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Reduction of the defect density in GaN films

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1. Introduction

GaN is a wide band gap semiconductor being actively investigated for applications to the short wavelength optoelectronic devices. The performance of those devices using GaN epitaxy thin film is given surprisingly high densities of their defects, which structure consists mostly of threading dislocation with a density of more than 10^{10} cm^{-2}. S. D. Lester et al. contended that dislocations in light emitting diodes fabricating from the III-V nitride materials do not act as efficient nonradiative recombication sites. It was hypothesized that this fundamental property arise from the more ionic character of bonding in nitride materials compared to other III-Vs. However, it is widely recognized that dislocations play important roles in determining optical performance of compound semiconductor devices.

Recently the origins of dislocations in GaN thin films have been studied by several groups. On sapphire substrates the main sources of threading dislocations were suggested to be low angle grain boundaries, which formed during coalescence of GaN islands. In GaN films on SiC substrates with AlN buffer layer, Ponce et al. proposed that the threading dislocations with a density of 10^9 cm^{-2} develope during growth in order to produce local coherence at the low angle domain boundaries. S. Tanaka obtained a low dislocation density GaN films of between high 10^7 cm^{-2} and low 10^8 cm^{-2} by using an ultra-thin AlN buffer layer on 6H-SiC substrates. Below the critical thickness of AlN buffer on 6H-SiC, the buffer layer is elastically strained with no misfit dislocation and its surface morphology is superior smooth over that of evoluted AlN surface.

In this research, the lowest defect density GaN films of low 10^7 cm^{-2} have achieved on 6H-SiC, by promoting a wetting in the nucleation stage. Thin AlN buffer layer was firstly grown on 6H-SiC before wetting. The wetting process which proceeded on thin AlN buffer have been carried out by means of alternating pulse supply of reactant gases and purging gas during 5 cycle before GaN growth.

2. Experimental

The growth system used for the present study was a conventional horizontal type metal organic chemical vapor deposition consisted of three gas flow channels, capable to separately introduce N_2, metal organic sources and ammonia with H_2 as a carrier gas. The Si faces of on-axis 6H-SiC(0001) substrate were used for GaN epitaxy growing. The graphite susceptor coated with SiC was heated by rf induction. The growth temperature was constantly sustained at 1060 ℃ during all the reaction. The wetting layer was alternately subjected to the trimethylgallium (TMG) of 32 μmol/min with carrier H_2 and ammonia of 2 slm on depositing the AlN buffer. The reactor pressure during growth was kept constant maintaining at 76 Torr. The growth rate of the GaN estimated by high resolution scanning electron microscope (SEM) for cutting-plane view was about 300 Å/min. The resulting films were characterized by several techniques including; SEM for etching pit density, double crystal

X-ray diffractometer (DCXRD) for film structure, photoluminescence (PL) for optical property and atomic force microscope (AFM) for observing the wetting in nucleation state on thin AlN buffer.

3. Results and Discussion

The wetting effects in the nucleation stage on AlN buffer of 6H-SiC substrate are especially marked in this study, as summarized in Table 1. The surface morphology and microstructure in initial growth mode of GaN on AlN buffer layers are examined using AFM. Apparent islands growth can be seen on the surface of the initial growth. The number of islands in wetted surface are $1.9 \times 10^{10} cm^{-2}$ less than non-wetted sample. On the other hand, the size of the former islands are wider than the latter. The resulting GaN film with wetting has a low defect density of $\sim 10^{7} cm^{-2}$, as in Fig. 1. The essential role of the wetting layer is thought to induce the promotion of lateral growth of the film due to the decrease in interfacial free energy between the film and the substrate.

In conclusion, the lowest defect density GaN films of low $10^{7} cm^{-2}$ has been observed on 6H-SiC. by promoting a wetting in the nucleation stage. The optical properties and crystallinity of the resulting GaN films are remarkably improved by using the wetting process on thin AlN buffer layer.

Table 1. The wetting effects in the nucleation stage on AlN buffer layer

	GaN films on wetting	GaN films on non-wetting
Film Thickness(㎛)	0.6	0.6
defect density(/㎠)	low 10^7	high 10^7-low 10^8
# of nuclear grain($\times 10^{10}$/㎠)	1.9	3.2
rel. PL Intensity of I_2	10	1
rel. PL Intensity of D-A	1/10	1
X-ray FWHM(arcsec.)	143	260

Figure 1. Etching pit density of resulting GaN films using wetting process