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Highly Transparent Structure for Nitride Ultraviolet Light Emitting Diodes

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1. Introduction

We studied the fabrication of a transparent structure for AlGaN-based ultraviolet light emitting diodes (UV-LEDs). We have already clarified that AlGaN is intrinsically emissive;[1)] that is, the internal quantum efficiency is comparable to those of conventional III-V LEDs and InGaN blue LEDs. For practical use, improvement of the external quantum efficiency is important. It is well-known in AlGaInP-LEDs the external quantum efficiency can be improved considerably by introducing transparent substrates and by optimizing the LED chip structures.[2)] Therefore, the fabrication of a transparent LED structure and its evaluation is one of the most important issues in nitride UV-LED research.

2. Results and Discussions

Figure 1 shows electroluminescent (EL) spectra and a schematic drawing of the device structure we fabricated. The device consists of an AlN wetting layer on a sapphire substrate, an $Al_xGa_{1-x}N$ buffer layer, an AlN lattice relaxation layer, and the LED structure. As shown in Fig. 1, the EL intensity of the transparent LED (AlGaN-buffer-LED) is about twice that of the LED using a GaN buffer layer (GaN-buffer-LED). The spectrum of the AlGaN-buffer-LED shows a few fringes. These are due to the reflection enhancement from the interface between the $Al_{0.1}Ga_{0.9}N$ buffer layer and the AlN wetting layer and from that between the AlN wetting layer and the sapphire substrate, which also implies that the epitaxial layers are transparent.

To further evaluate a transparency of the devices, we performed the transmittance measurement in which AlGaN-based UV-LEDs are used as light sources, as shown in Fig. 2. Here, we used two types of LEDs: a simple UV-LED and a UV-LED mounted in a white fluorescence dye (UV-white-LED). The measurement configuration is shown in the inset. We set the source LED below an epitaxially grown sample and measured the sample transmission spectra by collimating a quartz

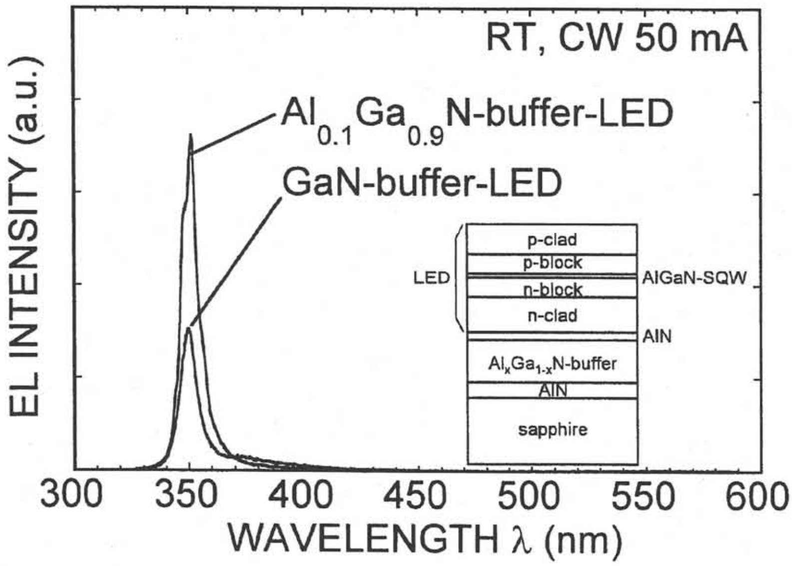

Figure 1 LED structure and EL spectra of AlGaN-buffer LED and GaN-buffer LED

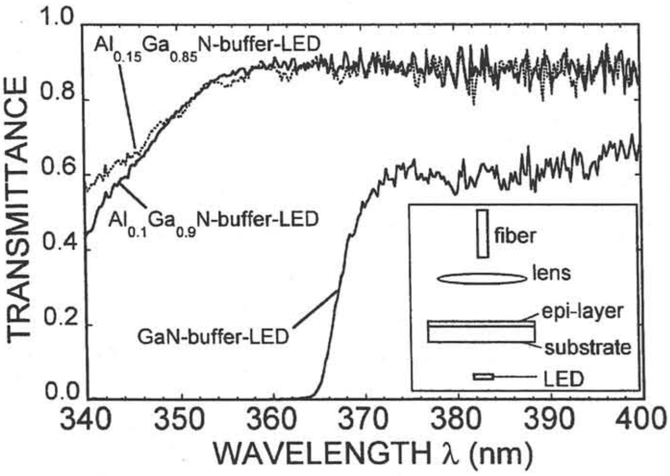

Figure 2 Transmission spectra measurement of LED wafer structures.

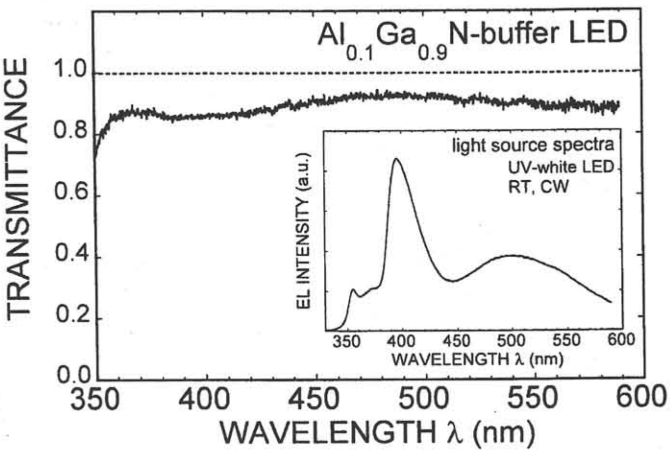

Figure 3 UV-visible transmission spectrum of AlGaN-buffer-LED by using UV-white LED

fiber. Figure 2 shows the transmission spectra of three different LED wafers obtained when the simple UV-LED was used. The buffer layers of each sample are $Al_{0.15}Ga_{0.85}N$, $Al_{0.1}Ga_{0.9}N$, and GaN, respectively. The transparency of the AlGaN-buffer LED at the wavelength of 350 nm is about 80%, and it does not depend on the Al molar fraction of the buffer layer. Both transmission decreases at the same band-gap wavelength of the active layer. Therefore, this absorption is due to the SQW active layer, and a small number of quantum wells in the active layer is preferable to suppress such self re-absorption at the active layer. When the UV-white-LED was used as a light source, the transparency of the AlGaN-buffer-LED from the near-UV to visible range was confirmed, as shown in Fig. 3. To the best of our knowledge, these transparency measurements are the first practical application of AlGaN-based UV-LEDs.

3. Summary

We fabricated transparent UV-LED structures based on an AlGaN buffer layer and evaluated their transparency. The emission suffers about 20% absorption due to the SQW active layer. We also demonstrated the practical application of UV-LEDs to transmission measurement within the near UV and visible range.

References

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