PROPERTIES OF ALGAN/GAN HETEROSTRUCTURES WITH DOUBLE GAN BUFFER LAYER FOR HFET FABRICATION

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1. Introduction

The high mobility of electrons in two dimensional electron gas (2DEG) which creates at the aluminum gallium nitride / gallium nitride interface makes the AlGaN/GaN heterostructure system a good candidate for fabrication of high frequency and high power transistors. Gallium nitride layers are mainly grown heteroepitaxially on sapphire, silicon carbide and silicon substrates and fabrication of these layers with very good quality (low concentration of structural defects, high resistivity of buffer GaN layer, uniformity of AlGaN layer, smooth AlGaN/GaN interface), which is mandatory for obtaining 2DEG with high mobility and concentration, is an challenging task.

Many various methods are applied to reduce threading dislocation density and to lower the build-in stress existed in gallium nitride buffer in order to grow better quality AlGaN/GaN heterostructures. Most popular ways are multi-step growth process and application of thin inter layers during GaN buffer epitaxy process [1]. In this work, influence of two step grow process and application of AlN inter layer on morphological, optical and electrical properties of nitrides heterostructures is investigated.

2. Experiment

The $Al_{0.2}Ga_{0.8}N$/GaN heterostructures were grown by Metal-Organic Chemical Vapor Deposition (MOCVD) epitaxy (Aixtron CCS 3×2”) on sapphire substrates. Three different types of structures were fabricated. Sample A consisted of a single GaN buffer layer (2.5 μm thick) presented in figure 1. Two other samples contained a double buffer GaN layer; in case of sample C it was 2 μm thick GaN layer grown on 2 μm thick gallium nitride layer, in sample D, the additional 10 nm thick AlN layer was placed between these layers (figure 1). Topography of samples was investigated in air using Veeco Multimode V Atomic Force Microscopy (AFM) in tapping mode. Mobility measurements at temperatures of 300 K and 77 K were performed using LakeShore 7604 equipment. The Hall measurement samples were van der Pauw structures with soldered indium contacts. Photoluminescence spectra at 15 K and 300 K were acquired by Horiba spectrometer based system.

3. Results

Topography of all samples presented typical for MOCVD AlGaN/GaN structures step flow structure with a number of pits in the places where threading dislocations reached the surface (figure 2). The root mean square surface roughness (R_{RMS}) of A, B, C samples presented in Table 1 were very similar and varied in the range from 0.59 to 1.42 nm what indicated to a good structural quality of all epitaxial layers.

Photoluminescence (PL) of all layers at 300 K was dominated by broad yellow luminescence what is characteristic for heteroepitaxialy grown nitrides layers (fig. 2a). For samples B and C additional peak with the center et 3.1 eV existed.

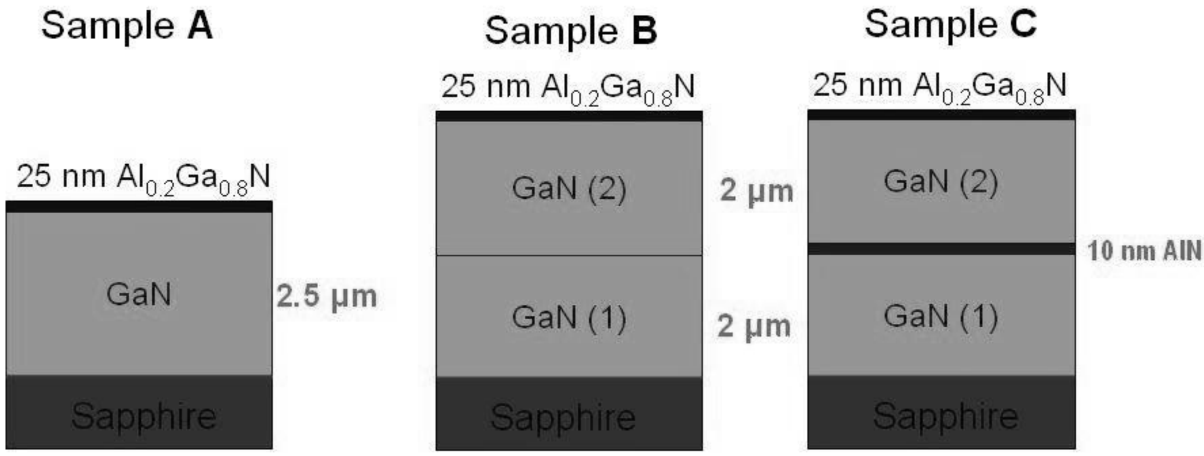


Fig.1: *Illustration of AlGAN/GaN heterostructures.*

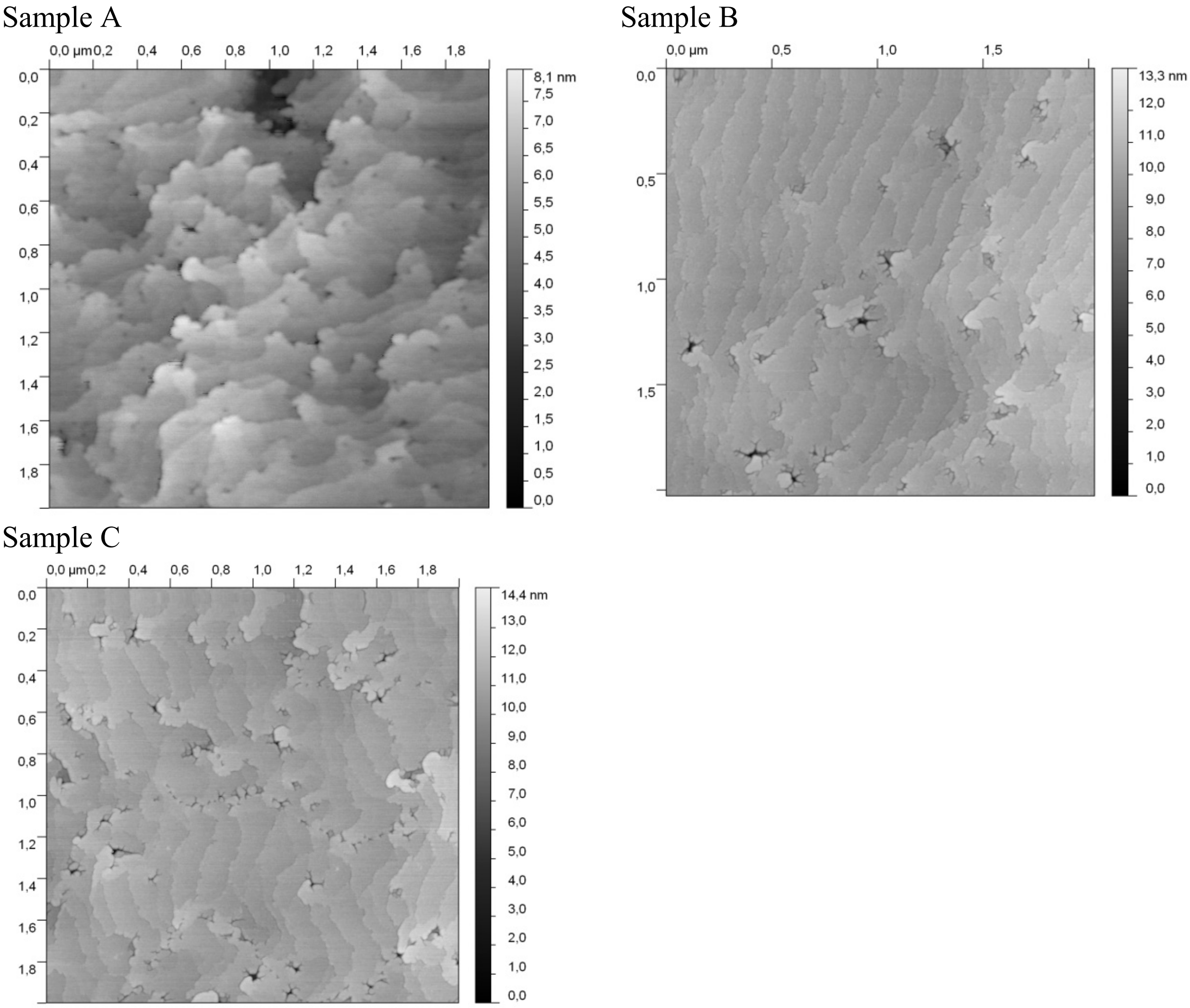
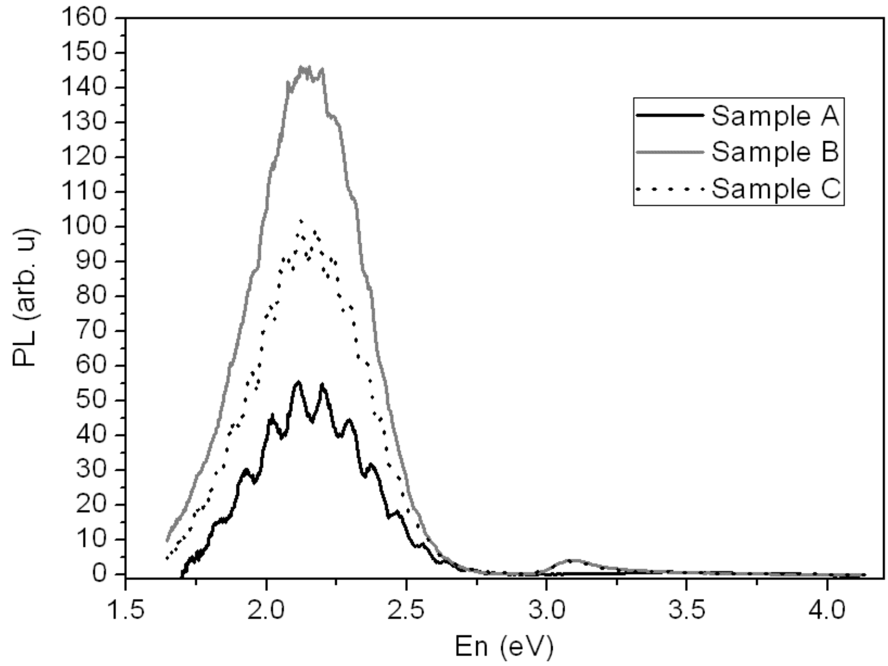


Fig.2: *AFM images of AlGAN/GaN heterostructures.*

This luminescence peak for B and C sample disappeared at 15 K (fig 2b). At low temperature, the luminescence spectra of that two samples were almost identical what could indicate that existence of AlN inter layer did not influence on distribution and concentration of optically active defects in structure. Yellow to near-band edge luminescence ratio of that layers was smaller than for sample A at 15 K. Additionally, sample A presented existence of 3.0 eV blue luminescence band at this temperature. That shows that optical quality of samples with double buffer layer was better than sample with single buffer layer.

a)



b)

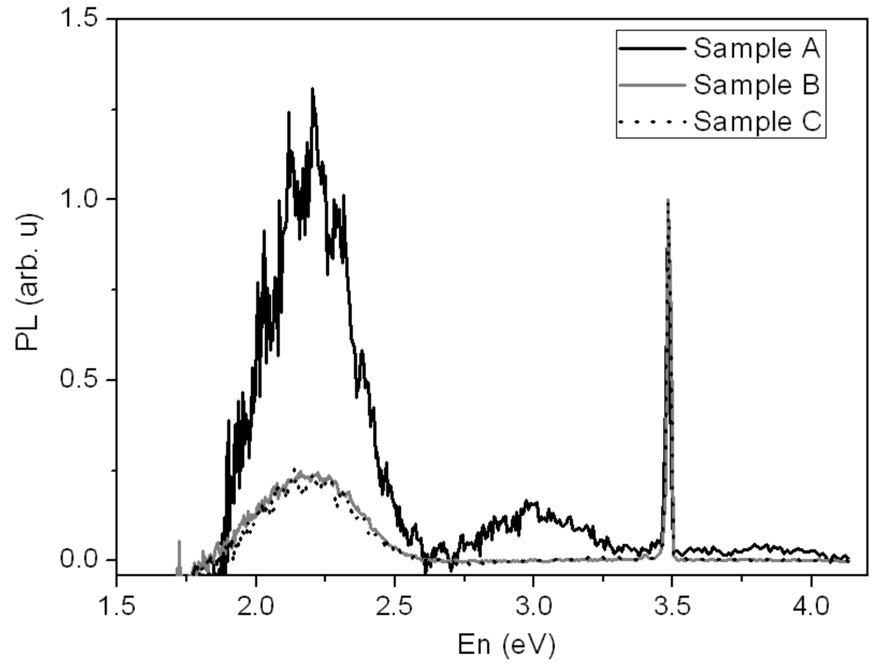


Fig.2: Photoluminescence spectra (normalized to near-band edge luminescence) at 300 K (a) and 15 K (b) of AlGAN/GaN heterostructures.

Based on assumption that below 150 K all free electrons in GaN are freezed out [2], it could be concluded from Table 1 that the maximal value of Hall carrier concentration in two dimensional electron gas (2 DEG) was obtained for sample B. It could be also noticed that the lowest conductivity of gallium nitride buffer had sample A. At 300K, the highest Hall mobility of carriers in 2 DEG was observed for sample C, and at temperature of 77 K both structures with double buffer layer had mobilities higher than sample A.

Tab. 1. *Roughness, Hall mobility and concentration parameters of AlGaN/GaN heterostructures.*

	R_{RMS} (nm)	μ_{Hall} 300K (cm^2/Vs)	$n_{S\ Hall}$ 300K (cm^{-2})	μ_{Hall} 77K (cm^2/Vs)	$n_{S\ Hall}$ 77K (cm^{-2})
Sample A	1.20	860	5.7×10^{12}	3470	5.27×10^{12}
Sample B	0.59	830	1.7×10^{13}	5020	8.7×10^{12}
Sample C	1.42	1280	6.4×10^{12}	5790	5.2×10^{12}

4. Summary

To summarize, application of double buffer gallium nitride in AlGaN/GaN heterostructure improved optical quality of layers observed in PL measurements. Application of multi step growth process did not change significantly morphology properties of the layers. The maximal value of Hall carrier concentration was observed for sample with double GaN layer. The highest Hall mobility of two dimensional gas at 300 K was obtained for structure with double GaN buffer layer and with additional aluminium nitride interlayer.

Acknowledgement

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References:

[1] J. Blasing, A. Reiher, A. Dadgar, A. Diez, A. Krost, *Applied Physics Letters*, **81**, 2722 (2002)

[2] S. B. Lisesivdin, A. Yildiz, S. Acar, M. Kasap, S. Ozcelik, E. Ozbay, *Appl. Phys. Lett.* **91**, 102113 (2007)