Reporting 100 kA-cm^{-2} Injection Current Density in 283nm-Band AlGaN UVB LED

Noritoshi Maeda,[1] M. Ajmal Khan,[1*] and Hideki Hirayama[1]

[1]RIKEN Cluster for Pioneering Research (CPR), 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

*Email: muhammad.khan@riken.jp

Eco friendly, smart, and high-power deep-ultraviolet (DUV) laser diodes (LDs) and ultraviolet-B laser diodes (UVB LDs), light sources are critically needed in the area of medical science, metal industry, bio- and chemical-sensing, small particle detection, disinfection, surface monitoring and COVID-19 suppression [1-3]. Recently, Zhang et al. successfully demonstrated to the single-peak electrically pumped stimulated lasing at 272 nm in AlGaN-based DUV LD grown on high cost bulk AlN substrate [1]. Therefore, by using different approach, first, we attempted to the optically-pumped AlGaN DUV LD devices grown on low cost AlN template on C-Sapphire substrate and stimulated emission spectra at 274 nm was clearly observed for the first time even at RT [2]. The world record threshold excitation power density of 69 kW/cm^2 were also demonstrated at RT [2]. Recently, our group also demonstrated to AlGaN DUV LD grown low cost AlN template on C-Sapphire substrate with improved injection current density of 48 kA/cm^2, however some abnormal stimulated oscillations were also observed for the first time in the DUV LD at 273nm emission [2]. However, electrically-pumped AlGaN-based 283-band UVB LD was quite challenging due to both the issue of low injection current density from p-side toward the multi-quantum-wells (MQWs) and poor optical confinement. Therefore, in this work both the conventional flat-type ud-AlGaN cladding layer and p-AlGaN hole source layer (HSL) were replaced with Al-graded undoped (ud)-AlGaN CL as well as Al-graded Mg-doped p-AlGaN HSL in AlGaN-based 283-band UVB LDs grown on AlN template (Fig.1). The light power as well as external-quantum-efficiency (EQE) in LD, respectively, were confirmed to be 3 mW and 0.4% on bare-wafer at RT in the LED mode.

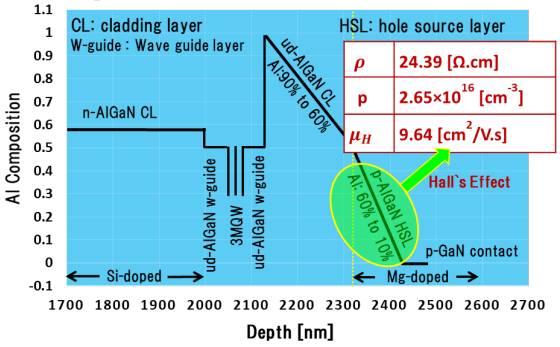

Fig. 1 The estimated Al alloy profile of AlGaN-based UVB LD (Inset: Hall`s effect data of p-AlGaN HSL is given).

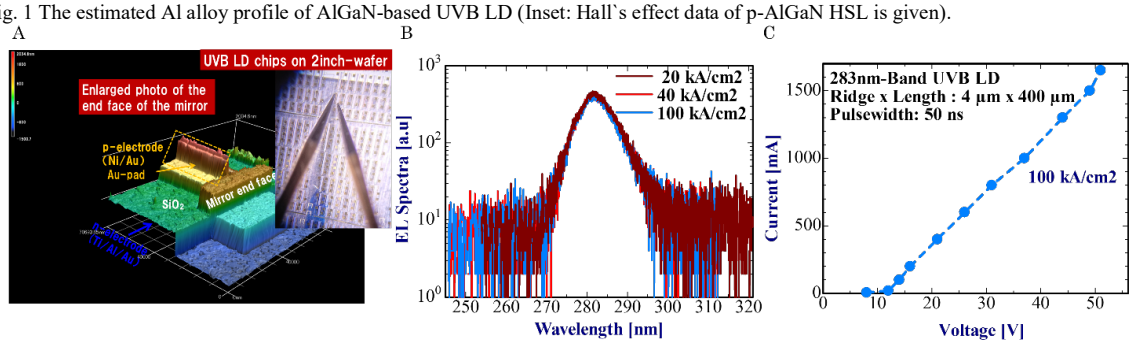

Fig. 2 (A). Laser micrograph of processed UVB LD structure (Inset: Image of real UVB LD devices on 2-inch wafer are shown), (B). Single peak spontaneous electroluminescence spectra at 283nm emission, and (C). Current density vs voltage characteristics of electrically pumped UVB LD at RT.

Based on the improved AlGaN-based MQWs [2], we re-designd our LD structure and grow electrically pumped UVB LD for better carrier injection (Fig. 1). The estimated layer by layer compositional and structural information, respectively, of the grown LD structure are shown in Fig. 1. An epitaxial growth of the LD device structure was confirmed by reciprocal space map (RSM) along (1,1,-4) reflections. Based on Hall`s effect measurement, quite low resistivity of ~ 24 Ω. cm and hole mobility of ~ 9.6 cm^2/V. s along with realtively high hole concentration of ~ 2.6×10^{16} cm^{-3} in the Al-graded p-AlGaN HSL were confirmed, as given in the inset of Fig. 1. Next, a new design of AlGaN UVB LD was fabricated and processed, as shown in Fig. 2A. The mesa structure was formed by the inductively coupled plasma (ICP) dry etching method to expose the surface of the n-AlGaN base layer for electrical pumping contact. Finally, LDs structure with ridged structure of area ~ 4 μm × 400 μm were processed including fabrication of gold pad and mirror, shown in the inset of Fig. 2A. The electrically pumped LD was demonstrated under pulse operation at RT and voltage-current density characteristic reached to 1700 mA at 283nm emission (Fig. 2B-C). Ultimately, UVB LD with improved injection current density of 100 kA/cm^2 was realized and stimulated oscillations were not observe this time as shown in Fig. 2B.

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References

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