

InGaN/GaN scintillation detectors – role of defects on luminescence

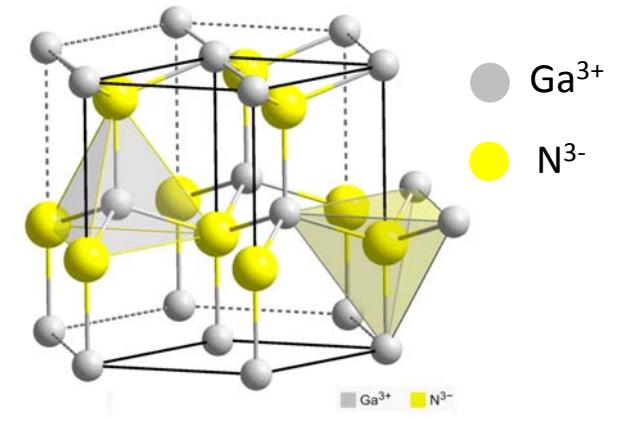
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Are all defects problem for improving
the quality of scintillation detectors ???

Nitrides – advantages for scintillators

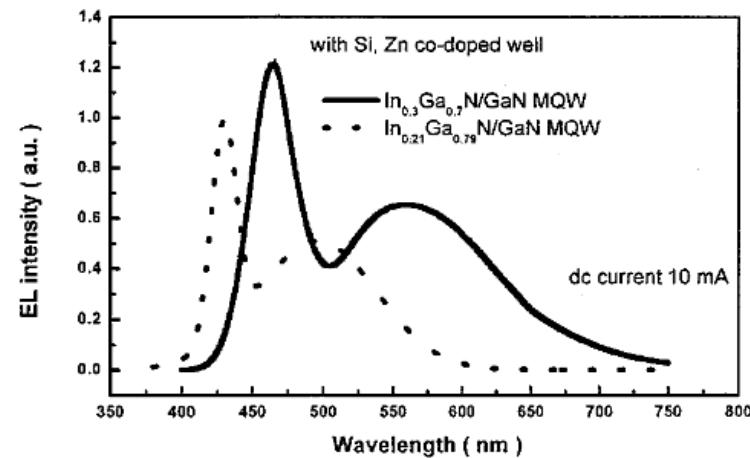
- High exciton binding energy
→ Short decay time in range of hundreds of picoseconds
- High radiation resistance
- Easily tunable emission wavelength
- External photon yield up to 100 000 photons/MeV
- High crystallographic quality and homogeneous layers (epitaxial layers grown with MOVPE technology)
- Perfect temperature and chemical stability → application in hostile environment



https://en.wikipedia.org/wiki/Gallium_nitride#/media/File:GaN_Wurtzite_polyhedra.png

On the other hand...

- Impurities in layers → defect states
 - Unintentional: Zn, Fe, Ca, etc.
 - Intentional: Si (create complexes)



J.K.Sheu et al., IEEE Photonics Technology Letters, Vol. 14, No. 4, 2002.

- Thickness of the MQW active region → limited detection efficiency
 - Usually about 500 nm thick MQW active region
 - Low efficient detection of X-ray, γ radiation
 - Problems with low excitation intensities
- **Threading dislocations → non-radiative centers**

- Lattice constants

- Sapphire $a = 0,476 \text{ nm}$
- GaN $a = 0,319 \text{ nm}$

Scheme of scintillation structure

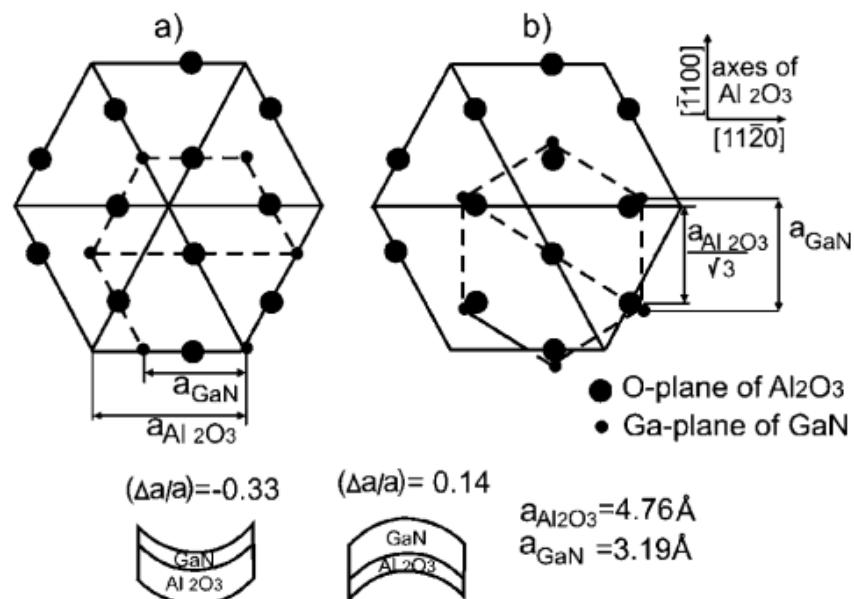
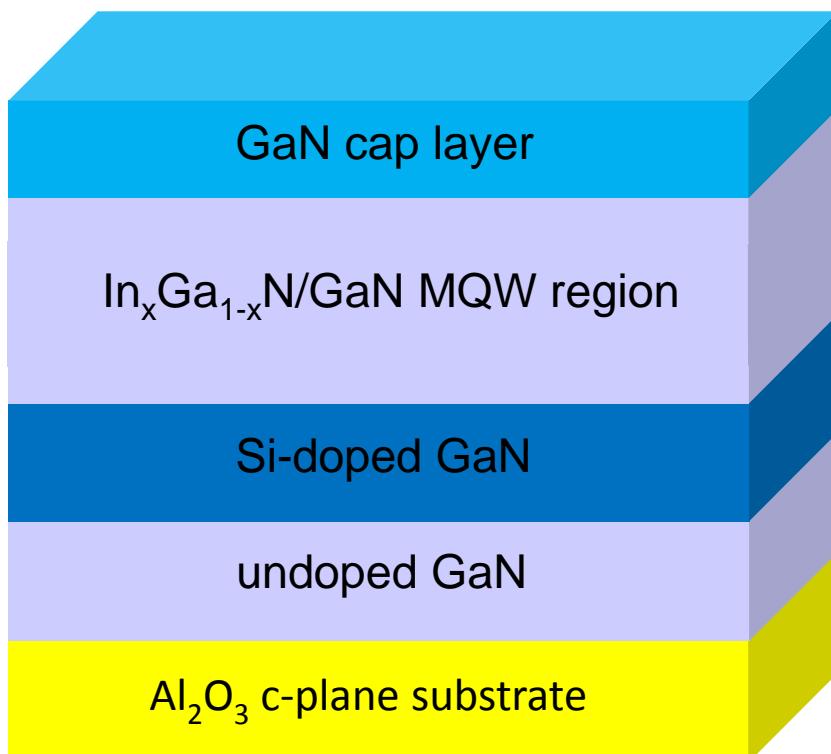
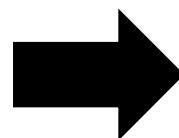
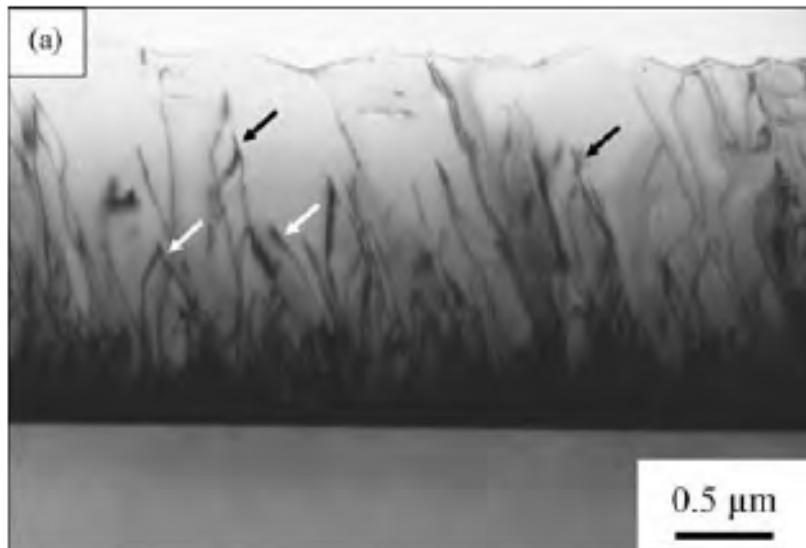


FIG. 1. Schematic presentation of atom arrangements in growth plane for the case of a (0001) GaN layer, grown on sapphire (0001) at mismatch of lattice parameters equal to -0.33 (a) and 0.14 (b).

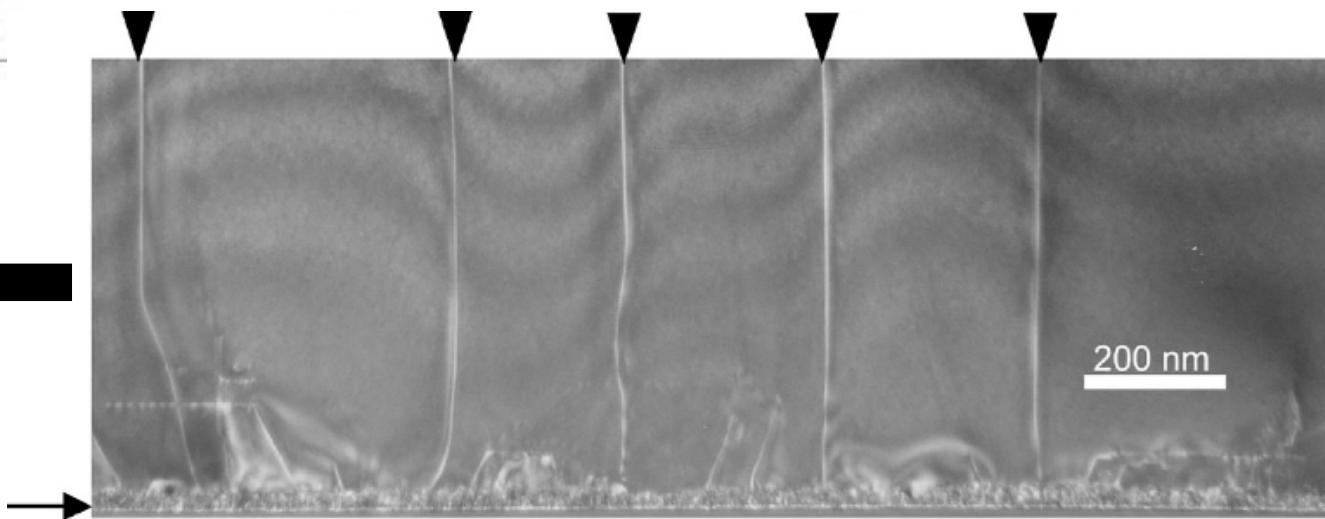
Low temperature buffer growth on sapphire

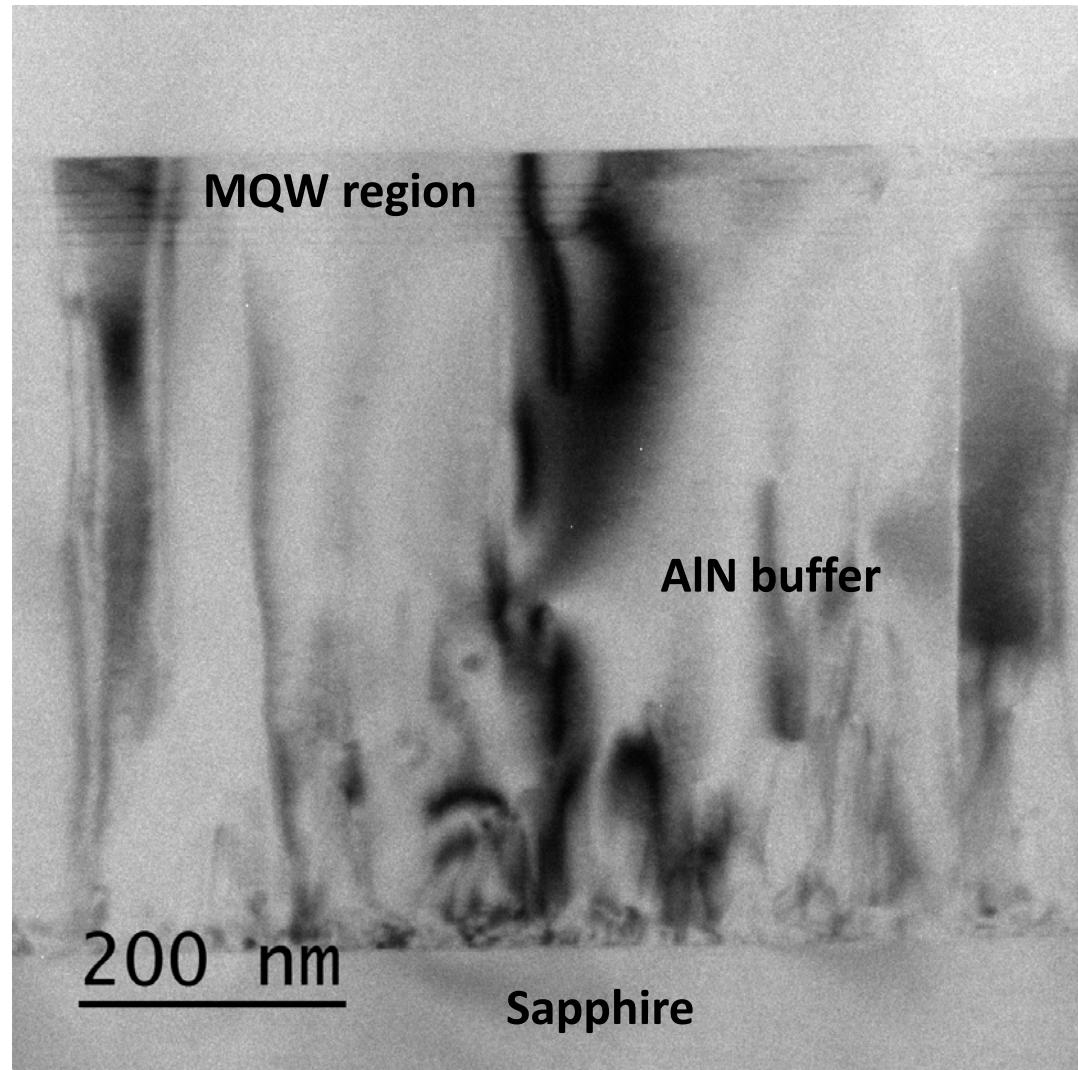
→ one part of Nobel prize in physics 2014 (Akasaki, Amano, Nakamura)



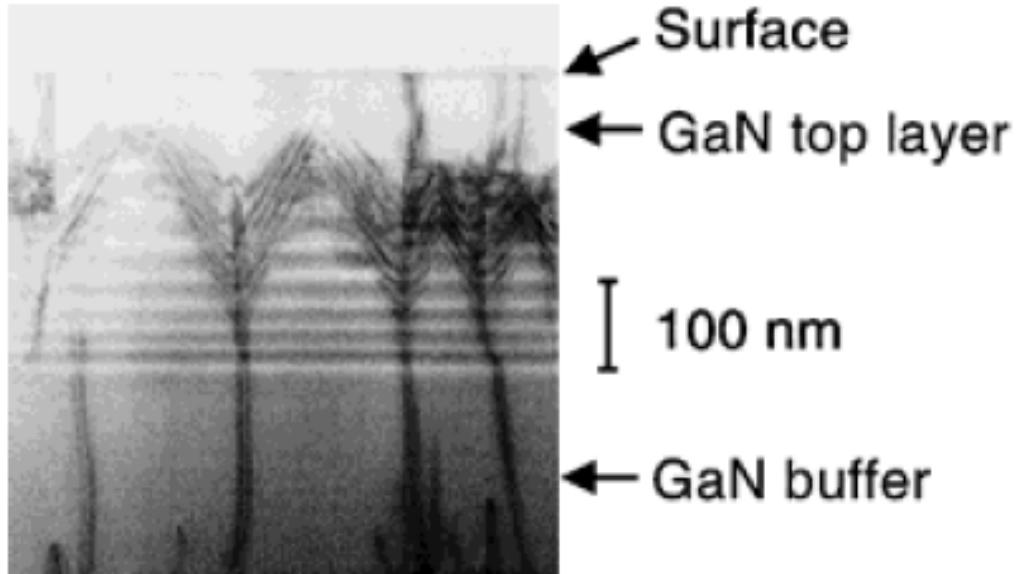
Growth without low temperature buffer

Improvement with low
temperature buffer growth





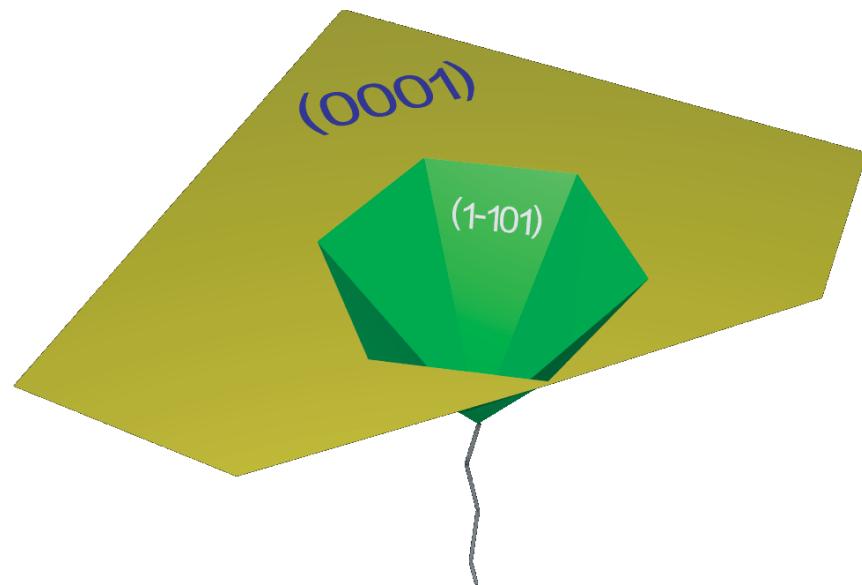
- Threading dislocations at the interface between sapphire and GaN (AlN)
- Screw and edge type
- Density $10^8 – 10^9 \text{ cm}^{-2}$



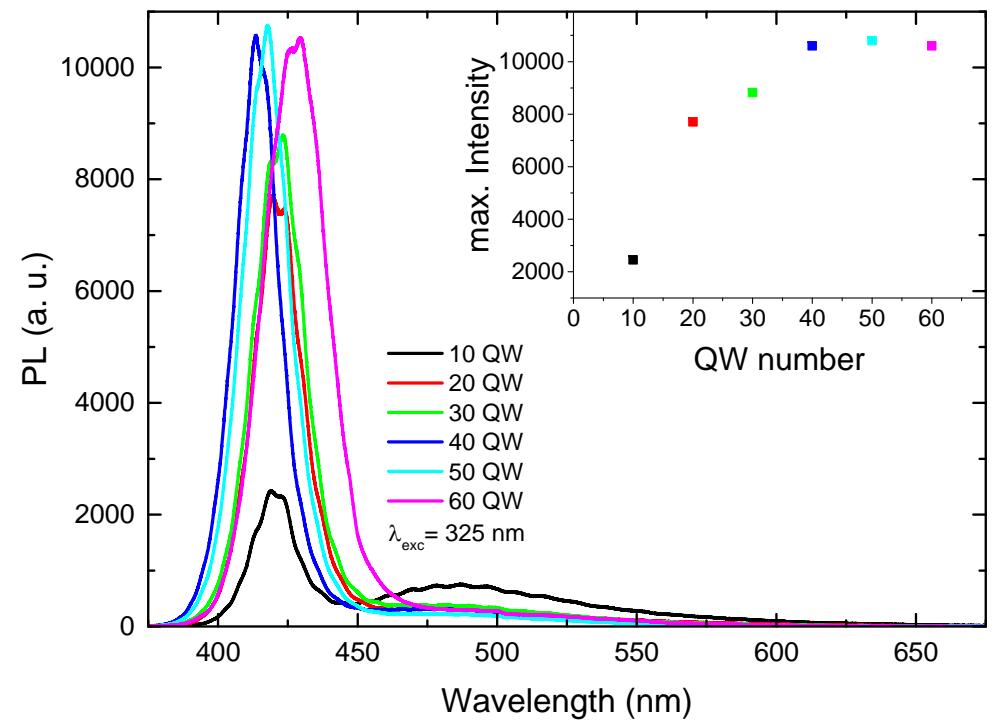
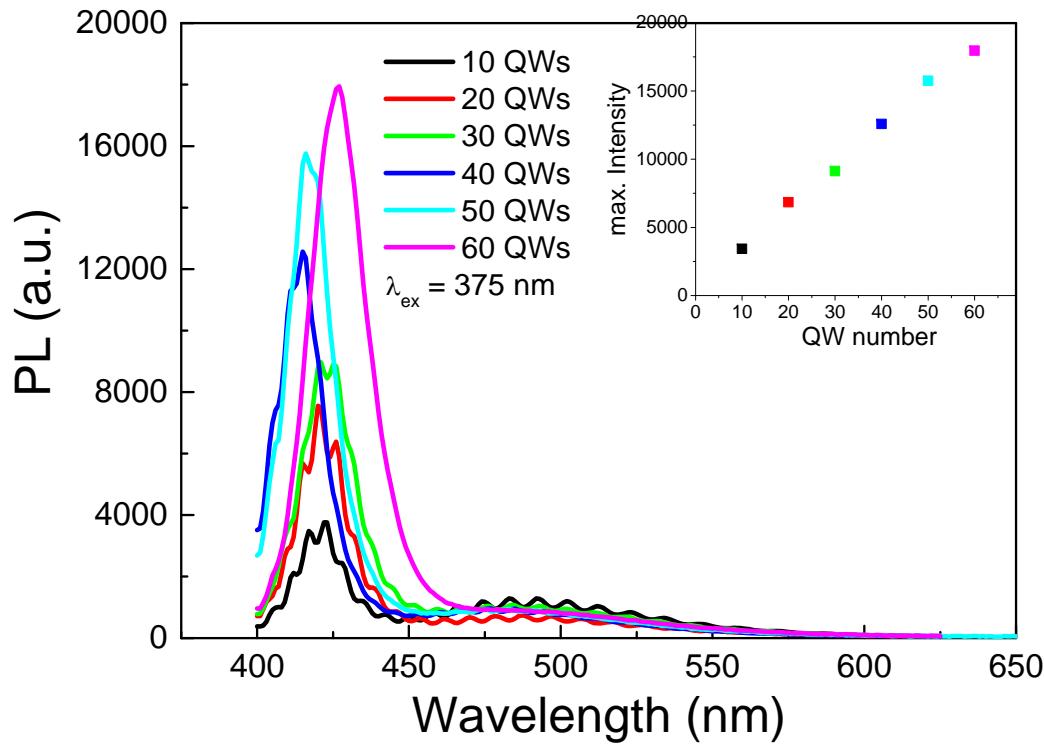
F. Scholz et al., Phys. Stat. Sol. (a) **180**, 315, 2000.

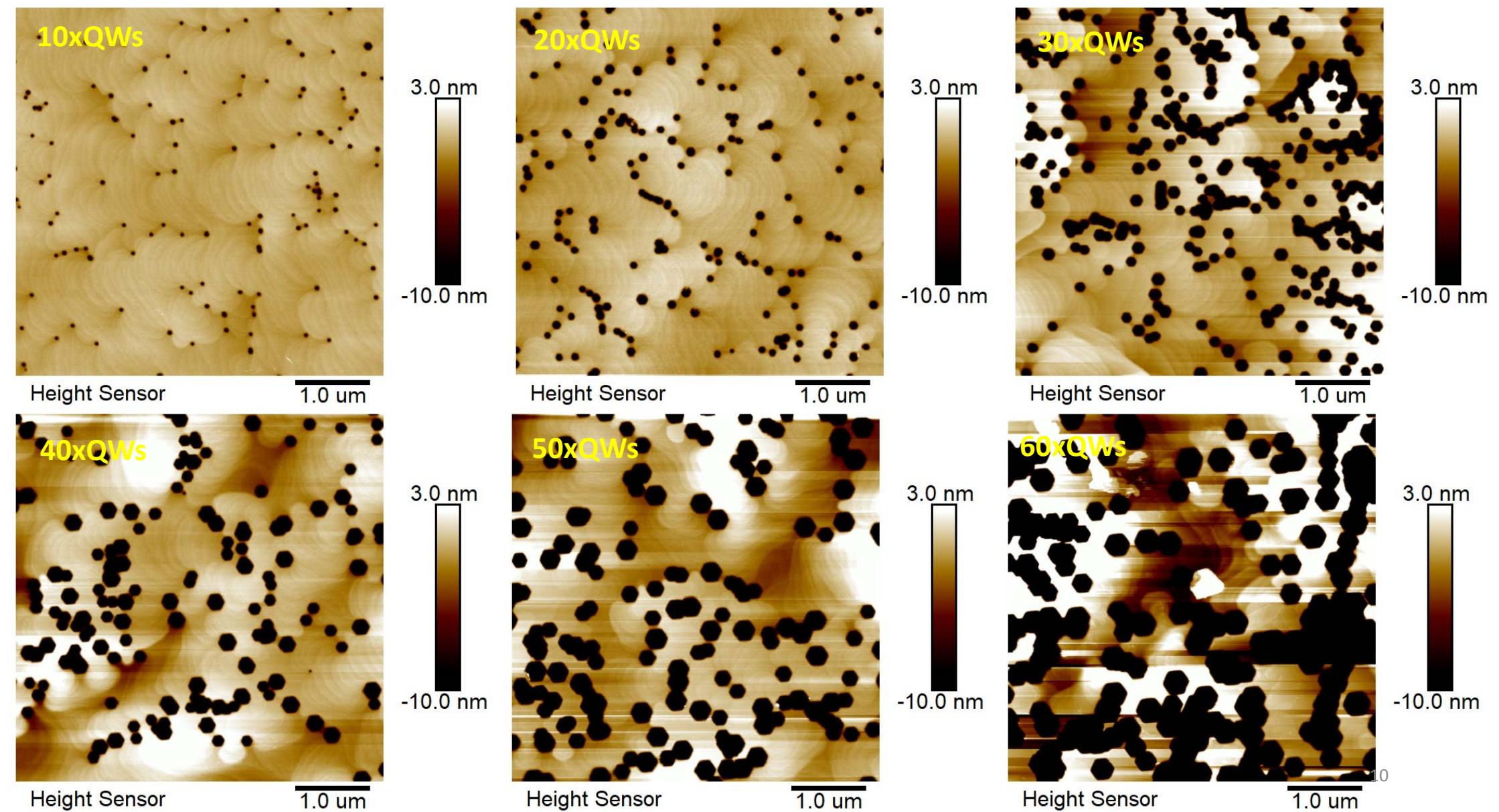
V-pits start appear in MQW region

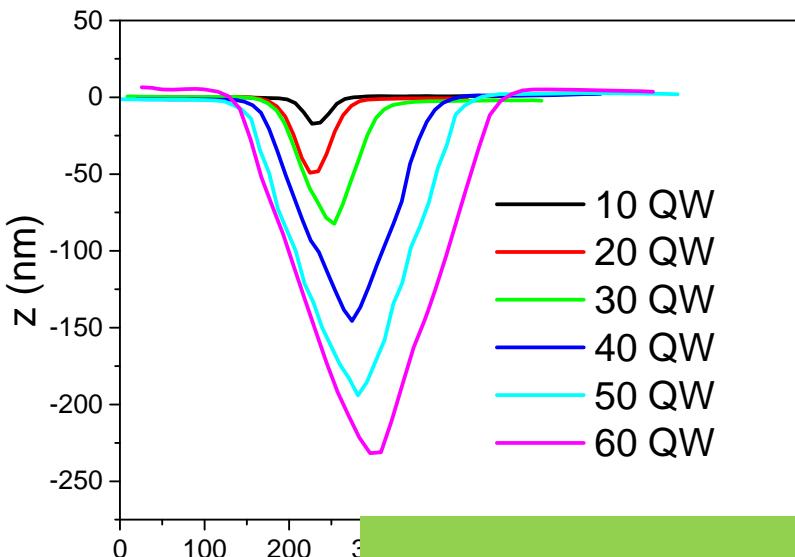
Fig. 2. STEM micrograph showing the changed growth behaviour of the MQWs within and in the vicinity of the V-shaped defect. Here the MQW packet is capped with about 100 nm GaN grown at 1000 °C. The top layer has a perfectly smooth surface



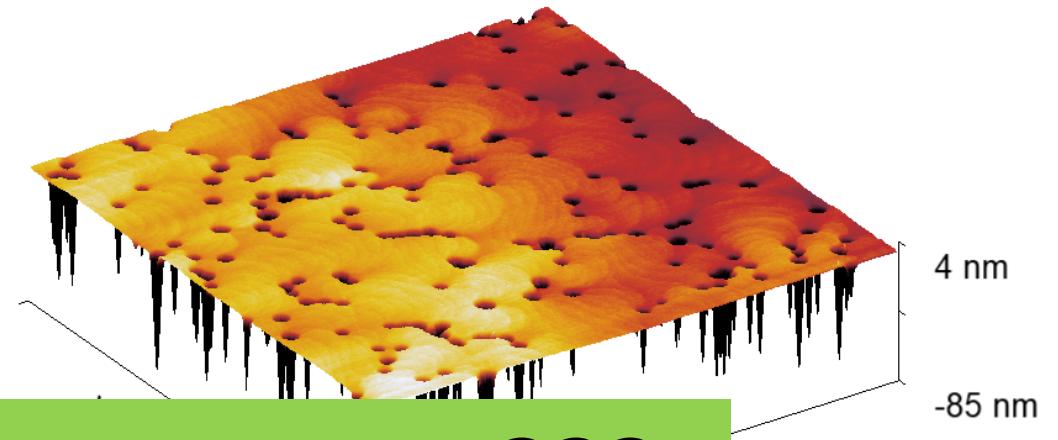
Number of quantum wells – sample series



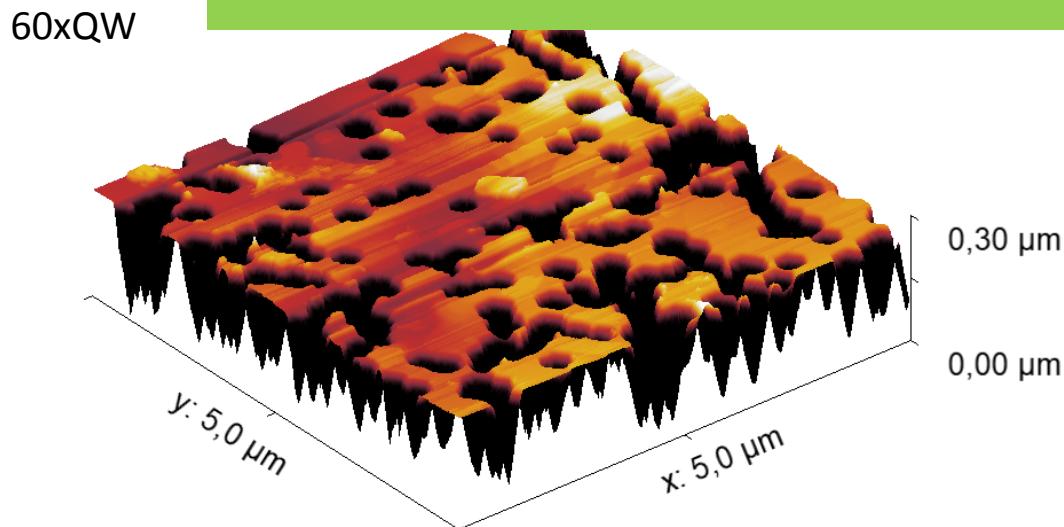




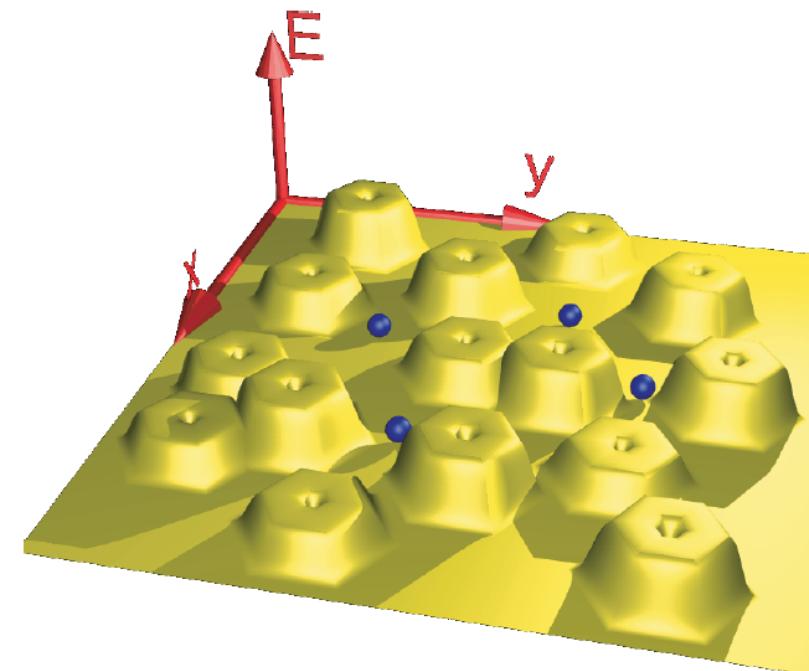
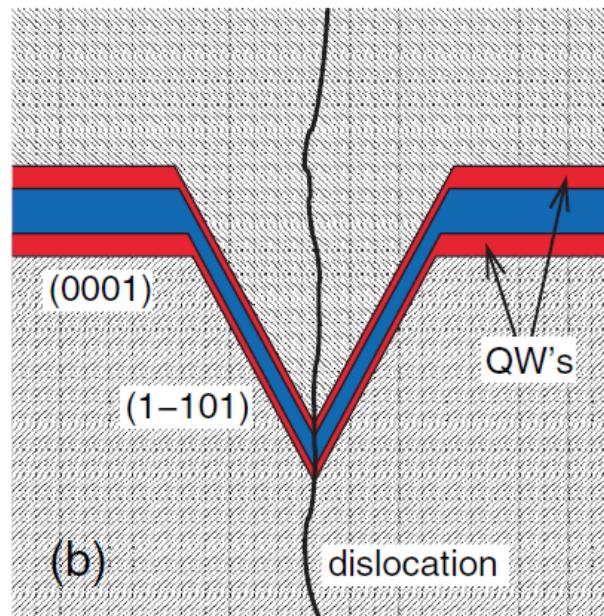
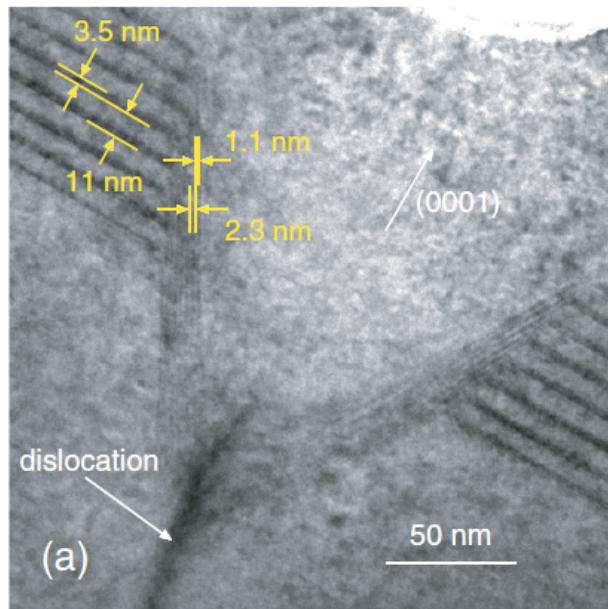
20xQW



ARE V-PITS HARMFUL ???

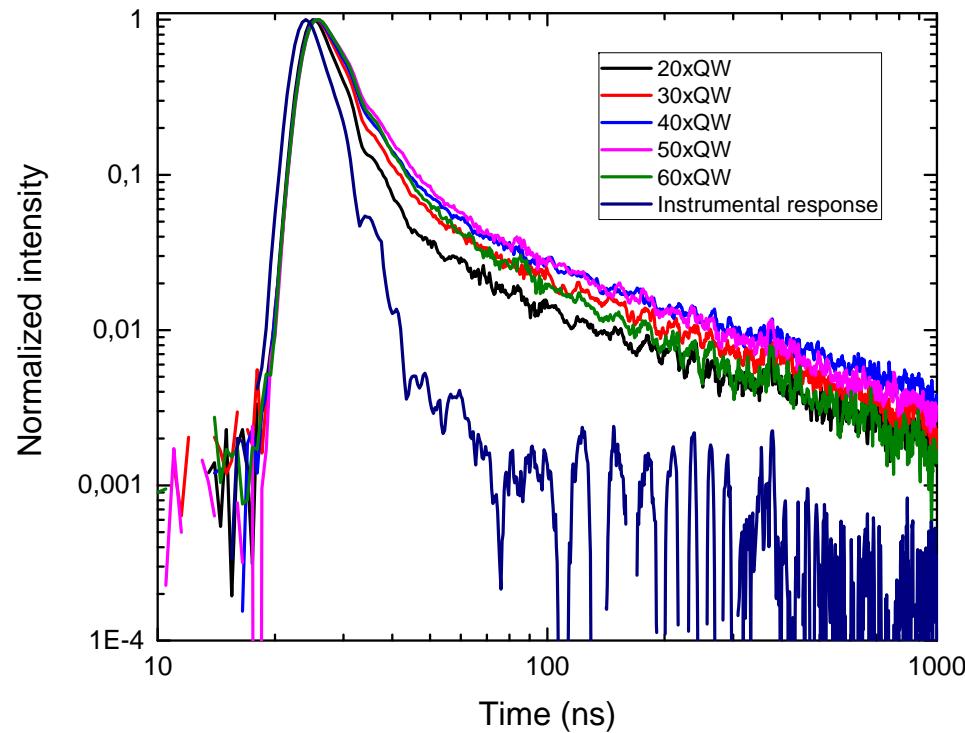


- Slower growth rate on sidewalls of V-pits → thinner QWs → potential barriers
- Potential barrier around defects keeps carriers from recombining nonradiatively at the defects

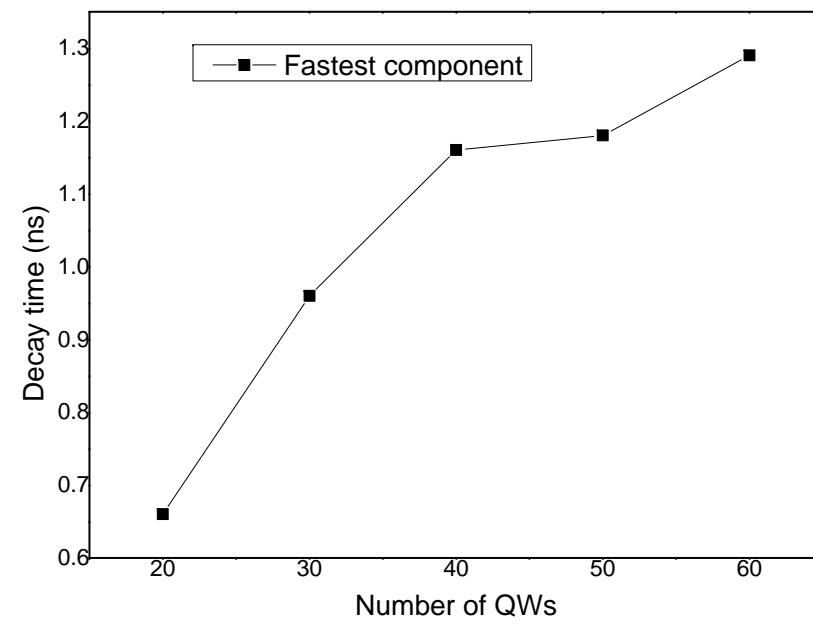


V-pits help to keep excitons from non-radiative centers

Decay time



- Soft X-ray decay time
- More quantum wells → bigger V-pits
→ less non-radiative recombinations



Conclusions

- Good properties of nitrides for scintillators
 - Fast response, high radiation resistance, etc.
- All kind of defect during epitaxial growth
 - Impurities, threading dislocations
- Not all defects are harmful for luminescence
 - V-pits on the surface
- V-pits help to keep excitons from nonradiative centers
→ better luminescence

**Thank you for your
attention !!!**