Electroluminescent characterization of InGaN light emitting diodes with varied p-type layers

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Introduction

Light emitting diodes (LEDs) have become ubiquitous in our lives, whether it be in our Playstation, Desktop, Cellphone, New York City's large advertisement displays or stop-lights, we encounter them daily. The majority of visible LEDs are manufactured using the InAlGaN or InAlGaP compound systems. Currently the external quantum efficiency for the blue and green LEDs is significantly smaller than that of the red LEDs and this is due to the limited internal quantum efficiencies. Figure 1 displays the current status of the industry (tentative) and the motivation behind our research in optimizing the green LED.

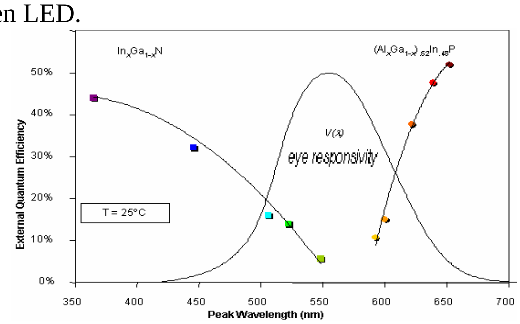

Fig. 1, lacking EQE in highly optically responsive green[1]

Procedure

In order to compare varying growth procedures for the p-type layer, the variable layers were grown on a standard structure shown in figure 2.

$In_{0.04}Ga_{0.96}N$:Mg+ or GaN:Mg+ (20 nm)	
$In_{0.04}Ga_{0.96}N$:Mg or GaN:Mg (50 nm)	
GaN:nid QWB (10 nm)	5 periods
$In_{0.25}Ga_{0.75}N$:nid QW (2.5 nm)	5 periods
GaN:nid QWB (10 nm)	
GaN:Si+ (120 nm)	
GaN:Si- (300 nm)	
GaN:Si+ (1000 nm)	
GaN:Si (2700 nm)	
GaN:nid (1100 nm)	
sapphire	

Fig. 2, InGaN/GaN MQW LED[2]

The p-type layers were grown using Mg-doped $In_{0.04}Ga_{0.96}N$ and GaN epitaxial layers. The substrate used for the LED structures was sapphire (0001) oriented substrates and the growth method was done by low-pressure metalorganic chemical vapor deposition (MOCVD). Trimethylgallium (TMGa), trimethylindium (TMIn), bis-cyclopentadienyl magnesium (Cp_2Mg), silane (SiH_4), and ammonia (NH_3) were used as precursors for Ga, In, Mg, Si, and N elements, respectively. The InGaN p-layer was grown under an N_2 ambient at 840ºC whilst the three GaN p-types were grown under different conditions. One GaN p-layer grown at 930ºC with an H_2 ambient and the two other samples were grown at 930ºC with an N_2 ambient; one sample was heat treated to activate its Mg doping, while the other was not.

Results and Discussion

The electroluminescence data was obtained using our in-lab quick testing setup. The data obtained is presented in Figure 3. It is clear that the InGaN layer had resulted in an improved LED luminescence performance. Measurements taken by Wonseok Lee[2] indicated that improved emission of the LED was a likely result of a superior crystal structure of InGaN/GaN multiple quantum well active region under the new growth environment for p-type layer (as indicated by XRD data in Figure 4).

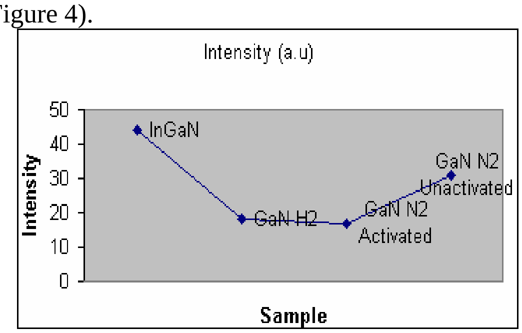

Fig. 3, quick test electroluminescence data

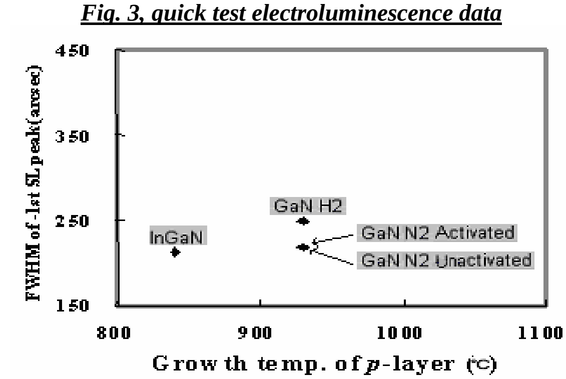

Fig. 4, FWHM of -1st peak obtained from XRD ω-2θ scan[2]

Conclusions

It is evident from the electroluminescent data that the InGaN p-layer would enhance the optical properties of the LED device. In addition to the optimized intensity the emission wavelength using an InGaN p-layer was shifted more towards the desired value of 530-540 nm[2].

References

1. ISBLLED 2006 / Montpellier, France / May 14-19, 2006
2. Wonseok Lee et al, "Nitride-Based Green Light-Emitting Diodes with Various p-type Layers", Journal of Display Technology 2006 (submitted for publication)

Acknowledgements

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