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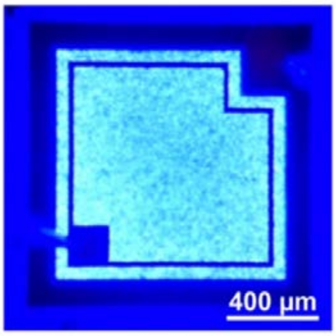
Heavily Ge-doped GaN films - Properties and applications

C. Berger

Otto-von-Guericke-University Magdeburg, Germany

In the last few years, germanium has evolved as a serious alternative to silicon for n-type doping of III-nitride semiconductors. In contrast to Si, using Ge in metalorganic vapor phase epitaxy based processes even carrier concentrations above 10^{20} cm^{-3} can be realized without degrading the crystal quality. We will report on different applications of highly Ge-doped GaN films and will highlight their benefits against conventional approaches.



of a 1 mm² LED with GaN :Mg/GaN :Ge tunnel junction

Highly-doped films are very attractive for the realization of tunnel junctions. We have grown GaN:Mg/GaN:Ge tunnel junctions on top of blue light emitting diodes [1]. Here, the GaN:Ge film acts as a transparent conductive nitride layer with negligible absorption that allows an efficient current spreading across large-area LED structures. By combining in- and ex-situ thermal activation steps, an efficient activiation of the buried p-GaN layer is ensured and tunnel junction LEDs with low voltage penalty are fabricated.

Monolithically grown GaN:Mg/GaN:Ge tunnel junctions also pave the way to realize cascaded LEDs with several pn-junctions with optically active regions stacked on top of each other. This approach aims for high power LEDs, that are driven at high operation voltage but low driving current. In this way, the LED efficiency droop, that drastically affects the wall-plug efficiency at high current-densities, can be significantly reduced for high power devices. Here we will present first growth experiments of a cascaded blue LED with two pn-junctions linked by a GaN:Mg/GaN:Ge tunnel junction.

Another application for Ge-doping is the realization of conductive distributed Bragg reflectors. We either used Ge-doping to achieve conductive lattice-mached AlInN/GaN DBRs or we realized DBRs by applying a periodic modulation of the GaN doping concentration only [2]. Due to the Burstein-Moss-effect, the refractive index is reduced at very high carrier concentrations. By alternately growth of 100 pairs of undoped GaN and highly doped GaN:Ge quarter wave layers, a DBR with a maximum stopband reflectivity of 95 % was realized.

References:

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Presenting author Email address: christoph.berger@ovgu.de