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Strong Ultraviolet Emission from InGaN/AlGaN Multi Quantum Well Grown by Multi-step Process

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1. Introduction

Nitride based semiconductors are attracting much attention for ultraviolet, blue and green light emitting diodes (LEDs) or laser diodes (LDs) applications. In particular, many research groups have paid tremendous efforts to develop strong luminescence and high efficiency UV-LEDs due to the requirements for white solid state lighting, medical field, biochemical process, environmental purification and high density optical storage [1]. However, the UV-LEDs with high efficiency and large output power can not be achieved by using conventional InGaN/GaN multi-quantum well (MQW) as active layer in devices resulting from poor carrier confinement effect. Therefore, it is necessary to improve the efficiency by replacing barrier layer material GaN with AlGaN, introducing quaternary InAlGaN-based system, or optimizing the device structure to enhance carrier confinement in active layer and increase injection current density [2-4]. Recently, Kwon et al. proposed ultra thin indium rich InGaN/GaN MQWs which exhibited strong near ultraviolet emission [5]. According to TEM and PL observations, the huge confinement of carrier by the high quality and ultra thin InGaN with abrupt interface cause strong UV emission.

In this work, we used AlGaN as barrier layer to increase the carrier confinement and reduce self-absorption effect. The multi-step growth process was introduced to grow InGaN well layers. From photoluminescence measurement of the samples, strong UV emission peak around 380 nm can be observed. The UV-LEDs also were processed and the preliminary characterization of electroluminescence was shown below.

2. Experimental

The InGaN/AlGaN MQWs were grown on C face (0001) 2 inch diameter sapphire substrates by metal organic chemical vapor deposition. Trimethylgallium (TMGa), Trimethylindium (TMIn), Trimethylaluminum (TMAl) and ammonia were used as Ga, In, Al and N source, respectively. Biscyclopentadienylmagnesium (Cp_2Mg) and disilane (Si_2H_6) were used as p-type and n-type doping source. Following the growth of a 2 mm-thick GaN layer with on sapphire substrate, InGaN/AlGaN MQW with three pairs was grown by multi-step process and the schematic diagram of the growth procedure was shown in Figure 1. During growth of InGaN layer, thin InN layers were grown under various growth temperatures ranging from 650~685 ^{o}C and before AlGaN barrier growth, a growth interruption was introduced to treat the InN layer and make interdiffuse between InN and (Al)GaN layer to obtain InGaN layer. The optical properties and growth morphologies of samples with various growth conditions were characterized by photoluminescence (PL) and atomic force microscopy (AFM). The PL experiments were performed using He-Cd laser (325 nm) as a pumping source. In addition, InGaN/AlGaN MQW LEDs also were fabricated. The LED structure consisted of a 500-nm-thick layer of n-type GaN:Si grown on 1-μm-thick GaN template, three pairs InGaN/AlGaN MQW, a 10-nm-thick p-type AlGaN:Mg and 0.15-mm-thick p-type GaN:Mg. The electrical properties and electroluminescence (EL) of LEDs was also characterized.

3. Results

Figure 2 show the PL spectrum of sample with various InN growth temperatures. It shows that the blueshift of PL emission peak occurs as increase InN growth temperature. The sample whose InN layers were grown at 685 ^{o}C exhibited strong PL emission at 380 nm. Figure 3 shows the AFM images of samples with various InN growth temperatures. According to AFM results, samples grown at the lower temperature exhibited rough morphologies and some hills which might be In-rich clusters can be observed; however, the smooth surface morphology can be observed on sample grown at 685 ^{o}C. It indicated that the growth temperature of InN significantly affect surface growth kinetics. Figure 4 shows the light-emitting pattern of the LED device. In order to realize the effect of growth temperature on PL peak shift and surface morphology modification, further microstructure analysis was required. The characterization of electroluminescence properties are in progress and the results of EL and detailed microstructure analysis will be presented in future presentation.

4. Conclusion

InGaN/AlGaN MQW were grown by multi-step process. It was found that the PL spectra of the samples showed a strong UV emission at 380 nm. The growth temperature of InN dominates the PL emission peak position. According to AFM observations, the growth temperature affect InN

decomposition and In atom surface migration. The preliminary electroluminescence result was also shown. The InGaN/AlGaN MQW grown by multi-step process can be candidate to efficient near-UV LED.

Acknowledgements

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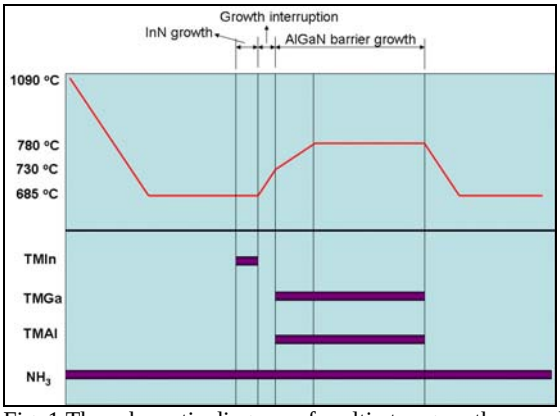

Fig. 1 The schematic diagram of multi-step growth procedure.

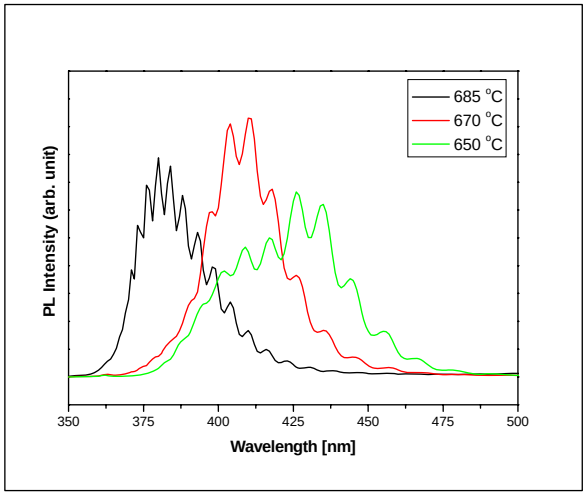

Fig.2 PL spectra from the MQW grown at various InN growth temperature

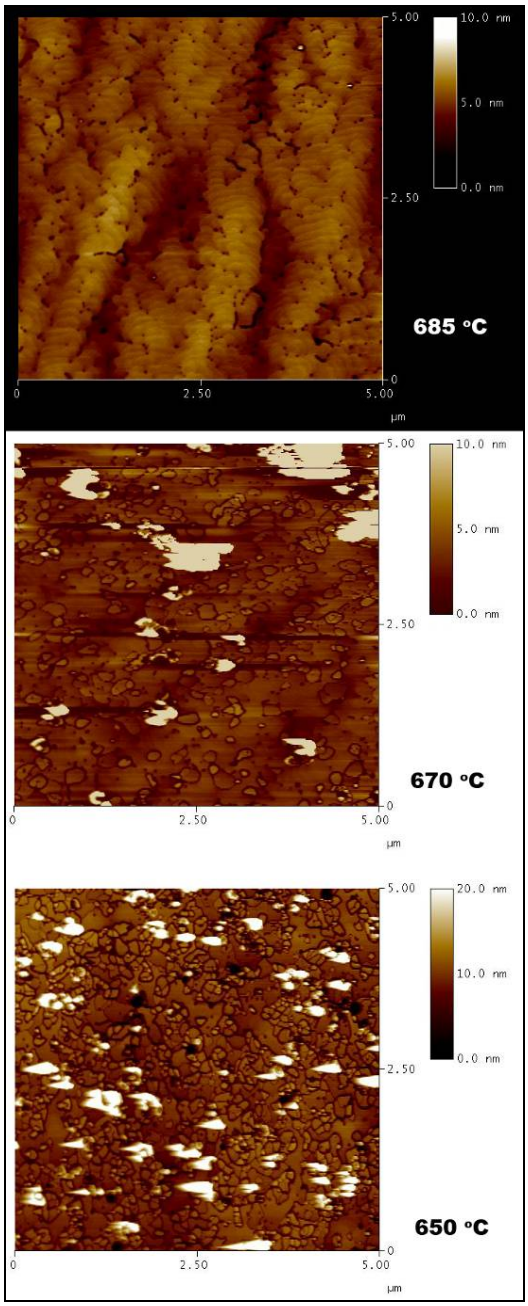

Fig.3 AFM images of the MQW grown at various InN growth temperature

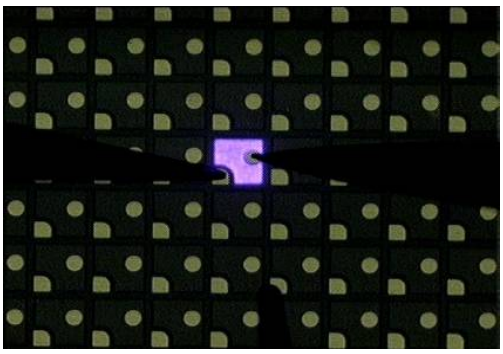

Fig. 4 The light-emitting pattern of the LED device.