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Improvement of AlGaInP MQW Light Emitting Diodes by Modification of Ohmic Contact Layer

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1. Introduction

In the last ten years, current-spreading [1]-[4] and current-blocking [4][5] ideas have been proposed to improve the optoelectronic characteristics of $(Al_xGa_{1-x})_{0.5}In_{0.5}P$-based LEDs. Recently, indium tin oxide (ITO) layer with high conductance ($\rho = 2.5\times10^{-4}\ \Omega$cm) and superior transparency (>90%) was also introduced to enhance the current-spreading ability and thus increase the brightness of LEDs [4][6]-[9]. In general, a GaAs contact layer with high doping concentration is used to decrease the contact resistance between ITO and semiconductor [9]. However, it comes with a drawback of the drastic absorption of the emitting light at shorter wavelength region by the GaAs contact layer. In this paper, a meshed GaAs contact layer was demonstrated to relieve the negative effect on the ITO-assisted LEDs and effectively lessen the generation of defects after aging test.

2. Device Fabrication

The AlInP/AlGaInP LED structure, designed for 570nm emission, was grown on an n-type (100) GaAs substrate by MOCVD as shown in Fig. 1. There were three different samples labeled device A, device B, and device C. Device A used GaP layer as a current-spreading layer while device B used both GaP and ITO layers to offer the current-spreading function. Note that the GaP layer of the same thickness used in device A and device B was to make sure that both devices had equivalent "escape cones" [4].

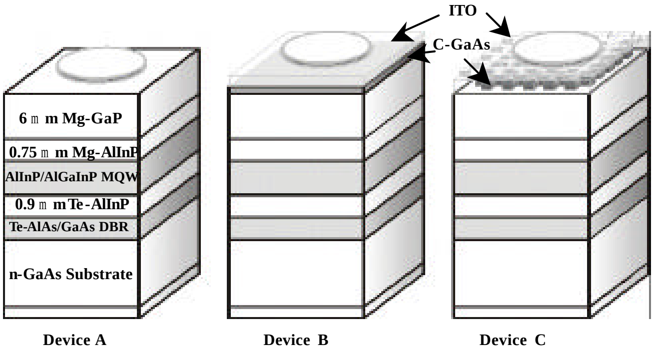

Fig. 1 Schematic structure diagram of AlInP/AlGaInP LED for devices A, B, and C.

Device C was similar to device B except the meshed GaAs contact layer. The meshed GaAs contact layer, with a thickness of 500Å, was made up of several 10μm×10μm square openings, as shown in Fig. 1. The fabrication processes of these devices were briefly described as follows. The GaAs contact layer was totally removed in device A and partially removed in device C. ITO was evaporated only on device B and device C, and then p-type (AuBe/Au) and the n-type (AuGe/Au) electrodes were deposited separately for devices A, B, and C.

3. Device characterization and Discussion

The current-voltage (I-V) curves (solid symbols) and the luminance intensity- current (L-I) curves (hollow symbols) of devices A, B, and C were shown in Fig. 2.

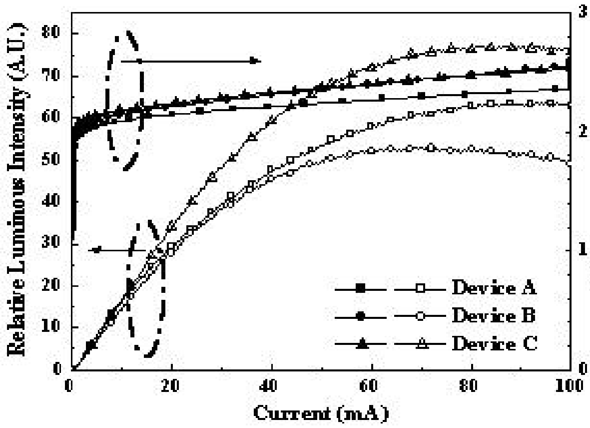

Fig. 2 I-V (solid symbols) and L-I (hollow symbols) curves of AlInP/AlGaInP LEDs for device A, device B and device C.

Though in device B there were double current-spreading layers, i.e., GaP and ITO, the luminous intensity of device B was lower than that of device A. The negative effect on device B was caused by the large absorption coefficient of the GaAs (5×10^4cm^{-1} at 570nm) contact layer, and nearly 22% of the emitted light was absorbed by the GaAs contact layer with a thickness of 500Å. In comparison with device B, device C with a meshed GaAs contact layer had less absorption area and most of the emitted light could pass through the openings so that the light extraction efficiency in device C could substantially be promoted. As shown in Fig. 2, the luminous intensity of device B was only 94.8% of that of device A while the luminous intensity of device C was 1.16 times higher than that of device A at an operating current of 20mA. As regards the electrical characteristics of devices, I-V curve of device C was similar to that of device B even though the ohmic contact area consisting of GaAs in device C was smaller than that in device B. The meshed GaAs contact layer could spread the injected carriers uniformly, and the experimental result was the same with our theoretical result [10]. The turn-on voltage and the dynamic resistance of device A were both smaller than those of device B and device C due to the absence of additional band discontinuity between the GaP layer and the GaAs layer. The larger series resistance in devices B and device C has made their luminous intensity saturate faster than that of devices A due to the joule heating effect.

Figure 3 shows the normalized luminous ratio of all devices plotted against the measurement current. The normalized luminous ratio was defined as the luminous intensity after aging divided by that before aging. Suffering the same stress by an aging current of 100mA for 10min, the minima of the measurement currents 8.1mA, 3.3mA, and 0.4mA were required for device A, B and C respectively to saturate the non-radiative recombination channels [11]. That means device C had the fewest defects among the three devices after aging. Therefore, we could infer that device C possessed better current-spreading ability than device B.

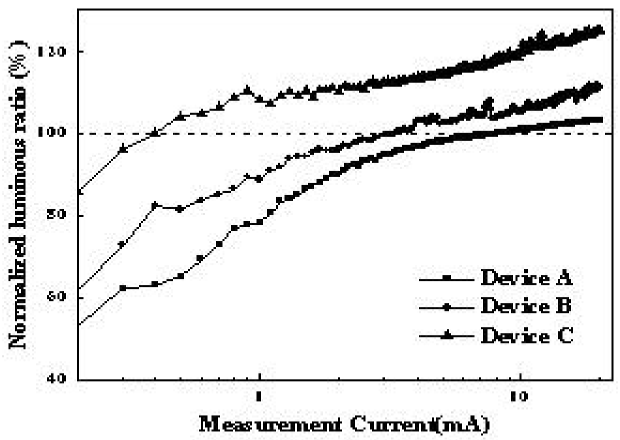

Fig. 3 The relative luminous intensity of device A, device B, and device C against the measurement current. The aging current was 100 mA and the stressed time was 10 min.

Here we presented a simple concept to explain why such meshed contact layer could enhance the current-spreading ability of devices. The contact between ITO layer and GaAs layer was ohmic-type but between ITO layer and GaP layer was schottky-type, which would retard carriers in vertical direction and compel them to move as laterally as possible. Therefore, the carriers would spread better in device C in comparison with device B due to the spatially blocking effect [5].

4. Conclusion

In this paper, the drawback of optical absorption in the conventional ITO LED (device B) has been exhibited in contrast to the conventional non-ITO LED (device A). Even if the ITO layer can spread carriers very well, the subsidiary GaAs contact layer drastically degraded the optical property of the device. As shown in Fig. 2, the luminous intensity in device B is only 94.8% of that in device A at 20mA. For diminishing such absorption drawback, we proposed an improved structure with a meshed contact layer and demonstrated its feasibility. This new structure can raise the luminous intensity up to 1.16 times higher than that of device A at 20mA. In addition, the reliability of such meshed-type LED (device C) was excellent even though its junction temperature was higher than other conventional LEDs. This outstanding property comes from the enhanced current-spreading ability due to double current-spreading layers and the spatially blocking effect caused by a meshed contact layer. Therefore, the current density striking the junction of LEDs with a meshed contact structure was less than the conventional devices and fewer defects were generated during aging process.

Acknowledgements

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