

MOVPE Growth of 4-inch GaN Epitaxial Wafers for FETs on a-face and c-face Sapphire Substrates

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FETs with an AlGaIn/GaN modulation-doped structure have the attractive feature of high-breakdown-voltage, high-power and high-temperature operating microwave applications [1,2]. We reported MOVPE growth of the AlGaIn/GaN modulation-doped hetero-structures on 2-inch (2") diameter c-face sapphire substrates (c-SA) [2], which were too small for the mass-production of the GaN FETs. The growth of GaN epitaxial layers on the substrates larger than 4" is now required. And the growth on a-face sapphire substrates (a-SA) is preferable to c-face ones from a viewpoint of cost reduction. However, the 2DEG properties on a-SA and the growth of 4" GaN epitaxial wafers on a-SA and also c-SA have never been investigated. In this study, the 2DEG properties on a-SA and the growth of 4" GaN epitaxial wafers on a-SA and c-SA were studied.

The 2" wafers of the AlGaIn/GaN modulation-doped hetero-structure (**Figure 1**) and the 4" GaN epitaxial wafers (**Figure 2(a)**) on a- and c-SA were grown in a horizontal MOVPE furnace.

The good electrical 2DEG properties of 2" wafers were successfully achieved on a-SA as shown in **Table 1**. It found to be available to grow the AlGaIn/GaN modulation-doped hetero-structure on a-SA.

Specular surface was realized across the whole 4" wafer on both SA as shown in **Figure 2(b)**. And the FWHM of XRD spectrum (GaN(0002)) was as small as 2" wafers, shown in **Figure 3**.

The growth on a larger diameter substrate must cause large bowing of the wafer owing to the difference of the coefficient of thermal expansion between GaN and SA, which may disturb the photolithography-process. From this viewpoint, the bowing of the 4" wafers was investigated. The values of the bow of 4" wafers were measured by mechanical and optical methods. The maximum value was about 80 μ m and 40 μ m on a-SA and c-SA, respectively. **Figures 4** show the fringes caused by the bowing of the 4" wafers in the optical measurement. One fringe corresponds to 3 μ m-bowing. In the case of a-SA, the bow has anisotropy in the wafer as shown in **Figure 4(a)**, and the bow toward the direction of c-axis (c-direction) is biggest. On the other hand, in the case of c-SA, there is almost isotropic bow as shown in **Figure 4(b)**. These differences seem to be caused by the anisotropy of their coefficient of thermal expansion. The bowing of 4" GaN epitaxial wafer, especially using a-SA, should be suppression of the practical use of GaN FETs.

Reference

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n-Al _{0.30} GaN(30nm) Si:2E+18cm ⁻³
un-Al _{0.30} GaN(3nm)
un-GaN(500nm)
un-Al _{0.20} GaN(100nm)
un-GaN(200nm)
Mg doped-GaN(1μm) Mg: ~ 1E+18cm ⁻³
LT-GaN(~25nm)
Sapphire sub.

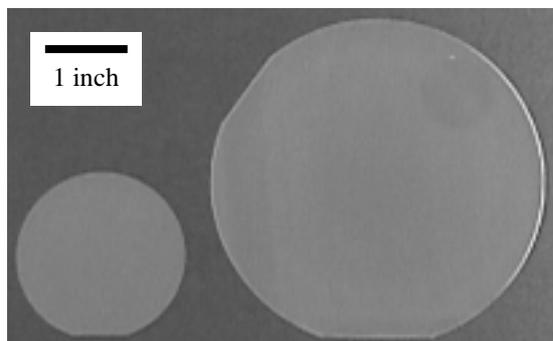
Figure 1. Sample structure of the AlGa_N/Ga_N modulation-doped hetero-structure on a- and c-SA.

Table 1. Electrical properties of the AlGa_N/Ga_N modulation-doped hetero-structure measured by the van der Pauw method.

	mobility(cm ² /Vs)		sheet carrier(cm ⁻²)	
	@300K	@77K	@300K	@77K
on a-face	1250	5800	1.61E13	1.40E13
on c-face	1270	5800	1.55E13	1.39E13

un-GaN(~2μm)
LT-buffer(~25nm)
Sapphire sub.

(a)



(b)

Figures 2. (a) Sample structure of 4" GaN wafers. (b) Photograph of 2" and 4" GaN epitaxial wafers.

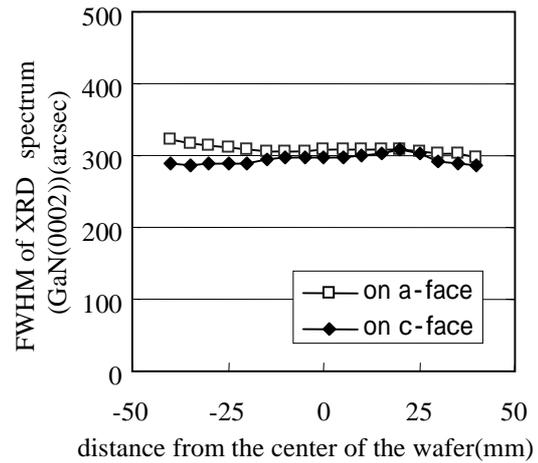
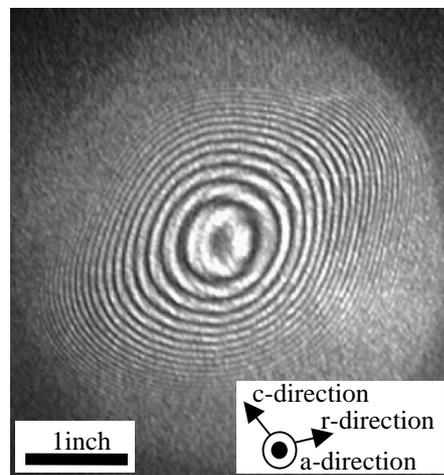
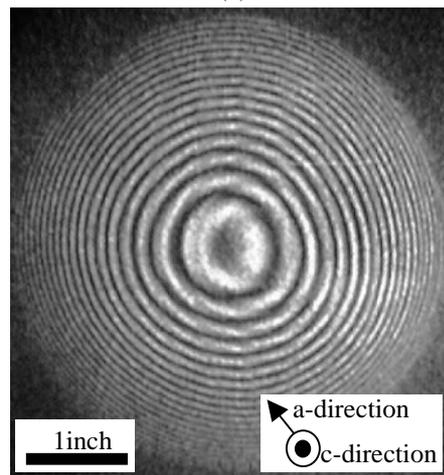


Figure 3. Distribution of the FWHM of XRD spectrum (GaN(0002)) across the 4" GaN wafer.



(a)



(b)

Figures 4. (a) and (b) Photograph of fringes caused by the bowing of the 4" GaN epitaxial wafer on a-SA and c-SA, respectively.