

Pyramidal morphology of InN thin films deposited by reactive RF-magnetron sputtering

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High density of pyramidal three-dimensional (3D) nano-islands of InN material deposited on AlN /quartz surface with an average aspect ratio of about 0.43 was observed by means of atomic force microscopy (AFM) imaging. The coatings were obtained by reactive radio-frequency (RF) magnetron sputtering method. It was identified a transition from two-dimensional (2D) to 3D growth mode of the InN material. The optical, structural and morphological characterization data are presented.

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1. Introduction

Preparation of indium nitride (InN) thin films is of considerable interest because of InN unique set of properties, such as high electron mobility and high saturation velocity [1]. It is highly desirable for applications in optoelectronic devices, high efficiency solar cells, high speed and high power electronic devices and various types of sensors [2].

Besides thin film growth, the fabrication of InN nanodots has been studied during the last years. The studies focused on the growth of self-organized InN islands on different substrates, mostly on GaN templates on sapphire or silicon, as well as directly on Si(111) [3].

In this work, we report on the reactive RF magnetron sputtering growth of InN dots on AlN/quartz glass substrate. The optical, structural and morphological characterization data are presented.

2. Experimental

AlN and InN films were successively deposited on quartz glass substrate heated at 550 °C in an AJA's ATC ORION RF magnetron sputtering system equipped with high purity indium and aluminum cathodes. Two 13.56 MHz AJA-Seren's RF generators delivered 100 W to the cathodes. The Al and In targets were sputtered in pure N₂ atmosphere at 0.2 Pa for 15 and 60 minutes respectively, ensuring an about 20 nm and 120 nm thickness of the AlN and InN layers. The base pressure in the deposition chamber was about 1×10⁻⁵ Pa. Prior to the deposition, the quartz substrates was chemically cleaned in an ultrasonic bath with isopropyl alcohol. Then, the substrates as well as the cathodes were sputter-cleaned in vacuum by Ar⁺ bombardment for about 10 minutes.

The crystallographic structure of the films was investigated by a Bruker D8 ADVANCE type X-ray diffraction (XRD) system equipped with a copper target

X-ray tube and a scintillation detector. A parallel beam geometry at grazing incidence $\alpha=3^\circ$ was used, with a Göbel mirror in the incident beam. An asymmetric channel-cut monochromator installed after the mirror provided a strictly monochromatic CuK _{α 1} primary X-ray beam. Film thickness, surface roughness and morphology were assessed with Veeco's Dektak 150 surface profiler and Innova scanning probe microscope (SPM) operating in tapping mode.

A Horiba Jobin-Yvon Raman spectrophotometer (HR-800) equipped with an Ar⁺ (488 nm) excitation laser was used for recording the PL spectra in normal incidence mode.

3. Results and discussion

Fig. 1 shows a typical AFM image with a 3 x 3 μm^2 scanning area of the surface of the InN/AlN/quartz sample. One can see that the surface of the coating consists of high density pyramidal-shaped 3D nano-islands, randomly distributed on the sample surface. Generally, the development of 3D nano-structures is due to the lattice mismatch between the deposited film and substrate (here, the AlN nucleation layer). Large mismatches produce 3D Volmer-Weber growth or starts with layer-by-layer growth and changes to three-dimensional after a critical thickness (Stranski-Krastanov growth) [4]. In our case, in analogy with a physical model of InN growth [5], it seems that the growth proceeds through dense nucleation sites and the mobility of active nitrogen species on the surface is much lower than the mobility of indium adatoms, which are transferred from the areas between islands to the islands themselves. The grown islands present an average lateral size of about 89 nm and average height of about 38 nm, meaning that they have an aspect ratio (the ratio between the vertical and lateral dimensions) of about 0.43. The measured root-mean-square (RMS) surface roughness is about 5.4 nm. The height of the dots is considerably

lower than the total thickness of the film, of about 170 nm, as measured by Dektak surface profiler. This morphology might indicate a transition from the 2D growth mode to the 3D growth mode. Similar experimental observations of InN pyramid-shaped islands grown on the top of thick 2D wetting-like layer have been recently reported [6].

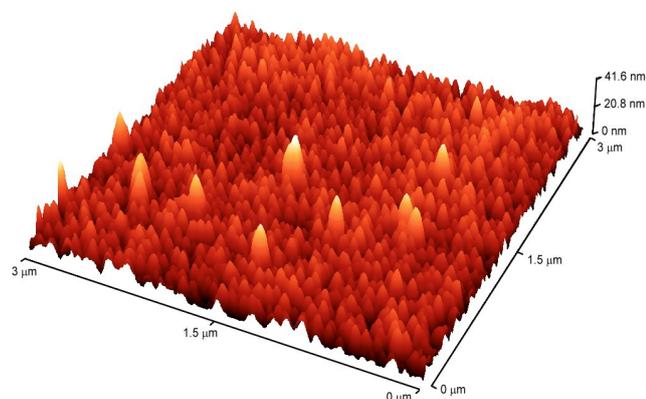


Fig. 1. Taping mode AFM image of InN/AIn/quartz sample.

The x-ray diffraction profile of InN samples is shown in Fig. 2. InN related XRD peaks located at 28.9° , 31.1° , 33.0° , and 56.7° have been observed, corresponding to hexagonal InN(100), (002), (101), and (103) planes respectively, indicating the polycrystalline nature of the film. The strong intensity of the InN (002) diffraction peaks and the absence of any indium oxide and metallic indium Bragg peaks suggest that the films consist of good purity InN with a wurtzite structure, which exhibits highly c-axis orientation. The lattice parameters were calculated to be $a = 3.568 \text{ \AA}$ and $c = 5.746 \text{ \AA}$, which are in good agreement with the reported theoretical and measured values of bulk InN [7].

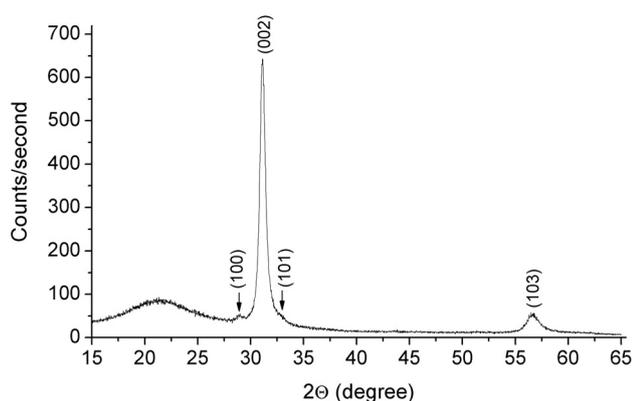


Fig 2. XRD pattern of InN/AIn/quartz sample.

Fig. 3 shows the PL spectra of the as-grown InN samples measured at room temperature. One can see that films exhibit a strong room-temperature visible luminescence with the emission peak located around 1.69 eV.

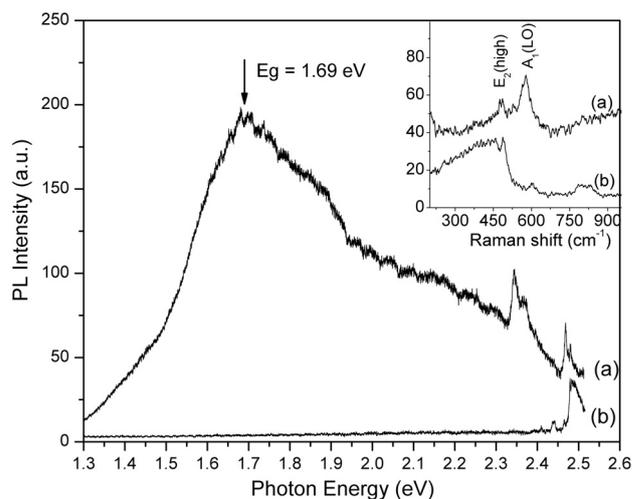


Fig. 3 Band-gap estimation of InN/AIn/quartz material from PL spectra. The inset show the InN Raman features. (a) -sample; (b) quartz substrate.

Other features can be identified in the PL spectra at about 2.47 eV. In a Raman shift representation seen in the inset of Fig. 3, those features are identified as peaks located at 485 cm^{-1} and 578 cm^{-1} , corresponding to the scattering of the excitation laser light from E_2 (high) and $A_1(\text{LO})$ phonons modes of InN respectively [8]. That confirms that InN material has a wurtzite structure, result that is consistent with the XRD findings. However, our E_2 (high) and $A_1(\text{LO})$ values are slightly red-shifted compared to ref. [8], which might be due to the weak compressive strain that could be developed across the InN islands.

4. Summary and conclusions

Pyramidal-shaped InN dots with average aspect ratio of about 0.43 have been grown on AIn/quartz substrate by reactive RF magnetron sputtering method. It was identified a transition from 2D to 3D growth mode. The deposited material consists of good purity InN exhibiting a wurtzite polycrystalline structure which exhibits highly c-axis orientation, with no contaminating phases. It manifests a band-gap of about 1.69 eV.

Further work is required in order to improve the quality of the deposited InN material, to study the evolution of the dots with the deposition parameters and to individually characterize the dots.

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