Chapter 5

Conclusions

In this thesis, the growth and characterization of GaN grown on sapphire (0 0 0 1) and silicon (1 1 1) substrates are systematically studied. The primary results obtained in this dissertation are summarized below:

(1) The crystal quality of GaN epitaxy layer on nitrided and non-nitrided sapphire has been studied. GaN epitaxy layer on nitrided sapphire shows better crystal quality due to superior thin AlN nucleation layer formed by nitridation treatment. The GaN epilayer was grown under slightly N-rich condition, GaN epilayer presents rough surface, but lower overall TDs. Under Ga-rich condition, GaN epilayer presents smooth surface, but higher overall TDs. The GaN epitaxy layer of symmetric (0 0 0 2) FWHM value reduces with decrease of nitridation temperature, but the GaN epitaxy layer of asymmetric (1 0 $\bar{1}$ 2) FWHM value shows inverse trend. For more improving crystal quality of GaN epitaxy layer, AlN-IL was introduced in GaN epitaxy layer. The AlN-IL can reduce the dislocation density of GaN epitaxy layer, which has been confirmed by above experiment. The GaN epitaxy layer on vicinal sapphire substrate (1.0^{o}-off cut) shows better quality due to macro-step.

(2) The simultaneous AlN/α-Si_3N_4 buffer structure with Al pre-seeding layer and novel substrate engineering (GaN-nanorods buffer) was applied to grow high quality GaN epilayer on Si (1 1 1) substrates. The crystal quality of GaN epitaxial layer is improved with increasing the deposition time of Al pre-seeding layer, because the 2D Al-island could avoid the amorphous SiN formation. It was found that the optimum Al deposition time is 45s at $Al_{BEP}=2.5\times10^{-8}$ torr. The simultaneous AlN/α-Si_3N_4 buffer structure could reduce the lattice mismatch due to the crystal α-Si_3N_4 (0001) lattice coincidently matches

(1:2) with the Si (111). The GaN epitaxial layer shows a wurtzite structure and exhibits excellent structural and optical properties as evidenced by XRD and PL measurements. The crack free surface of 1.22 μm thick GaN epitaxial layer was obtained by using simultaneous AlN/α-Si_3N_4 buffer structure. The growth condition dependence on hexagonal phase GaN nanorods, which are vertical to the Si (1 1 1) growth plane, has been investigated. The morphology of GaN nanorods strongly depends on growth condition, i.e. growth temperature, V/Ⅲ ratio. With the growth temperature increase, the density of GaN nanorods increase, the diameter of GaN nanorods decrease and the height of GaN nanorods increase, which are due to initial nucleation seeding site. With the BEP of the gallium increasing from 2.8×10^{-8} to 2.0×10^{-7} torr , the density of GaN nanorods reduces together with the diameter of GaN nanorods increase. However, the BEP of gallium=3.6×10^{-7} torr at Ga-rich condition, the individual nanorod bundles were coalesced together to form GaN thin film with a hexagonal-shape surface. As a consequent, we can control the density and diameter of GaN nanorods by growth temperature and V/Ⅲ ratio. The board emission around 3.30 ~ 3.40 eV is considered as GaN nanorods characteristics peak. From slightly N-rich to highly N-rich, the GaN nanorods characteristics peak present the blue-shift to higher energy due to the higher density and smaller diameter of GaN nanorods. The self-assembled GaN nanorods are high quality strain-free single crystal as evidenced by XRD measurement. The GaN epitaxial layer was grown on novel substrate engineering (nanorods buffer) by MBE and MOCVD. The lateral growth with a coalescence process was not easily occurred in the MBE-overgrown GaN with obvious coalescence grain boundary. However, the flat overgrown GaN layers were obtained by MOCVD-grown GaN. The high quality and strain-free GaN epitaxial layer is grown by using nanorods buffer as evidenced by XRD and PL measurements.