Advantage of Step-graded EBL to Improve the IQE of deep ultraviolet LED

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Abstract— In this paper, the effect of different kinds of compositional grading of electron blocking layer (EBL) on the internal quantum efficiency (IQE) of deep ultra violet (DUV) light emitting diode (LED) has been analyzed. It has been observed that the step graded EBL exhibits maximum IQE as compare to standard, linearly compositional graded EBL structure.

Keywords: Deep ultra violet, electron blocking layer, efficiency droop.

1 Introduction

Presently researchers, working on solid state lighting focusses to produce highly efficient DUV LEDs due to their wider applications which includes sterilization, water purification, medicine, biochemistry and high density optical recording etc. The tunable band gap of AlGaN makes it most suitable candidate for DUV emission. However, the efficiency of LED in DUV region is limited due to higher threading dislocation density, lower achievable p-type concentration [1].

2 Aim of the study

Step graded Al composition in EBL for blue and near UV LEDs have been reported by Liu *et al.* and Park *et al.* in AlGaN/ InGaN system [2][3], however, step grading in AlGaN/ AlGaN based DUV LED have not been studied or fabricated yet. An advanced device simulation has been demonstrated that Step graded EBL exhibits maximum IQE as compare to standard, linearly compositional graded EBL structure.

3 Methods

Three LED structures have been designed and analyzed using SiLENSE 5.8 module of SimuLED software tool (STR group Russia) [4]. Structure *N* is based on the LED fabricated by Hirayama *et al.* [5]. As shown in Fig.1, in *N*, EBL is Comprised of AlN. In *M1*, the Al content in EBL linearly decreased towards p-side keeping the rest same as *N*, in *M2*, the EBL has been divided into three sub-layer of equal thickness

with decreasing Al content towards p-side. The operating temperature is 300 K.

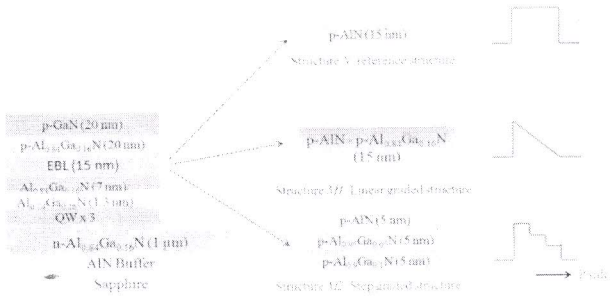

Fig. 1. Schematic of LED structures.

4 Results

The IQE characteristic as a function of current density for three structures have been shown in Fig 2. It is evident that the IQE of device structure *N* is 4% smaller than *M1* and 14% smaller than that of *M2*.

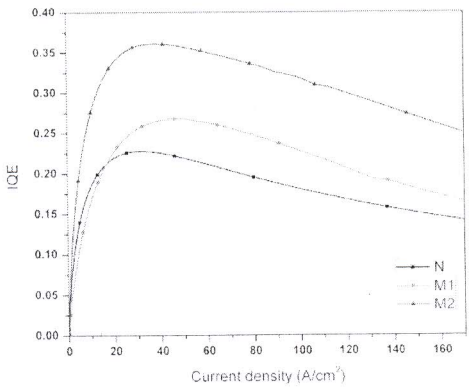

Fig. 2. IQE plots of structure *N*, *M1* and *M2*

Fig. 3a, 3b, and 3c. Exhibit the electron, hole concentration and radiative recombination rate at 170 A/cm^2 for the simulations. *M2* has maximum carrier concentration in active region, resulting in maximum radiative recombination rate compared to N & M1.

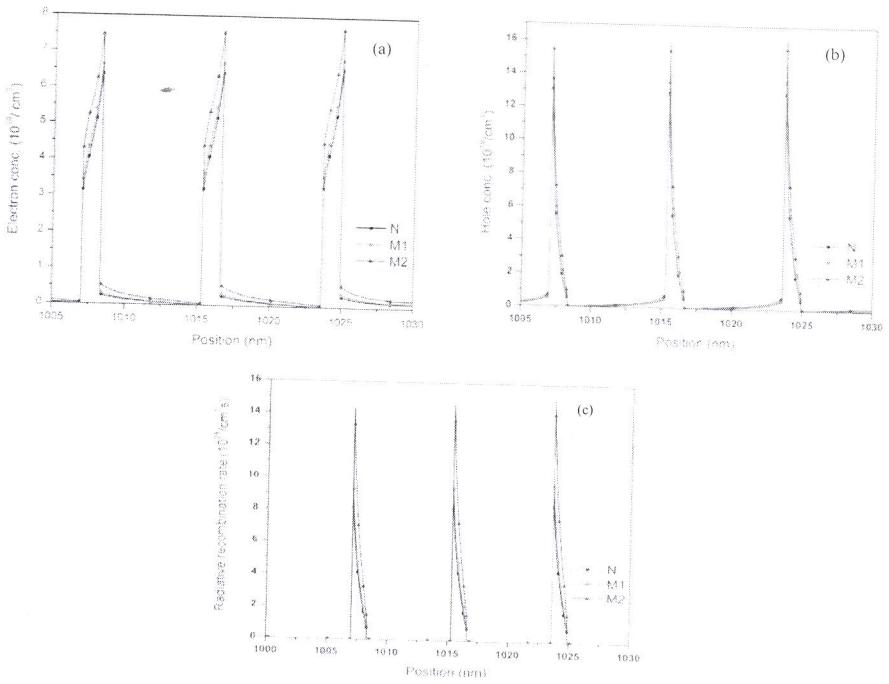

Fig. 3. (a) Electron concentration (b) hole concentration (c) radiative recombination of different structures at current density of 170A/cm^2

From Fig. 4, it is clear that *M2* has minimum leakage of electrons in p side this is because of higher hole confinement leading to lower electron leakage of M2 along the p side.

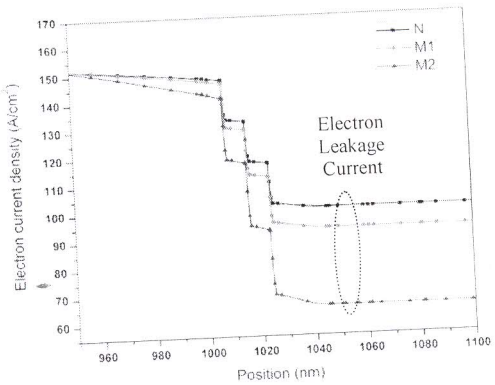

Fig. 4. Electron current density of simulated structures at current density of 170A/cm^2

Conclusion:

The results indicate that the step-graded AlGaN EBLs has improved the efficiency of the DUV LEDs.

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References

[1] H. Hirayama, S. Fujikawa, N. Noguchi, J. Norimatsu, T. Takano, K. Tsubaki, N. Kamata, 222-282 nm AlGaN and InAlGaN-based deep-UV LEDs fabricated on high-quality AlN on sapphire, Phys. Status Solidi Appl. Mater. Sci. 206 (2009) 1176–1182.

[2] C. Liu, Z. Ren, X. Chen, B. Zhao, X. Wang, Y. Yin, S. Li, Study of InGaN / GaN Light Emitting Diodes With Step-Graded Electron Blocking Layer, Ieee Photonics Technol. Lett. 26 (2014) 134–137.

[3] T.H. Park, T.G. Kim, Design of electron blocking layers for improving internal quantum efficiency of InGaN/AlGaN-based ultraviolet light-emitting diodes, Appl. Phys. A Mater. Sci. Process. 120 (2015) 841–846.

[4] U. Manual, Simulator of Light Emitters based on Nitride Semiconductors, SiLENSe, Phys. Summ. Ver. 5.8, STR Inc., Richmond, VA, USA . (2015).

[5] H. Hirayama, N. Noguchi, N. Kamata, 222nm deep-ultraviolet AlGaN quantum well light-emitting diode with vertical emission properties, Appl. Phys. Express. 3 (2010).