Growth and Characterization of III-N UV Emitters

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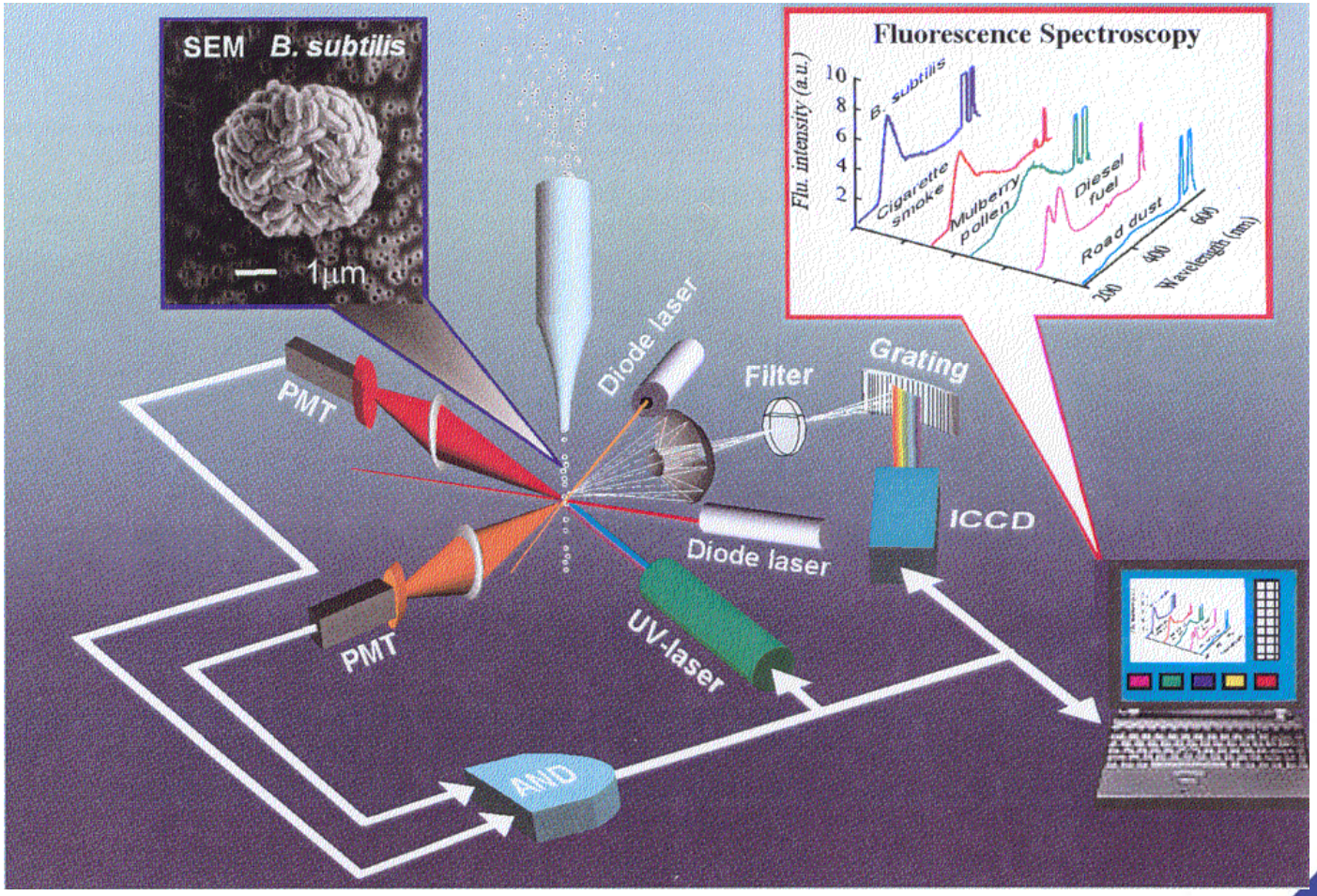
-
- Performance of UV LEDs
- Optical Efficiency and Investigation of Quaternary AlGaInN
- Stress and Strain Control
- Optically Pumped UV VCSELs
- Conclusions

*In collaboration with A. V. Nurmikko (Brown), K. E. Waldrip (Sandia)
R. K. Chang (Yale), J. A. Floro (Sandia), S. R. Lee (Sandia)

Real-time measurement of UV (266 nm) laser-induced florescence spectra from airborne biological particles



ARL, Yale, AECBC and NIOSH

Special Issue:
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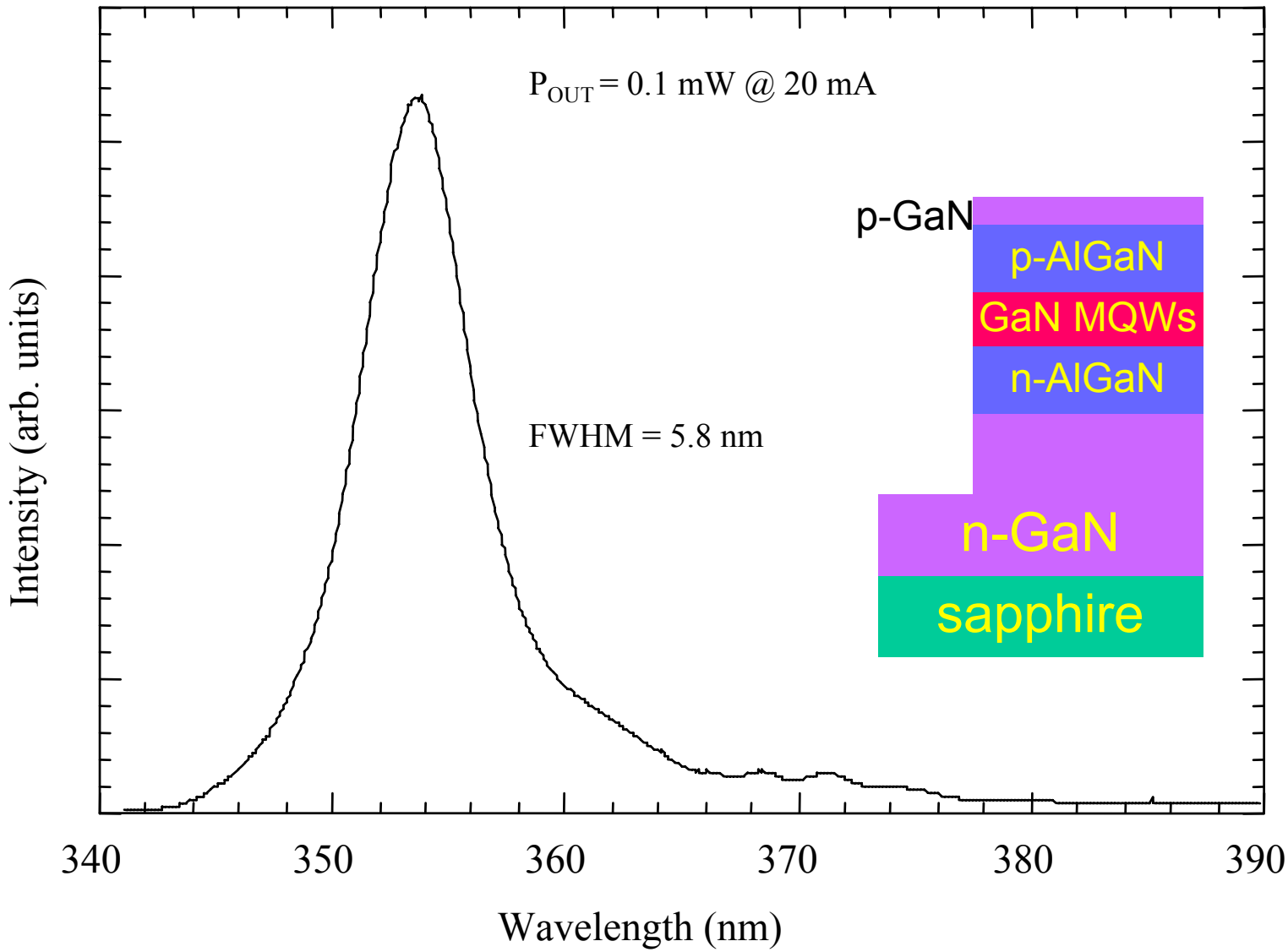
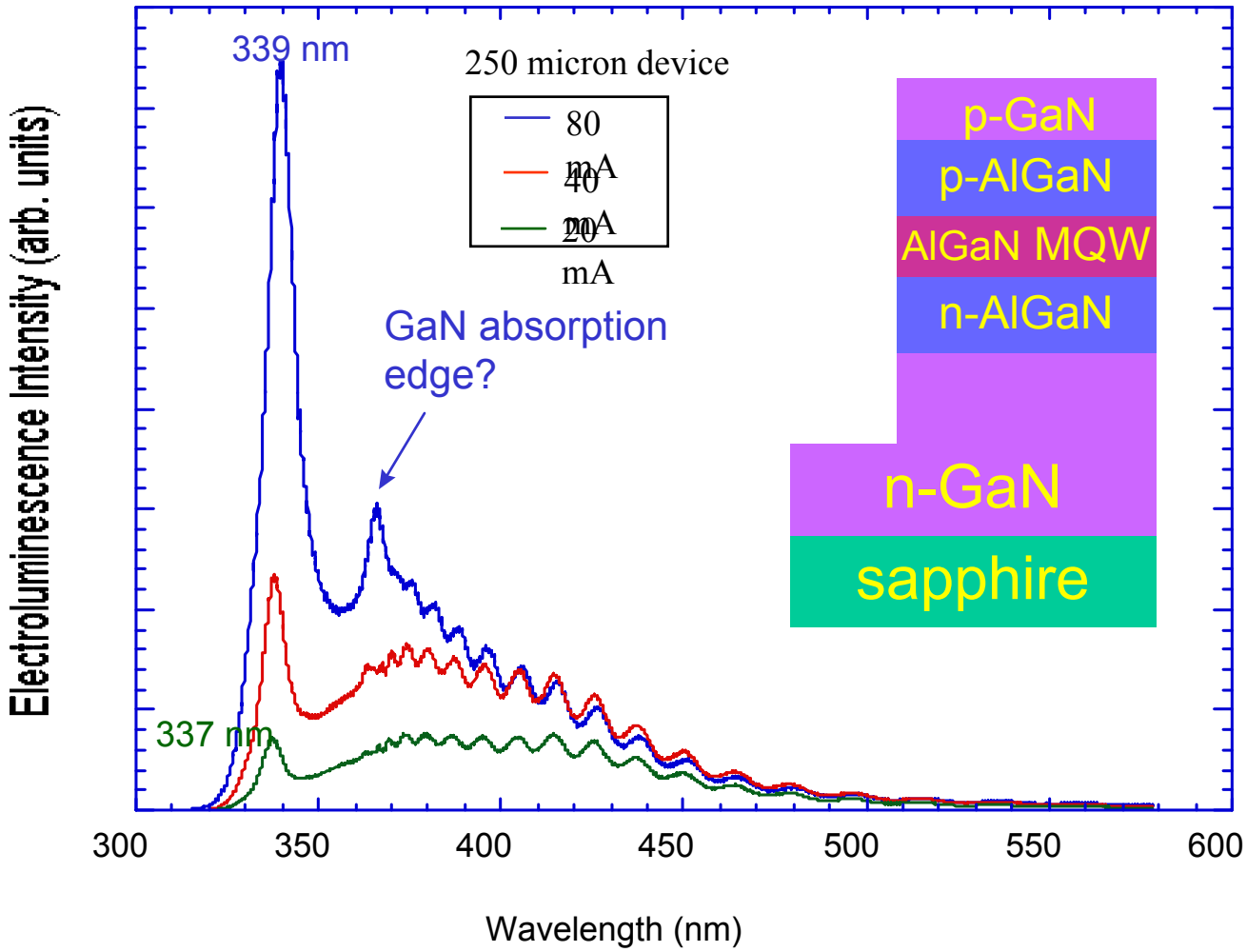
strumentation

LED spectrum from GaN MQWs



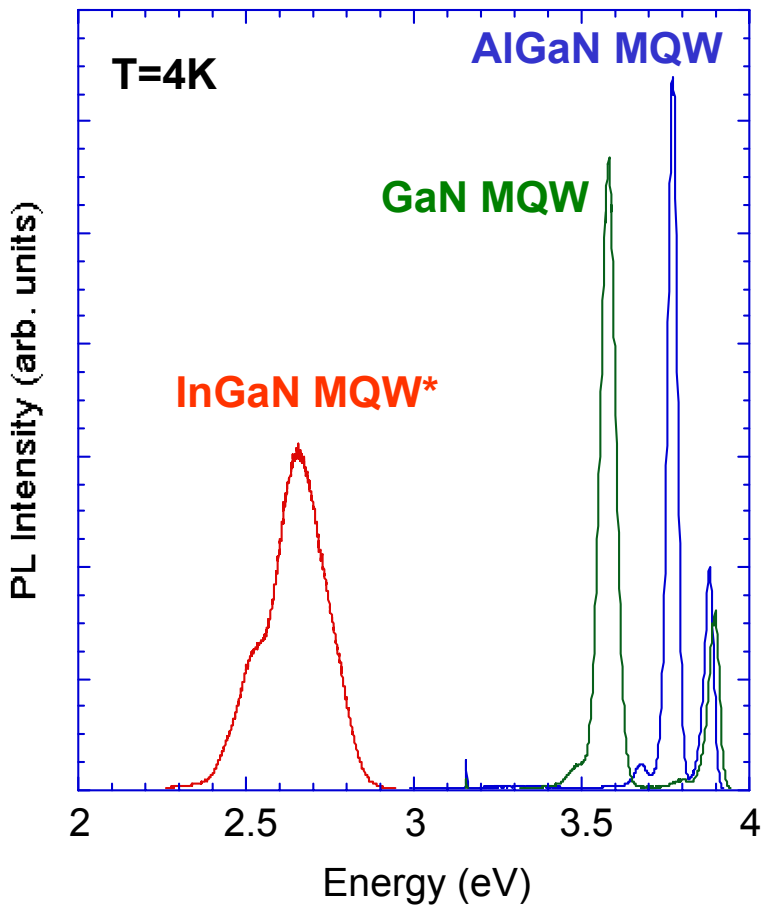
Han et al., APL 73, 1688 (1998)

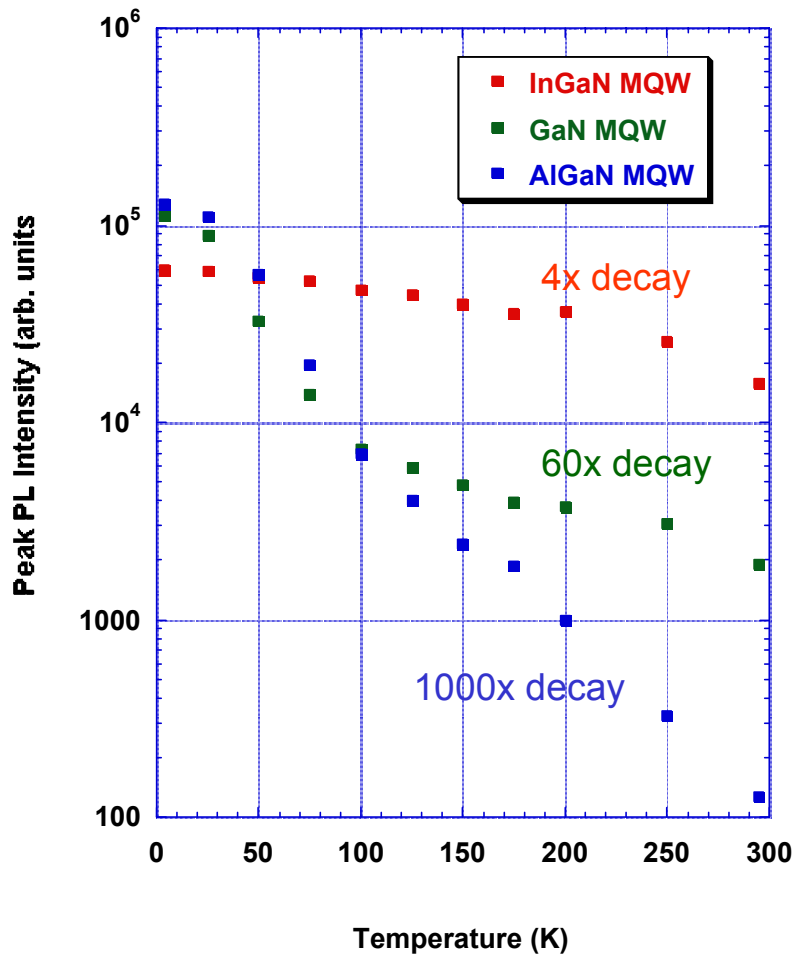
Using AlGaN QWs to shift LED emission below 340 nm



Crawford & Han, Fall MRS Meeting (1999)

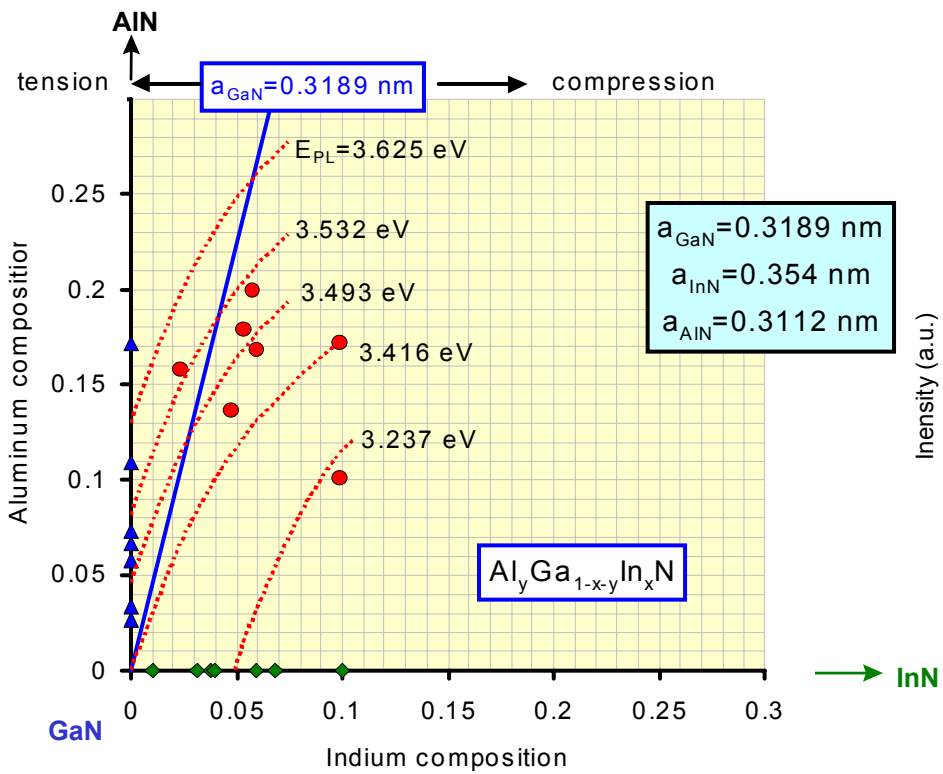
PL intensity vs temperature for InGaN, GaN, and AlGaN QWs



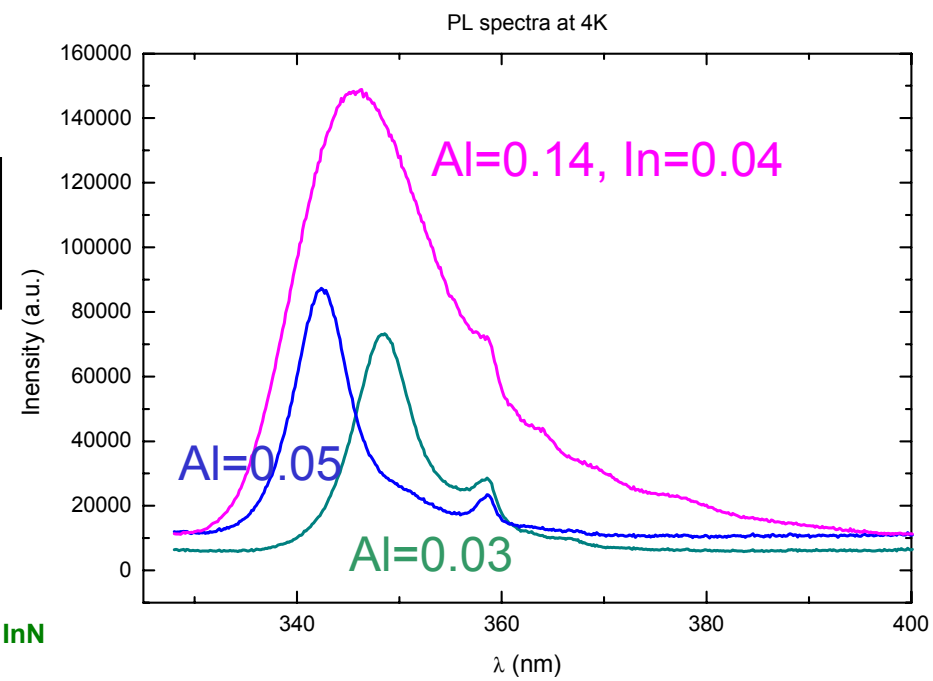


*InGaN MQW from H. Amano (Meijo University)

Quaternary AlGaInN: bandgap, lattice constant, and efficiency improvement in UV



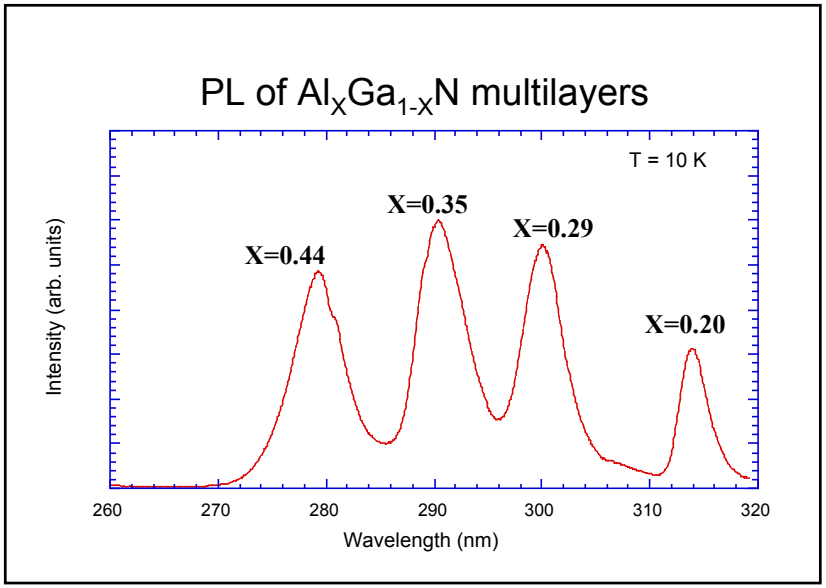
Han et al., JJAP 39, 2372 (2000)

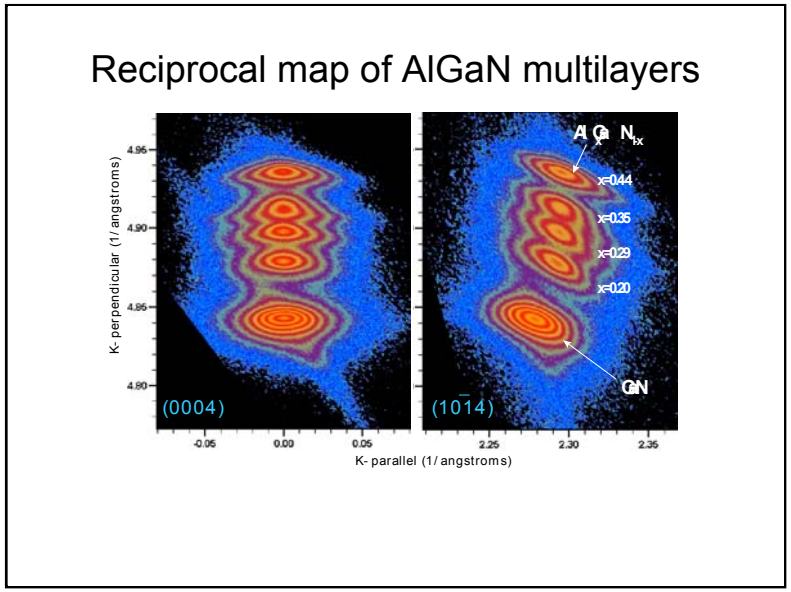


PL from AlGaN(Al=0.14)/AlGaInN (Al=0.14, In=0.04) QWs and AlGaN(al=0.14)/AlGaN (Al=0.05 and Al=0.03, respectively) QWs.

Han et al., 2000 EMC

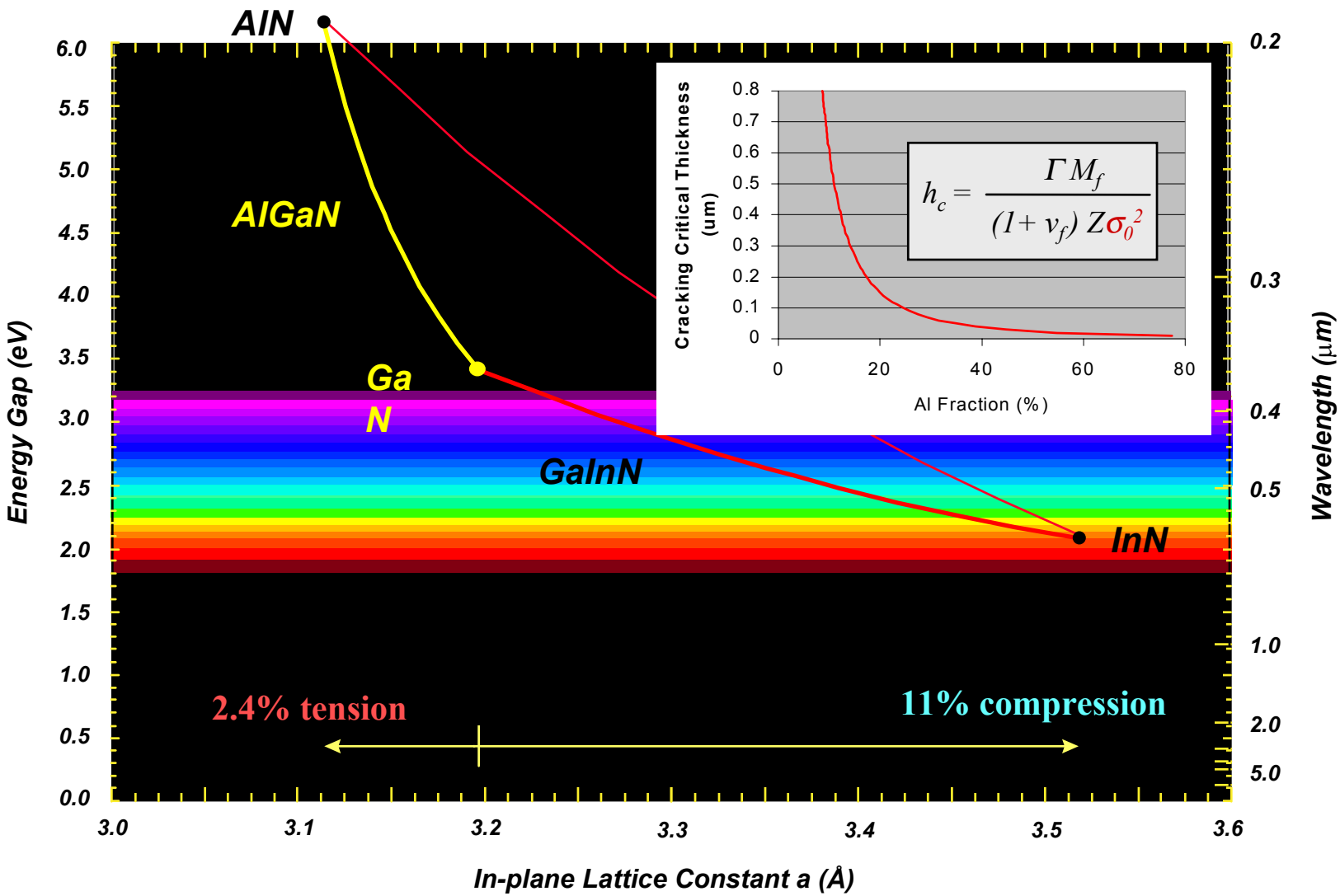
Using AlGaN for 280 nm UV emission



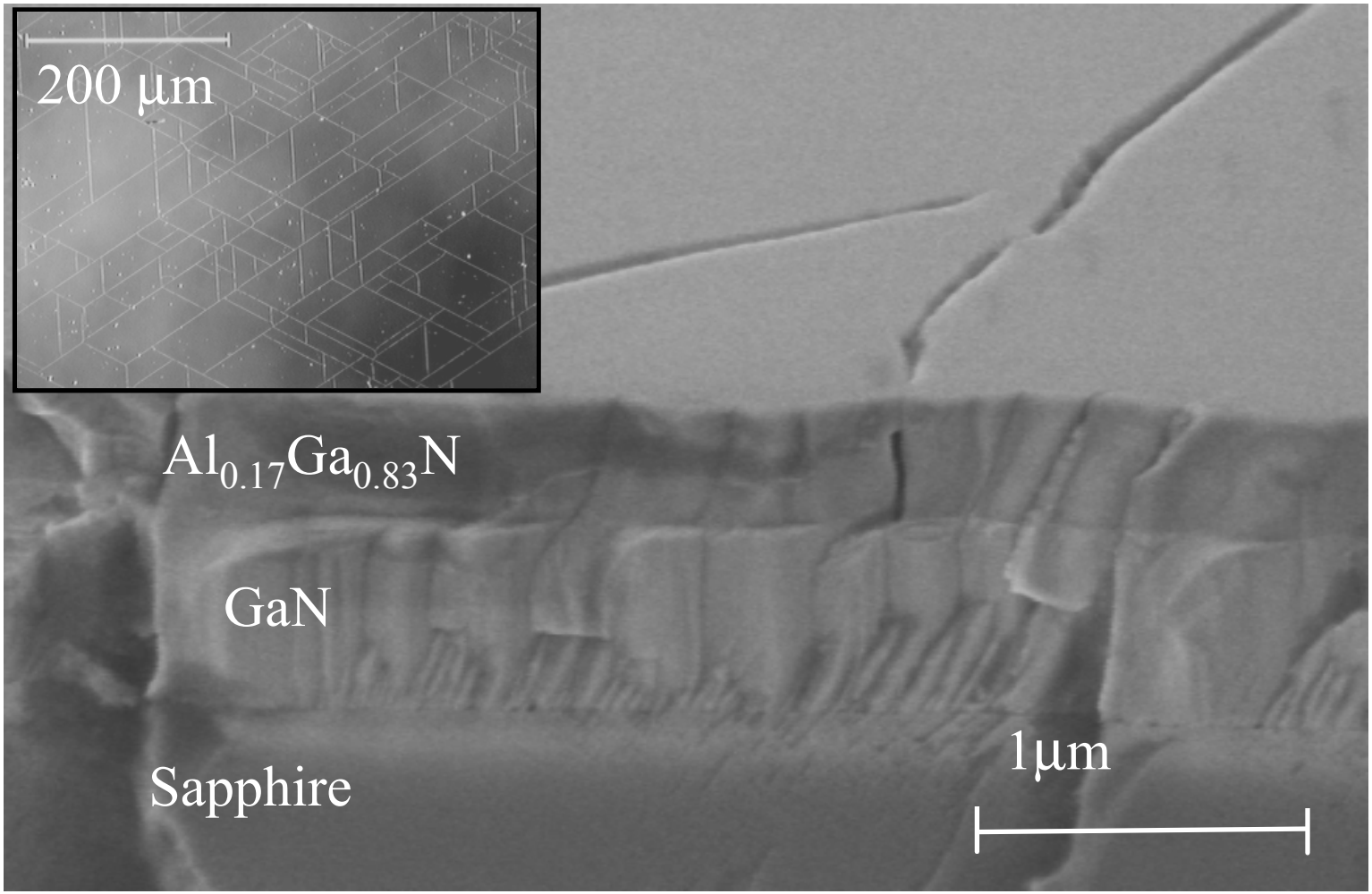


- 280 nm emission is observed with $Al_{0.44}Ga_{0.56}N$
- Partial relaxing of tensile stress (through cracking and dislocating) was determined through asymmetrical x-ray diffractions

Tensile strain in growing AlGaN: relaxation through cracking



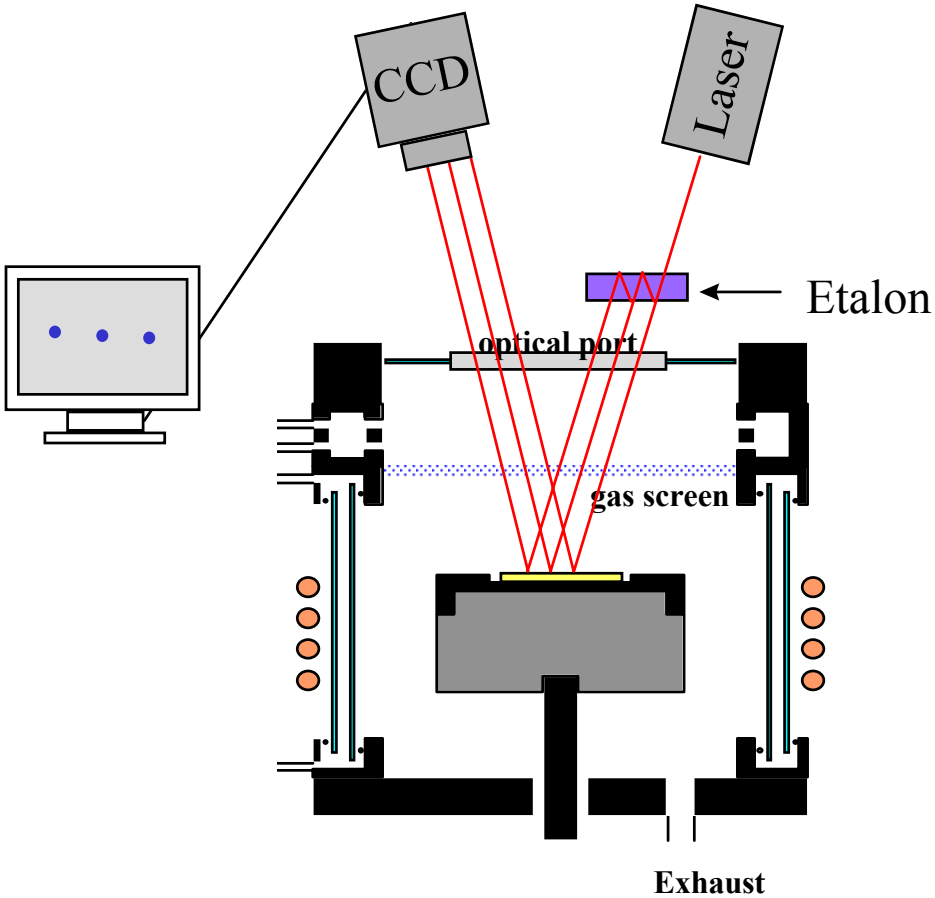
Challenges in III-N UV Optoelectronics: Tensile Stress and Cracking

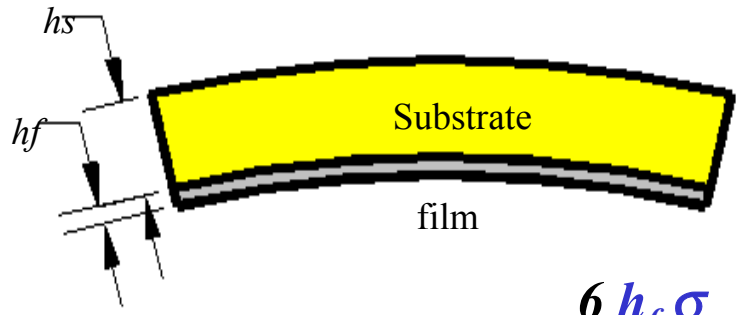


Hearne et. al, APL (2000)

Study of thin film stress and cracking using *in-situ* stress sensor (MOSS)

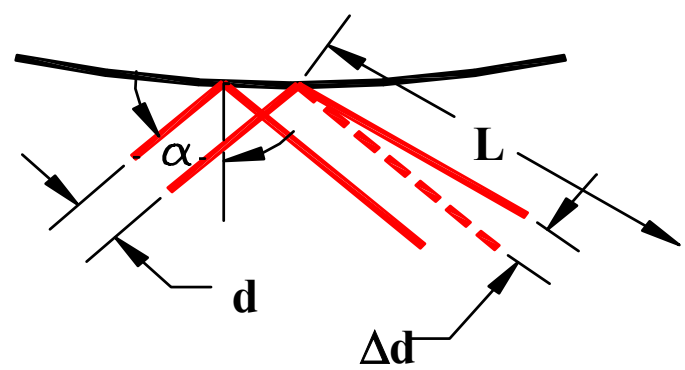
Multi-beam Optical Stress Sensor





Stoney Eq. (1909)

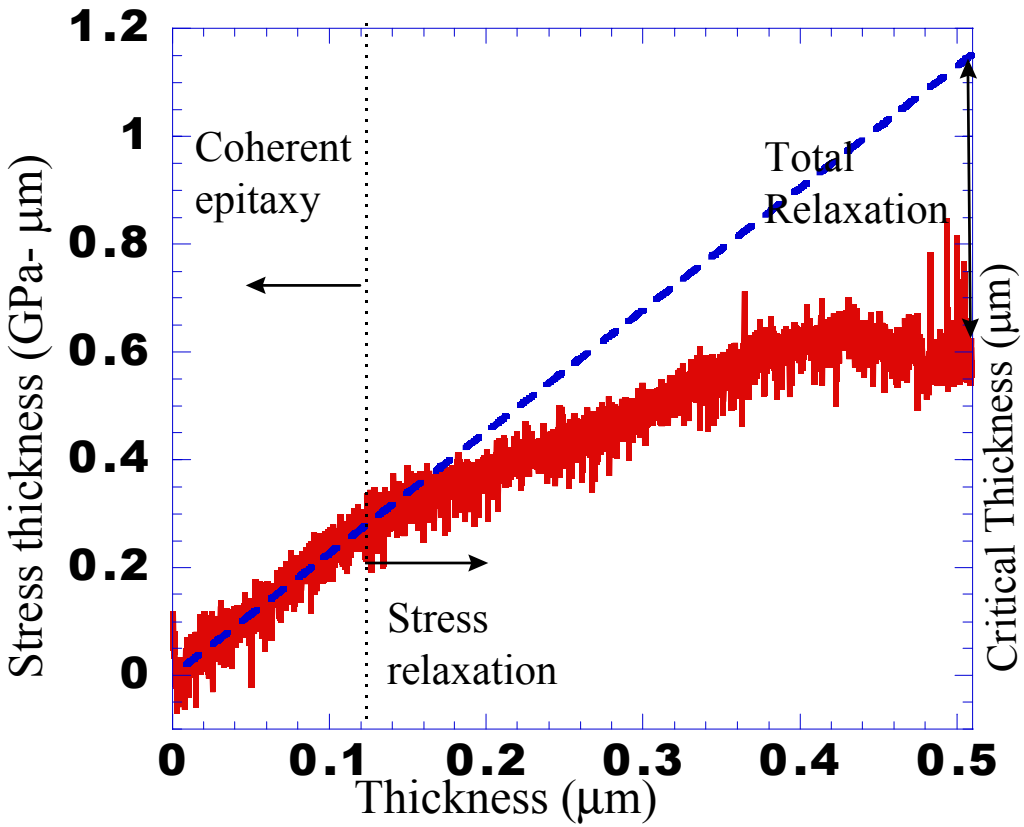
$$K = \frac{6\, h_f\, \sigma}{M_s\, h_s^2}$$

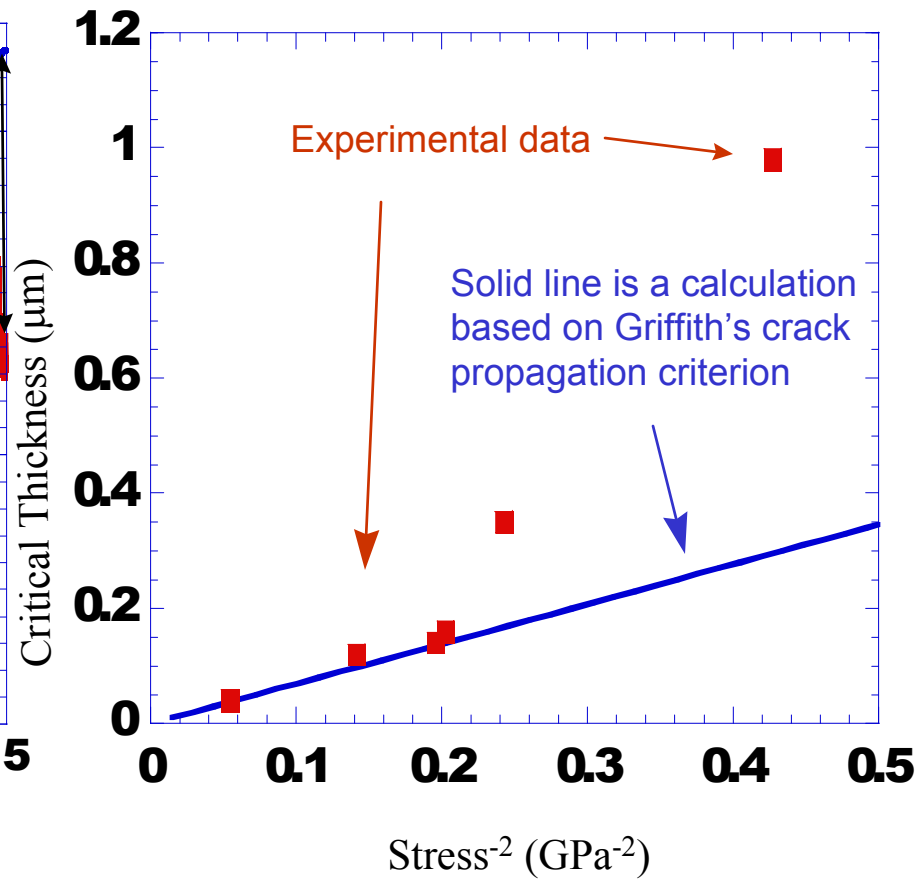


$$\sigma \bullet h_f = \frac{\Delta d}{d} \frac{M_s h_s^2 \cos(\alpha)}{12L}$$

Hearne et al., APL (2000)

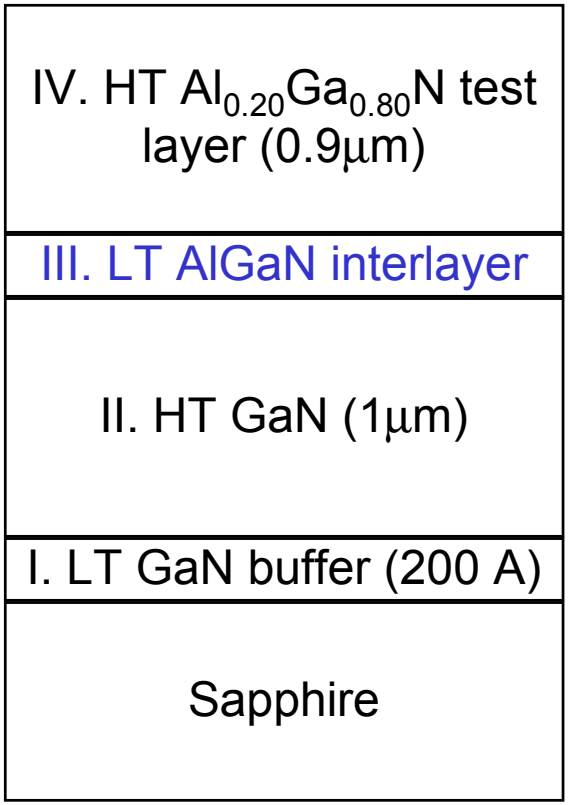
In-situ monitoring of stress relaxation and determination of cracking critical thickness



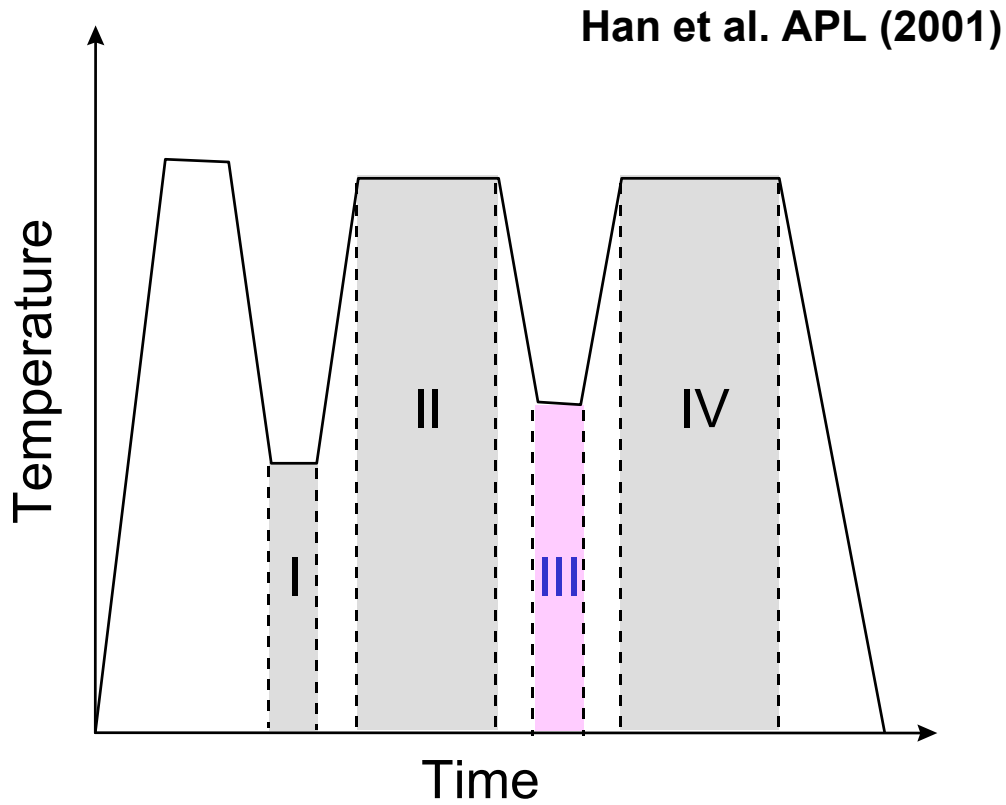


S.J. Hearne et. al, Appl. Phys. Lett. **76**(12) 2000

Control of growth stress using AlGaN interlayers



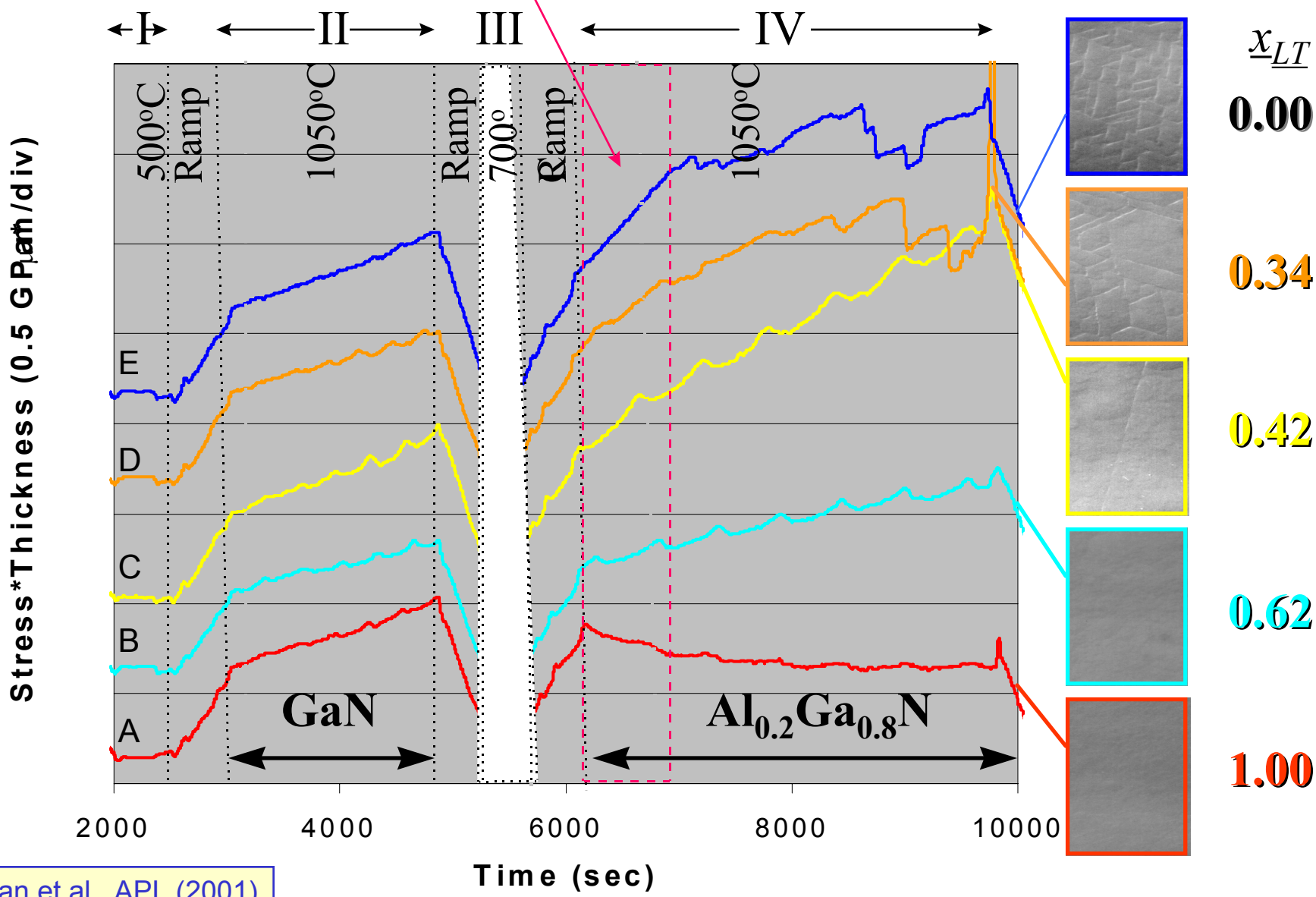
(a)



(b)

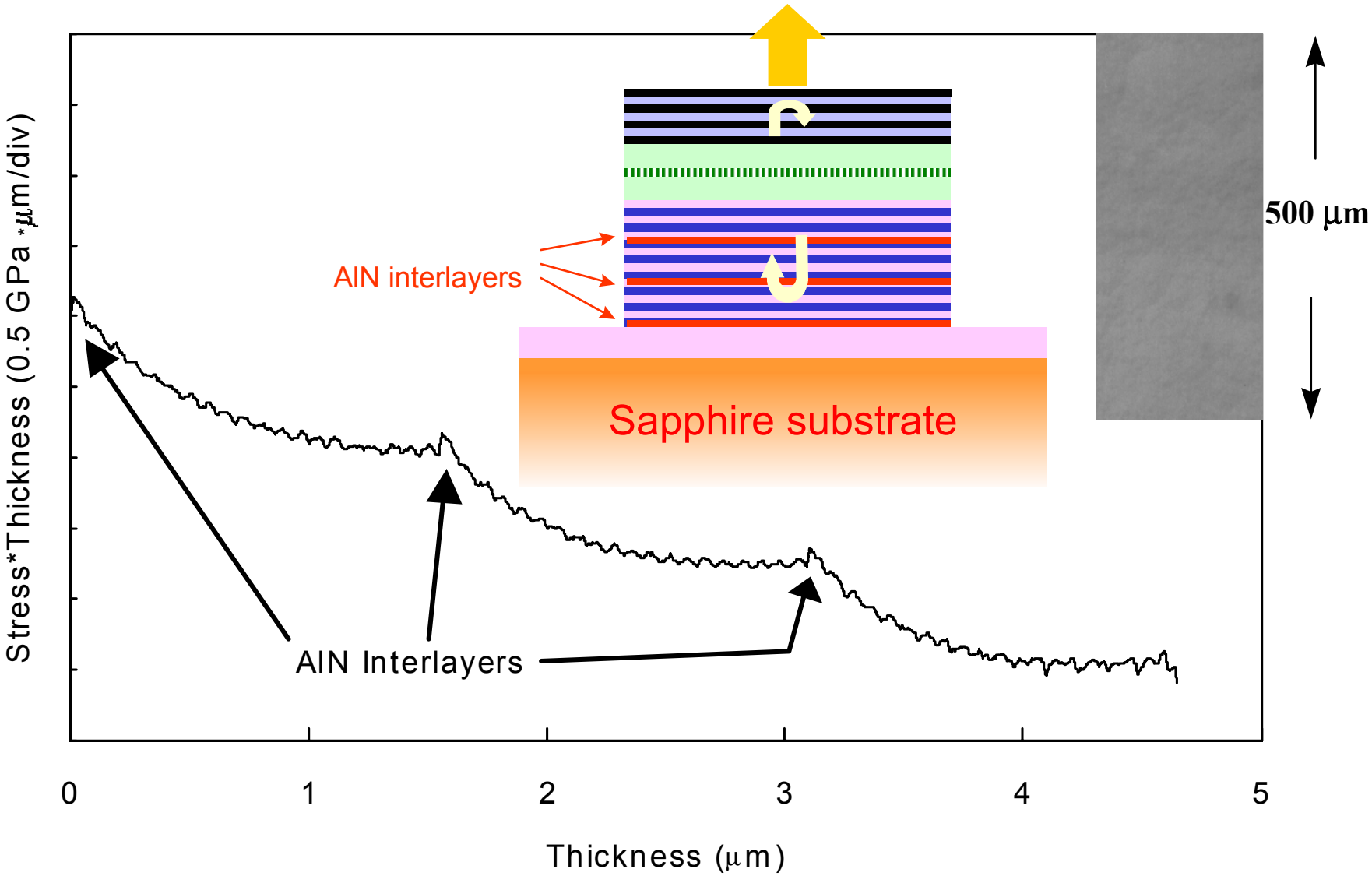
5 different compositions of AlGaN interlayers = 5 separate samples

Verification of strain engineering through in-situ stress monitor

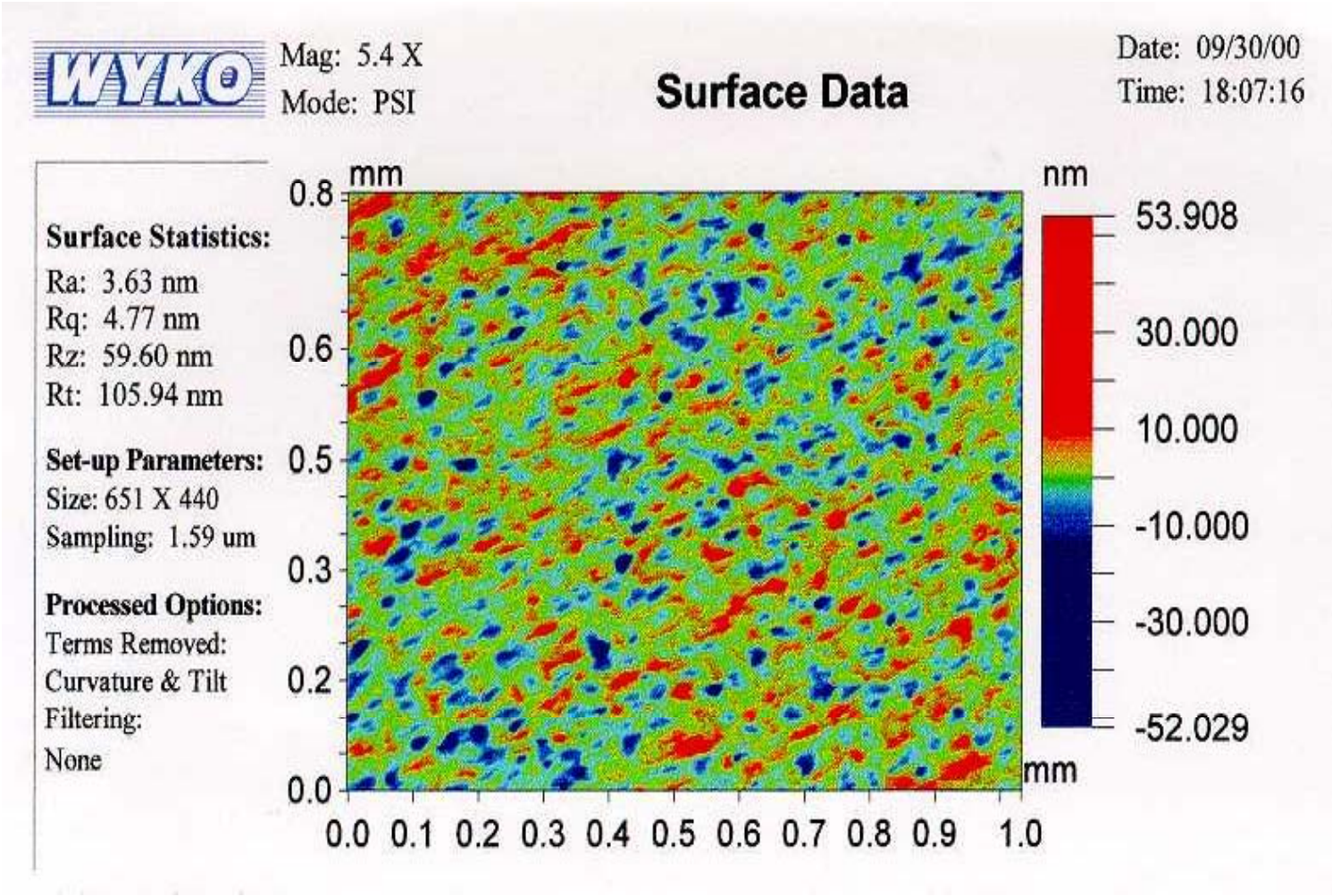


Han et al., APL (2001)

60-pair of $Al_{0.2}Ga_{0.8}N$ /GaN DBR with multiple AlN interlayers for stress management

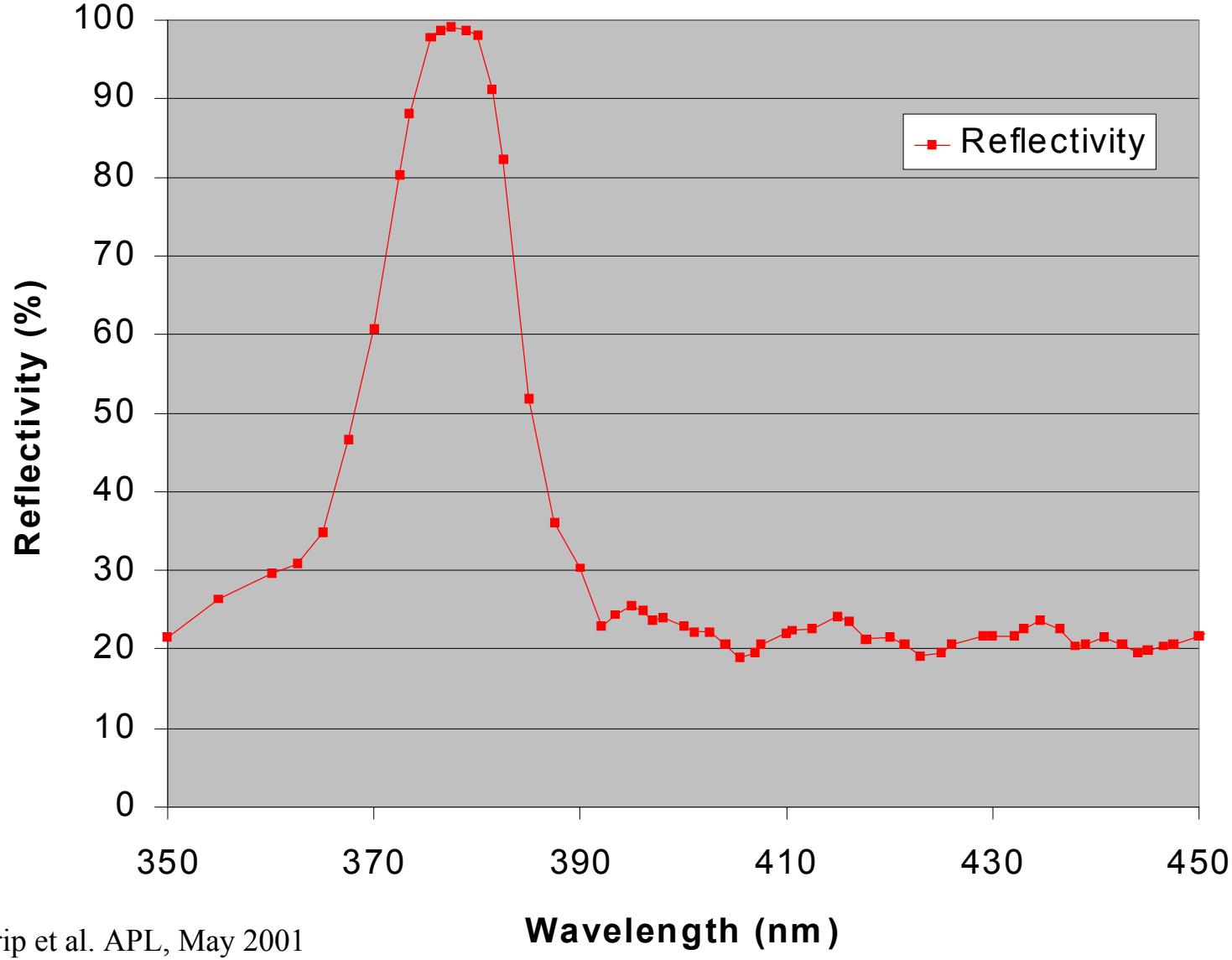


Surface morphology of AlGaN/GaN DBR



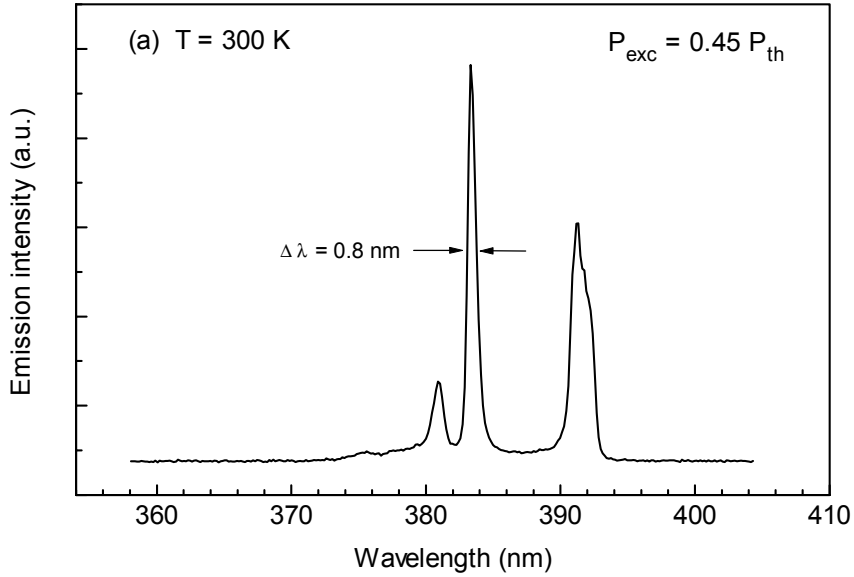
•RMS roughness over 1mm x 1mm area is around 4.5 nm

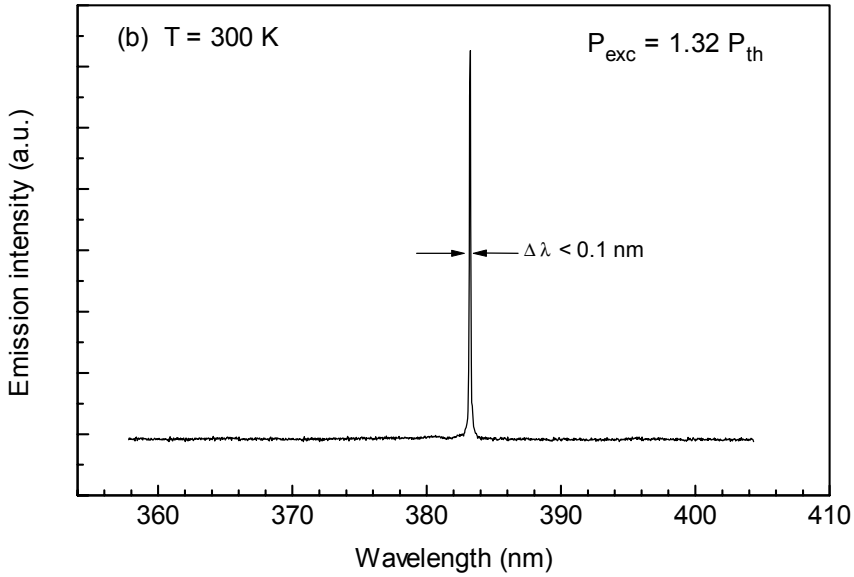
Reflectivity from a 60-pair AlGaN/GaN DBR

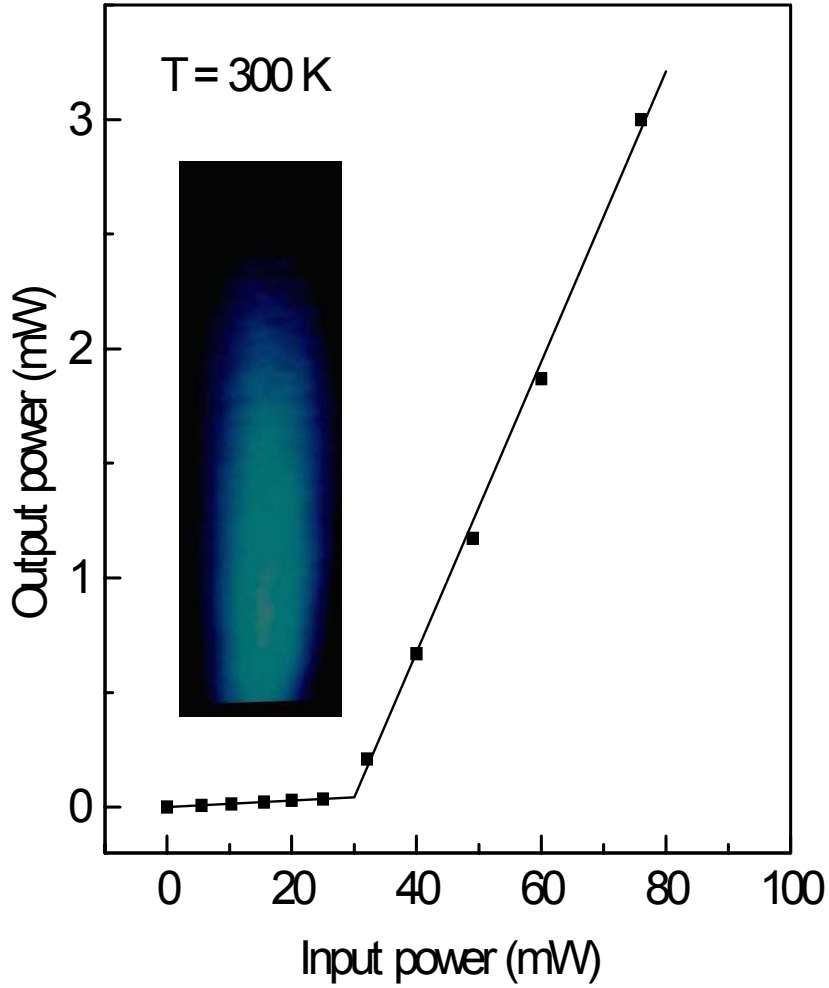


Waldrip et al. APL, May 2001

Photo-pumped Near-UV VCSEL operation







Zhou et al., EL (2000)

Challenges and Opportunities

- Optical efficiency of AlGaN: understanding of the nonradiative mechanisms (point defect related?)
- Material quality of AlGaN
  - Reduction of point defects (native and extrinsic)
  - Control of strain and stress
  - Enhancement of efficiency (Ex. In co-doping)
- Conductivity of p-AlGaN: incorporation and activation of acceptors
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