Photoluminescence Studies on III-V Nitride Light-Emitting Diode Wafers

by

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A Thesis Submitted to the Graduate
Faculty of Rensselaer Polytechnic Institute
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
Major Subject: PHYSICS

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December 2007
(For Graduation May 2008)

ABSTRACT

Light-Emitting Diodes (LEDs) have many advantages over traditional lighting sources. It is expected that LEDs will replace the traditional lighting sources in the near future because of their great advantage in efficiency. Since Shuji Nakamura and coworkers of Nichia Corporation achieved p-type doping in GaN with Magnesium in 1994, the III-V nitride material system has gained huge improvements in making efficient UV, blue and green LEDs. Photoluminescence (PL) is a technology which can be used to investigate bandgap, impurity levels, defects, recombination mechanisms, and material quality of semiconductors. The measurement can be done within a short time, before device fabrication, without causing any damage to the wafer. PL is a powerful tool in the research of light-emitting diodes.

In Chapter 1, a brief history of LEDs will be reviewed, and then the basic recombination mechanisms, material properties, and structure of III-V nitride LED will be introduced.

In Chapter 2, a detailed introduction of photoluminescence technology will be given, including the basic mechanisms and applications, the system in our lab, and important components in that system. Finally we discuss PL spectra of III-V nitride LED wafers.

Chapter 3, Chapter 4 and Chapter 5 will give three examples of applications of photoluminescence based on the research of this Master Thesis. In Chapter 3, we investigate the often observed parasitic blue emission in UV LEDs by measurement. We develop a theoretical model and find an explanation based on the UV-to-blue ratio for samples with different levels of silicon doping. The model shows that Si doping, related to compensating native defects, causes the parasitic blue emission. In Chapter 4, we investigate the cause of efficiency droop in GaInN LEDs by comparing the electroluminescence and photoluminescence of the same LED structure. The result shows that current overflow from quantum wells causes the efficiency droop in GaInN LEDs. In Chapter 5, we investigate three GaInN/GaN LED wafers with the same structure but different dislocation densities. We obtain the non-radiative recombination coefficient A of the three samples. The result shows that A increases with the value of the threading dislocation density.