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InGaN/GaN Light Emitting Diodes with a Lateral Current Blocking Structure

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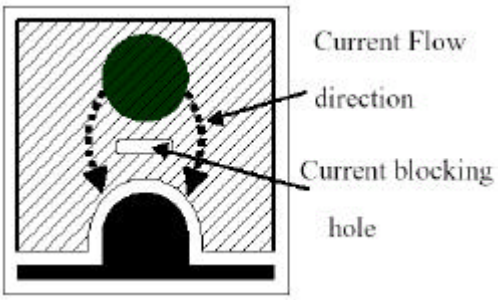
1. Introduction

The bandgap of AlGaInN alloy varies from 1.95 to 6.2 eV depends on its composition. Therefore, III-nitrides are useful in fabricating light emitting diodes (LEDs) of short wavelength [1,2]. In order to fabricate LEDs with better optical output and reliability, the current spreading must be improved. It is necessary to employ a lateral carrier injection due to the insulating sapphire substrate. However, the lateral current injection might exhibit a problem of nonuniform current spreading during the device operation. Conventionally, the current spreading was enhanced by depositing a semitransparent ohmic contact layer between the p-type GaN and the p-bonding pad. There is trade-off between the transparency and the current spreading in this semitransparent layer metallization. Kim *etl.* have investigated the effect of current spreading on the performance of GaN-based light emitter diodes [3]. Hue *etl.* have proposed a LED structure with a current blocking layer beneath the p-bonding pad to improve the light output of the LED [4].

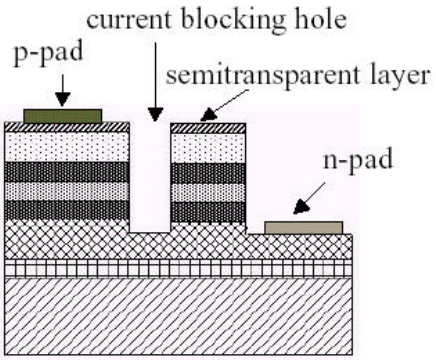
In this study, a new structure was proposed to improve the lateral current spreading in InGaN/GaN LEDs. The concept of the new method was shown in Fig. 1. A small portion of semiconductor layers between the p-type and n-type bonding pads was removed and the formed current blocking hole would enhance the lateral current spreading. With the blocking hole, the current will no longer flow directly along the nearest path from the p-bonding pad to the n-bonding pad but spread laterally to the nearby region, thus the uniformity of the current injected into the active region is improved.

2. Device Fabrication

The InGaN/GaN LED epilayers were grown by a vertical reactor MOCVD. The LED structure consisted of a 30 nm thick GaN low growth temperature buffer layer, a 2000 nm thick *n*-type GaN doped with Si, an active region, consisted of four-periods undoped 2/8-nm-thick InGaN/GaN multiple quantum wells, followed by a 200 nm thick *p*-type GaN layer doped with Mg. A thermal treatment of 700°C for 20 minutes was conducted to activate the Mg-doped GaN layer. The device fabrication started from the semitransparent contact layer metallization. The semitransparent layer consisted of Ni/Au (3 nm/6 nm) multi-layers. Inductively coupled plasma dry etching was then performed to define the p-mesa and the current blocking hole. The hold was 10 μm in width and 50 μm in length and put in the center of the path between the p-pad and n-pad. P-type and n-type bonding pads were then deposited sequentially. For p-type and n-type pads, a Ti/Al (30 nm/80 nm) layer was used. Finally, the wafers were put into a furnace at 475°C for 8 minutes to achieve a ohmic contact. The chip size is 350 μm×350 μm. All electrical and optical characteristics of the fabricated LEDs were measured via on-wafer probing of the devices. For comparison, conventional LEDs without lateral current blocking holes were also fabricated.



(a)



(b)

Fig. 1 Concept of lateral current blocking structure: (a) Top-view. (b) Cross-sectional view

3. Results and Discussion

The forward current-voltage characteristics and light output of LEDs with and without the lateral current blocking hole were shown in Fig. 2. The forward voltage of the LED with the blocking hole was 3.29 V at 20 mA, which is a little bit higher than that of the conventional

LED (3.26 V). The increase of the forward voltage was due to the current blocking hole. The injected current was forced to spread out instead of directly flew through the nearest path between the p-type and n-type bonding pads. Thus, the effective current path was increased and the forward voltage was also increased. The light output of LED with a current block hole at 20 mA was 7.2 % higher than that of the conventional LED.

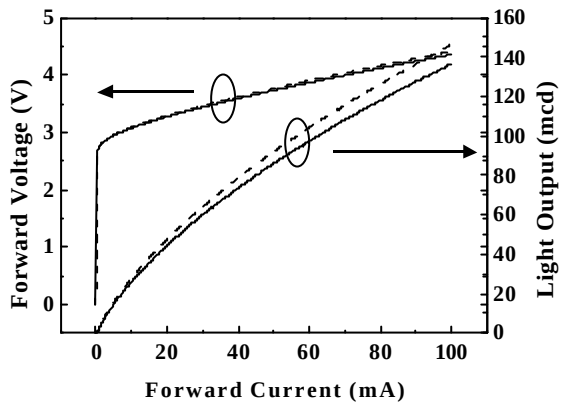


Fig. 2 I-V and L-I chacteristics of LEDs with and without the current blocking hole

Two possible reasons might result in the enhancement of the LED light output. The first reason was the improvement of the current spreading and the other one was the increase of the light extraction from the sidewalls of the etched hole. To distinguish the two different mechanisms, LEDs with smaller holes were fabricated as shown in Fig. 3. The 10 μm× 50 μm hole was divided into three 10 μm×16 μm holes and the distance between the holes was 20 μm. We found that the I-V and L-I characteristics of LEDs with three blocking holes were almost identical with those of conventional LEDs. If the increase of the light output is resulted from the increase of the light extraction, the LED with three holes should have a better optical performance due to its larger sidewalls areas.

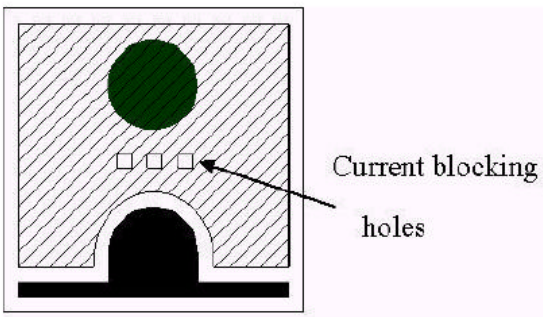


Fig. 3 Illustration of LED with small and separated current blocking holes

Thus we can conclude that the higher light output is attributed to the better lateral current spreading. The light output of LED with smaller blocking holes was not improved because smaller holes could not suppress the current effectively.

4. Conclusion

In conclusion, we have fabricated InGaN/GaN LEDs with a lateral current blocking hole between the p-type and n-type bonding pad. The lateral current spreading was improved by the current blocking hole and the light output was increased by 7.2 %.

Acknowledgements

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