Polarization doping for III-nitride optoelectronics

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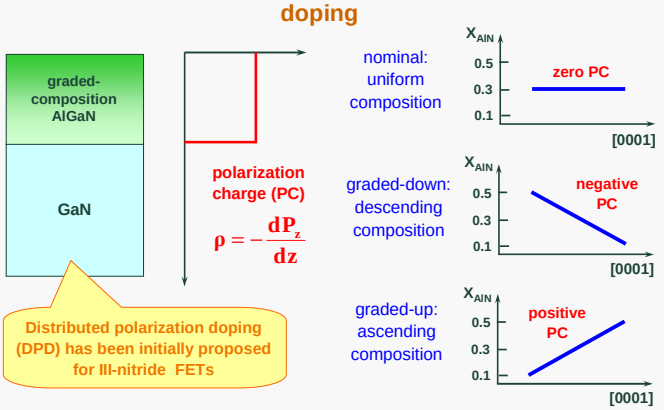
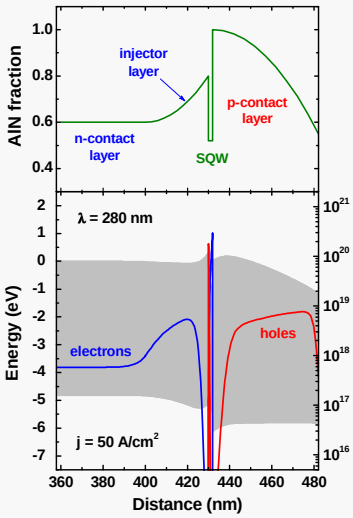
Fundamentals of distributed polarization doping



[1] D. Jena et al., Phys.Stat.Solidi (c) 0 (2003) 2339 – n-type DPD

[2] J. Simon et al., Science 327 (2010) 60 – p-type DPD

Acceptor-free deep-UV LED structure

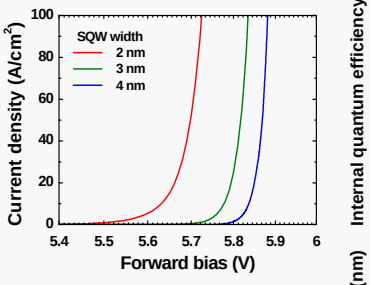


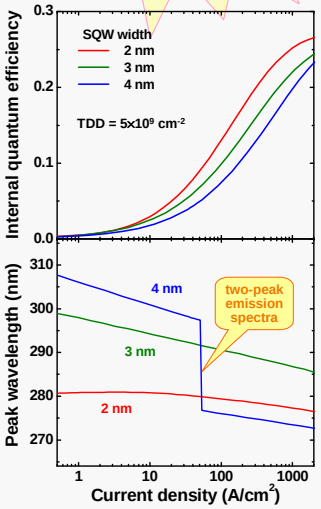
Requirements for structure design:

- high hole concentration in p-contact layer
- suppression of electron leakage in p-side of LED structure
- desired emission wavelength (280 nm)

high electron and hole concentrations near the SQW active region and in the p-contact layer are obtained by DPD in the graded-AlGaN alloys with parabolic composition variation

There are no Mg impurities in the LED structure !

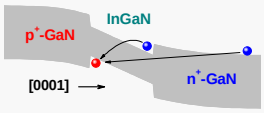




strong sensitivity of the LED structure characteristics to the SQW active region width, which is caused by huge built-in electric field in the quantum well

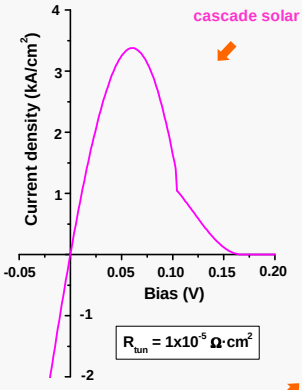
Simulations demonstrate feasibility and workability of a deep-UV LED structure having no Mg acceptors in its p-side. A high hole concentration is achieved by using the DPD in graded-composition AlGaN alloys.

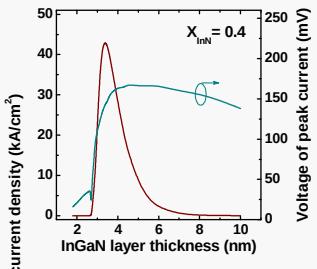
Tunnel junction for III-nitride cascade solar cells capable of high forward-current operation



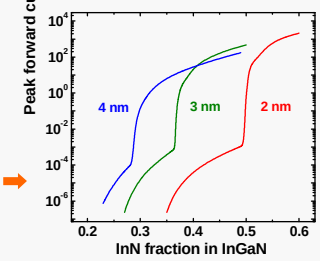
the use of a narrower bandgap insertion layer (InGaN) is advantageous over a wider bandgap layer (AlGaN) due to a higher tunneling probability

cascade solar cells need a high forward-current tunnel junctions to reduce its series resistance

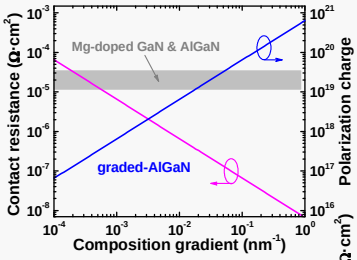




competition between the tunneling probability (increasing with InGaN layer width) and overlap between the n⁺-GaN conduction and p⁺-GaN valence bands (decreasing with InGaN layer width) results in complex dependence of maximum forward current on the width and composition of insertion layer

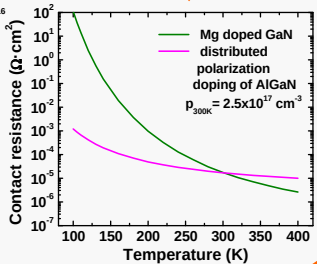


Ohmic contacts to graded-composition AlGaN alloys with p-type DPD



Ni/Au contacts to p-type AlGaN alloys are considered

higher temperature stability of the contact resistance



AlGaN with ~10% composition variation across the 20 nm layer may provide the contact resistance of ~10^{-6} Ohm·cm², which is currently unachievable for conventional technology

Conclusions:

- polarization doping, including DPD, is a powerful concept opening new ways for solution of various hot problems now hindering development of optoelectronic devices like LEDs and cascade solar cells
- our simulations have demonstrated feasibility of Mg-free deep-UV LED structures with high hole concentrations that can never been achieved by conventional impurity doping, polarization-enhanced tunnel junctions capable of high forward-current operation, and low-resistance Ohmic contacts to graded-composition AlGaN alloys