Carrier capture and recombination in InGaN/GaN light-emitting diodes

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III-nitride multiple-quantum-well (MQW) light-emitting diodes (LEDs) with identical structure but varying degrees of indium in the active region have been studied via temperature-dependent and current-dependent electroluminescence (EL) measurements. In the UV and blue LEDs, the peak energy exhibited a significant redshift in the range of 20-50 meV with a decrease of temperature from 200 K to 70 K, accompanying the appearance of LO-phonon replicas broadening the low energy side of the EL spectra. This behavior can be explained by carrier relaxation into lower energy states, yielding the dominant radiative recombination mechanism to carriers captured by localized states. However, the light output decreased drastically at temperatures below 150 K due to reduced carrier capturing by a limited number of localized states. In contrast, the emission energy of the green LEDs was found to be minimally affected by temperature, and the emission intensity increased monotonically with decreasing temperature down to 5 K. We attribute the enhanced radiative recombination and dominant localized-state emission in the green LEDs to efficient carrier capturing by a large number of localized states in the MQW region.