Growth and properties of GaN on Si substrates by rapid thermal process low-pressure metalorganic chemical vapor deposition

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GaN-based materials have attracted great interest because of its direct and wide band gap, high-saturation electron drift velocity and the excellent physical and chemical properties. In the recent years, the growth technology of GaN on sapphire has been relatively mature. GaN films grown on Si substrates are more attractive for their low cost, large size and the possibility of integrating GaN devices with Si-based electronics techniques. However there are still difficulties in growing high-quality GaN films on Si substrates due to the large lattice mismatch, thermal mismatch and difficult nucleation between GaN and Si. So, it is quite important to select and study appropriate buffer layer materials between GaN and Si. Some materials have been used as the buffers, AlN is a good buffer material because AlN can nucleate on Si favorably and the lattice mismatch between GaN and AlN is as small as 2.5%. In this paper, we report the growth and characteristics of GaN films on Si(111) using AlN buffer layer by rapid thermal process low-pressure metalorganic chemical vapor deposition (RTP/LP-MOCVD), and using these materials, simple photoconductive detectors were fabricated to characterize the material quality.

The high resistivity n-type Si (111) wafers off-cut $\sim 3^\circ$ were used as the substrates. The growth was carried out in RTP/LP-MOCVD system. Trimethylaluminum (TMA), trimethylgallium (TMG) and ammonia (NH3) were employed as sources of Al, Ga and N, respectively. H2 was used as the carrier gas. Before growing AlN, the substrate was annealed under H2 ambient at 1100°C to clean the surface. Pre-seeding Al for 5s, then introducing NH3 in the reactor. AlN layers were grown at 1070°C to about 150nm. After AlN growth, the temperature was decreased to 900°C to grow GaN epilayers, the thickness of which was about 800nm. In order to further prove that quality AlGaN layers can be grown on GaN epilayers sequentially, and polarization electric-field can be obtained, Al0.2Ga0.8N (15nm)/GaN (60nm)/Al0.2Ga0.8N (15nm) multilayer structures were also grown sequentially on 500nm GaN with AlN buffer layers under the same growing condition. The Al0.2Ga0.8N layers were grown at 1050 oC using TMA as the aluminum source.

The surface and crystal structures of GaN epilayers were characterized by scanning electron microscope (SEM), X-ray diffraction (XRD), photoluminescence (PL), Raman scattering and Hall measurements. Only the GaN(0002), (0004), and AlN(0002) peaks were present in XRD. In the PL spectrum at room temperature, the full width at half maximum (FWHM) at 365nm is 10nm. The PL at 77K shows a sharp and strong band emission. The free exciton emission (FXA), bound exciton emission (I2) and the donor- acceptor (DAP) can be seen clearly. Raman spectrum shows a narrow GaN E2 peak (FWHM is 6 cm-1) and broad AlN E2, E1 peaks. The Hall measurements shows that the background carrier concentration was about 1.3 x 10 17cm-3, and the Hall mobility was 210cm2/Vs. These results indicate a good crystallinity of GaN on Si (111) with AlN buffer, and are comparable to the results on sapphire.

The simple M-S-M photoconductive detectors were fabricated with the above materials. The interdigitated finger electrodes were fabricated on top layers. The spaces between the fingers were designed to be 10m. Ti/Al was used as ohmic contacts. The photocurrents as a function of wavelength for detectors of Al0.2Ga0.8N/GaN/Al0.2Ga0.8N multilayer structure (sample A) and GaN monolayer structure (sample B) show a sharp cut-off wavelength at near 365 nm. The maximum responsivities of 24A/W (sample A) and 7.0A/W (sample B) were achieved under 5.5V bias. Responsivity of sample A is higher then sample B, due to the polarization electric-field existing in the AlGaN/GaN/AlGaN heterojunction. The high polarization electric-field makes the light-induced carriers to separate in space and the recombination to decrease. The high responsivities of sample A and sample B show that the low defect density in the materials increased the lifetime of light-induced carriers. The above results indicate that high quality GaN and AlGaN/GaN epilayers on Si (111) can be obtained using the AlN buffer layer by RTP/LP MOCVD.

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