s

ESRF
ID03





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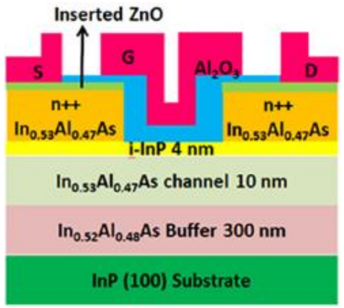

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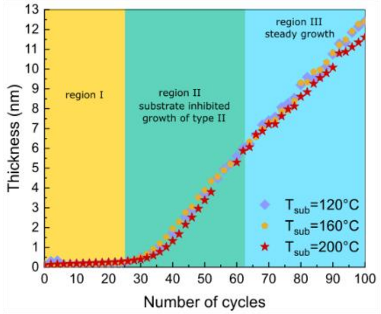

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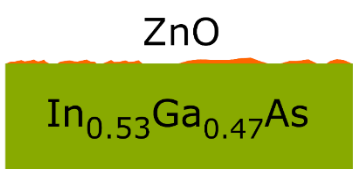

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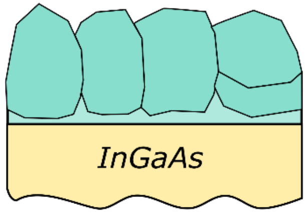

Conclusion

ZnO transient growth on InGaAs

Nanoscale

PAPER

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Cite this: *Nanoscale*, 2018, **10**, 11585

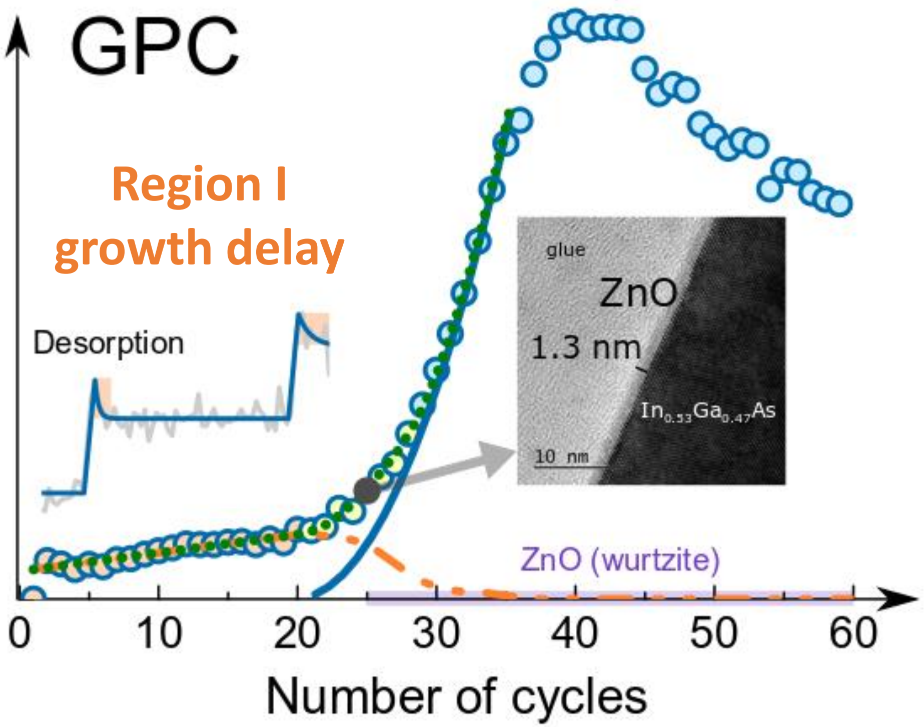
The initial stages of ZnO atomic layer deposition on atomically flat $In_{0.53}Ga_{0.47}As$ substrates†

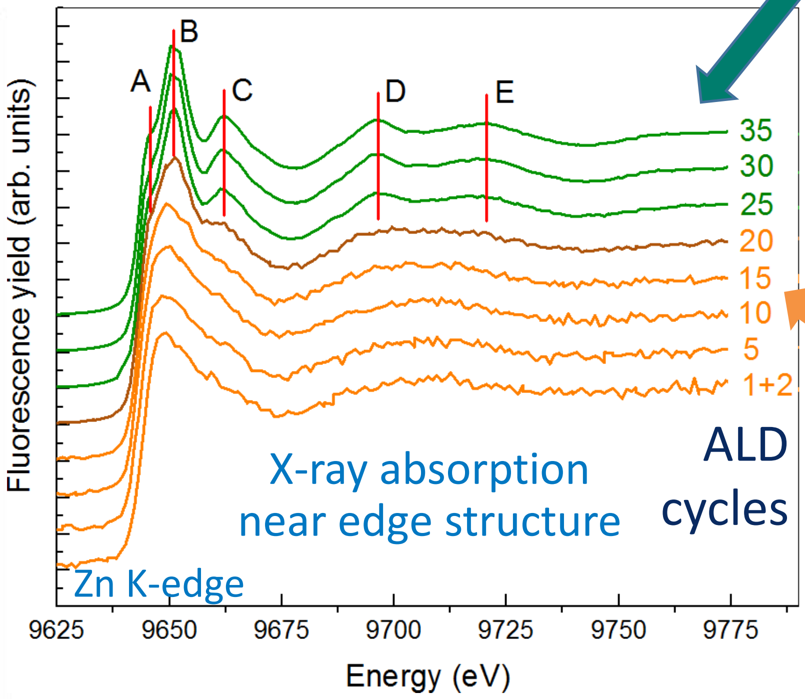
Evgeniy V. Skopin,[a] Laetitia Rapenne,[a] Hervé Roussel,[a] Jean-Luc Deschanvres,[a] Elisabeth Blanquet,[b] Gianluca Ciatto,[c] Dillon D. Fong,[d] Marie-Ingrid Richard[e,f] and Hubert Renevier *[a]

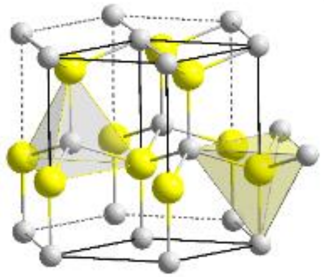
SOLEIL SYNCHROTRON
SIRIUS beamline

Region II
S-shape growth

Region I
growth delay

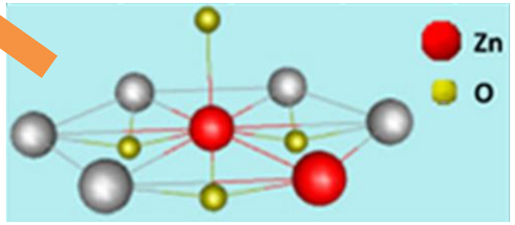






Wurtzite structure

Cryst. Growth Des. 2016, 16, 5339–5348

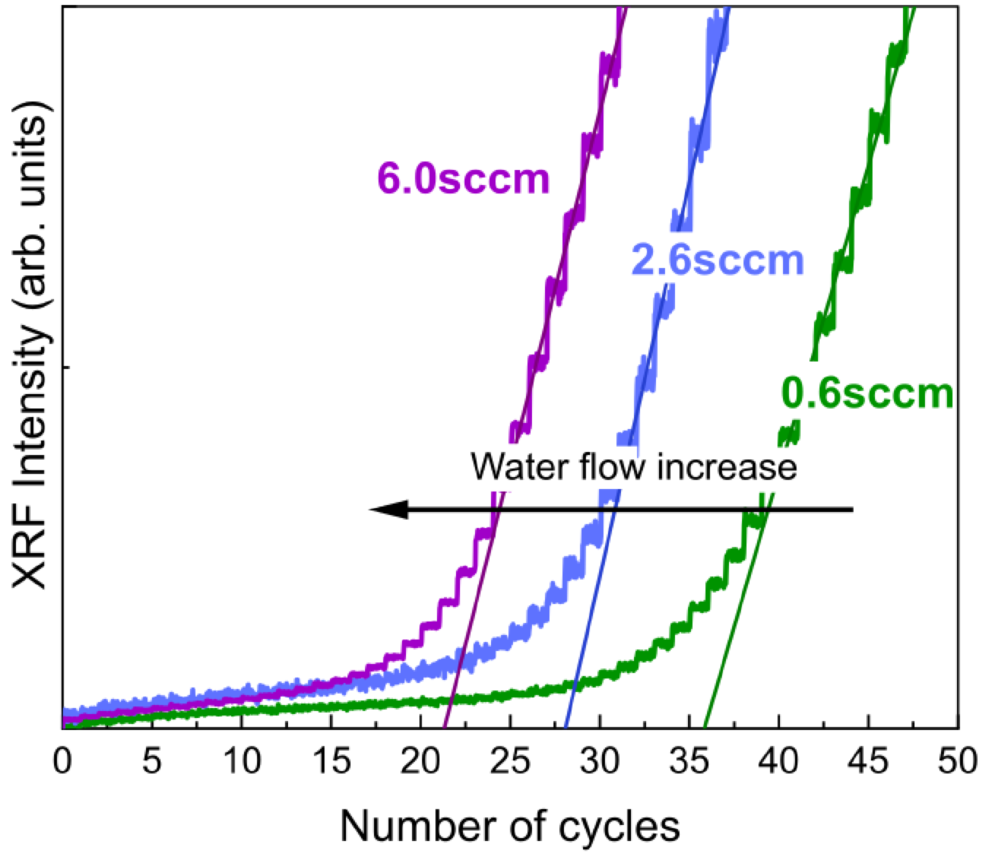


Disordered Zn local environment/ small islands

Precursor flow/inj.time effect on growth delay (regime I)

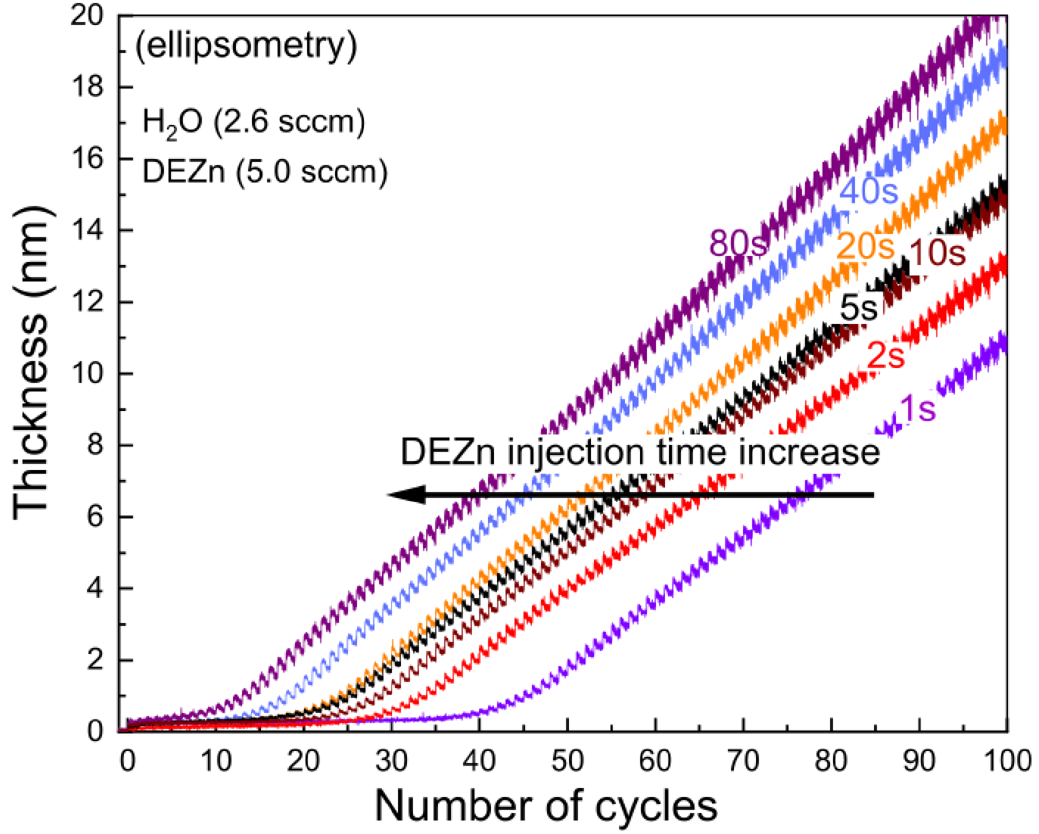
X-Ray Fluorescence

ESRF
ID03



Ellipsometry *in situ*

LMGP



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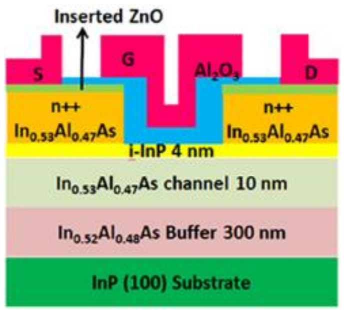

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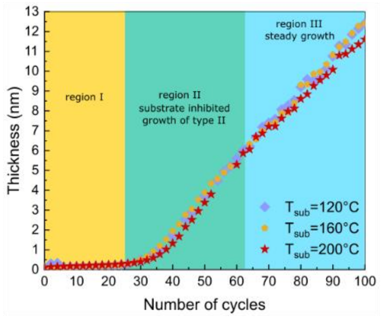

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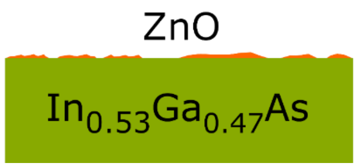

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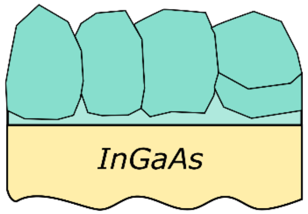
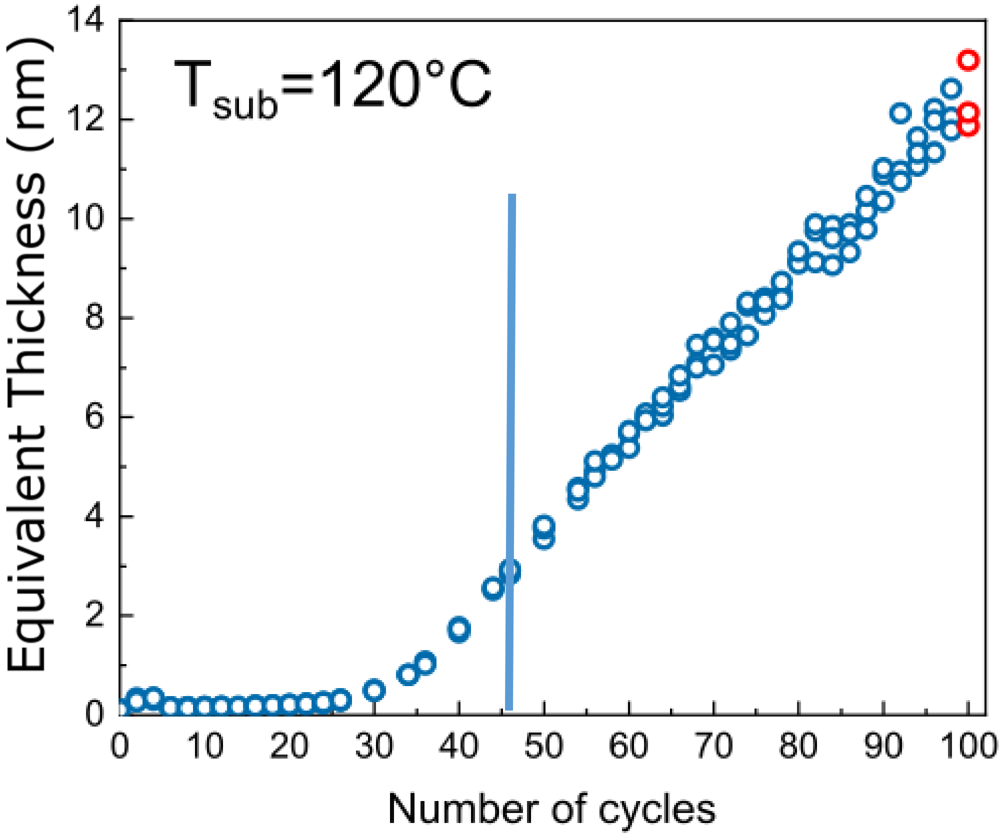


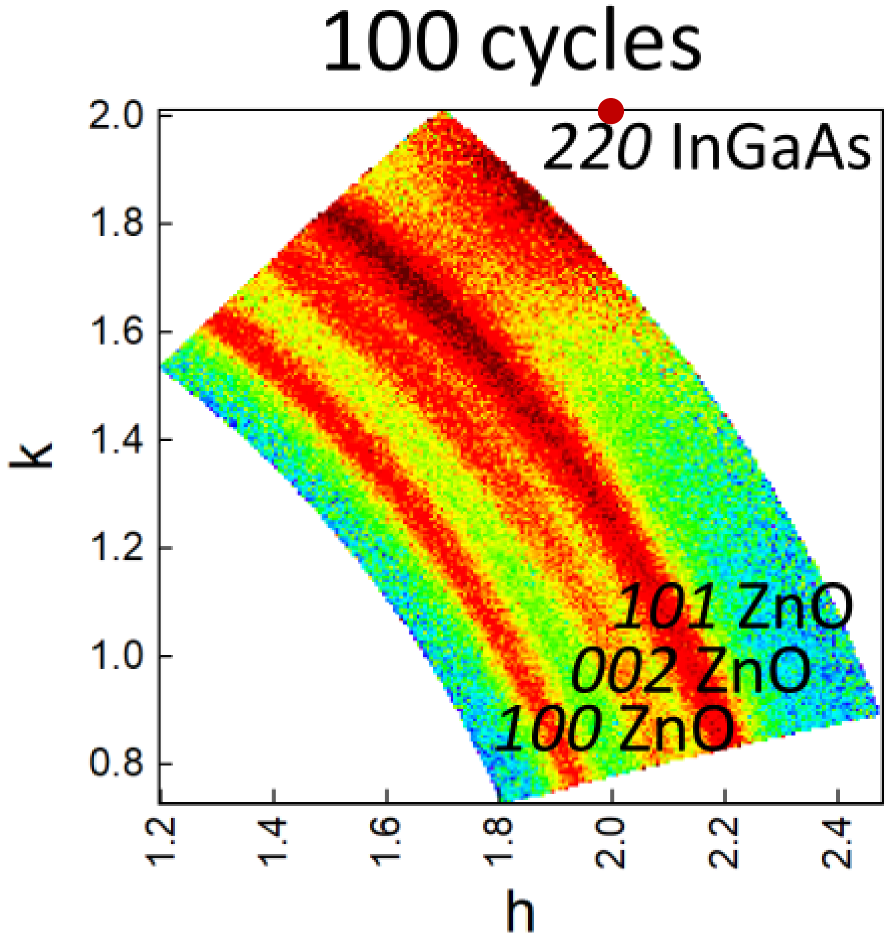
Conclusion

In-plane RSM vs ZnO film thickness

ESRF
ID03

Fast in-plane diffraction

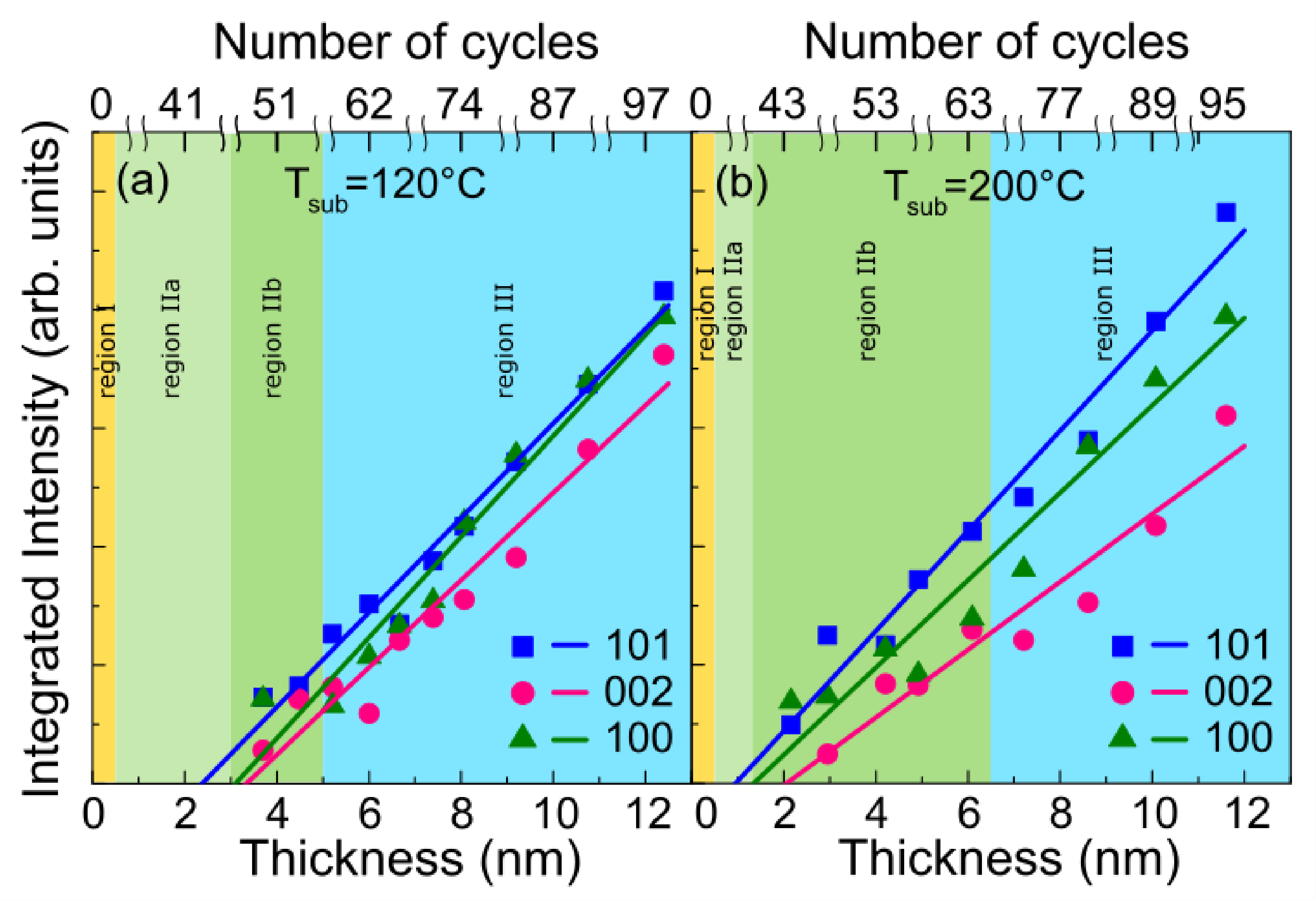


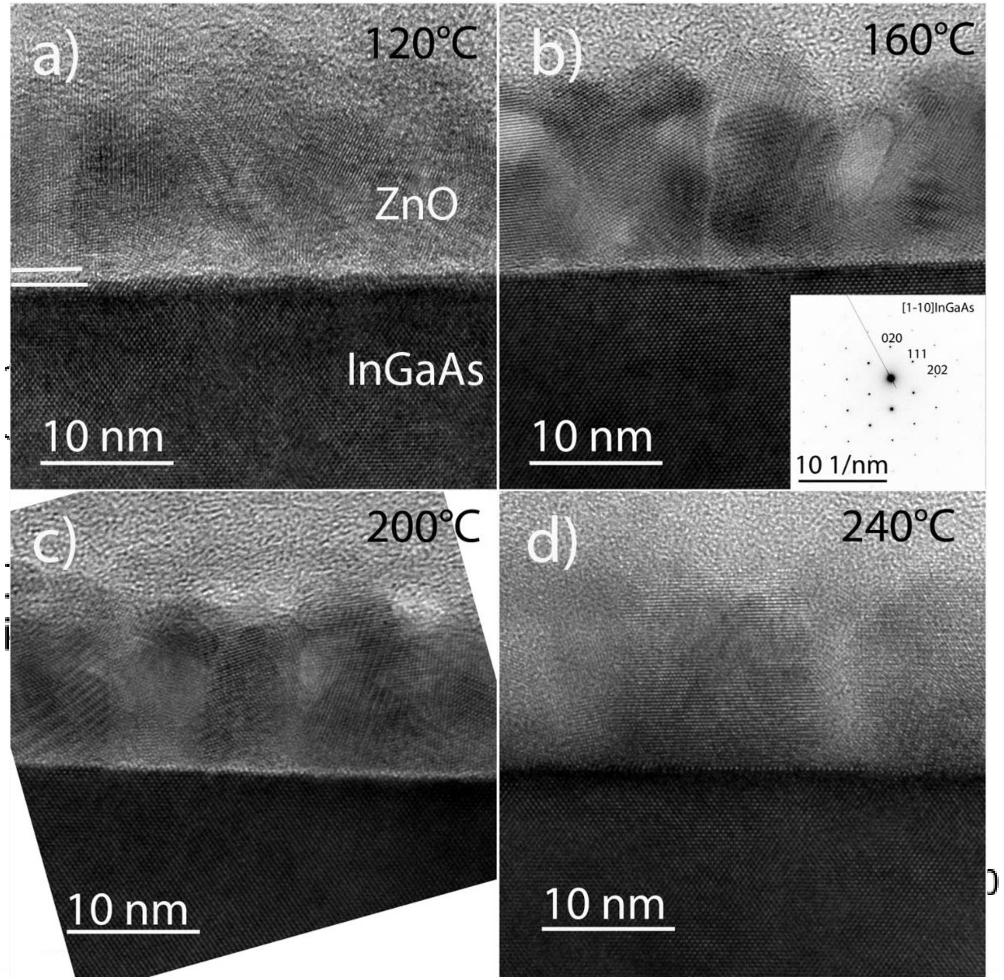


RSM : reciprocal space map

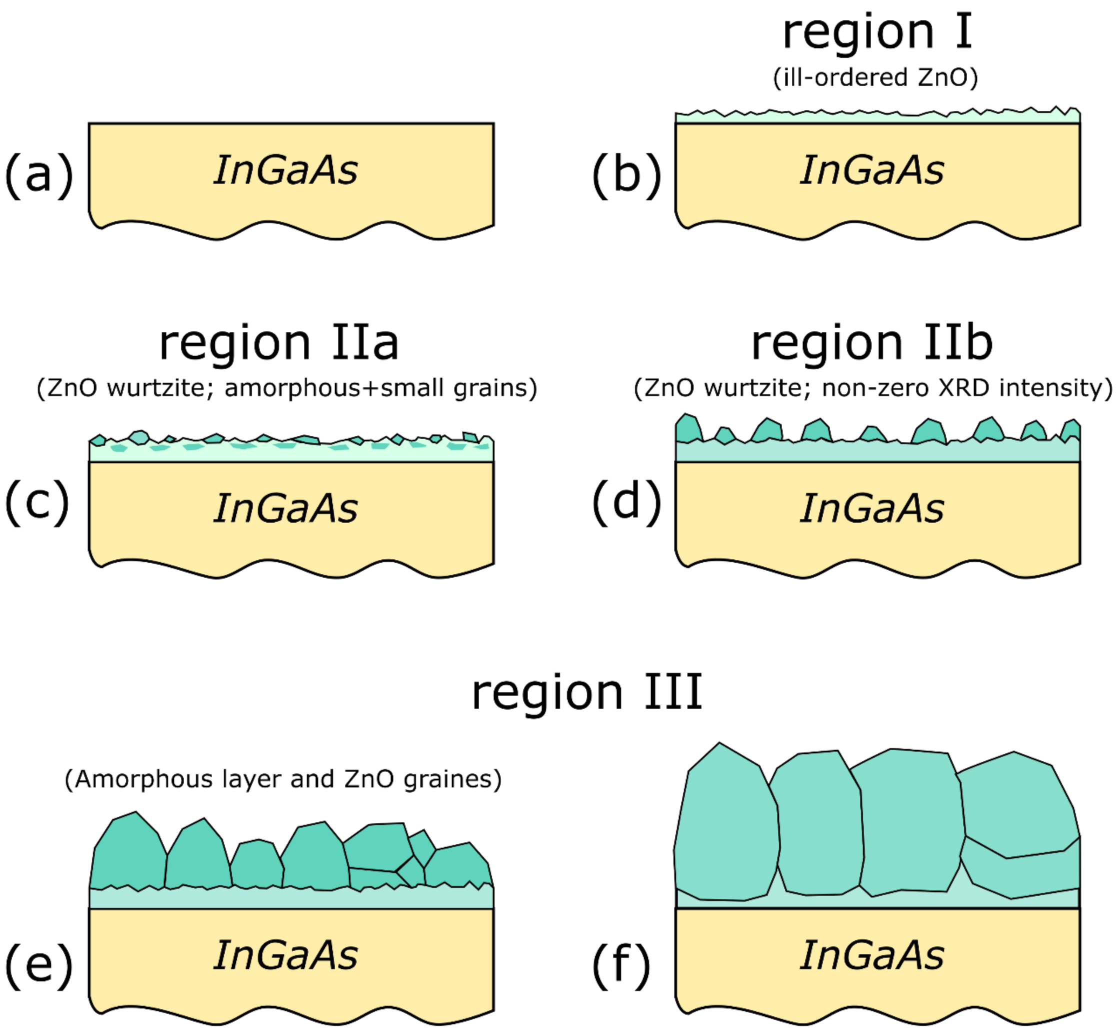
No in-plane texture

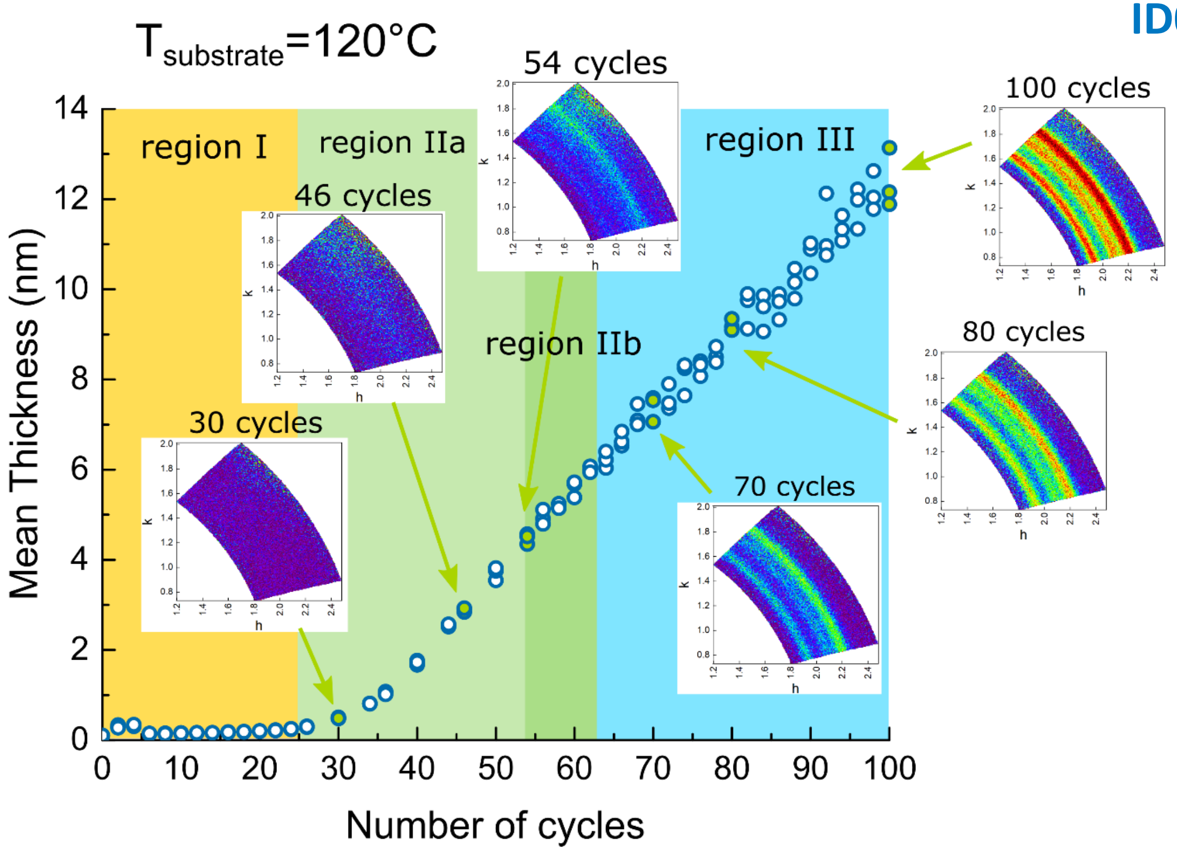
ZnO crystallization during growth





ZnO cristallisation on InGaAs





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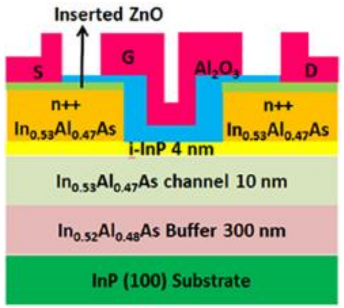

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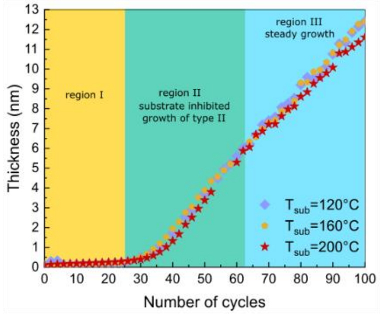

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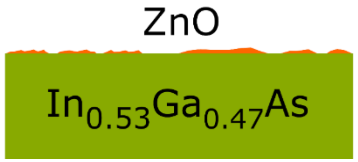

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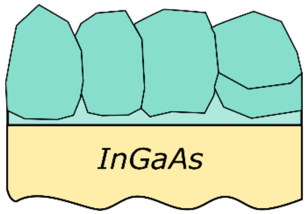

Conclusion

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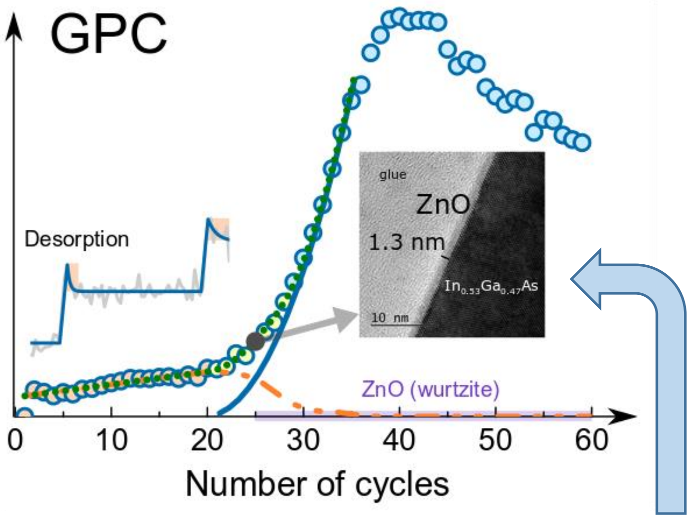
- ✓ GPC of ZnO ALD on InGaAs ~0.2nm.cy^{-1} in steady growth regime & ALD temperature window

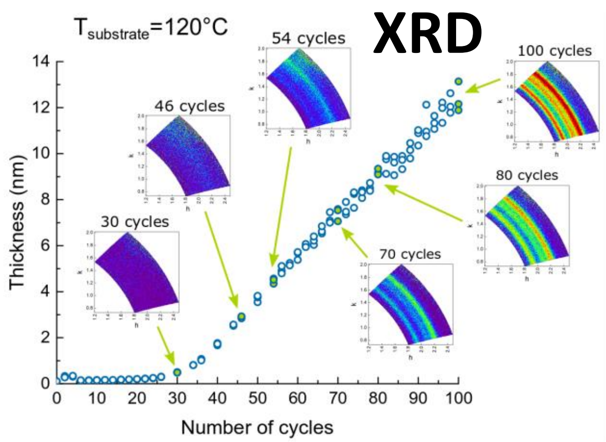
- ✓ Evidenced a transient growth regime (prior to steady growth)

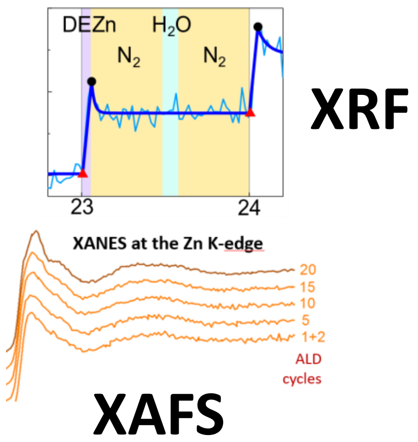


- ✓ 1-2 nm thick, continuous, ill-ordered ZnO film

E. V. Skopin et *al*. Nanoscale 10 11585 (2018)

- ✓ Further demonstrated the interest of *in situ* synchrotron experiments for studying the incipient growth of ALD





E. V. Skopin et *al*., in preparation (2019)

Thank you for your attention!