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Ion-beam-assisted molecular-beam epitaxy: a method to deposit gallium nitride films with high crystalline quality

S. Sienz*, J.W. Gerlach, T. Höche, A. Sidorenko, B. Rauschenbach

Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstraße 15, D-04303 Leipzig, Germany

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Abstract

Hexagonal gallium nitride has been deposited on 6H-SiC by low-energy-ion-beam-assisted molecular-beam epitaxy. X-Ray diffraction measurements indicate the high crystalline quality of the thin films. Cross-section transmission electron microscopy images prove that a two-dimensional growth mode is obtained with this technique in contrast to the columnar growth of gallium nitride, as it is known from other methods. Comparing the ion energy with the displacement energy of surface and bulk atoms, it can be understood that the ion bombardment enhances the surface mobility during growth but does not lead to defect generation.

Keywords: Gallium nitrides; Ion bombardment; Molecular beam epitaxy

1. Introduction

Hexagonal gallium nitride is a semiconducting material with large bandgap energy of 3.4 eV at room temperature. It is used in various semiconductor components including blue or white light emitting diodes, blue laser diodes, field effect transistors, and ultraviolet-sensors. Different methods to prepare highly crystalline gallium nitride thin films with a good optical and electrical quality have been developed. Most popular is metal organic vapour phase epitaxy as well as molecular-beam epitaxy (MBE). Ion-beam-assisted deposition, called ion-beam-assisted MBE in the case of low ion energy, represents another option for epitaxial growth of GaN on sapphire [1–4]. There it is shown that an ion-beam enhances the crystalline quality of GaN films if the ion energy is low (up to 35 eV). So far, there is no work reported on the deposition of gallium nitride thin films on 6H-SiC by low energy ion-beam-assisted MBE. In this letter the crystalline quality of films produced by ion-beam-assisted MBE on (0001) 6H-SiC substrates is demonstrated.

2. Experimental details

After sapphire, 6H-SiC is the most used substrate material for GaN growth. The (0001) faces of SiC wafers were etched for 1 min in hydrofluoric acid (48 vol.%) and subsequently rinsed with deionized water in order to reduce the surface oxygen content. Gallium nitride thin films were deposited in a common MBE system with a base pressure of 5×10^{-8} Pa at a substrate temperature of 630 °C. Gallium was evaporated by an effusion cell at a temperature between 1020 and 1060 °C. The resulting Gallium flux to the substrate was between 5×10^{13} and 2×10^{14} $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. But, instead of the commonly used radio-frequency-excited atomic and radical nitrogen source, a hollow anode ion source as described in Ref. [5] was employed. Due to a nitrogen flux of 12 sccm that is necessary to operate the ion source there was a working pressure of 8×10^{-2} Pa. According to Anders et al. [5], the ion energy distribution has two maxima at 5 and 15 eV, respectively, and the energy of the majority of ions does not exceed 25 eV. In contrast to most other groups we abandon the growth of any buffer or nucleation layers. During a deposition time of 2 h, a growth rate of 1.25 nm/min was achieved.

In order to examine the crystallinity of the GaN thin films, X-ray diffraction (XRD) measurements with a

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*Corresponding author. Tel.: +49-34-1235-2681; fax: +49-34-1235-2595.

E-mail address: stefan.sienz@iom-leipzig.de (S. Sienz).

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