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High Structural Perfection AlN Templates on Off-Axis 6H-SiC Grown by HVPE Aim to Improve Device Performance for Wireless Applications

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III-V nitride semiconductors are known to be excellent candidates for high-power, high-frequency RF power amplification. The primary advantages of III-V nitrides over other semiconductor materials stem from their large bandgaps (hence their corresponding large breakdown electric fields), excellent thermal conductivity, good electron transport properties, and their capability to form heterostructures. As compared to other III-V semiconductors and even SiC, these nitride heterostructures have extremely high 2DEG densities that are essential for high power High Electronic Mobility Transistors (HEMTs), which are intended to be used in high-power compact energy-efficient transmission amplifiers for 4G wireless mobile stations.

A conventional AlGaN/GaN heterostructure is generally formed by epitaxially depositing a layer of AlGaN on a thick GaN layer on semi-insulating or insulating substrates such as SiC or sapphire. Spontaneous and strain induced polarizations lead to a high positive polarization in the AlGaN, resulting in a two-dimensional electron gas (2DEG) at the AlGaN/GaN boundary.

Recently, studies have shown that HEMT device performance is greatly improved when conventional AlGaN/GaN heterostructures were grown directly on AlN layer using SiC substrate. By the insertion of these AlN templates, the dislocation scattering mechanism and the electron spillover into the bulk are reduced and the 2DEG confinement is improved. Such application has increased the demand for higher quality AlN template on SiC in order to enhance the new HEMTs device performance.

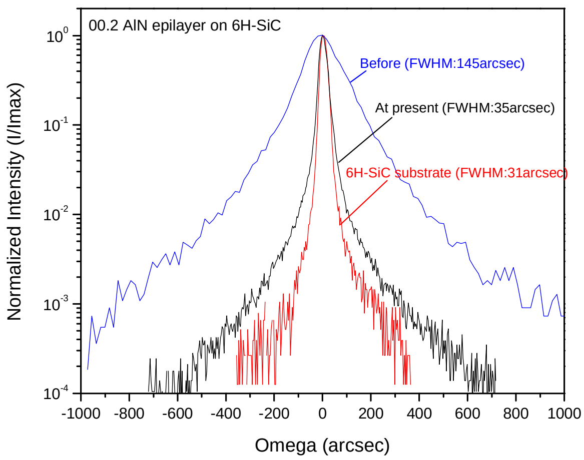
At Oxford Instruments - TDI, the group, led by V. Ivantsov V. Soukhoveev, and A. Volkova, have recently optimized the growth procedure to improve structural properties and surface morphology of thick AlN layers deposited via hydride vapor-phase epitaxy (HVPE) on off-axis 6H-SiC substrates. Using optimal nucleation and growth conditions, the group is able to produce AlN layer with FWHM of ~40 arcsec of rocking curve for (0002) reflex measured by high resolution X-ray diffraction (HRXRD), a great improvement over the previous reported results of ~150 arcsec. The line width is very close to that of the SIC substrate, suggesting the AlN epitaxial layer has a remarkably low screw dislocation density ($\leq 10^6$ cm^{-2}) and small tilting around the normal to the basal plane (refer to Fig. 1). Reciprocal space mapping of asymmetric reflexes and measured lattice parameters also suggest fully relaxed state of the epitaxial layer.

The surface morphology of AlN layer is further characterized by Atomic Force Microscopy (AFM). The mirror-like surface of the layer exhibits less than 2.5 nm Root Mean Square (RMS) roughness over 10x10 um^2 area (refer to

Fig. 2). Using the advanced technique, the group is able to produce high quality AlN templates with up to 20 um in thickness with low bowing of 80 um, making these templates ideal for high volume production of HEMTs.

Bernard Scanlan, General Manager of the Oxford Instruments - TDI division, commented, "The Oxford Instruments - TDI team has continuously improved our HVPE template products. We are extremely excited to report these new results and are expected to see a large increase in demand of these AlN template products in the very near future."

Figure 1. The XRD rocking curves taken from the SiC substrate and HVPE deposited AlN layers (symmetrical 00.6 and 00.2 reflexes, respectively). Note the remarkably low difference between the FWHMs of the substrate and the epitaxial layer that suggests high structural perfection of the AlN layer. The present method also showed a drastic improvement as compared to the previous reported data.



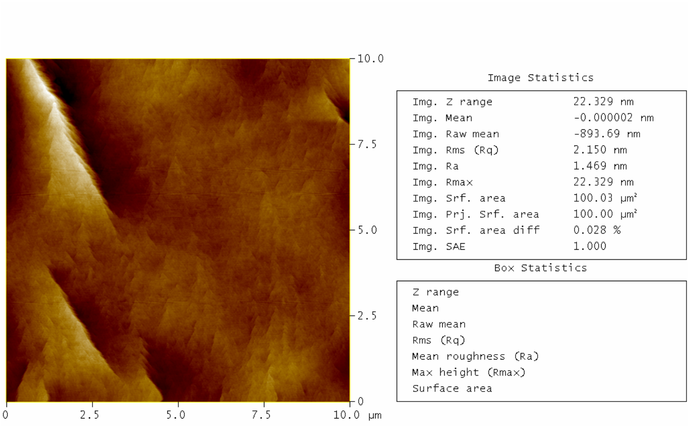


Figure 2. Atomic force microscopy measurements over 10×10 um^2 scan area of AlN layer shows ~2 nm RMS in surface roughness.

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