

Structural Investigation of Epitaxial Gd_2O_3 and $\text{Ga}_2\text{O}_3(\text{Gd}_2\text{O}_3)$ Films Grown on GaN

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We discussed pure Gd_2O_3 on GaN substrate. The GaN was grown on c-plane sapphire by the method of MOCVD. After GaN growth, the wafer was transferred (exposed to air) to multi-chamber UHV MBE system for the oxide growth. $\text{Gd}_2\text{O}_3/\text{GaN}/\text{sapphire}$ are examined by X-ray diffraction and X-ray reflectivity. **Table (1)** listed our experiments sample information.

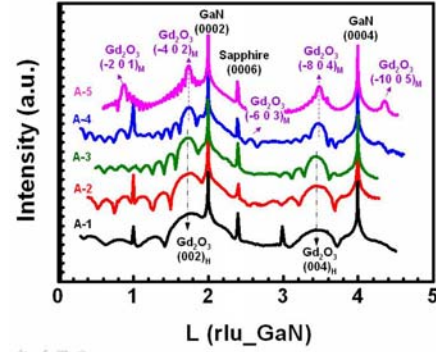
Sample NO.	Structure	Gd_2O_3 thickness	Gd_2O_3 Phase
A-1	$\text{Gd}_2\text{O}_3/\text{GaN}/\text{Sapphire}$	1.5 (nm)	Hexagonal
A-2	$\text{Gd}_2\text{O}_3/\text{GaN}/\text{Sapphire}$	2.2 (nm)	Hexagonal
A-3	$\text{Gd}_2\text{O}_3/\text{GaN}/\text{Sapphire}$	3.2 (nm)	Hexagonal
A-4	$\text{Gd}_2\text{O}_3/\text{GaN}/\text{Sapphire}$	4.3 (nm)	Monoclinic
A-5	$\text{Gd}_2\text{O}_3/\text{GaN}/\text{Sapphire}$	10 (nm)	Monoclinic
A-6	$\text{Gd}_2\text{O}_3/\text{GaN}/\text{Sapphire}$	20 (nm)	Monoclinic

Table 1: Sample information

To identify the structural properties of the $\text{Gd}_2\text{O}_3/\text{GaN}/\text{sapphire}$ hetero-system, all the samples have been thoroughly studied. The *ex-situ* x-ray diffraction measurements were carried out at beamline BL17B1 at the National Synchrotron Radiation Research Center (NSRRC), Hsinchu, Taiwan. The incident beam energy of 10KeV was employed in most of the measurements. Figure 1 illustrates the longitudinal scans along the as-deposited samples surface normal with different oxide thickness. The intense sharp peaks of GaN (0001) 、GaN (0002) 、GaN(0003) 、GaN(0004) and sapphire(0006) reflections, which are centered at 1.0 、2.0 、3.0 、4.0 and 2.395 rlu_{GaN} , respectively. The abscissa is rlu_{GaN} (the reciprocal lattice unit of GaN, $\text{rlu}_{\text{GaN}} = 2\pi/c_{\text{GaN}} = 1.212 \text{ \AA}^{-1}$) along surface normal. The presence of periodic

Pendellosung fringes between GaN(0001) and GaN(0002) which come from the interference between the top surface and buried interface reveals very smooth interface and good crystalline quality of the Gd_2O_3 epilayer. The layer thickness were calculated to be 15 Å 、22 Å 、32 Å 、43 Å and 100 Å from the fringe periods of 0.364 、0.24 、0.16 、0.12 and 0.051 rlu_{GaN} , respectively.

Fig. 1: The normal scans of Gd_2O_3 films grown on GaN with different film thickness



The intensity distribution of in-planer radial scan obtained that across $(\text{HK}0)_h$ surface reflections, which are performed in the grazing incidence diffraction geometry by keeping the surface normal almost perpendicular to the vertical scattering plane. Figure 2 displays the intensity distribution of the radial scans across intense sharp GaN(110) reflections. The peak $\text{Gd}_2\text{O}_3(110)_h$ was observed near the GaN(110) reflection. The positions of hexagonal Gd_2O_3 surface peaks are almost the same for all the samples of thickness below $\sim 32 \text{ \AA}$, indicating that oxide films (1) are almost close to fully relaxed at the interface and (2) are a hexagonal structure.

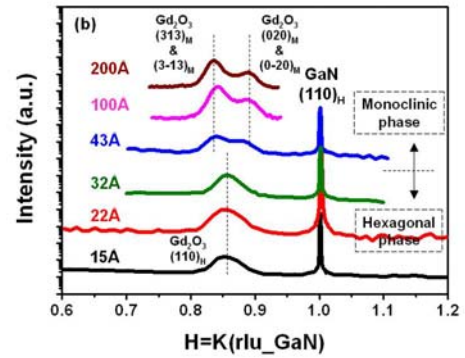


Fig. 2: radial scans along in-plane across GaN (110) reflection

Hexagonal Gd_2O_3 film is preferentially grown on GaN(0001) with the same hexagonal symmetry in the initial stage. High temperature grown Gd_2O_3 by MBE might be induced some thermal stress leads to the surface atoms move small displacement during epitaxial growth. Indeed, the hexagonal $(001)_h$ and the monoclinic $(-201)_m$ plane have similar lattice parameters. Moreover, the strain energy gradually accumulates as the film thickness increases. The structural transition to a more stable monoclinic phase occurred which might be regarded as a strain field induced lattice distortion as the critical thickness is reduced.