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Properties of nonpolar *a*-plane GaN films grown by HVPE with AlN buffers

T. Paskova[a,*], V. Darakchieva[a], P.P. Paskov[a], J. Birch[a], E. Valcheva[b], P.O.A. Persson[a], B. Arnaudov[b], S. Tungasmitta[a], B. Monemar[a]

[a]*Department of Physics and Measurement Technology, Linköping University, S-581 83 Linköping, Sweden*
[b]*Faculty of Physics, Sofia University, 5, J.Bourchier blvd., 1164 Sofia, Bulgaria*

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Abstract

The influence of high temperature AlN buffer layers on the morphology, structural and optical characteristics of *a*-plane GaN grown by hydride vapour phase epitaxy on *r*-plane sapphire was investigated. While the morphology of the *a*-GaN was found to be significantly improved by using *a*-plane AlN buffer layer similarly to the effect observed in *c*-plane hydride vapour phase epitaxy GaN growth, the microstructure ensemble was revealed to be more complicated in comparison to that of the *c*-plane GaN. Higher dislocation density and prismatic stacking faults were observed. Moreover, in-plane anisotropic structural characteristics were revealed by high resolution X-ray diffraction employing azimuthal dependent and edge X-ray measurement symmetric geometry. In addition, the near band edge photoluminescence peaks, red-shifted with respect to that in *c*-plane GaN were observed. The latter were explained by the influence of the higher defect density and more complex strain distribution.

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1. Introduction

Thick GaN films grown by hydride vapour phase epitaxy (HVPE) and separated from the substrate are currently considered as the best substitution of a real bulk substrate material for subsequent device growth. Such HVPE 2″ wafers are now offered on the market although being still very expensive and having a few critical problems that need to be resolved. A new present topic, attracting a lot of attention, is a developing of HVPE growth of thick nonpolar GaN films, e.g. $[1 1 \bar{2} 0]$ oriented (*a*-plane) GaN or $[1 \bar{1} 0 0]$ oriented (*m*-plane) GaN. Such films with thickness more

*Corresponding author. Tel.: +46 13 28 89 61; fax: +46 13 14 23 37.
E-mail address: tanya@ifm.liu.se (T. Paskova).

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than 300 μm are expected to have relatively low dislocation density similarly to the already demonstrated conventional [0 0 0 1] oriented (*c*-plane) GaN. Moreover, such films are expected to serve as quasi-substrates for growing of device structures without built-in electrical field due to spontaneous and piezoelectric polarizations, which is typical for the wurtzite structure along [0 0 0 1] direction.

In addition to the well known problems for growth of *c*-plane GaN on highly mismatched (lattice and thermal expansion) substrate, the GaN growth with $[1\,1\,\bar{2}\,0]$ *a*-plane nonpolar orientation having anisotropic nature of the growing unit-cell-surface is expected to experience in-plane anisotropy of all the properties. There are only a few reports up to now on the growth of thick nonpolar HVPE GaN material, which generally confirm the expectations for more difficulties, like in-plane anisotropy of the growth rate, and motivate a need for special buffers and/or templates [1–4]. Based on our previous results of using high temperature magnetron sputtered AlN buffer for improving the quality of *c*-plane HVPE GaN [5,6], we investigate the same approach for growing nonpolar *a*-plane GaN on *r*-plane sapphire substrates using *a*-plane AlN buffer. In this work, we report on the effect of high temperature *a*-AlN buffers on the morphology, structural and optical properties of thick HVPE grown *a*-GaN layers.

2. Experiment

The *a*-AlN buffer layers were deposited on *r*-sapphire by low energy ion-assisted reactive DC magnetron sputtering from an elemental Al targets in a ultra high vacuum system using pure N_2 as the working gas at a substrate temperature of ~1000 °C [7]. The buffer layer thickness was chosen to be 500 Å in analogy with our finding for the optimal buffer thickness for *c*-plane GaN [5]. GaN layers with a thickness up to 100 μm were grown in a horizontal HVPE system at a growth temperature of 1090 °C. The growth details for this system were described previously [6].

The morphology of the layers was evaluated by scanning electron microscopy (SEM) and atomic force microscopy (AFM) operated in tapping mode. The structural characterisation of both AlN buffers and HVPE-GaN layers was performed by high resolution X-ray diffraction (HRXRD) and reciprocal space mapping (RSM). The defect structure was revealed by transmission electron microscopy (TEM). The optical quality of the films were characterised by low temperature (2 K) photoluminescence (PL) spectroscopy.

3. Results and discussion

3.1. AlN buffers

We first describe the morphology and crystallinity of the buffer layers. AFM image [Fig. 1(a)] reveals an uniform faceted surface with an average grain size of 18 nm and root mean square (rms) roughness of 1 nm (from $1 \times 1\,\mu m^2$ area) for the *a*-AlN buffers with a thickness of 500 Å. The $\theta/2\theta$ and *phi*-scans indicate that the buffer layer studied has a monocrystalline character with $[1\,1\,\bar{2}\,0]$ orientation. Fig. 1(b) shows a RSM around the symmetric AlN 110 point with a typical elongated shape in the lateral direction, indicating a broadening caused by limited mosaic block dimensions. The full width at half maximum (FWHM) of the symmetric 110 reflection of the rocking curve (ω-scan) is of ~0.3°, while the FWHM of the radial scan ($2\theta/\omega$) is of ~0.4°. Both values are larger than the respective ones for reactively sputtered *c*-AlN with similar thickness [8]. The latter value indicates higher defect density reflected in a smaller coherent length in the growth direction for this type of crystal growth orientation. A significant broadening of the rocking curve of the *a*-AlN with respect to the relatively narrow ω-curve of *c*-AlN with comparable thickness (~0.02° [8]) most likely indicates a present of much higher density of defects intersecting the growth surface and limiting the lateral mosaic block dimensions.

3.2. Morphology of HVPE a-GaN films

The influence of buffer employment is clearly revealed in Fig. 2. While the surface morphology was found always rough [Fig. 2(a)] no matter of