Cathodoluminescence Studies of InGaN/GaN Multiple Quantum Well Structure Grown by Metal Organic Chemical Vapor Deposition

Ying Li[1, 2], Frank Lu[1], Frank Ramos[1], Edward Stokes[2]
1, Veeco Instrument Inc.
394 Elizabeth Ave, Somerset, NJ 08873, USA
2, Center for Optoelectronics and Optical Communication, University of North Carolina at Charlotte
9201 University City Blvd, Charlotte, NC 28223, USA

ABSTRACT

Scanning Electron Microscope (SEM) – Cathodoluminescence (CL) system is applied to InGaN/GaN Multiple Quantum Well (MQW) structure grown by Metal Organic Chemical Vapor Deposition (MOCVD). Emission from MQW and n-GaN layer beneath at various electron beam (EB) voltages show that MQW layer tends to have better luminescence efficiency grown on GaN layer with fewer defects. It is observed that areas with higher emission intensity always show a red shift in emission wavelength. It therefore indicates that high resolution CL system is able to image the Indium inhomogeneities formed during the epitaxial growth process in nanoscale.

INTRODUCTION

InGaN/GaN MQW Light Emitting Diode (LED) structure grown by MOCVD has been widely used in the semiconductor lighting industry. Many previous attempts (1-2) have been done on the InGaN epi-films on GaN, and MQW structures to correlate morphological features and InGaN phase separation with luminescence simultaneously using micro-PL, EL, and CL in accordance to microscopy. The previous studies, however, was restricted by the micron probes and/or limited spatial resolution of the spectroscopy equipment.

In the present work, high resolution CL has been applied to the InGaN/GaN MQW structure grown by MOCVD. Nano-scale v-pits and luminescence variations were observed. The EB voltage dependent luminescence properties are discussed. Emissions from v-pits and pit free areas are shown and discussed.

EXPERIMENT

CL studies were carried out using a field emission gun (Carl Zeiss 1550 SEM Gemini Column). The SEM was equipped with a Gatan MonoCL4 Elite high resolution CL system. The sample used in this study was an InGaN/GaN MQW sample grown on a (0001) sapphire substrate using K465i MOCVD system by Veeco Instrument. The sample consists of a 2 µm GaN buffer layer, 2 µm n-GaN, and 4 pairs of $In_{0.12}Ga_{0.88}N$/GaN (2.7 nm/10 nm) QWs. EB voltages of 3kV, 5kV and 10kV are used.

EXPERIMENT RESULTS

Figure 1 shows SEM images and corresponding monochromatic (432nm MQW and 368nm GaN) CL images taken at EB voltages of 10kV. The effect of fine morphological features, v-pits 10-20 nm in diameter, on the luminescence intensity is observed. Besides v-pits, luminescence variations at pit free areas are also observed.

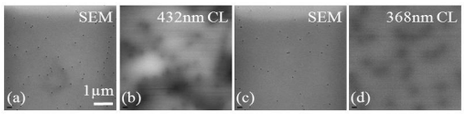

Fig. 1. (a) (c) SEM images, (b) (d) corresponding CL images at 432nm and 368nm, respectively.

Figure 2 shows the GaN and MQW emissions on v-pits and pit free bright and dark spots at different EB voltages. In both GaN and MQW emissions, bright spots show higher CL efficiency than dark spots. Dark spots correspond to the extended structural defects, particularly threading dislocations in GaN and v-pits in MQW. It indicates that MQW layer tends to have better luminescence efficiency grown on GaN layer with fewer defects. An overall trend of blue shift in MQW emission wavelength is observed. It is well-known that in the InGaN/GaN MQW structure, the strain induced piezoelectric field leads to bending of the energy bandgap, which is known as Quantum Confined Stark Effect. The blue shift with increasing carrier injection is attributed to either carrier screening of the piezoelectric field resulting in reduced band bending, or the band filling of lower energy states with carriers which forces higher energy states to become populated (3). It is observed that bright spots (~2 times of the intensity of the dark spots from Figure 2(b)) always show a red shift in emission wavelength compared with dark spot, which may indicate Indium inhomogeneities formed on the surface of the MQW structure.

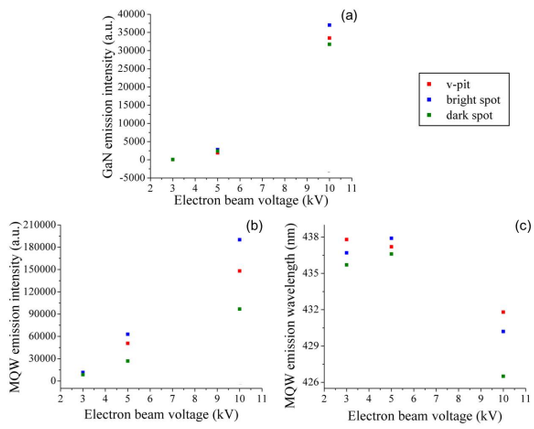

Fig. 2. GaN and MQW emission at v-pit, pit free bright and dark spots at different EB voltages

CONCLUSION

In summary, InGaN/GaN MQW structure grown by MOCVD has been studied by high resolution SEM and CL. Blue shift in MQW emission wavelength is observed with increasing EB voltage due to carrier screening of piezoelectric field. It is indicated that MQW layer tends to have better luminescence efficiency grown on GaN layer with fewer defects. The most promising discovery is that high resolution CL system may be able to image the Indium inhomogeneities of higher luminescence intensity.

REFERENCE

1. S. M. Pereira, K. P. O'Donnell, and E. J. Alves, Adv. Funct. Mater., 17, 37 (2007)
2. H. Ryu, J. Korean Phys. Soc., 56, 1256 (2010)
3. T. Mukai, M. Yamada, and S. Nakamura, Jpn. J. Appl. Phys., **38**, 3976 (1999)