

Growth and Structural Characteristics of GaN/Nano Thick γ -Al₂O₃/Si(111)

Chih-Hsun Lee (李志勳)¹, Zhi-Kai Yang (楊智凱)³, Yi-Jiun Lee (李毅君)¹,
Ming-Hwei Hong (洪銘輝)¹, J. Raynien Kwo (郭瑞年)², and Chia-Hung Hsu (徐嘉鴻)³

¹Department of Materials Science and Engineering, National Tsing Hua University, Hsinchu, Taiwan

²Department of Physics, National Tsing Hua University, Hsinchu, Taiwan

³National Synchrotron Radiation Research Center, Hsinchu, Taiwan

III-nitride compound semiconductors are suitable for applications in high-temperature and high-power electronics because of their wide band gaps and high breakdown fields. The epitaxial growth of GaN on silicon offers several advantages over that on sapphire or SiC, including substrates with high crystal-quality, cost advantages, and integration of high-power electronics and/or optoelectronics with the most advanced integrated circuits (ICs). Direct growth of GaN on Si is extremely difficult, due to the large lattice mismatch of $\sim 17\%$ ($a_{\text{GaN}(0001)} = 3.189 \text{ \AA}$, $a_{\text{Si}(111)} = 3.840 \text{ \AA}$) and difference in thermal expansion coefficients of $\sim 33\%$ between GaN and Si. Numerous intermediate layers, including AlN, HfN, SiN, and Al₂O₃, have been employed to effectively facilitate excellent epitaxial growth of GaN on Si. Recently, nano-thick cubic γ -Al₂O₃ single crystal films epitaxially grown on Si (111) with high crystal quality have been obtained using electron beam evaporation under ultra high vacuum (UHV). The in-plane symmetry of the γ -Al₂O₃ films is similar to that of sapphire (0001) (a -Al₂O₃), which has been commonly used for GaN growth. In this work, we have succeeded in achieving epitaxial growth of GaN using molecular beam epitaxy (MBE) on the γ -Al₂O₃/Si (111).

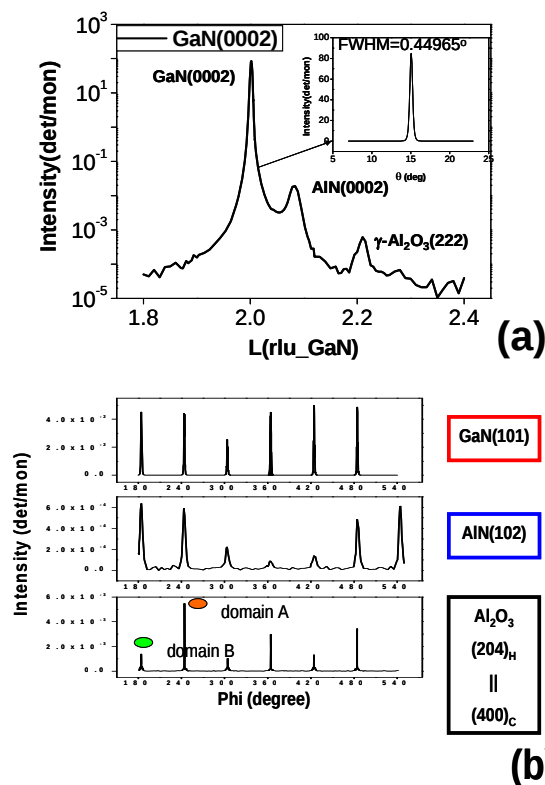


Figure 1. (a) high resolution x-ray diffraction of GaN/ γ -Al₂O₃/Si(111). From the peak position and peak intensity, the wurzite GaN (0002) and γ -Al₂O₃ (222) peaks were observed. The FWHM of the theta rocking scan is 0.44965° (inset of Fig. 3(a)) which is carried out at GaN (0002) peak position. (b) phi-cone scans showing an orientation relationship of GaN(0002)// γ -Al₂O₃(111)//Si(111) and GaN[1-100]// γ -Al₂O₃[4-2-2]//Si[4-2-2].

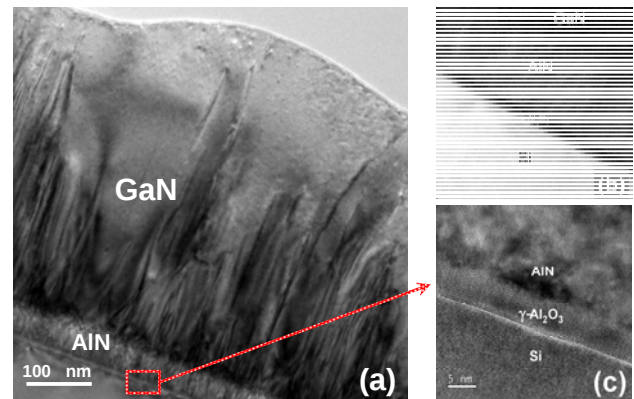


Figure 2. (a) Low-magnification TEM image of the GaN/AlN/ γ -Al₂O₃/Si (111) sample displaying thickness of GaN, AlN, and γ -Al₂O₃ film of 533.8nm, 41.6nm, and 4.8nm, respectively. Fig. 4 (b) shows the energy-filtering transmission electron microscope (EFTEM) mapping ,reveals that g-Al₂O₃ template can prevent interdiffusion of Si at the interface. The g-Al₂O₃ template epilayer is further illustrated in Fig. 4 (c)

In summary, we have grown GaN on 2-inch Si (111) substrates by nitrogen plasma-assisted molecular beam epitaxy with a thin single-crystal layer of γ -Al₂O₃ as a buffer template. The nano thick γ -Al₂O₃ has played an important role as a compressively strained nucleated layer for GaN, and has also prevented interdiffusion of Si and GaN. The GaN films with the thickness about 0.5 mm grown on g-Al₂O₃ exhibit a good crystal quality and the dislocation density is around 109 cm⁻². An orientation relationship of GaN(0002)// γ -Al₂O₃(111)//Si(111) and GaN[1-100]// γ -Al₂O₃[4-2-2]//Si[4-2-2] were determined using RHEED, high-resolution Xay diffraction, and high-resolution transmission electron microscopy.