Modelling III-Nitrides Optoelectronic devices with Quantum corrected drift-diffusion

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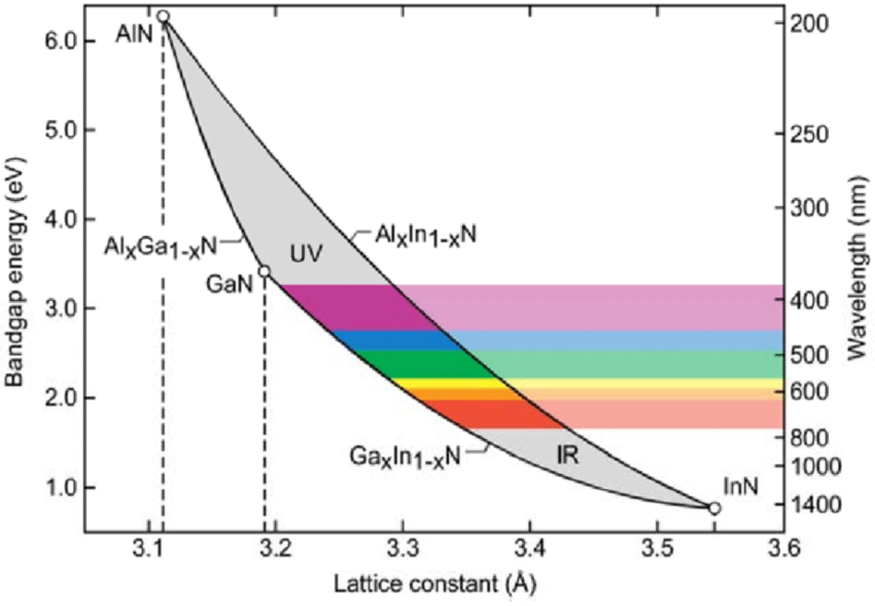
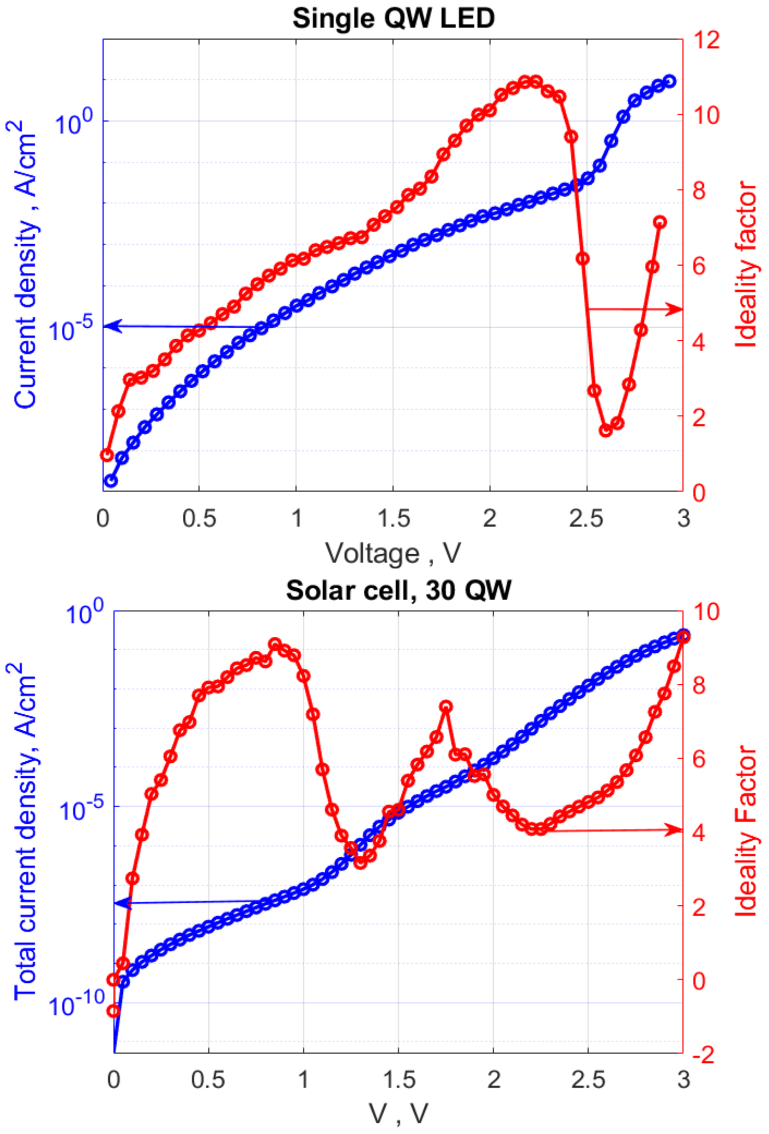
III-Nitrides



- III-Nitrides exhibit unique optoelectronic properties:
  - Wide range of bandgaps, allowing absorption or emission from UV to IR.
  - Direct band gap
  - Wide bandgap for high temperature applications
  - High efficiency of LEDs and Solar cells.

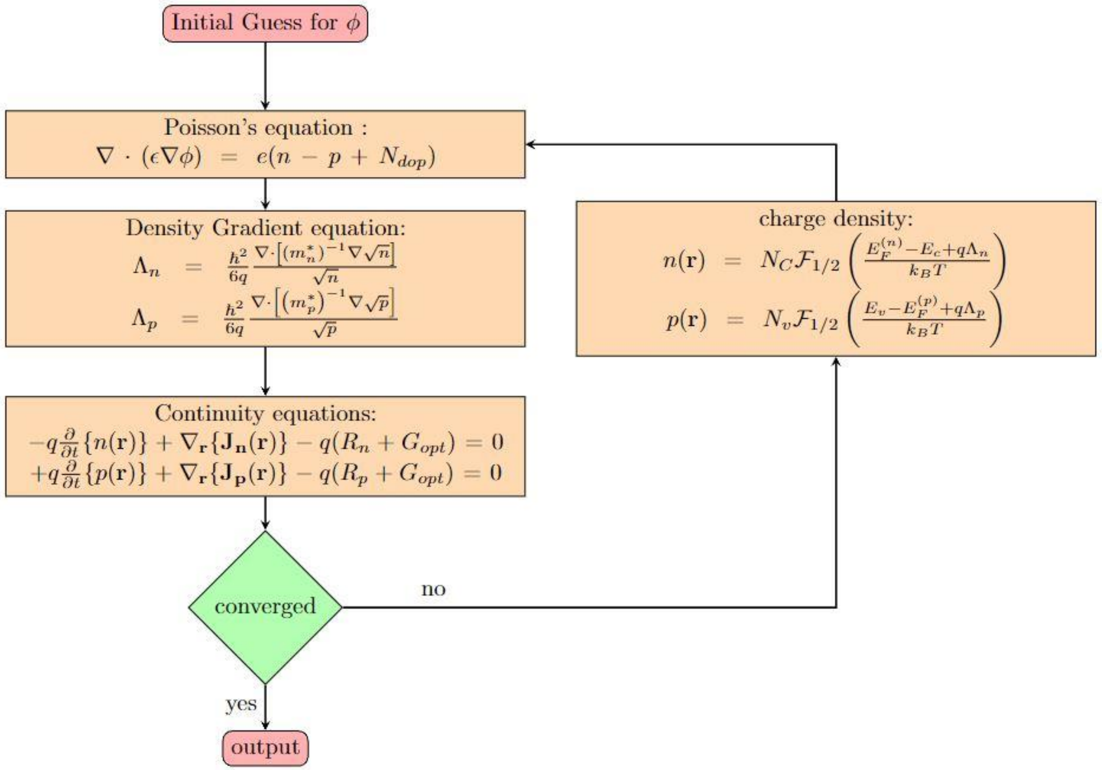
- However, the high difference in lattice constant makes heterostructures complex.
  - Only few nm of InGaN can be grown on GaN
  - Multi-quantum well structures needed to overcome this issue
  - Results in a high density of defects detrimental to the device performance

Experimental data



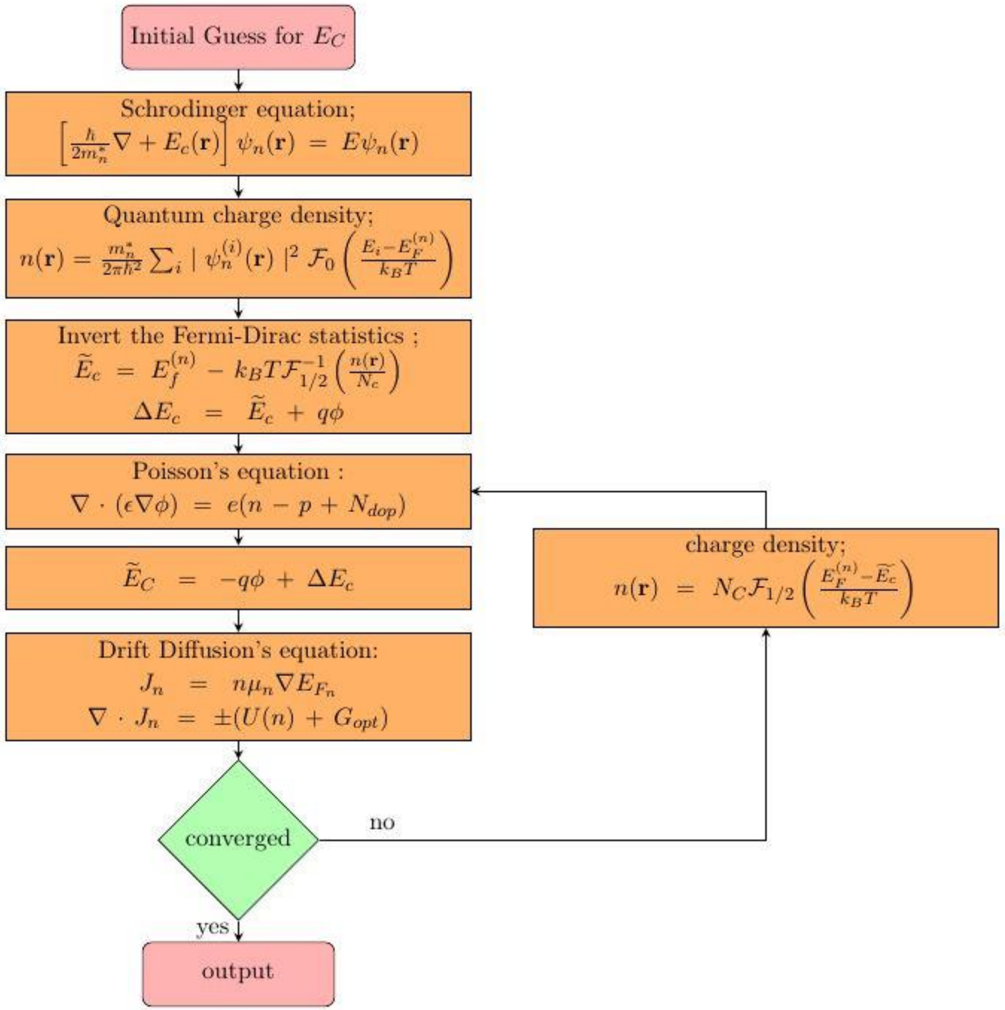
- Diode follow the Shockley equation
  - $I = I_s \cdot \left(\exp\left(\frac{qV}{\eta k_B T}\right) - 1\right)$
  - η is the ideality factor and should not be higher than 2 according to the SRH theory
- But, Experimentally, ideality factors higher than 2
- Explained in literature as trap-assisted tunneling.
  - Need to add quantum correction to drift diffusion
- However, not enough to explain some of these high ideality factors
  - Donor-acceptor pair model needed

Quantum correction



- Quantum effects does not allow to use normal simulation tools.
- Quantum corrections need to be included in the Drift Diffusion method.
- Two methods implemented, based on finding an effective quantum potential
  - Density Gradient
  - Poisson-Schrodinger

Quantum correction



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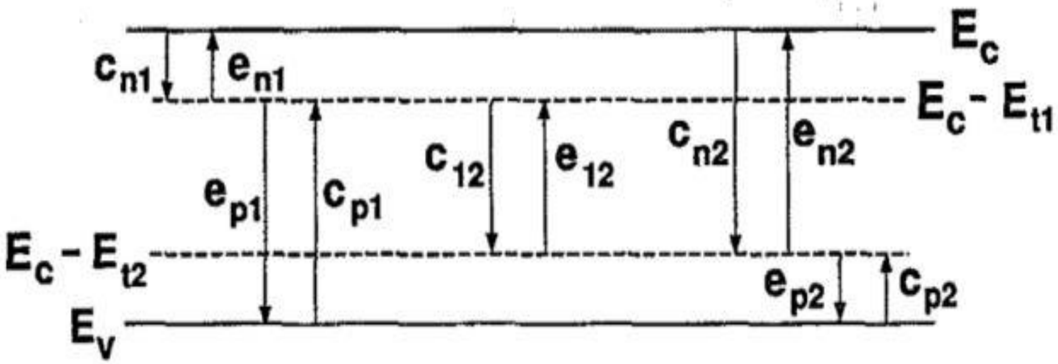
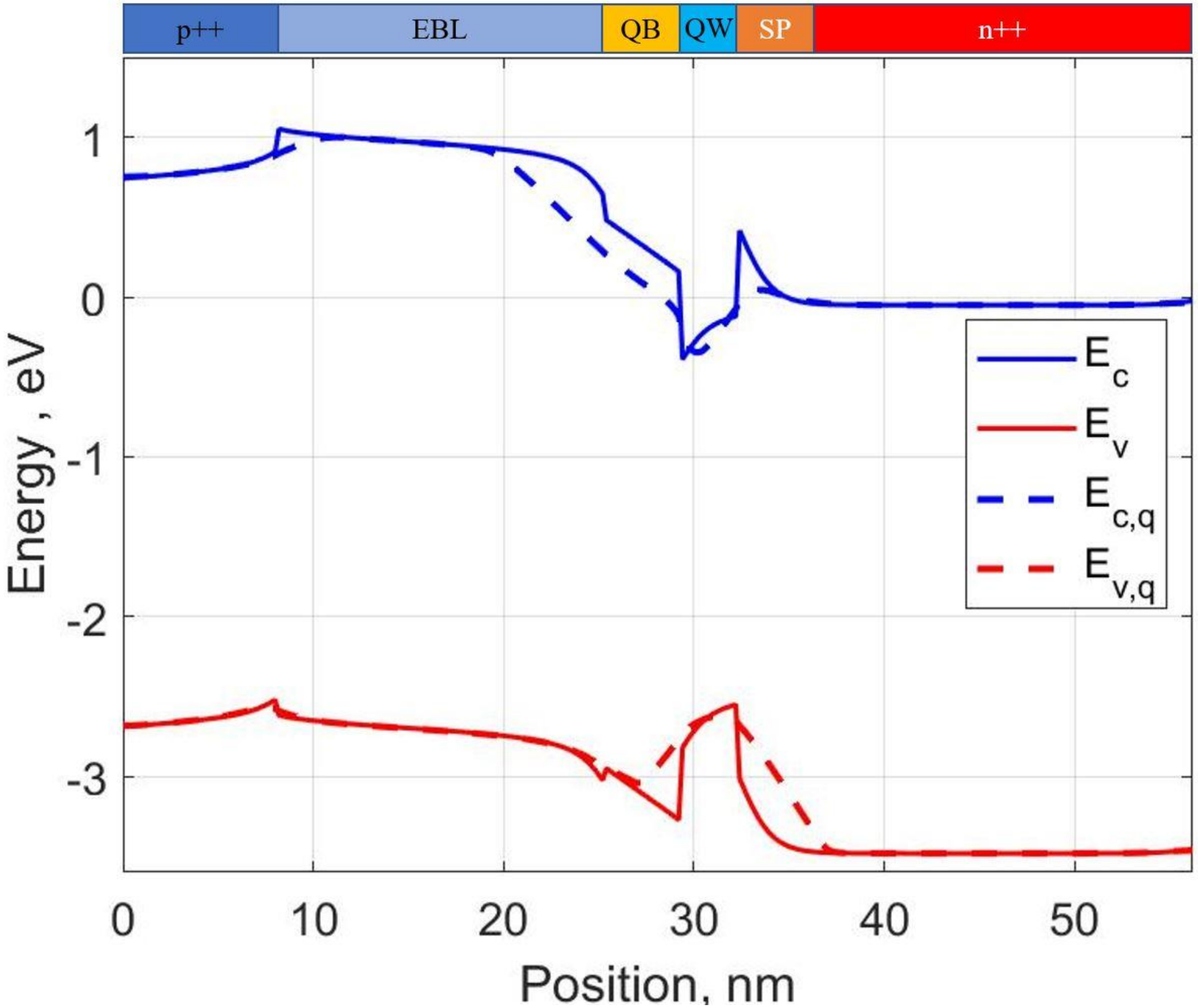
Donor-acceptor pair



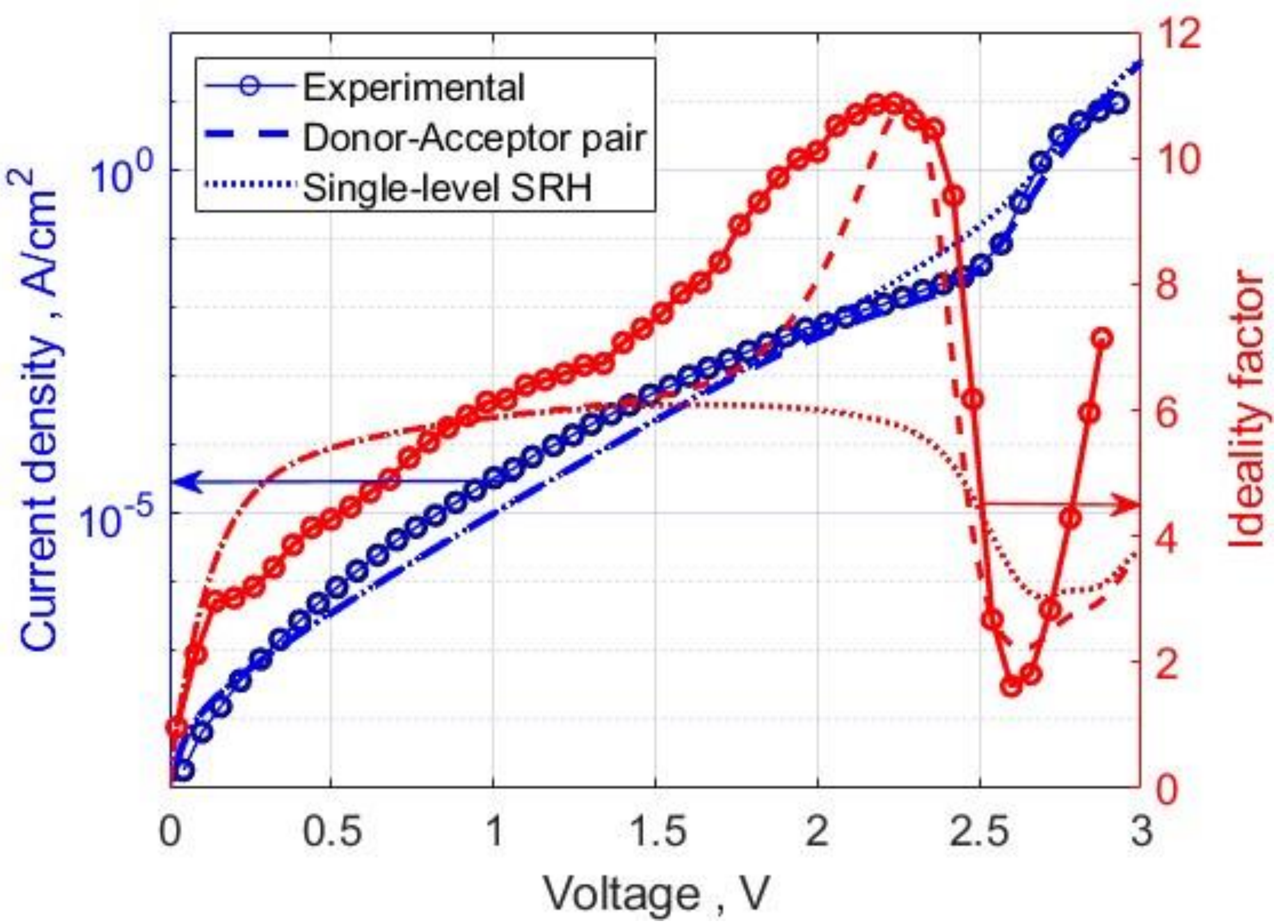
- Due to the high density of defects interaction between traps cannot be neglected
- Two <u>coupled defect levels</u> must be considered.
- If the level are set as a <u>Donor-acceptor pair</u>, the coupling rate between the levels can saturate the recombination channel.
  - The recombination current will grow slower, <u>increasing the ideality factor</u>

Single QW LED



- Single QW LED structure.
- Dashed line show the effective quantum band edges.
- Where it is below E_c, E_v indicates the presence of tail states, where there can be tunneling.
  - Where Trap-assisted tunneling can take place

Single QW LED



- At low voltage, trap-assisted tunneling increase the ideality factor to around 6.
  - Due to Trap-assisted tunneling
- After 2 V, the recombination channel is saturated increasing further the ideality factor.
  - Due to Donor-Acceptor pair model

Thank you for the attention