Temperature dependence of the quantum efficiency in green GaInN/GaN light emitting diodes

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Abstract

GaInN/GaN light emitting diodes are one of the most promising contenders for energy efficient solid state lighting. It is widely observed, that the efficiency of GaInN/GaN LEDs drops rapidly whenever the emission wavelength is extended into the green spectral region. Also, the efficiency is much higher at very low drive current than near the standard operating conditions. We here present a comparative study of the external quantum efficiency (EQE) in three nominally identical green LED dies emitting near 520 nm. EQE of those samples behaves differently as a function of current density. By help of a spectroscopic electroluminescence study at variable low temperature (as low as 7.7 K), we analyze the diodes' behavior. As the temperature drops, the maximum EQE increases until it reaches a maximum near 158 K. (Fig.1)

In parallel, the current value at which the EQE exhibits its maximum, shifts to lower values, as the temperature reduces. The peak emission exhibits a blue shift from 298 K to 158 K followed by a red shift from 158 K to 7.7 K. In the low current region, the emission peak shift is less pronounced than at higher currents. (Fig.2) At lower temperature, a secondary emission appears at shorter wavelengths. (Fig.3) We find indications, that this emission is caused by donor-acceptor recombination in the p-type GaN layer.

We present an interpretation of the findings by considering a competition of two temperature controlled mechanisms that apparently control the maximum of EQE. By simulating the results with an adaption of rate equations we analyze the role of possible carrier overflow into the p-type regions as a possible loss mechanism. Our findings will furthermore be complemented with low temperature cathodo-luminescence data. From this detailed analysis we anticipate to reveal further insights into the optimization needs of green and future deep green LEDs.

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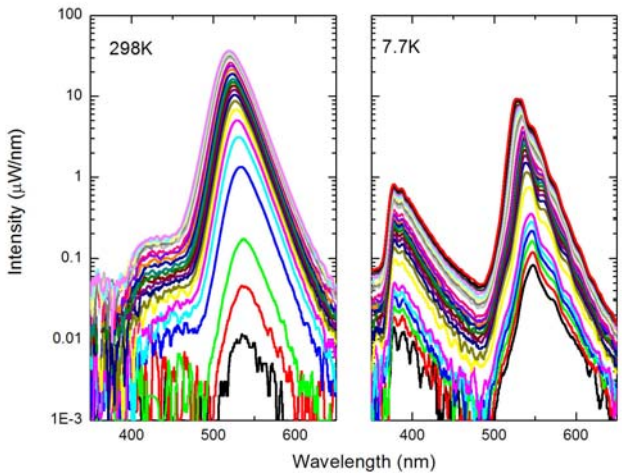

Fig.1. Electroluminescence of sample B under 7.7 K and 298 K with injection current varies from 0.2mA to 30mA.

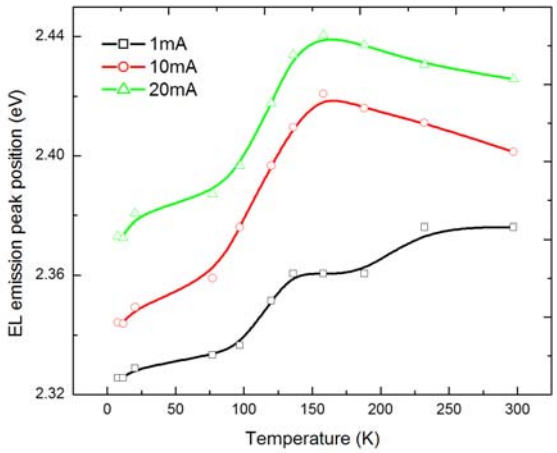

Fig.2 The temperature dependence of the peak wavelength of photon emission in GaInN/GaN MQWs LED sample B

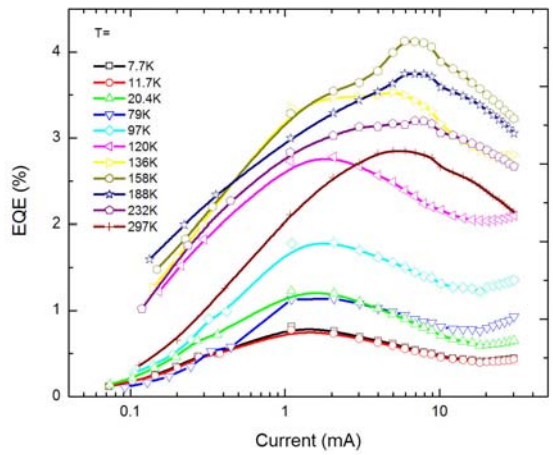

Fig.3 Current dependency of the external quantum efficiency (EQE) of sample B under different temperature

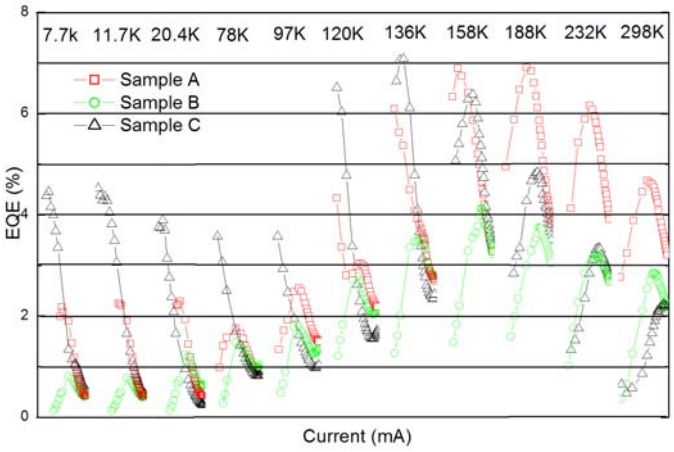

Fig.4. Temperature dependency of EQE for sample A, B and C