Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.364-365

F-3-3

# Study of InGaN red emission multiple Quantum Dots

Te-Chung Wang[1], Hao-Chung Kuo[2], Ching-En Tsai[1],
Min-Ying Tsai[2], Jung-Tsung Hsu[1]

[1]Opto-Electronics and System Laboratories, Industrial Technology Research Institute
Rm.206, Bldg.78, 195 Sec.4, Chung Hsing Rd. Chutung, Hsinchu, Taiwan, Republic of China
Phone: +886-3-5912004 Fax: +886-3-5915138 Email: WangWang@itri.org.tw
[2]Institute of Electro-Optical Engineering, National Chiao Tung University
Hsinchu, Taiwan, Republic of China

## 1. Introduction

GaN and related materials are currently the subjects of intense research due to their applications in laser diodes (LDs) and light-emitting diodes (LEDs) that operate between the ultraviolet and the visible regions.[1)] InGaN/GaN quantum wells (QWs) structures have successfully been used as the active layers in LEDs and LDs.[1)] However, the threshold current density is high for LDs with InGaN QWs structures. Having quantum dots (QDs) instead of QWs as the active layer is expected to improve the performance of LDs. LDs with QDs structures in the active layer have been theoretically predicted to have superior characteristics, including lower threshold currents and narrow spectra.[2)] Moreover, because of the localization of carriers trapped at dislocations, QDs structures have been expected to increase the efficiency of the luminescence of LDs.[3)] To ensure suitability for QDs laser applications, QDs layers with high spatial density and of uniform size must be grown.[4)] Several approaches have been investigated for fabricating InGaN QDs, including the Stranski-Krastanow growth mode[5,6)] and growth using anti-surfactant.[7,8)] The deposition of silicon anti-surfactant or a $SiN_x$ nano-mask alters the morphology of the AlGaN films from that of step flow to that of a three dimensional island, facilitating the formation of GaN[7)] QDs and InGaN QDs[8)] on the AlGaN.

The InGaN based red emission device is dominated by both the band-filling effect and the screening effect of the quantum confined stark effect (QCSE) due to the high Indium composition and the large thickness of the InGaN well layer. So the InGaN base red emission devices are very difficult to be realized. The InGaN quantum dots devices possess the potential to overcome the limitation and make the efficiency higher, the wavelength longer. By using the insitu-$SiN_x$ treatment process that we had reported[9)], the red emission InGaN multiple quantum dots layers was successfully developed. In this letter, we study the optical characteristics of InGaN red emission multiple quantum dots.

## 2. General Instructions

We reported the red emission study of InGaN multiple quantum dots layers. The InGaN multiple quantum dots layers construct with $SiN_x$ dots mask layers, InGaN dots layers and GaN cap layers as Figure 1 shown. The optical properties including Room temperature Photoluminescence (PL), temperature dependent PL and power dependent PL were examined and discussed.

Figure 2 shows the room temperature PL of InGaN multiple quantum dots layers, and the spectrum is a broaden emission from 480nm to 800nm. By peak fitting, the spectrum should be divided into seven individual wavelengths and the $\lambda 2$ to $\lambda 7$ should be with the same interference relationship. Consequently, the spectrum could be distinguished to two parts of emissions, $\lambda_1$ 531nm and $\lambda_{main}$ 618nm. The two emissions might come from the InGaN

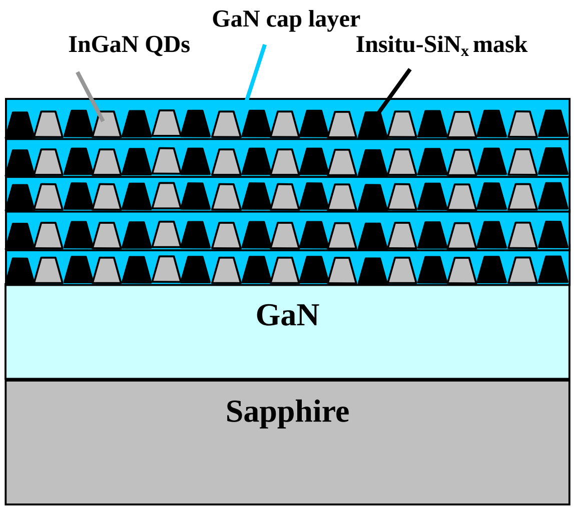


**Fig.1** Schematic of InGaN multiple quantum dots layer

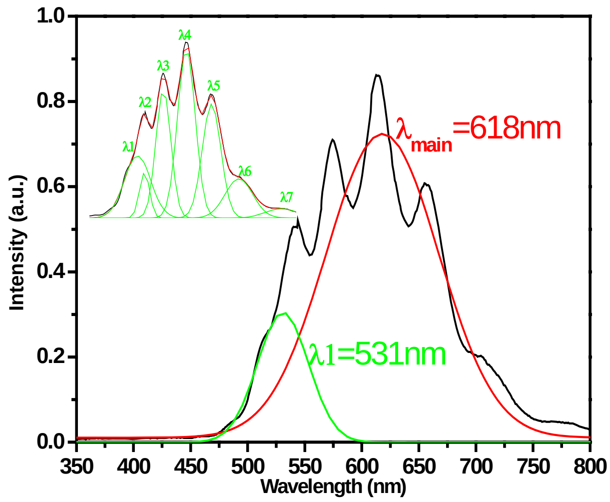


**Fig.2** Room Temperature PL of InGaN MQDs

wetting layers and MQDs layers respectively.

Fig. 3 shows the temperature-dependent PL of InGaN MQDs, there are three different PL peaks and all the intensities increase with temperature decreasing. By connecting the main peaks positions, shown as Fig. 4, we could realize the trend of the three peaks. The left peak is obviously blue shift from 540nm to 525nm as temperature decreasing and the phenomenon is like a wetting layer of quantum dots. The middle peak is stable around 567nm, it might come from the nature defect of GaN as so call yellow luminescence. The right peak above 600nm is blue shift first and red shift as temperature decreasing. This luminescence exhibits an “S-shaped” emission position shift with temperature, and the phenomenon (redshift-blueshift) was first explained by Cho[10] in terms of inhomogeneity and carrier localization in the InGaN. Consequently, we could conclude the insitu-$SiN_x$ treatment InGaN multiple quantum dots layers posses the same behavior of carrier localization and the wavelength could be pushed to red emission.

As Fig.5 shown, power-dependent PL of InGaN MQDs at 20K, there are three emission peaks also and all the intensities increase with power increasing. The left peak is blue shift from 530nm to 525nm as power increasing and the behavior is still like a wetting layer of quantum dots. The middle and right peaks are almost the same at different exciting power.

### 3. Conclusions

By comparing the results of room temperature PL and temperature-dependent PL, we can sure there are one wetting layer, one quantum dots layer and one defect emission center in the InGaN multiple quantum dots layers.


### Acknowledgements

The authors want to specially thank the financial support by the Ministry of Economic Affairs, Taiwan, Republic of China


## References


[1] S. Nakamura and G. Fasol: The Blue Laser Diode (Springer, Heidelberg, 1997).

[2] C. Adelmann, J. Simon, G. Feuillet, N. T. Pelekanos and G. Fishman, Appl. Phys. Lett. 76 (2000) 1570.

[3] B. Damilano, N. Grandjean, S. Dalmasso and J. Masies, Appl. Phys. Lett. 75 (1999) 3751.

[4] D. Bimberg, M. Grundmann and N. N. Ledentsov, Quantum Dot Heterostructures (Wiley, England, 1999).

[5] K. Tachibana, T. Someya and Y. Arakawa: Appl. Phys. Lett. 74 (1999) 383.

[6] B. Daudin, F. Widmann, G. Feuillet, Y. Samson, M. Arlery and J.-L. Rouvie`re: Phys. Rev. B 56 (1997) R7069.

[7] S. Tanaka, S. Iwai and Y. Aoyagi: Appl. Phys. Lett. 69 (1996) 4096.

[8] H. Hirayama, S. Tanaka, P. Ramvall and Y. Aoyagi: Appl. Phys. Lett. 72 (1998) 1736.

[9] R. C. Tu, C. J. Tun, C. C. Chuo, B. C. Lee, C. E. Tsai, T. C. Wang, Jim Chi, C. P. Lee and G. C. Chi, Jpn. J. Appl. Phys. 43 (2004) 264.

[10] Y. H. Cho, G. H. Gainer, A. J. Fischer, J. J. Song, S. Keller, U. K. Mishra, and S. P. DenBaars, Appl. Phys. Lett. 73( 1998) 1370.


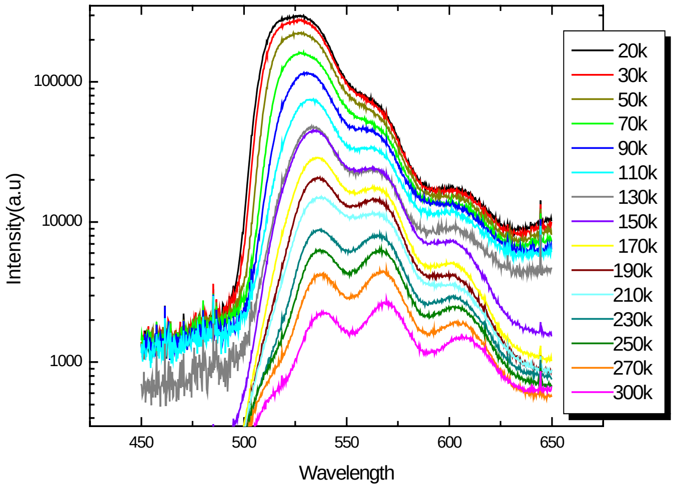


**Fig.3** Temperature-dependent PL of InGaN MQDs

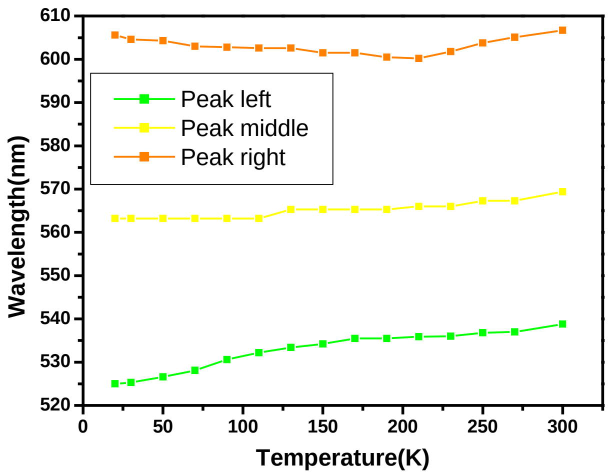


**Fig.4** Trend of main peak shift of temperature-dependent PL of InGaN MQDs

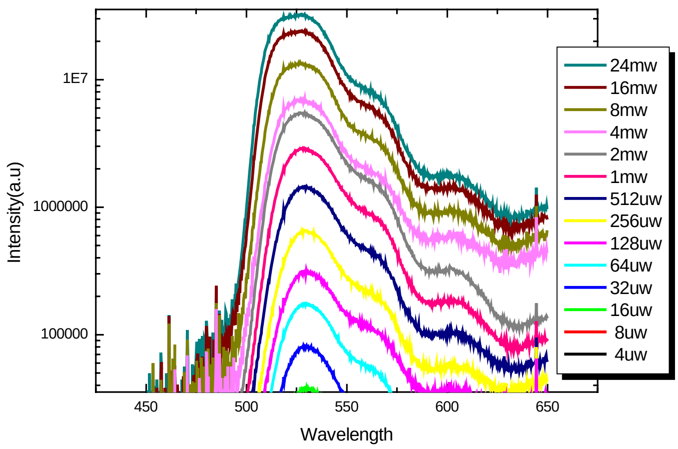


**Fig.5** Power-dependent PL of InGaN QDs at 20K