Realization of High Internal Quantum Efficiency over 35% in 330 nm-band deep-UV using Quaternary InAlGaN Quantum Well

H. Hirayama[1], Y. Yano[3], M. Shimizu[2], N. Akutsu[3], K. Matsumoto[3] and H. Okumura[2]

[1]*RIKEN (The institute of Physical and Chemical Research), 2-1, Hirosawa, Wako-shi, Saitama 351-0198, Japan*

[2]*AIST (National Institute of Advanced Industrial Science and Technology), Umezono 1-1-1, Central 2, Tsukuba, Ibaraki 305-8568, Japan*

[2]*Taiyo Nippon Sanso Co. Ltd., 10 Okubo Tsukuba, Ibaraki 300-2611, Japan*

We achieved extremely high internal quantum efficiency (IQE) as high as 35% for quaternary InAlGaN quantum well (QW) with emission wavelength at 336 nm. This is the highest IQE value ever reported for deep-ultraviolet (UV) emission range.

Al(In)GaN is attracting considerable attention as candidate material for the realization of deep-UV light-emitting diodes (LEDs) or laser diodes (LDs). However, it is difficult to realize high-efficiency deep-UV emitting devices, because of the difficulty in obtaining high emission efficiency of AlGaN-QW. The external quantum efficiency (EQE) of deep-UV LEDs ever reported was only 1-2% for wavelength below 350 nm at CW operation. Quaternary InAlGaN is very attractive for the application to the deep-UV emitters, because high efficiency 280-380 nm UV emission can be obtained due to In-incorporation effects.

The samples were grown on sapphire (0001) substrates by low pressure metalorganic vapor phase epitaxy (MOVPE). The MOVPE system we used is Taiyo Nippon Sanso Co. Ltd's SR4000 which is designed for the production of InGaN-based blue LEDs and violet LDs. We fabricated six periods of $In_{x1}Al_{y1}Ga_{1-x1-y1}N/In_{x2}Al_{y2}Ga_{1-x2-y2}N$ multi (M)-QWs on GaN buffer layers grown on sapphire substrates. We obtained intense photoluminescence (PL) with the wavelengths between 320-350 nm at room temperature (RT) from the InAlGaN MQWs. The intensity of the 336 nm UV-emission from the quaternary InAlGaN MQW was as strong as that of 430 nm blue-emission from $In_xGa_{1-x}N$/GaN MQW. The IQE of the QW was estimated by comparing the integrated PL intensities measured at 15K and at RT. The excitation power density was approximately 300W/cm^{-2}. The IQE values estimated for the InAlGaN MQW (336 nm emission) and the InGaN MQW (430 nm emission) were 35% and 38%, respectively. This is the highest IQE value ever reported for deep-UV emission range. From these results, it was demonstrated that InAlGaN QWs are very promising for the realization of high-efficiency deep-UV LEDs or LDs.

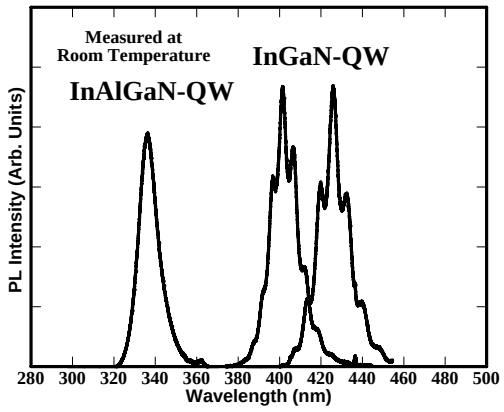

Fig.1. Photoluminescence (PL) spectra of quaternary InAlGaN-QW (UV;336nm) and InGaN-QWs (blue;400-430nm) measured at RT.

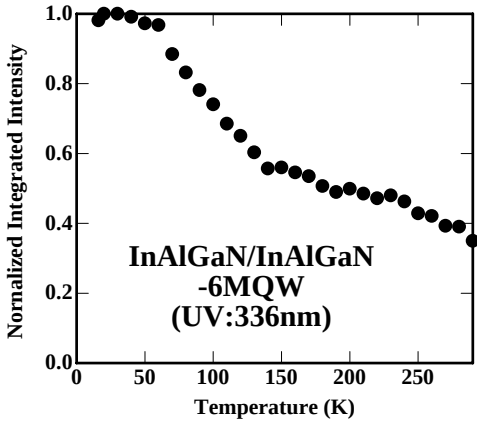

Fig.2. Temperature dependence of integrated PL intensity observed for quaternary InAlGaN-QW. The IQE was estimated to be 35% at 290K.

E-mail:hirayama@riken.jp