Spatial Spectral Analysis in High Brightness GaInN/GaN Light Emitting Diodes

T. Detchprohm[1,2], Y. Xia[1,2], J. Senawiratne[1,2], Y. Li[1,2], M. Zhu[1,2], W. Zhao[1,2], Y. Xi[1,2], E.F. Schubert[1,2,3], and C. Wetzel[1,2]
[1]Future Chips Constellation, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.
[2]Department of Physics, Applied Physics and Astronomy, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.
[3]Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.

GaInN based nitride semiconductors are widely implemented as common materials for high efficient light emitting device such as laser diodes (LD) and light emitting diodes (LED). With their high power and high efficient optical power output, the materials are one of most promising candidate for solid state lighting application. To further improve the light output performance of the device, there are several approaches under investigation worldwide such as (1) reducing threading dislocation density in the device, (2) improving internal quantum efficiency by minimizing piezo field across the quantum wells in active region and (3) increasing light extraction efficiency through special geometrical arrangement, e.g., by using photonic crystals, omnidirectional reflectors, or chip shaping.

However, prior to proceeding to these approaches, there are still many fundamental characteristics of the semiconductor materials that are not fully understood. Here we have investigated the emission distribution behavior of the current high brightness GaInN based LED covering peak wavelengths from 400 to 550nm via several spectroscopy techniques, i.e., photoluminescence (PL), electroluminescence (EL) and cathodoluminescence (CL) spectroscopy. CL was mainly used to study the spatial spectral distribution of the uncapped GaInN LED mounted on TO-46 headers by silver epoxy. The active regions of these LEDs consisted of GaInN quantum wells and GaN barriers. Series of CL images generated by the photon counting mode using a photomultiplier were collected for every nm across wide wavelength span covering the emission peak from the active region. By analyzing these CL images, we have found that the peak wavelength distribution from the active region of these LEDs spread within 0.5% while the peak intensities varied as high as 25-50%. For blue and green LEDs, there was a clear trend that CL spectra revealed with longer peak wavelength in lower emission intensity area while CL spectra with shorter peak wavelength were detected for higher emission intensity area as shown in Figure 1. This trend suggested strong dependence on the quantum-confined Stark effect (QCSE) in the quantum wells. However, this trend became milder in UV LED with a low indium content in the quantum wells. The results of the spectral distribution under various sample temperature will be presented and discussed as well as the correlation with PL and EL results.

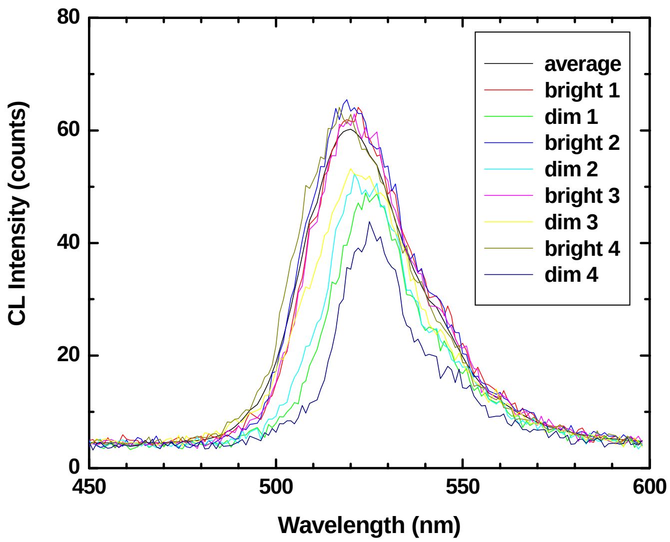

Figure 1: CL spectra of green GaInN/GaN LED at 7.8K. The spectra are derived from several locations with sampling size of 0.7 µm by 0.7 µm inside each frame of the CL images collected from 450 to 600 nm. The average spectrum represents average intensity derived from whole scanning area of 37 µm by 37 µm.

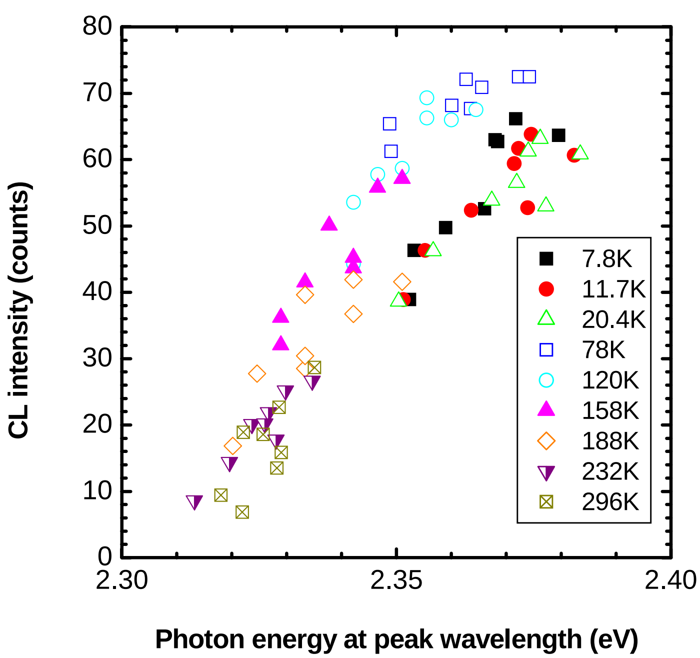

Figure 2: Summary of CL intensity of green GaInN/GaN LED under various measurement temperatures as a function of photon energy of peak wavelength.