The Study of Ohmic Contact to GaN and Investigations on Metal-Oxide-Semiconductor Photodetectors

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ABSTRACT

The main goal of this dissertation is to investigate the techniques of a low-resistance and high-transparency Ti/indium tin oxide and Ti ohmic contacts to n-type GaN by using plasma pre-treatment. Next, we also focused on the study of GaN metal-insulator-semiconductor photo-detectors (MIS-PDs) with liquid phase deposition oxide (LPD-oxide). We investigated the mechanism of the dark current for n-type GaN MIS. The responsivity of electrical and optical properties were also studied. Final, one- and two-step rapid-thermal-annealing (RTA) annealing in pure O2 and air ambient has been proposed to activate the Mg-doped p-type GaN films. This dissertation is divided into four parts. It is addressed as follows: Part 1(Chapter 1 and 2) investigates nonalloyed transparent Ti/indium tin oxide (ITO) and Ti-only contacts on n-type GaN using plasma pre-treatment. It was found that the ITO/Ti/n-GaN and Ti/n-GaN samples show very low specific contact resistances of 3.2x10-6 Ω-cm2 and 8.7x10-7 Ω-cm2, respectively. Plasma treatments were performed by using a sputtering system at a substrate temperature of 25 °C in Ar gas and 30 W plasma power. A novel transparent indium tin oxide (ITO) ohmic contact to n-type GaN with a specific contact resistance of 4.2x10-6 has been obtained. The interfacial properties involving with ITO to n-GaN ohmic contact are different from those of previous reported. Conventionally, ITO films were prepared using electron-beam evaporator and a Schottky contact was thereafter obtained with a barrier height of 0.68 eV. However, in our studies we relied on different deposition technique instead by sputtering the ITO films onto n-type GaN using a RF sputtering system and in result I-V curve revealed a linear behavior. Part 2 (Chapter 3) demonstrated an efficient and low cost approach to deposit silicon dioxide on gallium nitride by using liquid phase deposition(LPD) at low temperature (30~50 °C). The LPD technique, utilizing supersaturated H2SiF6 as a source liquid and H3BO3 as a deposition rate controller, has been in detail studied in our work. The effects of different concentrations of H2SiF6 (1 and 0.5M) and H3BO3 (0.01 and 0.005 M) on the LPD-SiO2 thickness and leakage current density were also approached. A maximum SiO2 growth rate of 50.5 nm/hr. Part 3 (Chapter 4) concentrates on nitride-based ultraviolet MIS-PDs with liquid phase deposition oxide. The minimum interface-trap density, Dit, of a metal-insulator-semiconductor (MIS) capacitor with a structure of Al/20 nm LPD-SiO2/n-GaN was estimated to be 8.4 x 1011 cm-2 V-1. After annealed in vacuum at 800 °C for 60 mins, the Dit was reduced to a value of 1.75 x 1010 cm-2 eV-1. The dark current density was as low as 4.41 x 10-6 A/cm2 for an applied field of 4 MV/cm. A maximum responsivity of 0.112 A/W was observed for incident ultraviolet light of 366 nm with an intensity of 4.15 mW/cm2. A large photocurrent to dark-current contrast ratio higher than four orders of magnitude and a maximum responsivity of 0.65 A/W were observed from the fabricated ITO/LPD-SiO2/GaN MIS UV photo-detectors. Part 4 (Chapter 5) discusses one- and two-step rapid thermal annealing (RTA) for activating Mg-doped P-type GaN films had been performed to compare with conventional furnace annealing (CFA). The two-step annealing process consists of two annealing steps: the first step is performed at 750 °C for 1 minute and the second step is performed at 600 °C for 5 minutes in pure O2 or air ambient. Compared to one-step RTA annealing and CFA annealing, the samples with two-step annealing exhibit higher hole concentration and lower resistiviy.

Keywords : GaN ; photo-detectors ; photo-current

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