ABSTRACT

The growth and characteristics of hexagonal and cubic gallium nitride (GaN) grown by metalorganic chemical vapor deposition (MOCVD) were investigated in this study. Optical grade polished (0001) orientation (C-face) sapphires are used as the standard substrates for the growth of hexagonal-GaN (h-GaN). The cubic-GaN (c-GaN) epilayers were grown on (001) GaP and (001) GaAs substrates. The abstract was separated into three parts as following: (1) h-GaN grown on sapphire substrate The role of temperature ramping rate during the two-step growth of GaN-on-sapphire by MOCVD is explored. The surface morphology and crystalline properties of the low-temperature-deposited GaN buffer layer annealed under various ramping rates (20~60°C/min) to 1000°C were investigated by atomic force microscopy (AFM) and X-ray measurements. For the lower ramping rates employed, a dramatic re-evaporation of the GaN buffer layer was observed. This makes the buffer layer thinner, yielding the GaN epilayer of hexagonal morphology. However, as the higher ramping rates applied, the surface becomes rougher and exhibits hexagonal three-dimensional islands. It could be due to the fact that the grains of the GaN buffer layer have no enough time to coarse. Under a temperature ramping rate of 40°C/min, a smooth buffer-layer surface can be maintained and result in a subsequent high-quality overlayer deposition. The mirror GaN epilayer shows a near-band-edge peak (25 K) centered at 3.477 eV with a full width at half maximum as narrow as 13.1 meV. The observed temperature-ramping-rate effects can be interpreted by the coalescence mechanism of the GaN buffer layer involving Ostwald ripening, sintering and cluster migration. (2) c-GaN grown on GaP substrate The GaN epilayers are grown on (001) GaP substrates by low-pressure MOCVD using the three-step growth method, which includes the growth of the GaN buffer, interlayer and high-temperature epilayer. From AFM examinations, it is indicated that the surface roughness of the GaN buffer layer grown at 515°C increases drastically with increasing the annealing temperature from 700 to 850°C in an NH3 ambient. The thickness and growth temperature of the GaN interlayer were optimized based on the X-ray and morphology measurements. It was found that a 0.2-μm-thick GaN interlayer grown at 750°C can improve the morphology of the high-temperature epilayer, which is an essential step for the subsequent growth at high temperature (900°C). Furthermore, as the epilayer thickness increased, the GaN surface became rougher due to the increase in the composition of the hexagonal component. The 77-K photoluminescence (PL) spectrum of the mirror GaN epilayer (0.6 μm in thickness) exhibits a near-band-edge emission peak at 3.36 eV as well as a yellow emission at 2.29 eV. The corresponding electron mobility and carrier concentration at 300 K were 15 cm²/V·s and 6.7x10¹⁸ cm⁻³, respectively. (3) c-GaN grown on GaAs substrate GaN epilayers are grown on (001) GaAs substrates by low-pressure MOCVD using a three-step growth method, which includes the growth of the GaN buffer, interlayer and high-temperature epilayer. From AFM examinations, the surface roughness of the GaN buffer layer (25 nm thick) grown at 515°C increases drastically as the annealing temperature increases from 700 to 850°C in an NH3 ambient. An enhancement in cubic crystalline quality was observed as the GaN buffer layers annealed at low temperatures (<750°C). However, the crystallinity of the buffer layer becomes poor and even disappears after high-temperature annealing (>800°C). It is found that a 0.2-μm-thick GaN interlayer grown at 750°C can improve the morphology of the final GaN epilayer grown at 880°C. In addition, the cubic component of the GaN epilayer can achieve over 99%. The 300-K PL spectrum of the c-GaN epilayer (0.67 μm thick) exhibits a near-band-edge emission peak at 3.39 eV. The blue shift in the PL peak as compared with the theoretically predicted value (3.2~3.3 eV) could be attributed to the heavily isoelectronic doping of As. A shrinkage in lattice constant of c-GaN were also observed by X-ray measurements. The degree of autodoping can be greatly improved by depositing a SiO₂ film on the backside of the GaAs substrate.

Keywords : Metalorganic Chemical Vapor Deposition ; cubic GaN ; hexagonal GaN ; sapphire substrate ; GaP substrate ; GaAs substrate ; GaN buffer layer
1. Introduction

1.1 Blue LED

1.2 Heterostructures of GaN for HEMT device

1.3 Structure properties of GaN

1.4 Suitable substrates

1.5 Outlines of this thesis

2. Measurement

2.1 Reactor system

2.2 Flow rate control and pumping system

2.3 Heating system

2.4 MO source and other gases

2.5 Substrates and cleaning

2.6 Growth of GaN epilayer

2.7 Measurement

3. Result and Discussion

3.1 Growth and characterization of hexagonal GaN on sapphire substrate

3.2 Growth and characterization of cubic GaN on GaP substrate

3.3 Growth and characterization of cubic GaN on GaAs substrate

4. Conclusions

4.1 Hexagonal GaN on sapphire substrate

4.2 Cubic GaN on GaP substrate

4.3 Cubic GaN on GaAs substrate

4.4 Future prospects

References

Appendix A


