EQE enhancement of AlGaN Based Lower Bound (295±nm) UVB-LED by using high reflective Ni/Mg electrode for medical applications

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UV-LED has a number of sensing applications, i.e., for many gases (e.g., SO_2, NO_x, NH_3) and biomolecules, which exhibit absorption bands in UV-B and UV-C LEDs spectral regions, including tryptophan, NADH, tyrosine, DNA, and RNA respectively[1]. Recently it was found that the phytochemicals in the fruits and vegetables can be enriched by using UVB light with NB, 310nm, even with mild output power around 20mW[2]. Fruits and plants enriched with phytochemicals can greatly reduce the risk of cancer as well as cardiovascular diseases[2]. An onset rate of atopic dermatitis were reported more than 10% in Europe, America and 2-3 % in the entire Japan, which can be cured by NB, UVB LEDs[1-3]. AlGaN-UV devices can be used in the area of gravitational sensors, e.g., for enabling the charge management systems in the ESA/NASA laser interferometer space antenna (LISA) mission [2-5]. UVB(280nm-320nm) LED is quite important for immunotherapy, skin care, cancer treatment, wound healing, and prevention of the plant blight[1-3]. In 2004, Kim et al., attempted for AlGaN based lower bound, LB-UVB LEDs grown on AlN epilayer on sapphire substrate and achieved maximum output power around 1.8mW at the EL emission about 290nm [4]. In 2017, Susilo et al., investigated the effect of GaN: Mg contact layer in AlGaN based UVB LEDs and the EL emission at 302nm with output power of 0.83mW at 20mA were realised just on-wafer [5]. Very recently Boston University of USA discovered that LB(293nm), UVB LED light source is 2.4 times more efficient than the sunlight for producing Vitamin D3 in human body[6]. Therefore we attempted to further improve the performance of smart, cheap and environmentally safe AlGaN based UVB LED on AlN template with EL emission wavelength around 293±nm for the production of vitamin D3 in human body.

In this work, 4-μm thick AlN template on sapphire substrate having XRC around 300 arcsec both for (002) and (101) diffraction respectively were used for the growth of LB-UVB LED structure as shown in Fig.1(a). Subsequently a 1.34μm Si-doped n-$Al_{0.5\text{-}0.6}Ga_{0.4\text{-}0.5}N$ as n-type contact layer on the epitaxial AlN layer, and then an over layer of active region, multiple quantum well (MQWs) consisting of a three-fold $Al_{0.35}Ga_{0.65\text{-}0.67}N$(1.5-2.5 nm)/$Al_{0.44}Ga_{0.55\text{-}0.60}N$ (6.5nm) were deposited, as shown in Fig.1(a). As we know that it is very challenging to achieve a reasonable hole concentration having shallow donor energy level in an AlGaN alloy with high Al mole contents, therefore two fold thin p-$Al_{0.65}GaN$ layer (10nm), as an electron blocking layer (MQBs) was inserted between MQWs and p-AlGaB. The p-side of the device was completed by lightly Mg-doped p-$Al_{0.6}Ga_{0.4}N$ layer and heavily doped p-$Al_{0.1}Ga_{0.9}N$ as a p-contact layer respectively. As a result, single peak PL emission of 294±3 nm were obtained as shown in the inset of Fig.1(c) and EQE was limited to 2.7% due to the transmitted light loss through Ni electrode as shown in the inset of Fig.1(a). When we replaced the Ni electrode with highly reflective (Ni/Mg) electrode then EQE were enhanced from 2.7% to 3.5% at the current 20mA with output power around 12.7mW, as shown in Fig.1(c) and 1(b) respectively. This LB(294nm)-UVB LED might be 2.4 times more efficient than the sunlight for producing Vitamin D3 in human body.

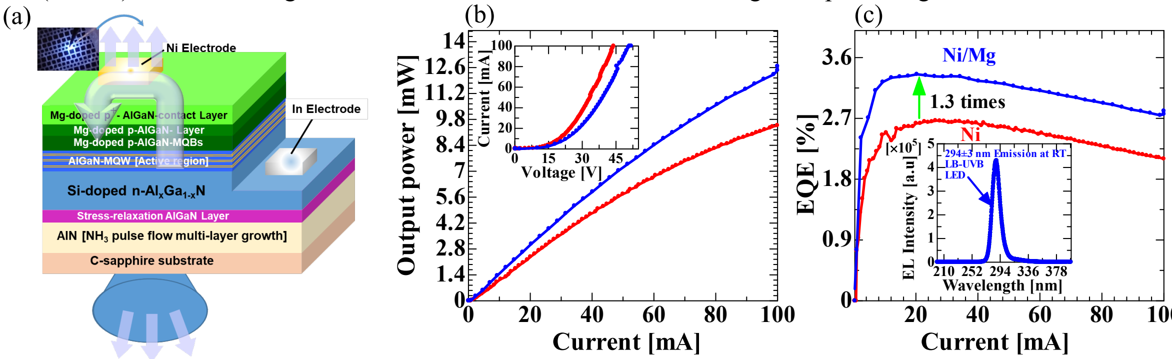

Figure 1(a) Schematic of AlGaN based LB-UVB LED, in the inset transmitted light through p-type (Ni) electrodes has been shown,(b) Current versus output power (I–L), and in the inset I–V characteristics, and (c) improved EQE (η_{ext}) characteristics, just on wafer of LB-UVB LED and in the inset EL emission under 20 mA dc driving current has been shown.

References

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