Structural and optical characterization of GaNAs layers grown by molecular beam epitaxy

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We have grown GaN_xAs_{1-x} layers by molecular beam epitaxy on GaAs(100) substrates using a radio frequency plasma nitrogen source and solid sources for Ga and As. Employing reflection high-energy electron diffraction (RHEED), the GaNAs growth mode was *in situ* monitored. A three dimensional (3D) growth mode was obtained at the low growth temperature of 420 °C. At higher temperatures streaky RHEED patterns were observed during all the GaNAs deposition, indicating a two dimensional (2D) growth mode. The structural and optical properties of the GaNAs layers were studied by employing high-resolution x-ray diffraction, atomic force microscopy, Raman scattering, and spectroscopic ellipsometry. The films grown in a 3D mode presented high density of crystal defects, degraded structural properties, and broad optical transitions. In contrast, GaNAs layers grown in a 2D mode are pseudomorphic with high crystal quality. The properties of samples with a high N concentration were improved by first growing a GaNAs layer with a low N content.
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I. INTRODUCTION

The study of III-V dilute nitride alloys, such as GaNAs, is interesting because of their fundamental physical properties and potential device applications.[1] One of the most important properties of GaNAs alloys is the strong reduction of the band gap energy obtained for a few percent of N atoms incorporated. For example, for 1% N added to GaAs the band gap energy is reduced by ~200 meV.[2] This characteristic makes GaNAs 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 infrared. However, the estimation of the N-solubility limit in GaNAs alloys has a small value of ~2%.[3] Thus by increasing the N content, GaNAs tends to phase separate due to the wide miscibility gap. As a result, the GaNAs crystal quality degrades when the N composition is appreciable. In order to obtain reproducible high quality GaNAs thin films additional studies on alloy growth and their properties are required. In this work we have studied the structural and optical properties of GaNAs alloys as a function of growth temperature. We evaluated the effects of the growth mode on the GaNAs crystal quality. The growth mode and N content in the samples were controlled by the growth temperature. We tried to improve the properties of samples with high N concentration by first growing a GaNAs layer with a low N content.

II. EXPERIMENT

The GaN_xAs_{1-x} layers were grown on (100) GaAs substrates by molecular beam epitaxy (MBE) employing a Riber C21 system equipped with solid sources for III-V materials. Active nitrogen was produced by a radio frequency (rf) plasma source. Ultrahigh purity nitrogen was introduced into the plasma source using a mass flux controller and a leak valve. In the MBE chamber the substrates were heated up to 580 °C to remove the surface oxides under an As_4 flux. Then, in order to smooth out surface imperfections, a GaAs buffer layer of 500 nm in thickness was grown at 580 °C. At the end of the buffer layer growth the surface exhibited a very sharp (2×4) reflection high-energy electron diffraction (RHEED) pattern. After the buffer layer growth, the growth temperature was fixed to the desired value and the N plasma was turned on to grow the GaNAs alloy. GaNAs layers were prepared at different growth temperatures but with the same thickness (~100 nm), using a growth rate of ~1 μm/h. The plasma excitation power and the N_2 flow were held constant at 100 W and 0.1 SCCM (SCCM denote cubic centimeter per minute at STP), respectively. The GaNAs growth mode was *in situ* monitored by RHEED. High-resolution x-ray diffraction (HRXRD) measurements

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