Elimination of small-angle grain boundary in AlN grown on sapphire substrate

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Single crystal sapphire (α-Al_2O_3) with corundum structure is a widely used substrate for heteroepitaxial growth of GaN, InN, AlN, and their solid solutions. Its advantages include transparency in the UV region and high melting point, making it an appropriate substrate for AlN growth, which is deposited at high temperature. Advancement in the heteroepitaxial growth of AlN on sapphire has led to the demonstration of optoelectronic devices such as light-emitting diodes (LEDs). However, edge dislocation array created by the small angle grain boundary (SAGB) has been observed [1]. Such dislocation array is detrimental to the performance of devices, and must be eliminated to further improve the efficiency. In this presentation, we study the origin of SAGB and propose the introduction of a buffer layer to eliminate it.

The ~1-μm-thick AlN epilayers were grown by metal-organic vapor phase epitaxy (MOVPE) either directly or with a low-temperature (LT) buffer layer (BL). For the direct growth, initially the substrate was thermally annealed (10 min) followed by AlN growth both done at the optimized AlN growth temperature (T_g), which is ~1285 °C. On the other hand, for growth with BL, ~10-nm-thick AlN LT BL was introduced before its growth at the optimized T_g. XRD and AFM measurements were used to study their structural qualities.

Figure 1 shows the typical AFM surface morphologies of AlN (a) grown directly and (b) with a LT BL (1050 °C). Although both growths exhibit smooth morphology with monolayer steps, the perfectly aligned step and terrace structure observed in the direct growth, which replicated that of the annealed substrate [2] is disturbed upon the introduction of a BL. Figure 2 shows the XRD ϕ scan of AlN (10-12) asymmetric plane of both samples with respect to their alignment with sapphire (11-23). The directly grown AlN shows two peaks, which is separated by ~4° [Fig. 2(a)]. This observation indicates the presence of SAGB having a twist component. On the other hand, a single peak was observed for AlN grown with a BL, indicating the elimination of SAGB [Fig. 2(b)]. TEM studies will be conducted to further confirm the elimination of SAGB and its correlation with the change in their surface morphologies. This technique can be also useful for studying the growth mechanism of AlN on diamond substrate.

References: [1] Hayashi et al., JAP **113**, 183523 (2013); [2] Banal et al., APL **92**, 241905 (2008).

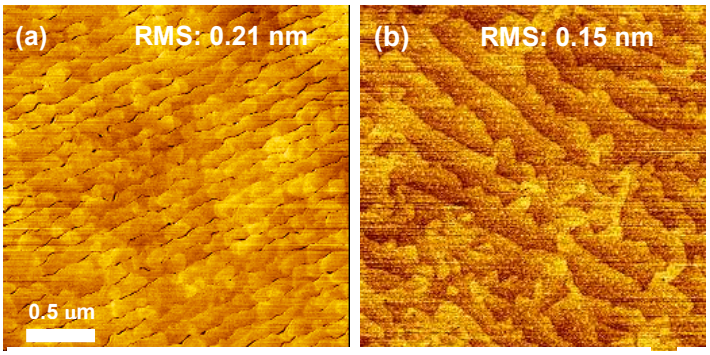

Fig. 1: AFM surface morphology of AlN (a) without (direct growth) and (b) with low-temperature buffer layer.

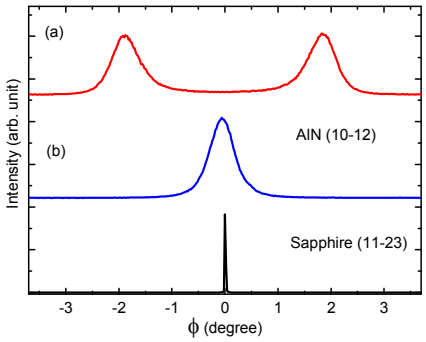

Fig. 2: XRD ϕ scans of (10-12) AlN during (a) direct growth and (b) with LT buffer layer.