Hourglass-graded Heterostructures as a Possible Route Towards Extremely High Efficiency Light Emitting Diodes

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In this study a theoretical analysis of hourglass-graded light emitting diodes (LEDs) is provided. The term hourglass-grading refers to the placement of a wide band gap material at the diode contacts, smoothly tapering to a smaller band gap material in the active centre region. Utilizing AlGaN as our model system, we show that such a device can both effectively confine carrier recombination and mitigate overflow under high doping conditions. Moreover, by lowering the Auger coefficient of recombination in the active region, room temperature internal quantum efficiencies (IQEs) of 95% or more might be achieved in hourglass-graded LEDs at drive currents near $10^3$ A/cm$^2$.

Fig 1. ABC model IQE in the absence of leakage current as a function of the carrier concentration and Auger coefficient for a SRH recombination time of (a) 10$^{-7}$s and (b) 10$^{-8}$s. (c) Al$_{0.5}$Ga$_{0.5}$N to GaN to Al$_{0.5}$Ga$_{0.5}$N hourglass graded device IQE versus drive current for SRH constants of 10$^{-6}$s (red) and 10$^{-7}$s (blue), at Auger coefficients of 10$^{-32}$cm$^6$/s (solid), 10$^{-31}$cm$^6$/s (dotted), and 10$^{-30}$cm$^6$/s (dashed). (d) Same device IQE with respect to carrier temperature at a constant current of 10$^3$A/cm$^2$, in addition to the assumed radiative recombination coefficient as a function of temperature (dash-dotted black). (c) and (d) use the same coloration and line type assignments for Auger and SRH constants.

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