Influence of Growth Interruption of Quasi-quantum Dot Nanosstructure in InGaN/GaN Multiple Quantum Well Heterosystems

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Abstract:

A significant performance has been founded in InGaN/GaN multiple quantum well heterostructures with growth interruptions during the procedure of epitaxial fabrications which resulted a higher turning-point temperature among a certain range of temperature and a better PL intensity.

1. Introduction:

The studies of the quantum dot nanostructures have received more attention in recent years. The experimentally observed the temperature dependence of the photon energy of the InGaN/GaN multiple quantum well (MQW) heterostructures on the Berthelot-type dynamical mechanisms [1, 2]. Many correlative studies have provided different methods to change some factors to observe and study for the recombination of the carriers and excitons and to improve the efficiency of the luminescence. This study confirmed and focused on the effect of growth interruptions between different layers during the epitaxial fabrications. With mathematically and statistically analysis of experiments, a significant observation was found in this work.

2. Experiments:

Samples investigated were grown on (0001) sapphire substrates, followed by a 25-nm GaN buffer layer and about 4-μm n-type GaN with saline (SiH₄) as dopant. MQWs is consists of 4 periods of InGaN/GaN (2 nm/12 nm) on n-type GaN layer. Furthermore, we used the interruption time to samples, treated in nitrogen rather than trimethylgallium (TMGa) and trimethyldimethyl (TMIn). After growing MQWs structures, the p-type GaN layer 100-nm-thick was grown with bis(cyclopentadienyl)magnesiu (Cp₂Mg) as dopant, followed by 5 periods of AlGaN/GaN superlattice structure. Photoluminescence (PL) properties were measured at room temperature with a He-Cd laser as the excitation source which wavelength of 325 nm, being combined with a 0.25 m monochromator equipped with a 600 gr/mm grating. The PL signal was processed by a standard lock-in technique.

3. Results and Discussion:

To elucidate the correlation between quantum dot like (QD-like) structures and quantum confinement effect, a PL emission peak energy measurements over a temperature range from 0 K to 400 K is performed, shown in Fig. 1. While the temperature increased, both of the two samples tend to had blueshift; however, Samples with G.I. had a smaller PL emission peak energy below 300K.

Also, it performed a relatively smooth curve which represented closer energy level that showed more stable blueshift. All spectral position blueshift at tempera-

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Fig. 1. Plot of PL intensity versus temperature for samples with G.I. and conventional samples.
ture lower than the turning-point temperature, which is designated as $T_t$, leading to the so-called Berthlot-type process. $T_t$ is greater with the samples with G.I. than it is with conventional samples at high temperature. According to the analytical formulations developed by Singh and John [1], once again interpreted that the $T_t$ of samples with G.I. were more conspicuous than the conventional samples. Under the assumption of the band gap shrinkage with a linear thermal coefficient of $C_2$, the temperature dependence of the abnormal optical properties is uniquely characterized by [2]

$$\frac{E_{ph} - E_g}{T} = -C_1 - C_2 T^{-2} \tag{1}$$

where $E_{ph}$ is the photon energy, $E_g$ is the gap energy at 0 K, $C_2$ is a static-microbarrier-related parameter of a disorder InGaN layer, $T$ is the absolute temperature. Knowing the $C_1$ allows $T_t$ to be estimated from the extracted slope of $C_2$, according to [2]

$$T_t^3 = \frac{2C_2}{C_1} \tag{2}$$

It has been found that the slopes of the least-squares regression lines decrease when the temperature increases. For further observation, we use the Arrhenius plot to analyses the condition of luminescence strength and the thermal quench, shown in Fig. 3. The Plot showed that samples with G.I. exhibit a greater PL intensity compared to conventional samples. The activation energies of sample

with G.I. and conventional samples were 80 and 70 meV, respectively. The higher activation energy leads to the energetic carriers being circumscribed in the active region.

4. Conclusion

By using growth interruption method during growth procedures with four-period InGaN/GaN active layer, it was found that the quantum confinement effect has been enhanced in a QD-like in InGaN/GaN MQW heterostructures. Furthermore, over a temperature range from 0 K to 400 K, the $T_t$ was greater with the samples with G.I. than it was with conventional samples at high temperature due to a higher density of QD-like nanostructure. These experimental results indicate that sample with G.I. can significantly affect carrier confinement and enhance the quantum efficiency of In-rich InGaN heterostructures due to stronger localization of the excitonic resonances in the active region of the MQW structure.

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References
