The effects of the growth rate along with nucleation layer on the qualities of GaN epilayers grown on Si(111) substrate using 3C-SiC intermediate layer

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Group III-nitrides having direct transition-type band structures with the wide bandgap energy are chemically and thermally more stable. They have potential application for the fabrication of blue/ultraviolet light emitting devices. They are also applicable to high power and high speed transistors, wich are able to operate in a harsh environment and at high temperatures.[1] Recently, GaN based blue laser diodes led to the level of long lifetime operating under the continuous wave conditions.[2] Due to the lack of GaN substrate, sapphire is generally used as a substrate for the growth of GaN film. However, the large lattice mismatch between GaN and sapphire results in the high defect density in the GaN films causing the possible deterioration of the optoelectronic properties of the GaN thin films.

The silicon carbide(SiC), that is a wide bandgap semiconductor with higher mobility and relatively smaller lattice mismatch to GaN(in-plane lattice mismatch ($\Delta d/d$ =4 %) than commonly used sapphire, has attracted much attention as an alternative substrate. However, the limited availability, such as the high cost and small size, represent significant practical obstacles to the use of SiC as substrares for GaN growth. We have demonstrated the ability to grow GaN films on Si substrates using SiC intermediate layer. The SiC films grown on Si substrate have a rough interface, a poor single crystal quality, a high concentration of lattice defects and high level of background doping impurities. But the SiC intermediate layers act on redudce the lattice mismatch and relax thermal expansion.

We report here the characteristics of the GaN thin film by adjusting the growth rate of the epilayer on the various nucleation layers by varying the flow rate of Trimethylgallium(TMGa). AlN, AlGaN, and AlN/GaN superlattice structures were used as the nucleation layers on the 3C-SiC intermediate layer in order to improve surface morphology and crystal quality of GaN thin film.

The GaN thin film has been grown atop 3C-SiC intermediate layer on Si(111) substrate. The Si(111) wafer was thermally cleaned at 1100 ℃ for 5 minute in H_2 ambient. Then the 3C-SiC intermediate layer was grown at 1250 ℃, and reactor pressure of 10^{-3} torr by chemical vapor deposition(CVD) using tetramethylsilane(TMS) as the single source precusor. The GaN thin film was grown at 1040 ℃, by low pressure metalorganic chemical vapor deposition(LP-MOCVD) using TMGa, Trimethylalluminum(TMAl), and Ammonia(NH_3) as Ga, Al, and N precursors, respectively. Before the growth of nucleation layer, the substrates were thermally treated at 1050 ℃ for 10 min in H_2 ambient. After the reator temperature was cooled down, to AlN(1040 ℃), AlGaN(800 ℃), and AlN/GaN superlattice(800 ℃),then nucleation layers were grown. The GaN epilayers were grown on these individual nucleation layers for 1hour with TMGa flow rates varing from 120 μmol/min to 26 μmol/min. The surface morphologies were observed by optical microscope, atomic force microscopy(AFM), scanning electron microscopy(SEM) and the crystal qualities of GaN thin film were investigated x-ray diffraction(XRD), double crystal X-ray diffraction(DCXD) measurements. The optical properties of GaN films were characterized with photoluminescence(PL) and Raman spectroscopy.

The AFM micrographs of surfaces of GaN epilayer of TMGa flow rates from 60 μmol/min to 26 μmol/min with AlN nucleation layer are shown in Fig 1 . The root mean square roughnesses of surfaces are reduced from 9.124 nm to 2.157 nm(4 μm*4 μm) as decreasing TMGa flow rates, and the DCXD full width at half maximum values of GaN(0002) are also reduced. Therefore, the growth rate of GaN thin film plays a important role of surface and crystal quality.

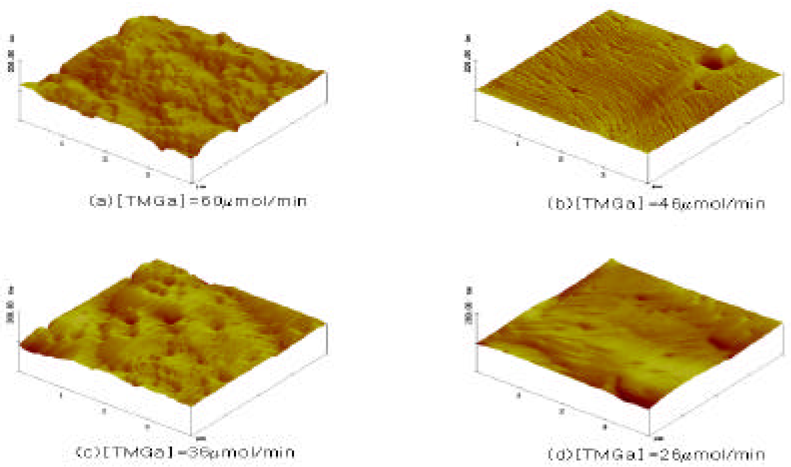

Fig1. The AFM micrographs of surface of TMGa flow rates from 60 μmol/min to 26 μmol/min GaN epilayers with AlN nucleation layer are shown. (a)[TMGa]=60 μmol/min. (b)[TMGa]=46 μmol/min. (c)[TMGa]=36 μmol/min. (d)[TMGa]=26 μmol/min

References

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