P-8-7

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high quality of a-plane (11-20) GaN using a high pressure buffer layer

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Abstract

Growth and characterization of a-plane GaN epitaxial layers on r-plane sapphire substrate by metal-organic chemical vapor deposition (MOCVD) using a high pressure (HP) GaN buffer layer on the low temperature (LT) GaN buffer layer have been studied. The insertion of HP GaN buffer between GaN nucleation layer and top GaN layer resulted in highly smooth and flat surface morphologies of nonpolar GaN without any v-defect or grooves as observed by normalski optical microscopy and atomic force microscopy (AFM). The crystalline nature of the GaN film was analyzed by X-ray diffraction (XRD) measurements and observed to be improved by introduction of thick buffer layer. The strong emission features of photoluminescence (PL) at room temperature were obtained.

1. Introduction

The InGaN/GaN based devices for these applications usually grown on c-plane [0001] with Ga-polar. However, the polarization discontinuities at interface in the III-nitride-based heterostructures grown along the c-direction carry a strong electric field, which has baleful effect on the properties of the whole structures since it causes band tilting and decrease in the overlapping of the electron and hole wave functions within quantum well (QW) structure. Due to the strong piezoelectric and spontaneous polarization fields along c-plane GaN, radiative recombination lifetimes in III-nitride-based devices as well as InGaN quantum well are affected. Recently, there are many studies to alleviate the polarization related problems GaN based device by having a-plane GaN layer on r-plane sapphire. [1-2] Unfortunately, the nonpolar growth of GaN materials still has suffered from poor crystalline quality due to high density of threading dislocations, basal stacking faults and rough surface morphology [3-4]. It induces non-radiative recombination centers that reduce the internal quantum efficiency and additionally act as charge scattering centers that decrease the carrier mobility. Also for device application using non-polar GaN layers it should have clear surface to ensure stability of the device. So, in our study, we researched a-plane GaN using HP GaN buffer layers of different thickness and this effect on the surface morphologies, crystalline quality and optical feature.

2. Experimental

Nonpolar a-plane GaN films were grown on r-plane sapphire substrate using MOCVD. Trimethylgallium (TMGa) and ammonia (NH_3) were used as Ga and N sources. In all two samples namely A and B were grown by this method. The growth parameters are as follows. The low temperature (LT) GaN buffer layer (*d*~30 nm) was grown at 550 ^oC with V:III gas flow ratio of 6000 in H_2 ambient. The growth LT GaN nucleation layer was followed by HP GaN layer with the reactor pressure at 300 mbar and grown at 1030 ^oC. For sample A and B, LT buffer growth was carried out and then followed by growth of HP buffer GaN layer with different thicknesses of 0.5 μm and 1.5 μm respectively. After the HP buffer layer growth, both sample A and B were subjected to growth of top GaN layer. For growth of top GaN layer, gas pressure was reduced to 80 mbar and growth temperature was maintained at 1160 ^oC. The top GaN layer thickness for sample A and B are 5 μm and 4 μm, respectively. The surface morphology of nonpolar GaN films was characterized using Normalski optical microscope (OM) and atomic force microscope. The crystalline nature was investigated by High Resolution X-Ray Diffractometer (X'PERT-MRD). The optical properties were characterized by room-temperature (RT) and low temperature (LT) photoluminescence measurements using He–Cd laser (325 nm).

3. Results and discussion

Using high pressure GaN as buffer layer, we can obtain the clear and flat surface morphologies of non-polar GaN without any wavy stripes or v-defect. The normaski optical microscope images of surface of two GaN grown with HP buffer layer are shown in Fig. 1. The results imply that the improvement of nanoscopic surface quality of a-plane GaN can be achieved by inserting a HP buffer layer. The sample with different HP buffer layer thickness i.e. sample A and B

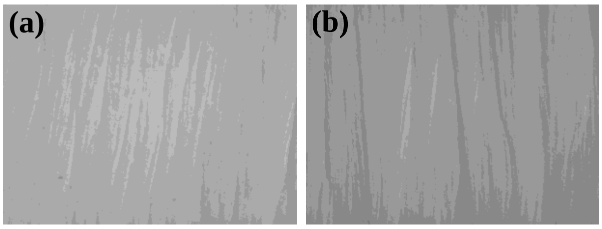

Fig 1. Normalski optical microscope (OM) images with 500 X magnification: samples A (a) and B (b).

were characterized by HR-XRD to probe the structural anisotropy of a-plane GaN. Fig. 2 shows the variation of full width at half maximum (FWHM) of (11-20) x-ray rocking sample A and sample B with respect to the in-plane beam orientation. Angles of 0^o to 90^o indicate that the projection of the incident X-ray beam parallel to the c-direction [0001] and m-direction [1-100]. The FWHM values for sample A and B are 648 arcsec and 486 arcsec respectively. In non-polar GaN growth, lateral growth toward c-direction and m-direction are important to improve the asymmetric crystal quality of a-plane GaN. During growing GaN at high pressure, the growth mode change of 3D mode to 2D mode were delayed which offers better crystal quality.

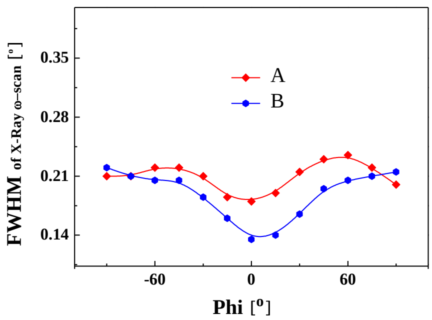

Fig 2. FWHM of HR-XRD (11-20) ω-scans for sample A and sample B which respect to the in-plane beam orientation

In fig 3(a), the ratio of relative intensities of GaN peak (~3.42 eV) and yellow luminescence (I_{GaN}/I_{YL}) peak for Sample B and A were 7.6 and 21.7, respectively. The relative PL intensity ratio generally is related to concentration of structural defects in the sample concerned. The results suggest that concentration of structural defects could be minimized by modifying thickness of HP GaN buffer layer. The LT PL spectra of both the sample are shown in Fig. 3(b). Different from Sample A, Sample B shows the much less pronounced defect related emission. It indicates that a-plane GaN with thicker HP buffer layer release the defect emission and induced a better optical quality.

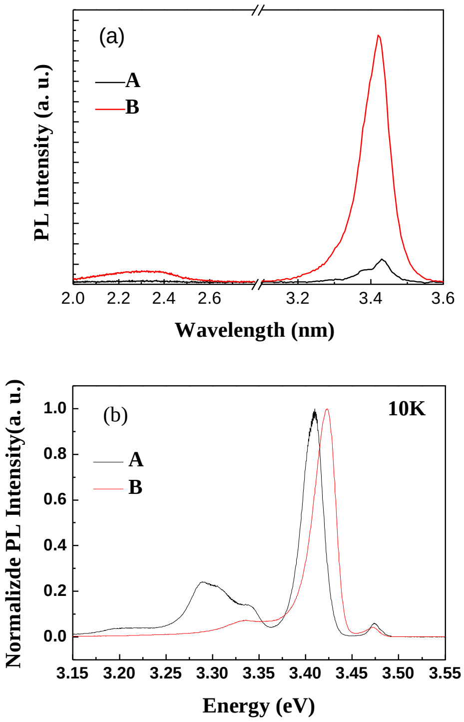

Fig 3. Photoluminescence; (a) Room-temperature PL spectra of sample A and B. (b) Low-temperature PL spectra of samples A and B.

4. Summary

Highly clear surfaces were obtained by multiple step growth process with HP GaN buffer layer. The crystal quality was improved by insertion of HP GaN buffer as found from reduced values of XRD FWHM values. The PL emission results suggest that the film had good material quality and can be improved by manipulating thickness of buffer layer.

Acknowledgement

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