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Journal of Crystal Growth 301–302 (2007) 565–569

JOURNAL OF CRYSTAL GROWTH

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Study of optical properties of GaAsN layers prepared by molecular beam epitaxy

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Abstract

We have grown GaAsN layers (with nitrogen concentration between 1.2% and 3.2%) on GaAs(1 0 0) substrates by molecular beam epitaxy (MBE) using a radio frequency (RF) plasma nitrogen source, and solid sources for Ga and As. The growth temperature was varied from 420 to 600 °C, and the GaAsN growth mode was in situ monitored by reflection high-energy electron diffraction (RHEED). The optical properties of the layers were studied by photoreflectance spectroscopy (PR) and phase modulated ellipsometry (PME). For the growth temperature of 420 °C the films grew in a three-dimensional (3D) mode as indicated by the appearance of transmission spots in the RHEED patterns. In contrast, GaAsN layers grown at higher temperatures presented a two-dimensional (2D) growth mode. These GaAsN layers are pseudomorphic according to high-resolution X-ray diffraction (HRXRD). The PR spectra of all samples exhibited Franz–Keldysh oscillations (FKO) above of the GaAs band gap energy. From these oscillations we obtained the built-in internal electric field intensity (F_{int}) at the GaAsN/GaAs interface. In the low-energy region of the PR spectra we observed the transitions associated to fundamental band gap of the GaAsN layers. The variation of the GaAsN fundamental band gap obtained by PR as a function of the N content was explained according the band anti-crossing model (BAC). On the other hand, the E_1 and $E_1+\Delta E_1$ critical points were obtained from the analysis of spectra of the imaginary part of the dielectric function obtained by PME. We observed a shift of these critical points to higher energies with the increase of N content, which was explained by a combination of strain and alloying effects.

PACS: 73.61.Ey; 81.15.Hi; 78.68.+m

Keywords: A1. Optical properties; A1. Structural characteristics; A3. MBE; B2. III–V–N semiconductors

1. Introduction

Currently, there is considerable interest in III–V–N dilute nitride thin-film alloys, such as GaAsN, both because of their fundamental physical properties and potential device applications [1]. The substitution of a few percent of As atoms in GaAs by N atoms leads to a strong reduction of the band gap energy, for example; for 1% N added to GaAs the band gap energy is reduced by ~200 meV [2]. This characteristic makes GaAsN alloys very attractive for applications in 1.3/1.55 μm semiconductor lasers, and for extending the wavelength range of GaAs-based solar cells further into the infra-red. There has been substantial progress in the synthesis of GaAsN alloys by molecular beam epitaxy (MBE). However, in order to obtain reproducible high-quality dilute nitride thin films additional studies on the alloys growth and their properties are required.

It is well known that in the heteroepitaxial growth of materials with a small lattice mismatch the epilayer can be grown pseudomorphically, that is with the same in-plane lattice constant of the substrate, up to certain critical thickness which depends on the lattice mismatch value and on elastic properties of the materials. In order to obtain pseudomorphic layers an appropriate growth mode is

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doi:10.1016/j.jcrysgro.2006.11.241