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Nitride-based blue LEDs withGaN/SiN double buffer layers

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1. Introduction

In recent years, tremendous progress has been achieved in GaN-based blue and green light emitting diodes (LEDs). These blue/green LEDs have already been extensively used in full-color displays and high efficient light source for traffic light lamps. However, there still exist some problems to be solved, such as mismatches in lattice constants and thermal expansion coefficients between the epitaxial layers and the underneath sapphire substrates. Conventional nitride-based devices use a low temperature GaN or AlN nucleation layer as the buffer layer. Recently, it has been reported one can reduce the defect density in nitride-based epitaxial layers by using a SiN buffer layer or a GaN/SiN double buffer layer [1-3]. Nitride-based ultraviolet (UV) LEDs using these novel buffer layers have also been demonstrated [1]. However, the exact reasons why defect density could be reduced by these novel buffer layers are still not very clear yet. In this paper, Nitride-based blue LEDs grown with conventional single low temperature GaN buffer layer and the GaN/SiN double buffer layers were both prepared. The performance of these fabricated LEDs will also be evaluated.

2. Experiment

The InGaN/GaN LED structures used in this study were grown on c-face (0001) 2-inch sapphire (Al_2O_3) substrates in a vertical metalorganic chemical vapor deposition (MOCVD) system. Details of the growth procedures could be found elsewhere [4]. The conventional InGaN/GaN multiquantum well (MQW) LED, labeled as LEDI. The structure of LEDII was exactly the same as that of LEDI except a SiN layer was deposited directly on top of the sapphire substrate prior to the growth of GaN nucleation layer. During the growth of the SiN layer, the flow rates of NH_3 and SiH_4 were 20 slm and 40 sccm with hydrogen for 5 min at 600 ^{o}C. *In-situ* normal incidence reflectance was measured during the whole growth steps by irradiating the samples using a tungsten lamp. Reflected light through a spectrometer was collected by a photodiode.

We fabricate of 350um×350um blue InGaN/GaN LED chips. Current-voltage (I-V) characteristics of the fabricated devices were then measured at room temperature by an HP4156 semiconductor parameter analyzer. Reliability of these LEDs was also evaluated.

3. Results and Discussions

Figure 1(a) and (b) show the cross-sectional transmission electron microscopy (TEM) images of the LEDs with conventional GaN single buffer and GaN/SiN double buffer. From figure 1(a), the LED I with conventional GaN single buffer, one can easily find that the threading dislocation originates from the low temperature buffer layer and high temperature growth GaN layer. However, from figure 1(b) the LED II with GaN/SiN double buffer, there is almost no threading dislocation to be observed from the low temperature buffer layer and high temperature growth GaN layer.

Recently, Koleske et. al. have demonstrated that transition from three-dimensional (3D) grain to two-dimensional (2D) coalesced growth can be intentional prolonged by reducing the NH_3 flow during the initial high temperature GaN growth [5], and such a phenomenon could be observed by *in situ* optical reflectance during growth. They reported that one could reduce the threading dislocation density by prolonging the 3D to 2D transition time. In this study, we also used *in situ* optical reflectance to characterize our samples. Figure 2.shows reflectance waves observed from the two LED structures with conventional single GaN buffer and GaN/SiN double buffer. It was found that transition time observed from the sample grown on GaN/SiN double buffer was longer. Such a result also suggests that we could reduce the threading dislocation density by using GaN/SiN double buffer.

Electroluminescence ntensity-current (L-I) characteristics of the LEDs with conventional GaN single buffer and GaN/SiN double buffer were also measured. With a 20 mA current injection, it was found that EL peaks occurred at around 465 nm for both LEDs. From L-I measurements, it was found that output powers of these two LEDs were also about the same.

Figure 3 shows life test of relative luminous intensity measured from these two LEDs, normalized to their respective initial readings. During life test, all two LEDs were driven by a 50mA current injection and the temperature was controlled at 80°C. It was found that the luminous intensity decreased by 7.2% for LEDI after 24 hours. In contrast, the luminous intensity only decreased by less than 1% during the same period for LEDII. Furthermore, it was found that the luminous intensity decreased by 23% and 14% after 72 hours for LEDI and LEDII, respectively. The rapid decay in luminous intensity observed from the conventional nitride-based LED (i.e. LEDI) is again due to its higher dislocation density. Thus, LEDI will have a large leakage current problem especially under high current injection operated at high temperatures. As a result, the lifetime of LEDI is much shorter. In contrast, the lifetime of nitride-based LED with GaN/SiN double buffer (i.e. LEDII) is much longer.

4. summary

In summary, nitride-based MQW LED structures with conventional single GaN buffer and GaN/SiN double buffers were prepared by MOCVD. It was found that we could reduce defect density and thus improve crystal quality of the GaN epitaxial layers by using GaN/SiN double buffers. It was also found that we could use such a GaN/SiN double buffer to achieve more reliable nitride-based LEDs.

Acknowledgements

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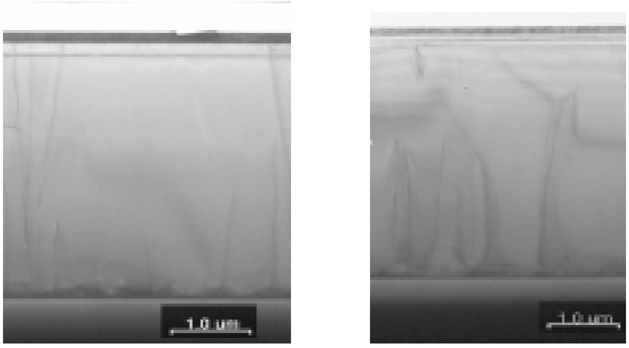

(a) **(b)**

Figure 1. Cross-section TEM of GaN grown on sapphire with(a) and without (b) SiN buffer layer.

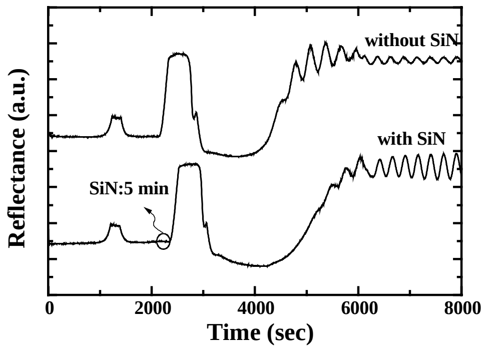

Figure 2. The reflectance wave from of two LED structure are shown versus the time.

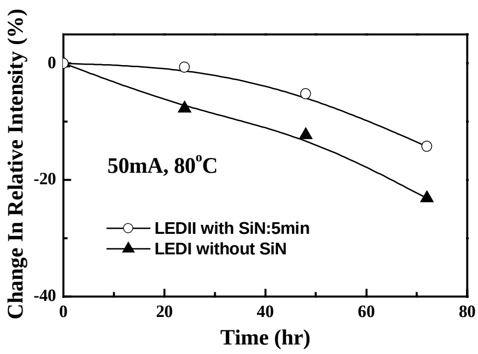

Figure 3 Life test of relative luminous intensity measured from the two LEDs, normalized to their respective initial readings.