Nitride based Power Chip with ITO p-Contact and Al back-side Reflector

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1. Introduction
Recently, tremendous progress has been achieved in GaN-based blue and green light emitting diodes (LEDs) [1-3]. However, for high power applications such as projector, mobile lighting and flash lamp, we still need to further increase the output power of the chips. One possible way is to increase the LED output power by enlarging the chip size. The other possible way is to improve the extraction efficiency of the chip by using the highly transparent p-contact metal and reflective Al metal on the back-side of the substrate. Conventional nitride-based LEDs use semi-transparent p-contact material and reflective Al metal as the p-contact material. However, the transmittance of Ni/Au is only around 60-75%. In order to solve this issue, one can use highly transparent ITO to replace Ni/Au. Very recently, we reported the fabrication of nitride-based LEDs with an n'-short period superlattice (SPS) tunnel contact layer and an ITO transparent contact. It has been shown that we can simultaneously achieve a reasonably small specific contact resistance and a high upper contact transmittance by using such a combination [4-5]. However, ITO-based large size (i.e. 1mmx1mm) power LED chips have not been reported yet. In this investigation, we report the fabrication of large area nitride based power chips with ITO (80nm) and Ni(5nm)/Au(10nm) p-contacts. To further increase the output power, we deposited a reflective Al metal on the back-side of the chips. The opto-electronic characteristics and the reliability of these power chips will also be investigated.

2. Experiments
The InGaN/GaN epitaxial layers used in this investigation were all grown by MOCVD on sapphire (Al₂O₃) (0001) substrates. Details of the growth procedures could be found elsewhere [1-5]. The n⁺-SPS tunnel contact structure consists of 4 pairs of n⁺-In₀.₂₃Ga₀.₇₇N/GaN (5Å/5Å) growing on top of the p-GaN cap layer [6-7]. These as-grown samples were subsequently annealed at 750°C in N₂ for 20 minutes to active Mg in the p-type layers. Surfaces of the samples were then partially etched until the n-type GaN layer was exposed. P and n contacts were subsequently deposited. The epi-wafers were lapped down and then laser cut into single chip (i.e.1 mmx1 mm) and packaged. The output power was then measured with an integrated sphere detector from top of the devices. The reliability of these power chips were also evaluated by injecting 500 mA DC current at room temperature for more than 1000 hours. For the optical properties of the contact materials, we also deposited Ni/Au, ITO and Al onto glass substrates and then measured their transmission and reflection characteristics.

3. Results and discussion
Figure 1 shows reflection spectra of the Al metal layers. It can be seen clearly that Al is highly reflective (i.e. 90% reflection in the wavelength region 440–475 nm). On the other hand, the transparency of the ITO films could reach more than 90% at the 460 nm. Therefore, we should be able to enhance the LED output intensities with transparency ITO and reflective Al. Figure 2 shows the specially designed pattern of the power chips used in this study to minimize current crowding effect due to the large chip size. Current-voltage (I-V) characteristics of these power chips were also measured. It was found that the 350mA operation voltage was 3.8 V for ITO power chip which was slightly larger than that measured from Ni/Au power chip (i.e. 3.7 V). Figure 3 shows intensity-current (I-I) characteristics of the fabricated devices. It can be seen that the output power of these LEDs increased linearly as the current increases. With a 350mA injection current, it was found that the output powers were 84.6, 69.5 and 47.7 mW for power chips with ITO+Al, ITO and Ni/Au, respectively. The much larger 350mA output power observed from LED with ITO+Al could again be attributed to the more transparent nature of the ITO films. These values also indicate that we could achieve a 20% increase in LED output power by using the Al reflector at the back-side of the chips. Figure 4 shows lifetime tests of relative luminous intensity measured from these three power chips, normalized to their respective initial readings. After more than 1000 hours, it was found that the luminous intensity only decreased by 5% for the power chip with Ni/Au p-contact. In contrast, the luminous intensity decreased by 10% for the power chip with ITO p-contact during the same period. The relatively poor reliability of the LED with ITO p-contact could be attributed to the larger specific contact resistance of the ITO on n⁺-SPS, as compared to Ni/Au on n⁺-SPS. As a result, more heat would be generated at the ITO/n⁺-SPS interface and thus a shorter lifetime for the devices. Although ITO LEDs are not as reliable as Ni/Au LEDs, lifetimes of ITO LEDs are still reasonably good.
4. Conclusion

In summary, large size (i.e. 1mmx1mm) nitride-based power LED with Ni/Au and ITO p-contacts were fabricated. It was found that the 350 mA output power was 84.8 mW (W-P-E=7.2 %) at 460 nm for the power chip with ITO as p-contacts and Al as back-side reflector. The reliability of ITO power chip with Al reflector was also found to be still reasonably good.

References