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GaN nucleation on (0 0 0 1)-sapphire via ion-induced nitridation of gallium

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Abstract

The growth of epitaxial GaN films on (0 0 0 1)-sapphire has been investigated using X-ray photoelectron spectroscopy (XPS) and low energy electron diffraction (LEED). In order to investigate the mechanism of the growth in detail, we have focused on the nitridation of pre-deposited Ga layers (droplets) using ion beam-assisted molecular beam epitaxy (IBA-MBE). Comparative analysis of XPS core-level spectra and LEED patterns reveals, that nitride films nucleate as epitaxial GaN islands. The wetting of the surface by GaN proceeds via reactive spreading of metallic Ga, supplied from the droplets. The discussed growth model confirms, that excess of metallic Ga is beneficial for GaN nucleation.

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Keywords: GaN nucleation; X-ray photoelectron spectroscopy (XPS); Low energy electron diffraction (LEED); Epitaxial growth

1. Introduction

The GaN semiconductor family has been in the focus of semiconductor research for the last decade due to new applications, in particular for optoelectronic devices in the blue wavelength region. Different deposition techniques, such as metal-organic chemical vapour deposition (MOCVD), hydride vapour phase epitaxy (HVPE) and molecular beam epitaxy (MBE), have been applied successfully to achieve a heteroepitaxial growth of GaN thin films [1]. Most recently it has been also demonstrated that ion beam-assisted deposition (IBAD) may provide GaN layers of similar crystalline quality as MBE samples [2]. For the optimization of the growth conditions the knowledge of processes on a microscopic scale is important – the mechanism of the film growth however is often not well understood, different models are discussed.

Recently, a theoretical model has been proposed for MBE of GaN based on an adlayer enhanced lateral diffusion mechanism (ALED) [3,4]. According to this approach the advantage of Ga-rich conditions during MBE GaN growth is explained by an improved atomic transport – of both N and Ga – due to a Ga adlayer. This changes the concept of MBE GaN growth from classical approach of on-surface diffusion of predecessors to the approach of quasi-liquid phase epitaxy, as was pointed out in Ref. [5]. Furthermore, it has been reported, that Ga metal spreads over the surface supported by a treatment with activated nitrogen [6,7]. In this manner GaN can be formed far away from the initial location of the metallic Ga droplets.

Kim et al. [8] have grown thin GaN buffer layers on SiC. Based on photoluminescence measurements they conclude, that excess of Ga in the layer effectively reduces tensile stress applied to the samples. This was found to be beneficial for adatom mobility (see references in the work [8]). In accordance, an improvement of thick epitaxial film quality was reported, when starting from Ga-rich GaN buffer layers.

In the presented work we study the GaN formation on sapphire using X-ray photoelectron spectroscopy (XPS) and low energy electron diffraction (LEED). In order to investigate the mechanism of the growth in detail, we focus especially on the nitridation of pre-deposited Ga layers (droplets) using ion beam-assisted molecular beam epitaxy (IBA-MBE).

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