Trap-assisted Tunneling in InGaN/GaN Single-Quantum-Well LEDs

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250 word abstract:

III-nitride LEDs often exhibit abnormally high ideality factors. Based on numerical simulations and comparison with measured current-voltage characteristics of blue single-quantum-well devices, we demonstrate that a trap-assisted tunneling model introduced for pn-junctions by Hurkx et al. in 1992 can accurately describe III-nitride quantum well LED currents at low forward bias. By adjusting trap energy level, density and spatial location, we obtain a good fit for a series of devices with different quantum well thicknesses between 3-5 nm and Indium content in the range of 16-22%.
We find that the low forward leakage current of devices with ideality factors < 4 can be ascribed to tunneling in the electron blocking layer assisted by trap states with parameters compatible with the Magnesium dopants. The studied devices with higher leakage currents and ideality factors > 10, on the other hand, can be well described by mid-gap trap states inside the active region. We also find that the density of trap states needed to fit the IV characteristics in the latter case is correlated with the planar strain energy density in the active region. Since the shape of the non-exponential current-voltage characteristics of these devices strongly depends on the electric field, we used a certain amount of polarization field relaxation as additional fitting parameter. The amount of this relaxation is also found to be correlated with the planar energy density.
Our results suggest the appearance of deep trap levels in the active region for Indium contents > 18%, and a dependency of the amount of such traps on the amount of strain energy in the quantum well.

100 word abstract:

III-nitride LEDs often exhibit abnormally high ideality factors. Based on numerical simulations and comparison with measured current-voltage characteristics of blue single-quantum-well devices, we demonstrate that a trap-assisted tunneling model can accurately describe LED currents at low forward bias. Fitting of several device structures having different quantum well thickness or Indium content, some of the trap parameters like their energy level, density and spatial location can be deduced. These parameters are found to be correlated with the different lattice mismatch induced strain energy in the quantum wells.