The role of surface kinetics on AlN and Al-rich AlGaN

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AlN based AlGaN technology offers a great potential as materials for deep UV optoelectronic and high-power electronic devices. In order to realize such devices, high quality epitaxial films with controlled surface morphology are necessary. We have developed a surface kinetic framework for the control of surface morphology of AlN epitaxial thin films grown on both vicinal (0001)-oriented native single crystal AlN substrates and AlN templates grown on vicinal (0001)-oriented sapphire. A Burton, Cabrera, and Frank (BCF) theory-based model is utilized to understand the dependence of the surface kinetics on the vapor supersaturation, σ, and substrate misorientation angle, α. The surface energy of the Al-polar surface of AlN was experimentally determined using BCF theory to be 149 ± 8 meV/Å^2. The critical misorientation angle for the onset of step-bunching was determined to be ~0.2° for a growth rate of 500 nm/h and temperature of 1250 °C (Fig. 1). Transitioning from a surface with 2D nuclei to one with bilayer steps required a decrease in σ or an increase in α, whereas the suppression of step-bunching required an increase in σ or decrease in α.

We extended the same framework of surface kinetic model in AlN growth to the case of Al-rich AlGaN growth. The composition of bilayer stepped AlGaN was uniformed, while step-bunching resulted in strong compositional inhomogeneity as observed by Z-contrast STEM (Fig. 2). Quantum efficiencies were lower for MQWs grown on step-bunched surfaces as opposed to bilayer stepped surfaces. These results demonstrate a control scheme for consistently obtaining smooth Al-rich AlGaN epitaxial thin films needed for improving the efficiency of heterostructure- and superlattice-based devices.

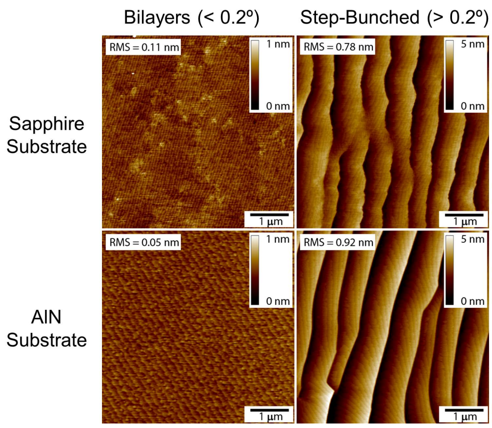

Fig. 1. AFM images of AlN films on vicinal (0001)-oriented sapphire and AlN substrates respectively

Fig. 2. Z-contrast STEM images of step-bunched AlGaN grown on AlN substrate.