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High Indium Content InGaN/GaN Multiple Quantum Well Yellowish Green Light Emitting Diodes

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1. Introduction

Recently, major developments in wide band-gap III-V nitride compound semiconductors have led to the commercial production of high brightness green light emitting diodes (LEDs) [1-3], which can be used in full-color displays and light sources for traffic light lamps with high efficiency, high reliability and high speed. For nitride-based LEDs, the longest peak wavelength of the electriluminescence (EL) achieved thus far is 540 nm because the crystal quality of the InGaN active layer of MQW LEDs becomes poor when the indium mole fraction is increased to obtain a yellow band-edge emission. Nakamura et al. have reported the first experiment yellow InGaN/GaN SQW LED. As their results, the peak wavelength, FWHM, output power, and the external quantum efficiency with 20mA DC current of these yellow LED were 590nm, 90nm, 0.5mW, and 1.2%, respectively [4]. In this study, we fabricated the yellowish green InGaN/GaN MQW LEDs, and studied its electronic and optical characteristics.

Yellow LED device structures were grown using AIXTRON MOCVD 2400-G3 systems. The structure was discussed in the list papers [5-6]. The growth temperature of InGaN well are 680℃. The indium mole fraction of the InGaN active layer was 0.7 in order to achieve the yellow peak wavelength.

Figure 1 shows the typical room temperature photoluminescence spectra of the $In_{0.7}Ga_{0.3}N$/GaN yellow LED. The peak wavelength and FWHM of yellow LED were 578.7nm and 55.6nm, respectively. The larger values of the FWHM suggested that the poor quality of $In_{0.7}Ga_{0.3}N$/GaN MQW due to the overrange higher indium mole fraction. The room temperature electroluminescence (EL) of these yellow LED with different amount of DC injection current is shown in Fig. 2. It was found that when 1 mA current injected into LED, the color shown by LED was almost orange and the EL peak wavelength of yellow LED was 597nm. It was also found that the EL emission peak wavelength of this LED was around 574nm with a 55.6nm FWHM under a 20mA current injection. Also, we observed a large 83meV blue shift in EL peak position from 597nm to 574nm as the injection current is increased from 1mA to 40mA for this LED. It is known that lattice mismatch induced piezoelectric field will produce a large quantum confined Stark effect (QCSE) in nitride-based LEDs. The large EL blue shift observed in MQW yellow LED can be attributed to the fact that the injection current will weaken the QCSE, thus, the transition energy will become larger. The strain effect in these yellow LED is larger probably due to the too high indium mole fraction of $In_{0.7}Ga_{0.3}N$ well layer induced partial relaxation. Thus, the EL peak position is more sensitive to the amount of injection current. The same result is shown in Fig. 3. At small current, it was found that the shift characteristic of EL dominated wavelength was an exponential decay mode as a function of increasing injection current. Above 40mA, the dominated wavelength was almost like a constant and the light condition was stable for these yellow LED. On the other hand, it is very interesting to investigate the CIE diagram from these yellow LED under different current

operation. Figure 4 shows the shift characteristic of yellow LED with increasing current in CIE diagram. The resulting color has the coordinates (x,y) with different current. When injection current increased, the resulting color will be changed from orange to yellow, and will be closed to the white light region. Therefore, during high current operation, the color of yellow LED was yellowish white.

In summary, we have discussed about the nitride-based yellow LED and show their PL, EL, and CIE characteristics. The real reasons for these results are now unknown, but a lot of studies will be under the way.

Acknowledgements

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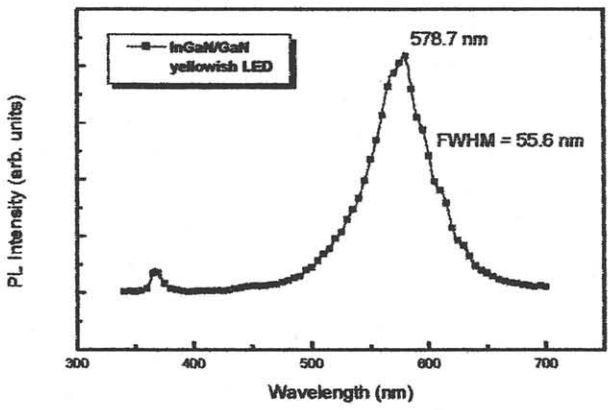

Fig. 1 Typical room temperature photoluminescence spectra of the InGaN/GaN yellow LED.

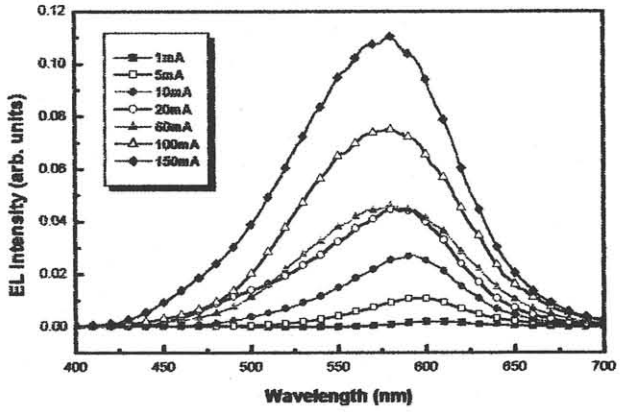

Fig. 2 Room temperature electroluminescence spectra of the InGaN/GaN yellow LED as the function of different injection current.

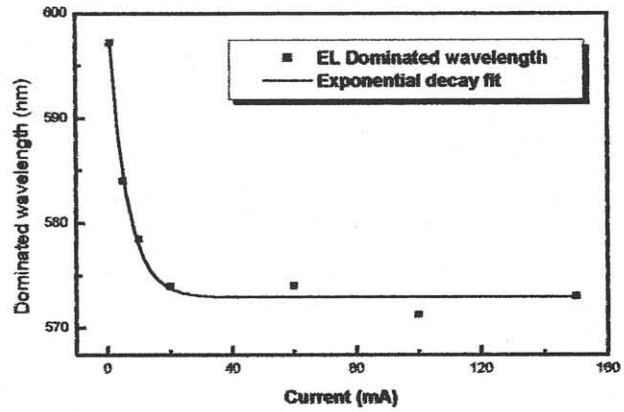

Fig. 3 The shift characteristic of EL wavelength as a function of increasing injection current.

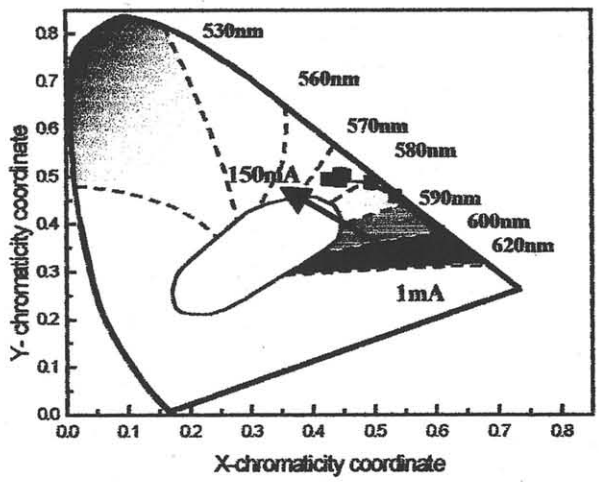

Fig. 4 The shift characteristic of EL wavelength with increasing injection current in CIE diagram.