Ohmic contacts to p-type GaN for high brightness LED applications

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GaN-related semiconductors are of great technological importance for the fabrication of optoelectronic devices, such as blue and ultra violet light emitting diodes (LEDs), laser diodes, and photo-detectors. One of the most important applications of GaN-based LEDs is solid-state lighting, which could replace incandescent bulbs and ultimately fluorescent lamps. For solid-state lighting applications, the achievement of high extraction efficiency in LED structures is essential. For flip-chip LEDs (FCLEDs), the formation of low resistance and high reflective p-GaN contact is crucial. So far, a wide variety of different methods have been employed to improve the ohmic properties of p-type contacts to GaN. For example, surface treatments using different chemical solutions have been successfully used to produce high-quality ohmic contacts. Metallization schemes, such as Ta/Ti contacts to p-GaN, were also investigated. For these contacts, the removal of hydrogen atoms from the Mg atoms doped in the GaN was argued to be responsible for low contact resistances.

In this work, in order to improve extraction efficiency in LED structures, we introduced Ni-based oxide with different elements, such as Mg, Zn, and La, on GaN. It is shown that the Ni-Mg and Zn-Ni solid solution schemes produce high-quality ohmic contacts with very low specific contact resistances of 10^{-5} ~ 10^{-6} cm^2. LEDs fabricated with these schemes give a forward-bias voltage of 3.17 – 3.20 V at an injection current of 20 mA. In addition, the Ni-La alloy/Au contacts are shown to give specific contact resistances as low as ~ 10^{-5} Wcm^2 and transparency higher than 83% at 470 nm, when annealed at 550 ºC in air ambient. Finally, novel Zn-Ni/Ag ohmic scheme for FCLEDs is reported. The Zn-Ni solid solution/Ag contacts produce very low specific contact resistances when annealed at temperatures of 350 – 550 °C in air ambient. Blue LEDs are also fabricated using the Zn-Ni solid solution/Ag and Ag p-type electrodes. The I-V characteristics of the LEDs are assessed.