Emission properties of equal width GaN/AlN superlattice systems: temperature dependent and time resolved study

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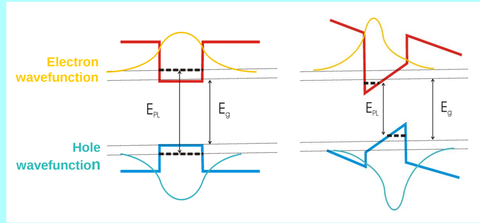
Motivation

- ✓ Nitrides crystalize in wurtzite structure ⇒ the performance of nitride devices is hampered by the presence of strong **spontaneous** and **piezoelectric** polarization, and resulting built-in electric field along the typical [0001] growth direction
- ✓ The built-in electric field induces the Quantum Conned Stark Effect (QCSE), which causes spatial separation of electron and hole wave functions in the wells (⇒ lower efficiency of the optical transitions), and a red shift of the transition energy
- ✓ In GaN/AlN quantum wells (QWs) the electric field decreases with increasing width of the QW.

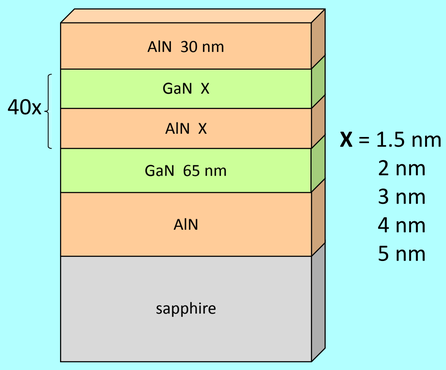


$$E_{PL}=E_g+E_e+E_h-qLF-E_x$$

QW transition energy; electric field; exciton binding energy; band gap; confinement energy; QW width

Our goal: check the influence of the QW geometry on the emission properties of GaN/AlN QWs.

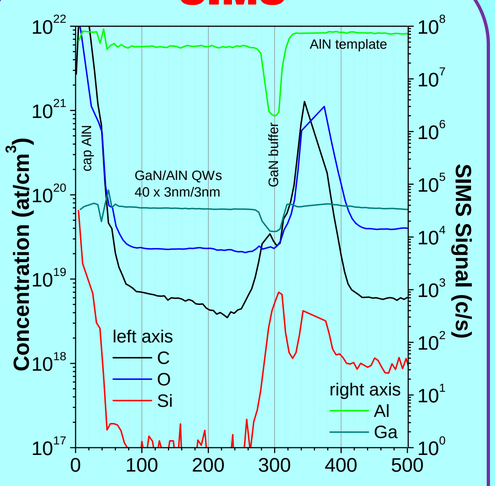
Samples



Grown by PA MBE on c-plane sapphire

GaN/AlN MQWs: E. Monroy, CEA Grenoble

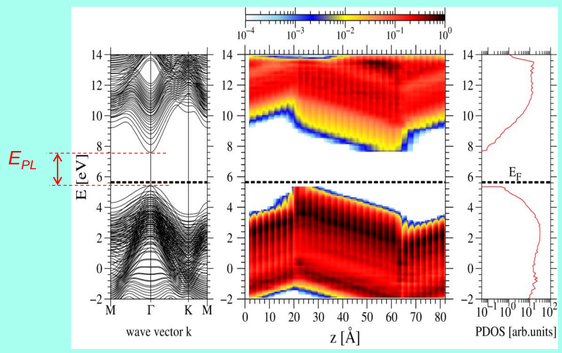
SIMS



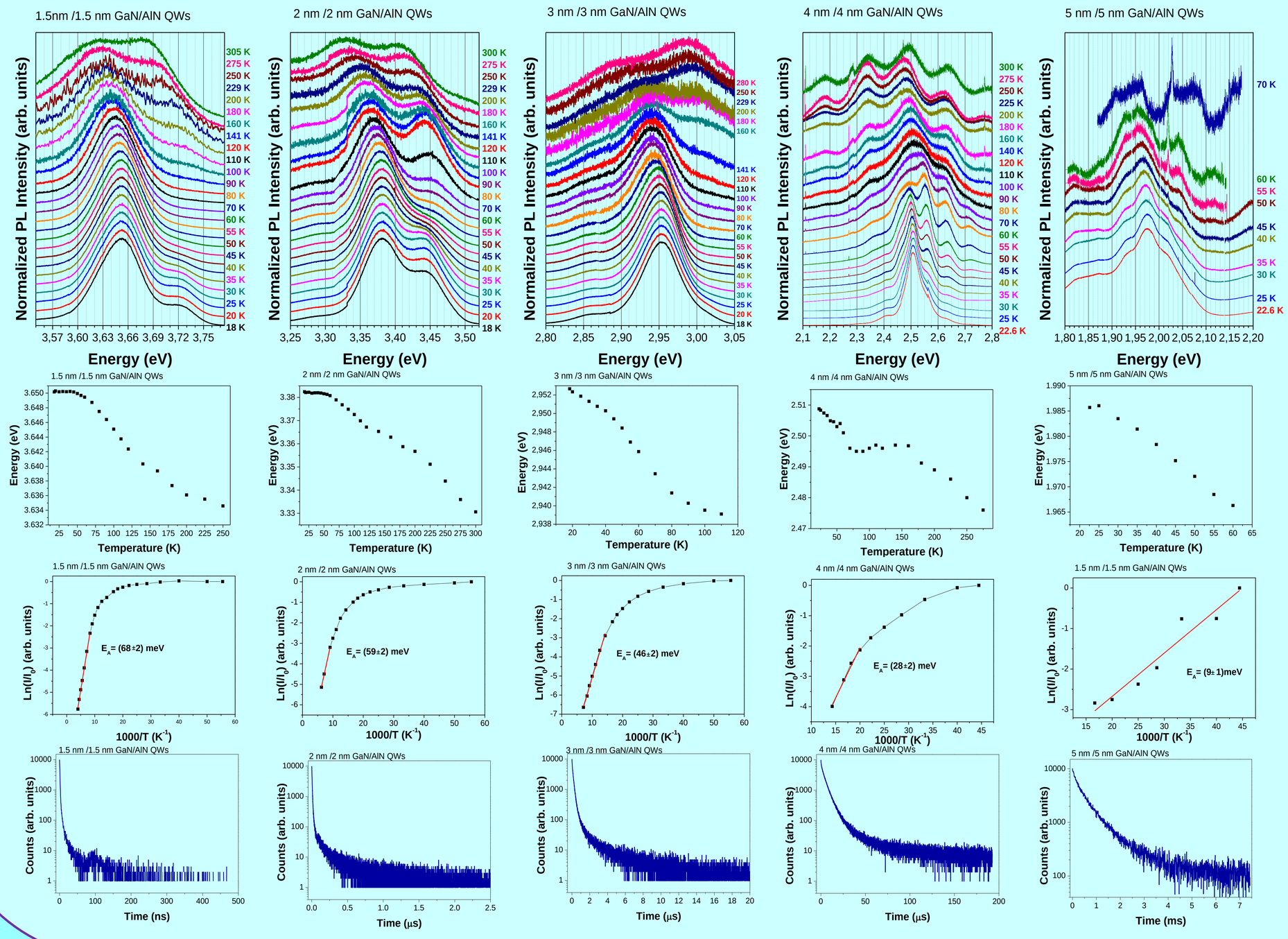
Unintentional doping:
[C] ~ 6×10^{18} cm^{-3}
[O] ~ 2.2×10^{19} cm^{-3}

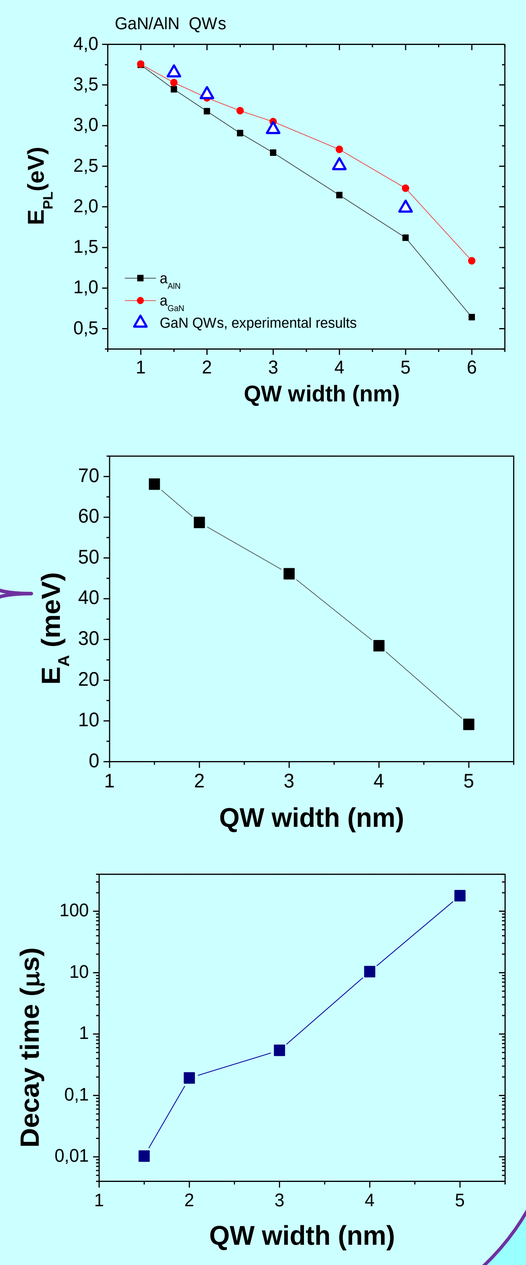
Ab initio calculations

- *Ab initio* calculations were performed for number of AlN/AlGaN MQWs using the VASP package.
- The **a** lattice parameter was set equal to that determined experimentally; it was fixed, and the structure was allowed to relax freely along **c** lattice parameter to minimize the elastic energy.
- It has been assumed the electric potential drop across the whole structure was close to zero
- In order to determine the effect of the built-in electric field, the potential profile was obtained by averaging in the plane perpendicular to c-axis.
- The emission energy shift, related to change of the energy of quantum states caused by electric field (QCSE) was obtained directly from *ab initio* calculations.



Experimental results & theoretical data





Summary

- **Good quality X nm GaN / X nm AlN (X = {1.5;2;3;4;5}) multi-quantum well structures were obtained by PA MBE growth.**
- **Due to the Quantum-Confined Stark Effect the GaN/AlN MQWs PL peak energies decreased by more than 1.6 eV for QW width increase from 1.5 nm to 5 nm (which is the fingerprint of the presence of internal electric field in the structure); this effect was accompanied by the drastic drop of the PL efficiency.**
- **Activation energy of thermal quenching of PL decreases with increasing QW width.**
- **Due to the strong built-in electric field PL decay times increased from about 100 ns up to 150 μs for QW width increasing from 1.5 nm to 5 nm.**
- **The strong dependence of PL lifetimes on QW widths indicates that in MQW system free electron-hole recombination is more probable than excition recombination.**