

Growth by MOVPE of AlGaN/GaN structures with intersubband transitions in the 1.2-1.7 μ m region of the spectrum

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Outline

- Motivation
- Design
- Growth
- Electron microscopy
- Absorption
- Conclusions

Motivation

- C.B. Offsets in AlN/GaN system 1.8eV
 - THz modulation rates at Telecom wavelengths possible
- But:- no device yet despite 10 years of research
- Difficult material system –highly strained, piezoelectric fields and high dislocation densities
 - MBE used for previous studies

Why MOVPE?

■ Against:-

- High growth temperatures
- Widely divergent optimum growth conditions

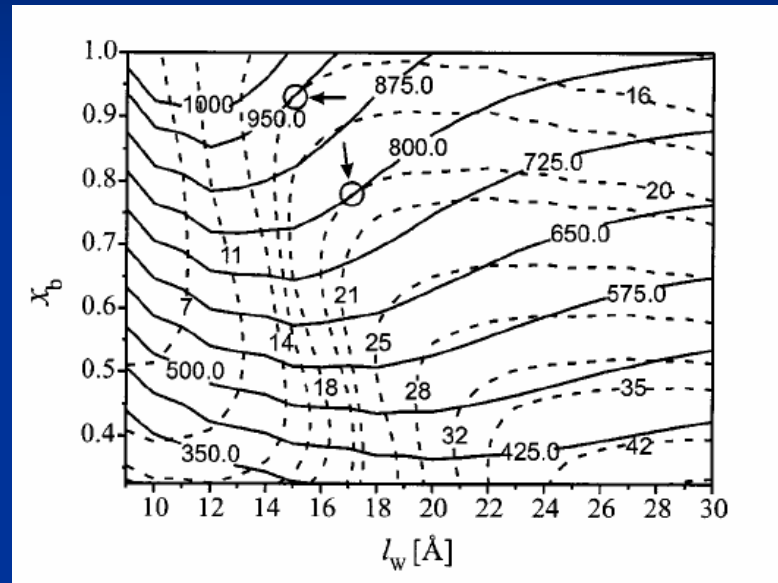
GaN $T_g < 700^\circ\text{C}$ AlN $T_g > 1000^\circ\text{C}$

■ For:-

- Rapid improvements in Technology due to mass production of Blue LEDs and Lasers
- Cheap technology for mass produced devices

Minimizing Al in Barrier

V. D. Jovanovic, Z. Ikonc, D. Indjin,
P. Harrison, V. Milanovic, and R. A.
Soref J. Appl. Phys. 93, 3194 (2003)



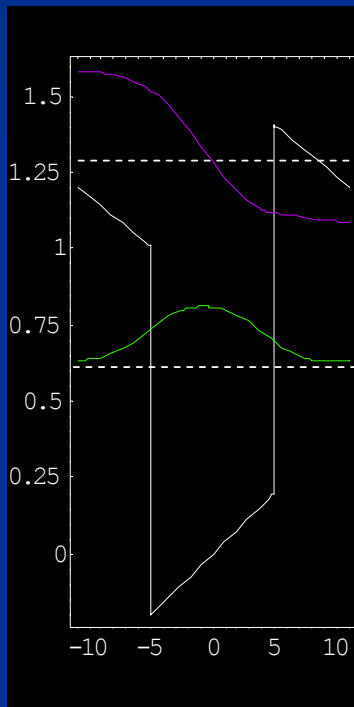
- Assume barrier thickness 1nm
- Plot E_1 - E_2 energy counters as function of barrier Aluminium fraction and well width

Design

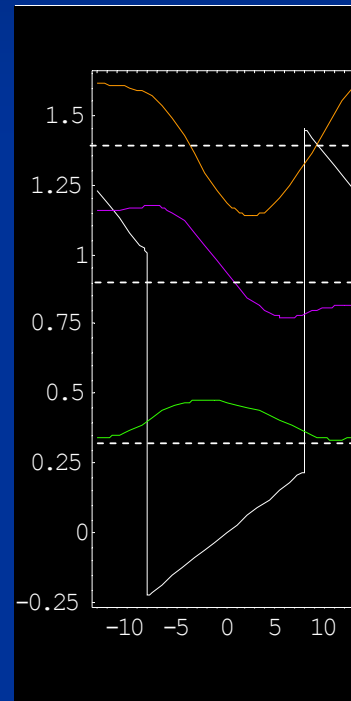
- Optimal growth conditions for AlN and GaN divergent, therefore $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$ chosen for barrier material as compromise
- Two designs grown with differing doping levels
- Aim to achieve E_1 - E_2 transitions at $1.5\mu\text{m}$ and E_1 - E_3 at $1.3\mu\text{m}$

Sample number	GaN well (nm)	$\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$ barrier (nm)	Repeats	Doping level electrons/cm ³
1	1.2	1.0	300	1×10^{17}
2	1.6	1.0	300	1×10^{17}
3	1.2	1.0	300	3×10^{17}

Potential profiles



$\lambda \sim 1.54 \mu\text{m}$



$\lambda \sim 1.3 \mu\text{m}$

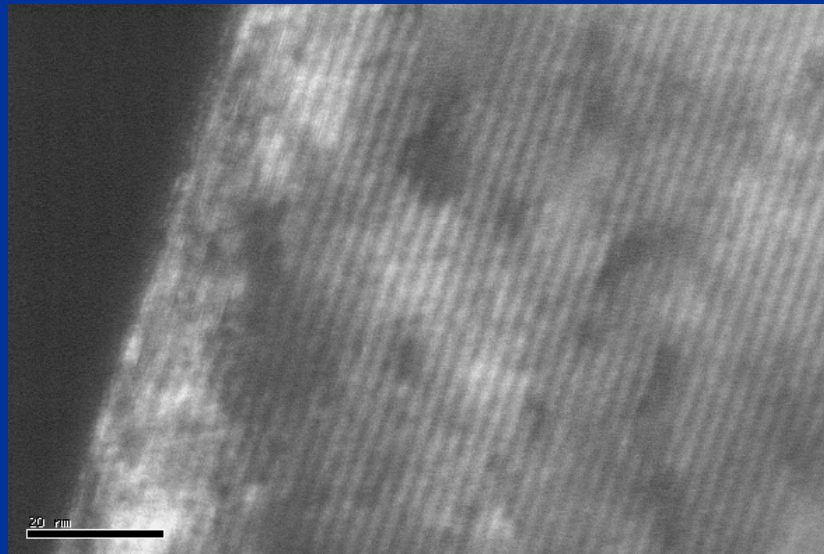
$\lambda \sim 1.7 \mu\text{m}$

Growth

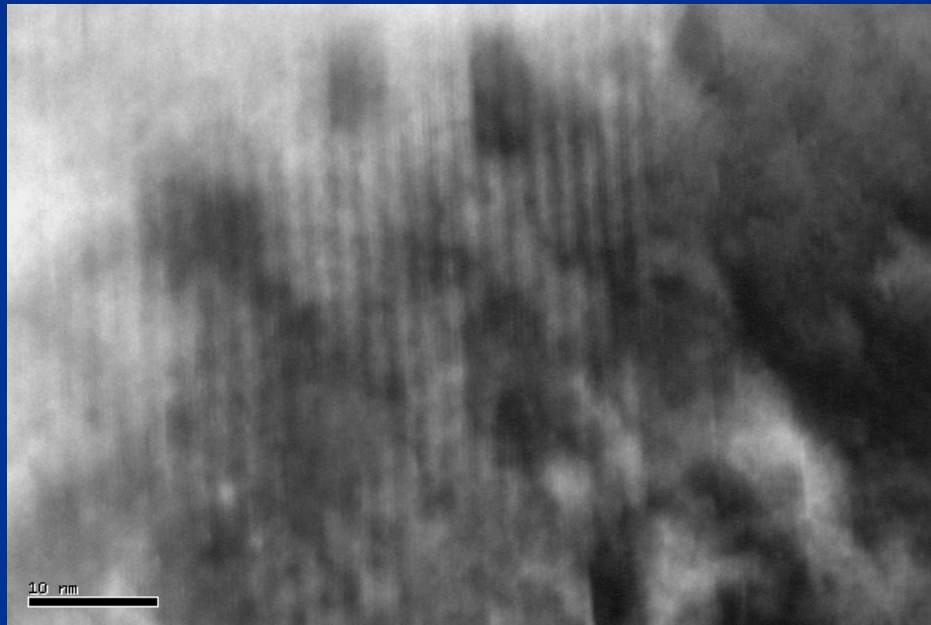
- Growth by standard shower head MOVPE reactor on sapphire
- High temp AlN grown on Sapphire first
- $\text{Al}_{0.3}\text{Ga}_{0.7}\text{N}$ 10nm strain balancing interlayer
- Compressive strain at base of superlattice relaxed by interlayer
- X-ray used to confirm structure

Electron microscopy

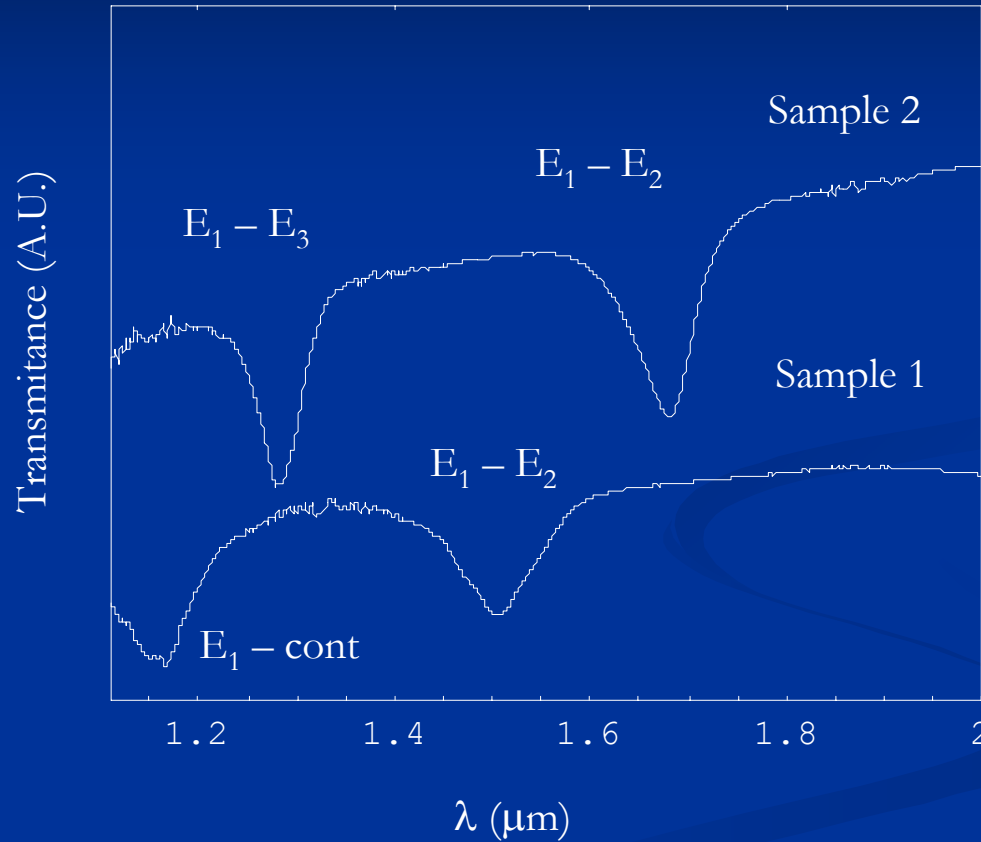
Top of superlattice



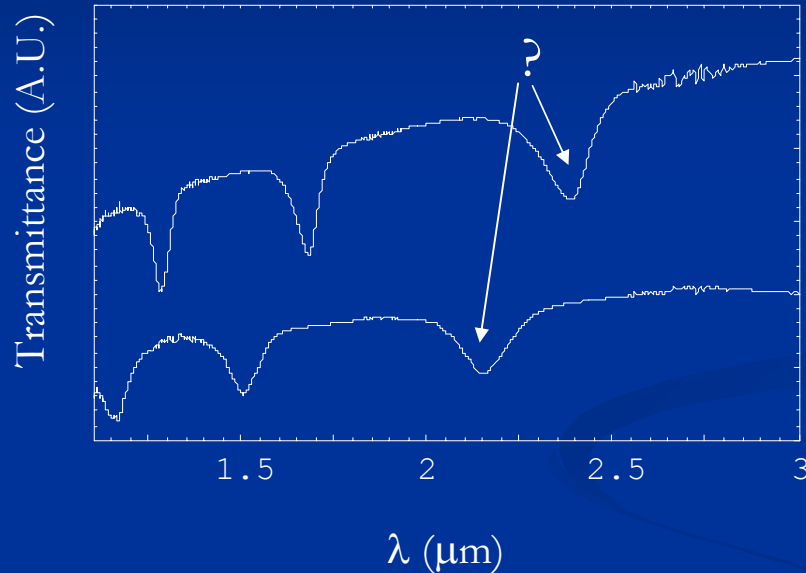
AlN buffer Region



Absorption

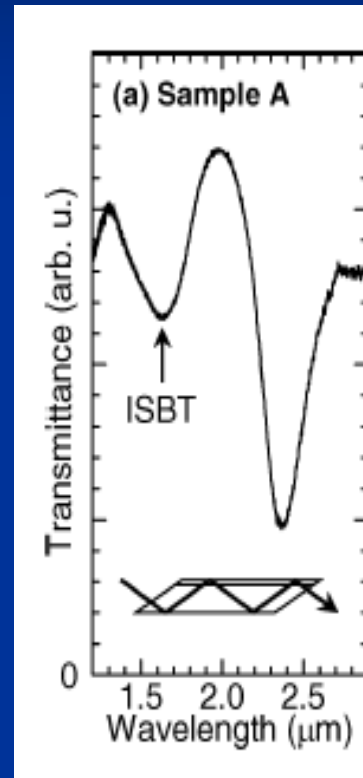
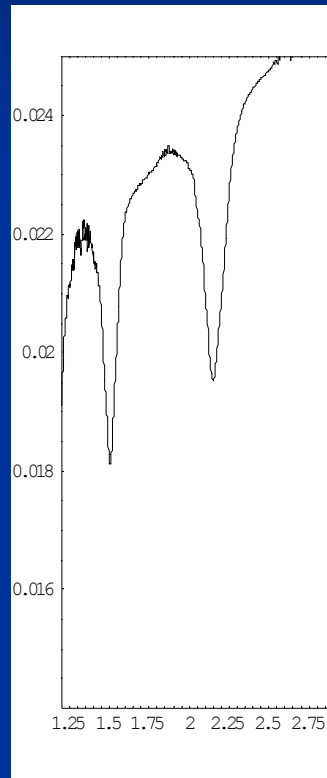


But- longer range absorption



- Peak Shifts with period and has right polarisation for ISBT
- Energy corresponds to calculate $\text{HH}_1 - \text{HH}_3$ transition energy

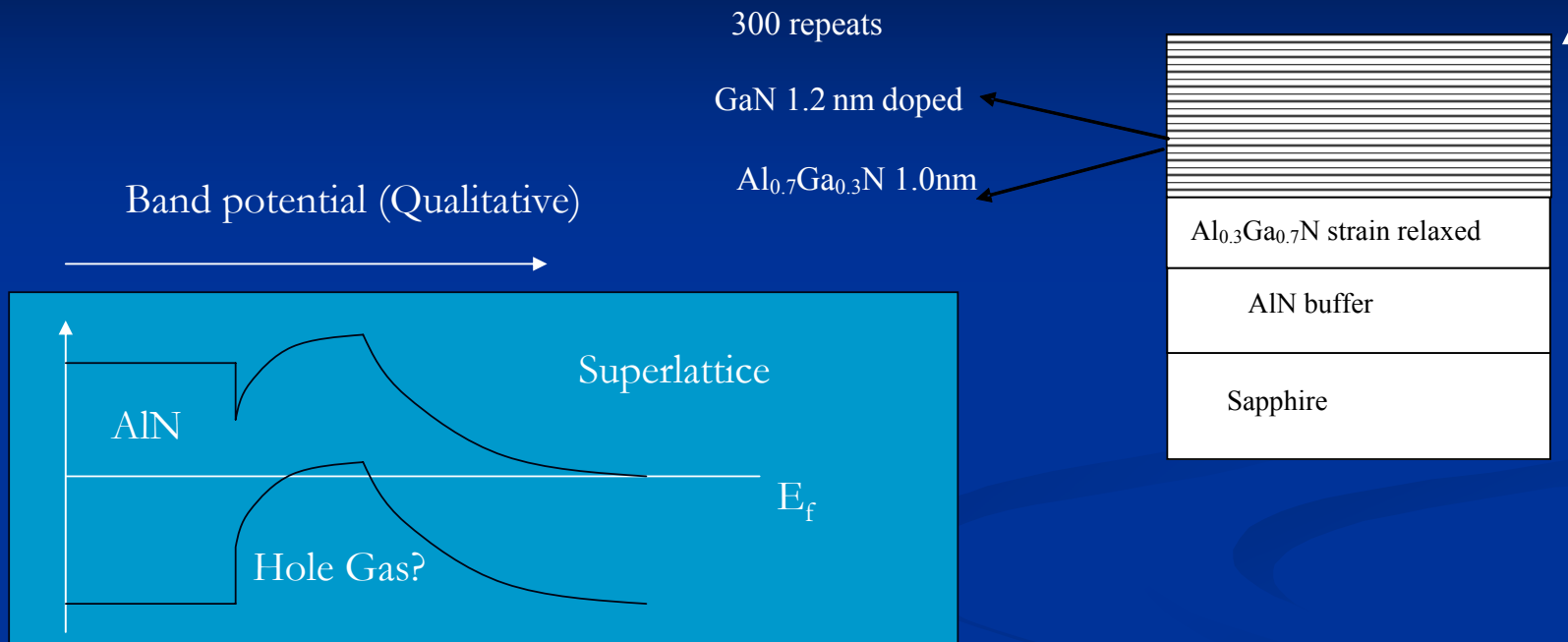
Comparison to published data



Lizuka et al 2002

Heavily doped
AlN/GaN
structure on AlN
buffer

Sample structure and strain

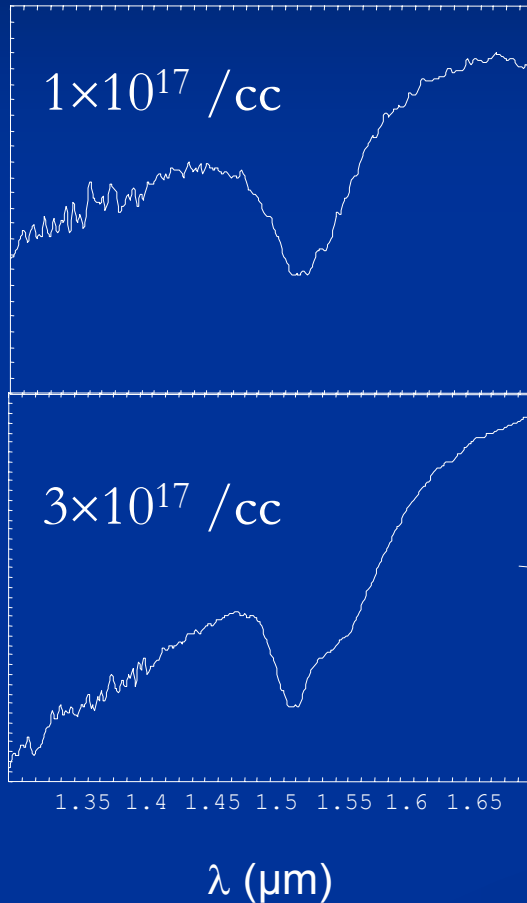


- Previous reports of absorption features due to hole gases in AlGaN grown on AlN
e.g. M. S. Shur, A. D. Bykhovski, and R. Gaska, Solid-State Electronics **44**, 205-210 (2000).

Absorption due to holes

- Strain induced hole gas must be present at base of superlattice stack
- Only HH_1, HH_2 and HH_3 transitions in well
- HH_1-HH_2 not observed due to absorption of by Sapphire substrate
- For device control of strain and removal of p-region essential

Effect of doping Density



- broadening due to inhomogeneous process

- probably related to fermi-level variation

Conclusions

- MOVPE can produce AlGa_N/Ga_N intersubband structures with transitions in the telecoms region of the spectrum.
- The use of MOVPE with AlN on sapphire technology gives superior sample quality and lower linewidths compared to current MBE samples
- Presence of hole gas at sample base indicated by hole ISBTs in absorption

Acknowledgements

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