یک ساختار جدید برای دیودهای نورگسیل چند چاه کوانتمی InGaN/GaN با طول موج گسیلی ۴۰۰-۴۵۰ نانومتر

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چکیده – در این مقاله یک ساختار جدید برای دیود نور گسیل (*LED*) چند چاه کوانتمی *InGaN/GaN (MQW)* با طول موج گسیلی ۴۰۰-۴۵۰ نانومتر و بیشینه طول موج ۴۳۵ نانومتر ارائه شده است. در این طراحی، تغییراتی در چاه پتانسیل موجود اعمال شده است که در اثر آن شاهد بدست آمدن بازده کوانتمی بالای ۸۰٪ بوده‌ایم. همچنین از آنجایی که حامل ها مقطع بیشتری از تراز های محلی شده *(localized states)* را در چاه بیرونی تجربه می‌کنند، گسیل با طول موج کوتاه و بازده کوانتمی پایدارتری مشاهده شده است.

کلید واژه- بازده کوانتمی، پاسخ طیفی نوری، چند چاه پتانسیل، دیود نورگسیل.

A New Structure for Multi Quantum Well InGaN/GaN light emitting diodes with emission wavelength of 400-450 nm

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Abstract- In this paper a new structure for InGaN/GaN multi quantum well (MQW) light emitting diodes (LEDs) with emission wavelengths of 400-450 nm and peak wavelength at 435 nm is reported. In this configuration a tri-step quantum wells have been considered that high quantum efficiency up to 80% was obtained. Since carriers would experience more cross-section of the localized states at outer well, both short wavelength emission and stable quantum efficiency have been observed.

Keywords: Light emitting diode, multi quantum well, optical spectral response, quantum efficiency.

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1 Introduction

III-nitride semiconductors have attracted great attention in recent years. These materials are potentially useful in optoelectronics and high power electronic devices due to their wide range of bandgaps and high temperature stability [1]. Incorporation of indium into GaN generally used to control the bandgap was found to induce advantages and disadvantages in terms of the electrical characteristics, optical output, and spectral properties of LEDs. For example, the growth of InGaN alloy for quantum-well structures was found to further enhance radiative recombination through indium localized states, originating from fluctuations in the indium composition [2-10]. However, the incorporated indium-induced compressive strain in the InGaN wells, forming an internal piezoelectric field. This field eventually resulted in a spatial separation of electron and hole wave functions and hence reduced radiative recombination and modified spectral properties. Indium-induced strains were also found to relax through the generation of dislocations, which may cause the evolution of leakage current as well as the modification of spectral properties [2].

Short wavelength emitters are of interest for various fluorescence-based chemical sensing applications, high efficiency lighting, flame detection, and possibly optical storage applications. Conventional nitride-based MQW LEDs use InGaN as the material for well layers and GaN as the material for barrier layers. To achieve a short wavelength emitter, one needs to reduce the indium composition in the well layers so as to increase its bandgap energy. However, a reduction in indium composition in the well layers will result in a small bandgap discontinuity at the well/barrier interfaces. Thus, the quantum well depth in the MQW active region will become smaller and the carrier confinement effect will be reduced. As a result, severe carrier leakage problem might occur in the short wavelength InGaN/GaN MQW LEDs [11].

According to figure 1.c a LED with two level wells of InGaN faced to one GaN barrier is presented. Tri-step configuration provides short wavelength emission and high carrier confinement due to outer well and inner well respectively. In this paper Electrical and optical characteristics of this device is reported.

2 design

In this work we proposed a new structure for InGaN/GaN MQW LEDs. The device performance was investigated by ATLAS software created by

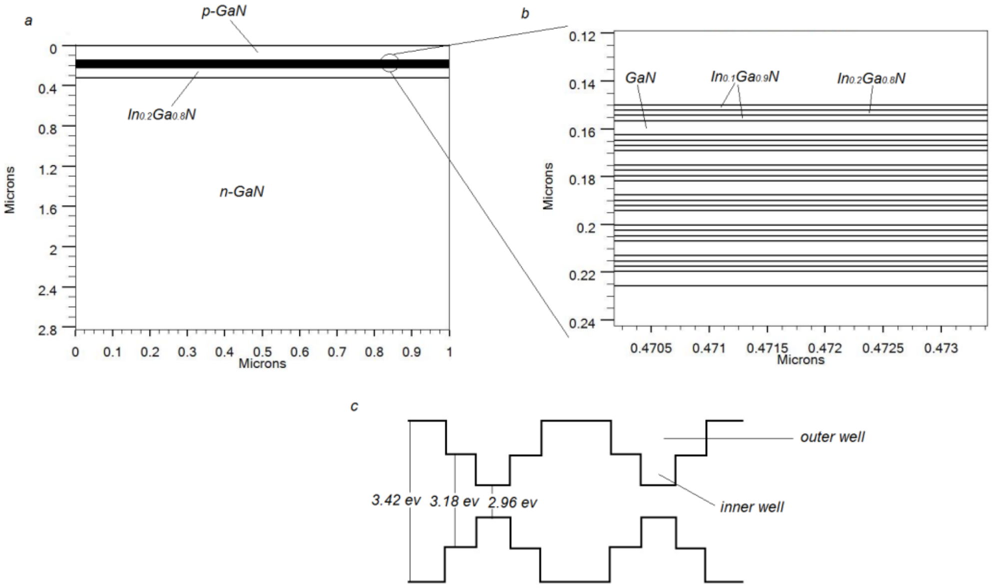

Figure 1: a) structure of MQW LED, b) new structure for quantum wells, and c) band gap energy for two wells.

Silvaco Company. Figure 1.a shows the structure of this device consists of 2.5µm thick n-GaN with doping concentration of 10^{20} cm^{-3}, 100 nm $In_{0.2}Ga_{0.8}N$ as spacer [2], 6 multi quantum wells, and 150 nm thick p-GaN as p contact. As figure 1.b and 1.c show each well includes $In_{0.1}Ga_{0.9}N$ (2.2 nm) /$In_{0.2}Ga_{0.8}N$ (2.2 nm) / $In_{0.1}Ga_{0.9}N$ (2.2 nm) / GaN (6 nm). The band gap of $In_xGa_{1-x}N$ layers were Calculated by Equation (1) [3].

$$E_{g,InGaN} = xE_{g,InN} + (1-x)E_{g,GaN} - x(1-x)1.0ev \quad (1)$$

Where band gaps of InN and GaN are 1.95 and 3.42 respectively. The width of device considered to be 1µm in this simulation. The outer well causes emitting of deep blue wavelengths and the inner well increases the quantum efficiency.

3 Results and Discussion

Figure 2 show the optical spectral response of device. It is obvious that the emission wavelengths are 400-450 nm and the peak wavelength is at 435 nm. From figure 2 it is clear that lower side of the curve extended to shorter wavelength. Therefore this device can be used for designing deep blue laser diodes by choosing the shorter wavelength and amplifying them to lasing.

In recently reported work for InGaN/GaN LEDs, the emission wavelengths are about 429-467 nm and the maximum quantum efficiency is less than 50 %. Also for shorter wavelengths quantum efficiency decrease. For example for wavelength of 434 nm this is about 30 % [2]. Figure 3 shows that with new configuration for quantum wells, quantum efficiency about 80 % for wavelength of 435 nm can be obtained.

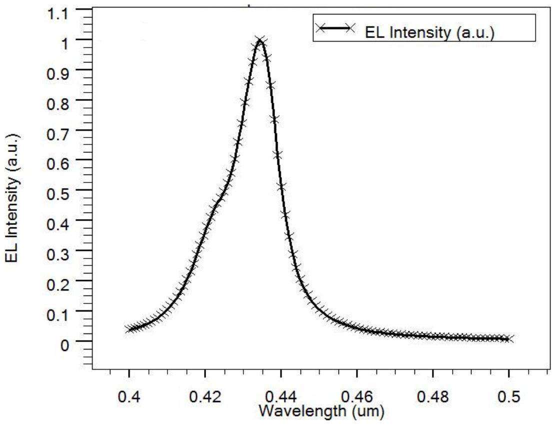

Figure 2: Optical spectral response of InGaN/GaN LED with new well configuration.

We can see the quantum efficiency raises immediately after device turn on. With higher amount of currents the quantum efficiency has small decrease and stay constant. At low currents, most injected carriers are expected to recombine at deep indium localized states. With increasing current, however, a large fraction of carriers would recombine at strained wells due to the limited cross-section of the localized states. In this case, the efficiency droop occurs due to the dominance of quantum-confined Stark effect (QCSE) vs. quantum-confined effect (QCE) [2].

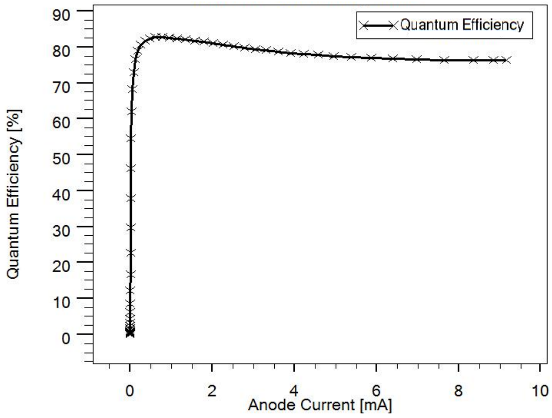

Figure 3: High value and less variable external quantum efficiency of LED.

According to figure 1.c carrier in outer well experience more cross-section of the localized states than device recently reported by Jung et al [2], this Results in having higher and more stable quantum efficiency for high currents.

Figure 4 shows electrical characteristics of device. It is shown that the threshold voltage is about 8 volt. Since InGaN LEDs are high drive current devices [12], the current for small amount of voltages is high for this device.

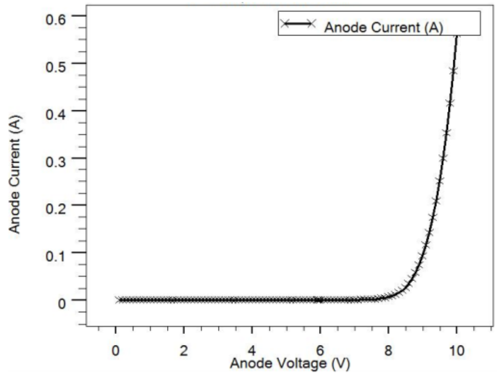

Figure 4: Current-voltage characteristic of InGaN/GaN LED.

4 Conclusion

In this paper we presented the electrical and optical characteristics of an InGaN/GaN MQW LED with new quantum well Structure for achieving high quantum efficiency about 80 % and deep blue wavelength around 435 nm. This Structure cause stable and high quantum efficiency.

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