Efficiency improvement of green light-emitting diodes by employing all-quaternay active region and electron-blocking layer

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1. Introduction

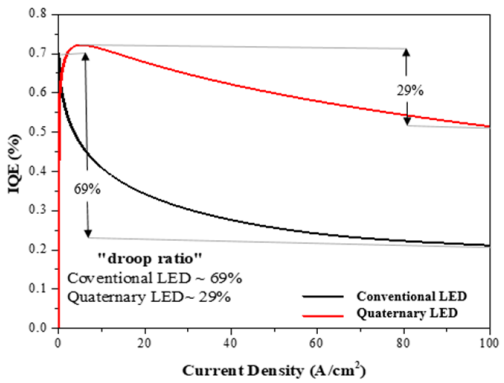
Despite great advancement in the development of GaN-based light-emitting diodes LEDs, efficient LEDs in green wavelength range are still a challenge and this challenge is commonly known as 'green-gap'. The optoelectronic performance of InGaN-based green LEDs is significantly affected by the strong built-in field in the active region [1-5]. Many solutions have been proposed to mitigate the strong effect of built-in field including the insertion of AlGaInN as a polarization-mattched layer between the active region and the electron blocking layer (EBL)[7]

In this work, we proposed a numerical solution for the improvement in the IQE of InGaN-based coventional green LEDs by replacing the conventional InGaN QW, GaN barrier and AlGaN EBL with GaAlInN QW, GaAlInN barrier and GaAlInN EBL respectively. IQE of the proposed structure has been found to be significantly improved because of the reduced lattice mismatching and improved polarization-matching between the epilayers.

2. General Instructions

Contents

In the figure shown, the conventinal LED shows a strong droop ratio ~69% whereas the proposed structure shows a reduced droop ratio of ~29%. This is a signifcant droop reduction considering the typical efficiency droop for green LEDs in the higher current regime. The incorporation of GaAlInN barriers leads to the suppression of thermionic escape from the active layer due to the increase in the effective barrier height for electrons.



A correlation of IQE as a function of current density for both quaternary and conventional LEDs respectively.

3. Conclusions

The proposed design results provides increased effective barrier height for electrons reducing electron overflow. In addition, the structure provides reduced effective barrier height for holes resulting in improved hole injection in the last QW of the proposed structure. Though the hole distribution is not uniform in the active region of the proposed design but by utilizing quaternary QW, quaternary barrier and quaternary EBL, not only carrier overflow is suppressed but overall radiative recombination is improved resulting in higher IQE of quaternary LED as compared to conventional LED despite uniform carrier distribution in the latter. Hence proposed green LED design is a promising solution in addressing the 'green gap'.

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