Short Period Alloy Superlattice for Transparent Conductive Layer of UV-emitter

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UV light is chemically active and has a precise spatial resolution. Therefore, it will provide a variety of applications in the field of chemistry, biology, environmental science, and optics. Present UV light sources are energy consumptive and quite large. Compact and efficient semiconductor light source will present a solution to these problems. AlGaN is one of the candidates for ultraviolet (UV) and deep-UV light source [1] and its combination with SiC substrates is one of the most promising candidates. The band gap wavelength of AlGaN lies in the UV-region between 200 nm and 370 nm and direct growth of AlGaN alloy on SiC substrate [2] is much easier than that on the other substrates such as sapphire, because of small lattice mismatch between substrates and epitaxial layers. We have already reported band edge emission at 346 nm from AlGaN multi-quantum-well (MQW) LED grown on SiC substrate [1].

For the applications to light emitting devices, electrically conductive layers, which supply carriers, are desirable to be transparent. The enhancement of carrier generation by introducing strained layer superlattice (SLS) is a practical method, and hole concentration above 10^{18} cm^{-3} has been reported [3]. For the UV light sources, band gap widening of carrier supply layer is the most important issue. Longer period and larger difference in Al molar fraction result in the band gap narrowing, although they provide higher hole concentration. Such band gap narrowing due to internal polarization field becomes especially remarkable for quantum well wider than 4 nm [1, 4, 5]. In order to reduce this band gap narrowing effect, we introduced short period alloy superlattice (SPASL) as a transparent conductive layer, which consists of 1.5-nm-thick $Al_{0.14}Ga_{0.86}N$ and 1.5-nm-thick $Al_{0.18}Ga_{0.82}N$, and its application to AlGaN-based LED.

Figure 1 shows the XRD measurement result of reference sample of $Al_{0.14}Ga_{0.86}N$ /$Al_{0.18}Ga_{0.82}N$ multi-layer structure. To characterize periodicity, we set the period at 30 nm which is ten times of SPASL structure, because the 3 nm period of SPASL is too small to obtain XRD yield. As shown in Fig.1, clear satellite peaks are obtained in spite of the small difference in Al molecular fraction of 4%, which indicates the validity of structure control. Figure 2 shows the photoluminescence (PL) spectra of the p-type SPASL and the p-type GaN reference sample. The molar fraction of Mg source (Cp_2Mg: cyclopentadienylmagnesium) to Gallium source (TMGa: trimethylgallium) was set at the same value in both p-type layer growth. Clear blue emissions due to hole generation were confirmed and their intensity is almost the same. The hole concentration of these layers was 1 x 10^{18} cm^{-3} and 2 x 10^{17} cm^{-3}, respectively.

By using SPASL, we fabricated AlGaN LED structure which are schematically drawn in the inset of Fig. 3. We grew n-type $Al_{0.16}Ga_{0.84}N$ buffer layer directly on an on-axis SiC substrate, 75 periods of n-type SPASL, $Al_{0.1}Ga_{0.9}N$ /$Al_{0.14}Ga_{0.86}N$ MQW, 75 periods of p-type SPASL, and 15-nm-thick p-type GaN contact layer. The band gap wavelength of SPASL was confirmed 338 nm by PL spectrum of n-type SPASL. Ten-nm-thick Ni and Au are used as semi-transparent p-type ohmic contact metal. The p-type electrode was 400 μm square and emission was collected by a bundle fiber attached to a monochromated CCD-array.

Figure 3 is the result of spectrum measurement under continuous current injection of 250 A/cm^2. The peak wavelength of the emission spectrum was 343 nm which is slightly shorter than the previous report, although extra emission from D-A pair and p-type material was also observed. This result shows a successful combination of the AlGaN-based active layer and the transparent wide-gap SPASL layer, which will realize practical nitride UV- and deep-UV- emitters.

In summary, we confirmed high hole generation in the short period alloy superlattice (SPASL) and successful application of SPASL to the AlGaN-based UV emitters as a transparent conductive layer.

References

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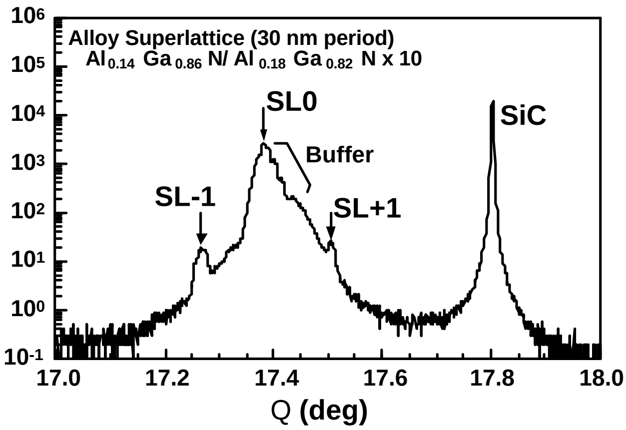

Fig. 1: XRD measurement results of reference samples of 10 periods of 15-nm-thick $Al_{0.14}Ga_{0.86}N$ / 15-nm-thick Al0.18Ga0.82N multi-layer structure

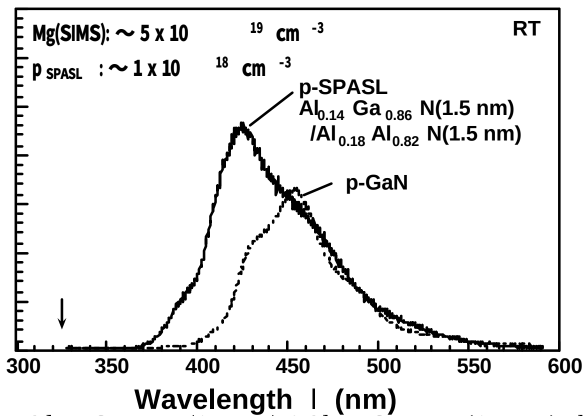

Fig. 2: PL spectra of p-type $Al_{0.14}Ga_{0.86}N$ (1.5 nm) / $Al_{0.18}Ga_{0.82}N$ (1.5 nm) short period alloy superlattice and p-type GaN.

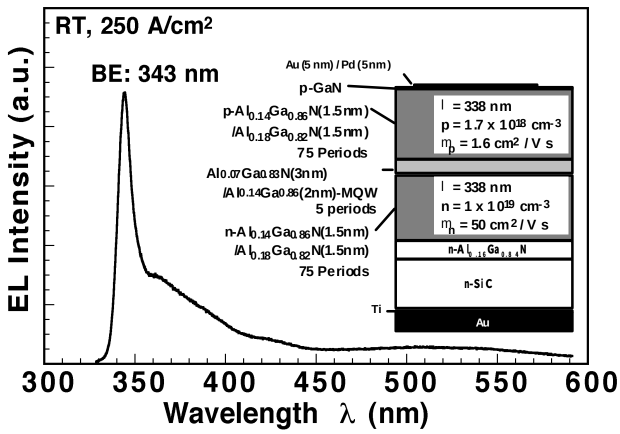

Fig. 3: Device structure and EL spectrum of AlGaN-based LED. The band edge wavelength was 343 nm.