Study of Efficiency Droop in Light-Emitting Diodes Using Light-Emitting Triodes and Electroluminescence Quick Test

by

Jiuru Xu

A Thesis Submitted to the Graduate
Faculty of Rensselaer Polytechnic Institute
in Partial Fulfillment of the
Requirements for the degree of
MASTER OF PHYSICS

Approved:

_____
Prof. E. Fred Schubert, Thesis Adviser

_____
Prof. Jong Kyu Kim, Thesis Adviser

Rensselaer Polytechnic Institute
Troy, New York

December, 2007

Abstract

Solid-state lighting represents the future of illumination, in which efficient, reliable and environmental friendly solid-state light emitters will replace the currently used fluorescent and incandescent light sources. Within the solid-state lighting family, III-V Nitride based light emitters are endorsed with great hope due to their wide wavelength coverage ranging from deep ultraviolet to infrared. In this Master Thesis, three important issues for III-V Nitride based light emitters are addressed.

First, the efficiency droop, a real and long-standing problem for high power light-emitting devices, is investigated by using the light-emitting triode (LET) design. Effective-area modulation of the active region in the LET is observed and modeled. A new approach for efficient hole injection is presented. This approach is based on the lateral acceleration of holes so that they can easily overcome the barrier caused by the electron-blocking layer (EBL).

Second, the electroluminescence quick test, a fast but also reliable feedback method for epitaxial layer growth, is standardized in procedure and data processing. Electroluminescence characteristics of fabricated light-emitting diodes are predicted by the electroluminescence quick test with very good accuracy.

Third and last, Ohmic metal contacts to p-type GaN, the only path for hole injection, are optimized in terms of rapid thermal annealing (RTA) conditions for three different metal contact structures. The specific contact resistance is reduced to the order of $10^{-5}\ \Omega\mathrm{cm}^2$ for optimized processing conditions.