Exceeding 30% IQE of AlGaN quantum well 304 nm UVB emission and single peak operation of 326nm UV LED

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Research and development of the ultraviolet rays of UV-A with wavelength 320 - 400 nm, UV-B with wavelength 280 - 320 nm, and part from UV-C less than 280 nm can be used for various applications. The UV range from 300 - 350 nm are aimed to be used for water cleaning, skin cure treatment. Narrowband UV-B therapy with the light of a very short domain of the wavelength in neighbourhood of 310 nm becomes mainstream recently due to its application toward immunotherapy. As we also know that UVC-LDs and LEDs has many application in metalworking industry, like fine pattern manufacturing, cutting and bending of metal. UVC is also very useful for sterilization purposes and also for water purification [1,3]. Similarly the deep UV and UVB has tremendous applications toward optical storage devices and deep UV DVD. Most importantly it has many applications in medical science area and agriculture side [3], using UVB LDs for skin cure and for the prevention of plant disease. UVB (280 - 320 nm) light is quite important for the application fields in immunotherapy, prevention of the plant blight. On other side the UVA applications can be used in UV curing resins, the UV cure (resin hardening, print, the painting), UV adhesives, 3D printers etc. It has wonderful applications in the printing, painting, ink-jet printers, UV coating industries [2]. In 2015, Hamamatsu photonics successfully demonstrated to AlGaN based LD below 330 nm shortest wavelength of LD device on GaN templates with threshold current density of 25 kA/cm^2 (pulse current, 10 ns, 5 kHz, RT). We decided to use AlN/sapphire template or AlN single crystal wafer in order to realize high efficiency AlGaN UVB LEDs towards the next goal to achieve UVB LDs.

The UVB LED device structure was optimized initially by optimizing the the buffer n-AlGaN layer and then optimizing the quantum well (QW) layer structure for the targeted UVB LED/LDs device structure. The n-AlGaN/i-AlGaN and QWs growth sample PL measurement data as a function of QW thickness has been shown in Fig. 1(a). As one of the trials, we introduced two-stage n-AlGaN buffer layer. The n-AlGaN buffer layer is composed of two layers, a layer having a relatively high Al composition and a normal layer with relatively low Al composition. The three specimens of QWs were prepared in which the film thickness of the ordinary QW layer was changed by growth time, like 10, 15 and 20 sec under the same growth condition. Subsequently we optimized the buffer growth condition and then the desired photoluminescence (PL) emission around 290 nm to 305 nm were successfully achieved from the QWs on n-AlGaN buffer. The PL emission of 304 ± 2 nm were obtained and high IQE around 30% were estimated for this UVB range from PL intensity measured at RT.

Next by using the growth conditions obtained for n-AlGaN buffer layer and QWs, we fabricated LEDs and achieved single peak electro luminance (EL) around 326± 2 nm, as shown in Fig. 1(b). Off course the EQE is still as much low as 0.4%, it is relatively lower as a whole, and the film thickness of QW grown by 15 sec time give us as low as 0.4 % EQE (using Ni/Au for the p-electrode) with output power around 0.1mW as shown in Fig.1 (c-d). In this study we did not optimized the p-AlGaN, especially the EBL layer to further improve the EQE and LEE.

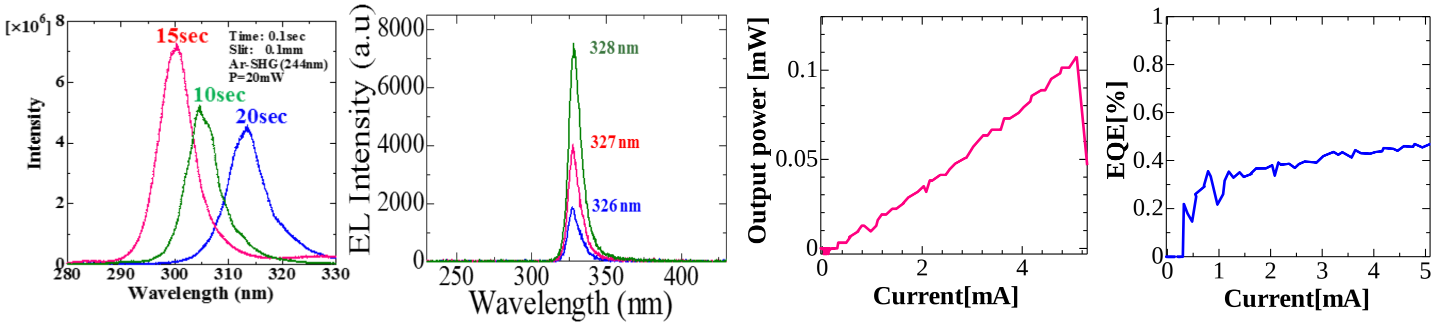

Figure 1(a) PL spectra of fabricated AlGaN based QWs grown with 10, 15, 20sec, (b) EL spectra of the AlGaN QW UV LED with emission wavelengths between 326 and 328 nm, all measured at RT with an injection current of approximately 5 mA, (c) current *vs* output power (I-L) and (d) current *vs* EQE (I-EQE) characteristics of 326-328 nm UV LED.

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