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A p-down InGaN/GaN MQW LED Structure Grown by MOVPE

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The development of III-nitride light emitting devices is quite successful over the past ten years[1]. The best results are based on the InGaN/GaN or InGaN/AlGaN multiple quantum well (MQW) structure using sapphire substrate. The epitaxial sequence is as follows: n-type cladding layer, MQW active layers and p-type cladding layer. In this study, we call it n-down sequence, as shown in Fig. 1(a) with the arrows showing the forward carrier injection path. Such an n-down sequence is adopted not only for the III-Nitride blue/green LED and LD devices on sapphire substrates with non-symmetrical structure, but also for the AlGaInP red/yellow LED and LD devices on GaAs substrates with symmetrical structure. The first reason for such an epitaxial sequence is based on the structure consideration. The crystal quality of n-type cladding layer is usually better than that of p-type cladding layer. As a result, the crystal quality of the top cladding layer will be better for samples with n-down sequence. The second reason is that n-type layer conductivity is normally much larger than that of the p-type layer. Thus, we can achieve a smaller device resistance and a smaller turn on voltage with n-down structure.

The above-mentioned advantages of the n-down structure are not as significant for III-nitride light emitting devices on sapphire substrate. For III-Nitride LED, we normally have to adopt non-symmetrical arrangement since sapphire substrate is an insulator. If we want to use ITO as the transparent contact metal to the top layer of the n-down III-Nitride LED, we need to deposit ITO onto the p-GaN layer. However, low ITO contact resistance is only achievable on n-GaN layer[2], while ITO on p-GaN normally forms Schottky contacts. Also, if we want to use wet etching to etch away the top layers of the III-Nitride LED, it will be much more easier when the top layer is n-GaN. Thus, p-down III-Nitride LED with an n-GaN top layer seems to be promising in real device application.

Accordingly, we have studied the performance of the III-Nitride LED with p-down, or inverted epitaxial sequence, as shown in Fig. 1(b). In Fig. 1(b), we also inserted a co-doped layer in between the p-cladding and MQW active layers. To our knowledge, not much study has been reported with such a p-down structure, probably due to the difficulties in growing high quality active layers on top of p-type cladding layer. In this study, we report the improvement of the crystal quality of the p-down InGaN/GaN MQW LED structure. Figure 2 shows the room temperature PL spectra of the III-Nitride structures. It can be seen that although the PL intensity of the p-down LED without co-doped interlayer is much smaller than that of the n-down III-Nitride LED, we can significantly increase the PL intensity of the p-down LED by inserting a co-doped interlayer. Figure 3 shows the DCXRD of the (a) n-down, (b) p-down with and (c) without co-doped interlayer LEDs. As can be seen from Fig. 3, we found that the crystal quality of the p-down sample without co-doped interlayer is indeed inferior to that of the n-down sample. However, the crystal quality of the p-down sample with co-doped interlayer is almost the same as that of the n-down sample. Such an improvement also agrees with the PL result observed in Fig. 2. LEDs with these three different structures were also fabrication and their electrical properties were evaluated respectively. It was found that we could achieve a low turn-on voltage by modifying the p-GaN under layer. These results suggest that p-down GaN LED is quite promising for real device application.

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References

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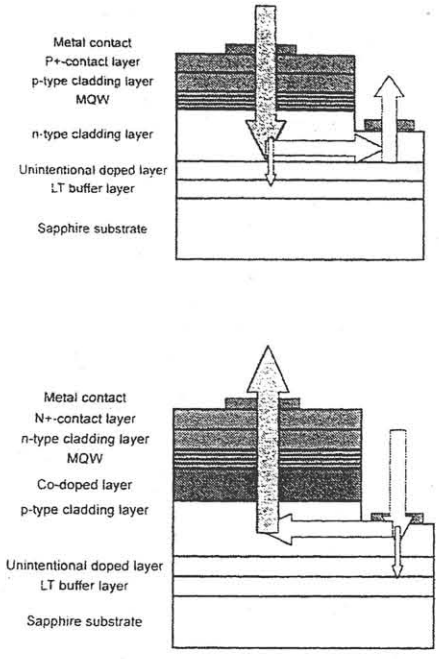

Figure 1. Schematic diagram of (a) LED structure with n-down arrangement, (b) LED structure with p-down arrangement and co-doped interlayer. Arrows show the current injection path with small leak.

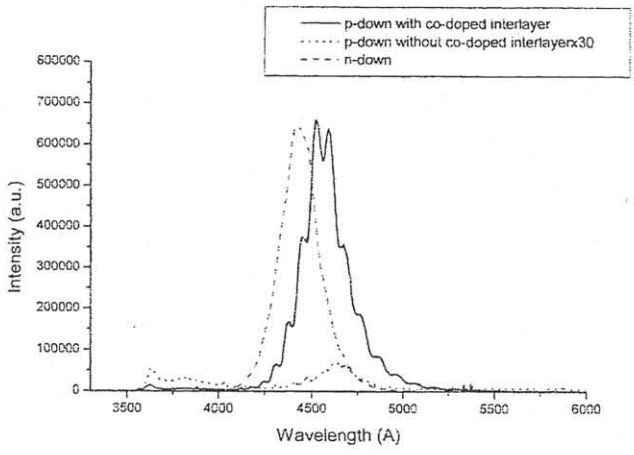

Figure 2 Room temperature PL spectra of (a) n-down, (b) p-down with and (c) without co-doped interlayer LEDs.
Solid line: p-down with co-doped interlayer
Dot line: p-down without co-doped interlayer × 30
Dash line: n-down

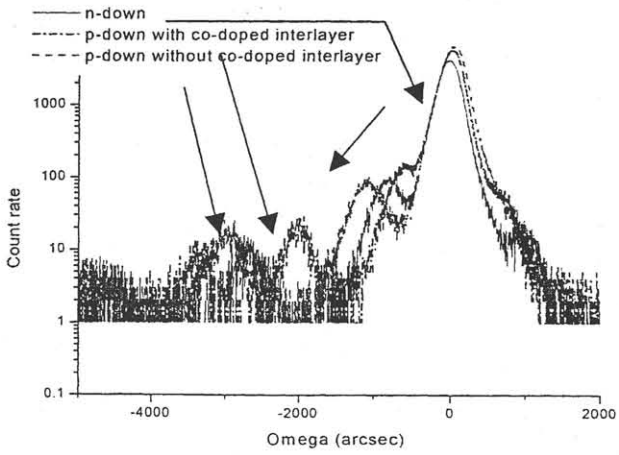

Figure 3 DCXRD spectra of (a) n-down, (b) p-down with and (c) without co-doped interlayer LEDs
Solid line: n-down
Dash-dot line: p-down with co-doped interlayer
Dash line: p-down without co-doped interlayer