Performance Enhancement of Deep Ultra-Violet LEDs with Electrode Design Optimization

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Abstract: Enhancement in UV LED performance is reported by optimizing the electrode design. Three electrodes D1, D2 and D3 have been considered with chip size 500x500 μm² having λ_{em}= 265nm. The device with D2 electrode having 74.5% effective emission area is found to exhibit the best optoelectronics properties and thermal management.

1. Introduction

The AlGaN-based deep ultra-violet (DUV) LEDs are attracting considerable interest as a replacement of the toxic mercury based UV lamps due to its wider environmental friendly applications in the field of lithography, optical data storage, biomedical research, water purification etc. [1]. However, current crowding and self-heating effects are some of the limiting factors in the pathway to achieve high efficiency and high power DUV LEDs [2]. In this paper, optimized electrode patterns for deep UV LED are designed in order to achieve uniform current and temperature distribution along with maximum possible emission area, which are responsible for improvement of the device performance.

2. Designs and Simulations

Design and simulation of DUV LEDs with different kinds of electrodes having emission wavelength of 265 nm, have been carried out using SpecLED module of SimuLED software (from STR Group, Russia) [3]. DUV LED structure having emission wavelength of 265 nm, is shown in Fig. 1[4], has been considered as reference. Ti/Al/Ti/Au and Ni/Au have been employed as n-contact and p-contact having specific contact resistance of 2.0×10^{-5} and 6.4×10^{-4} Ω cm² respectively [5]. Three electrodes, D1, D2 and D3 having effective emission area of 73.5%, 74.5% and 72.1% respectively, having chip size of 500x500 μm² have been studied and their optoelectronics properties have been compared. Considering the fabrication feasibilities, we keep the radius of circular contact and width of p-electrode and n-electrode to be 50μm and 20μm respectively with an isolation area of width 5μm around n-electrode.

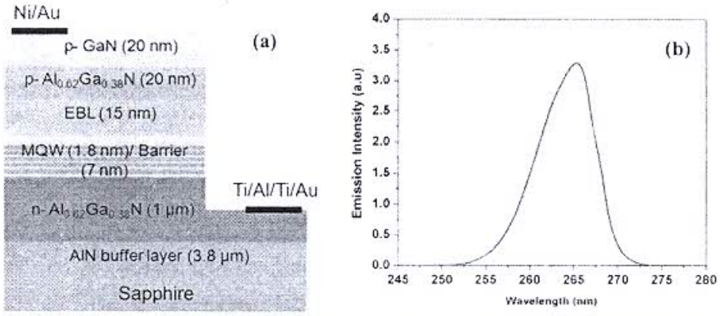

Fig. 1. (a) Schematic of the referred LED structures (b) emission spectra of the referred LED structure

3. Results and Discussions

The current density distributions of D1, D2 and D3 are shown in Fig. 2. From the figure, it is clear that D2 provides the best current uniformity and less current crowding among those. Fig. 3 expresses the comparative temperature mapping of the electrodes. The external quantum efficiency (EQE) and optical output power with respect to current density is plotted in Fig 4. At lower current density, the performance of three different designs are similar, however D2 produces higher EQE and optical power at higher current density. Fig. 4 describes J-V characteristic and temperature vs. current density (J) plot. It can be inferred from this plot that the design D2 have lower series resistance compared to D1 and D3 and its effect is reflected in temperature vs. current density curve. Due to lower series resistance in D2, lower heating in the active region is expected, which is also reflected from the plot.

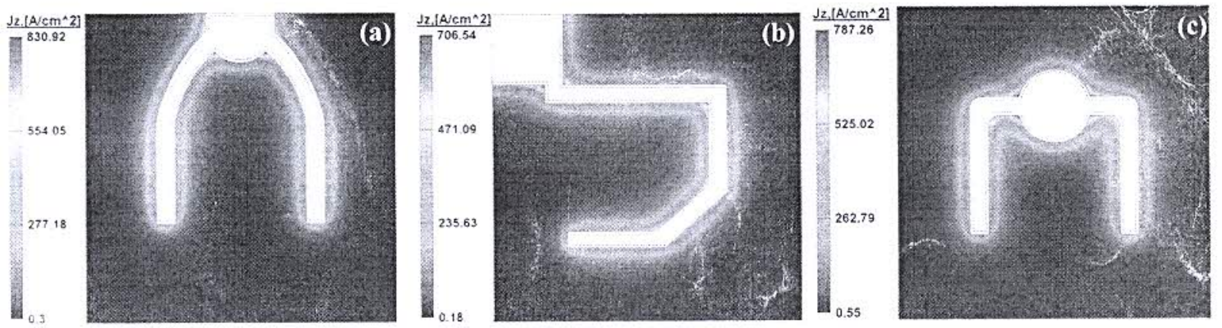

Fig. 2. Current density distribution at 50 A/cm^2 for (a) D1 (b) D2 (c) D3 electrode pattern

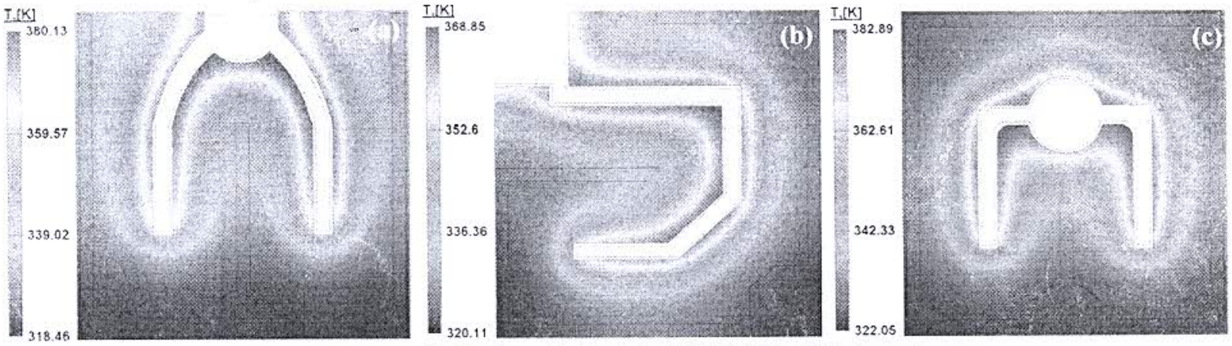

Fig. 3. Temperature distribution at 50 A/cm^2 for (a) D1 (b) D2 (c) D3 electrode pattern

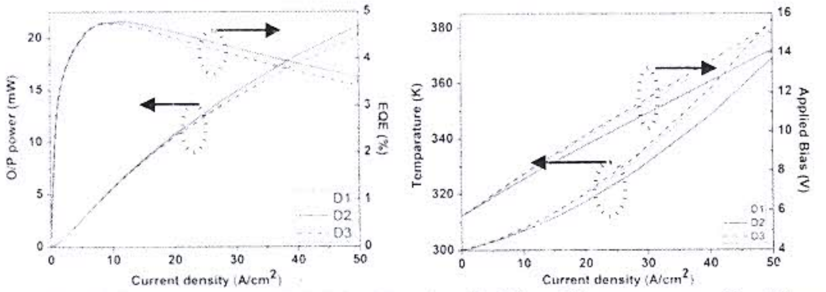

Fig. 4. Comparison of (a) EQE and output power (b) Temperature and applied bias with respect current for different electrode pattern

4. Conclusions:

Above study confirms that the UV-LED chip with electrode D2, having 1% and 2.4 % more effective emission area compared to those with electrodes D1 and D3, shows enhancement in output power by 3.4% and 5.3% . Further D2 possesses the best performance having minimum efficiency drop of around 25.2% at current density of 50 A/cm^2.

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