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InN thin films deposited on flexible substrates by reactive RF-magnetron sputtering

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Indium nitride is an attractive semiconductor material for optoelectronic applications, high-speed electronics and solar cells. We report successful deposition of polycrystalline InN thin films onto kapton polyimide flexible substrates by reactive RF magnetron sputtering method. The optical, structural and morphological characterization data are presented.

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1. Introduction

There is a growing interest in the development of high-performance, large-area, low-cost flexible electronic structures with the ability to bend and handle electronic devices. They are designed to address problems of space and weight that cannot be solved with traditional wiring methods and rigid printed circuit boards, having the potential for a wide range of applications [1, 2].

Preparation of indium nitride (InN) thin films deposited on flexible substrates is of considerable interest because of InN unique set of properties, such as high electron mobility, high saturation velocity and high radiation resistance [3, 4]. It is highly desirable for applications in optoelectronic devices, low cost solar cells with high efficiency, high speed and high power electronic devices and various types of sensors [5, 6].

In this work, we report the electrical, optical, structural, and morphological properties of InN thin films deposited onto kapton polyimide flexible substrates with an intermediate aluminium nitride (AlN) nucleation buffer by reactive RF magnetron sputtering method.

2. Experimental

InN films with a thickness of about 400 nm were reactively deposited on kapton polyimide substrates in an AJA's ATC ORION RF magnetron sputtering system equipped with In and Al cathodes in pure N_2 atmosphere. The base pressure in the deposition chamber was of about 1×10^{-5} Pa. Prior to deposition, the kapton substrates were chemically cleaned in an ultrasonic bath with isopropyl alcohol. Both the substrates and the magnetron target were sputter cleaned in vacuum by Ar ion bombardment for 10 minutes. A 13.56 MHz AJA-Seren's RF generator with auto-matching network delivered 100 W power to each cathodes. Two sets of samples were prepared at 0.6 and 0.8 Pa, respectively. The absolute pressure was measured with a MKS 626 Barocel capacitance manometer. The substrates temperature was kept constant at about 500^0C, monitored continuously by a backside not contact thermocouple. The deposition time was about 90 minutes for both sets of samples.

The crystallographic structure of the films was investigated by a Bruker D8 ADVANCE X-ray diffraction (XRD) system using Cu Kα1 excitation line set-up for 2^0 grazing incidence geometry in 2θ/ θ scan mode. Film thickness, surface roughness and morphology were assessed with Veeco's Dektak 150 surface profiler and Innova scanning probe microscope (SPM) operating in taping mode, respectively.

Optical properties where studied by room temperature photoluminescence (PL) and optical transmittance (T%) and reflectance (R%) measurements. A Horiba Jobin-Yvon HR-800 Raman spectrophotometer equipped with an excitation HeNe laser (632 nm) was used for recording the photoluminescence spectra in normal incidence mode. The optical T% and R% measurements have been performed on the 190-2500 nm spectral range by a double beam JASCO V670 spectrophotometer with an integrating sphere attachment.

3. Results and discussion

The X-ray diffraction profiles of the two sets of InN samples with about 20 nm AlN buffer on kapton substrate are shown in figure 1. InN related XRD peaks located at 31.4°, 33.1°, 43.3°, 57°, and 61.6° have been observed from the samples deposited at 8 mtorr, corresponding to hexagonal InN(002), (101), (102), (103), and (112) planes respectively, indicating a wurtzite polycrystalline nature of the film and no contaminating phases. In comparison, the samples deposited at 6 mtorr show a strong InN(002) peak, five times more intense than previous samples and only a small track of InN(103). All other diffraction peaks are absent. The strong intensities of the InN(002) diffracted

peaks and the absence of any indium oxide peaks indicate that the films consist of high purity InN with a wurtzite structure which exhibits highly c-axis orientation, perpendicular to the substrate surface. The lattice parameters were calculated to be around a = 3.55 Å and c = 5.74 Å for both samples, values which are in good agreement with reported theoretical and measured values of high quality hexagonal InN [7].

The AFM images of InN films are presented in Fig. 2. Their analysis reveals that the deposited InN films consist of columnar structures oriented normal to the substrate surface, having diameters of about 275 nm and 350 nm when the films were grown at 0.6 Pa and 0.8 Pa, respectively. The layers exhibited a surface morphology with root mean square roughness of about 3 nm and 5 nm.

Fig. 3 shows the PL spectra of the InN samples measured at room temperature. It is interesting to note that the present InN films exhibit a strong room-temperature photoluminescence with the emission peak at 1.74 eV and 1.78 eV respectively. For comparison, the Fig. 2 shows also the optical band gap estimation from the extrapolation of the linear fit of the $(\alpha h\upsilon)^2$ graph, based on the Tauc's equation for direct band gap semiconductors [8]: $\alpha h\nu = A(h\nu - Eg)^2$, where A is the constant which is different for different transitions and Eg is the band gap.

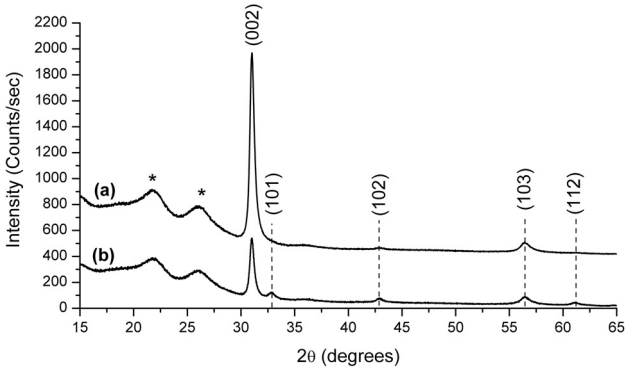

Fig. 1. XRD pattern of the as-deposited samples of InN grown on kapton substrate with AlN buffer in 0.6 (a) and respectively 0.8 Par (b) of pure N_2 atmosphere.

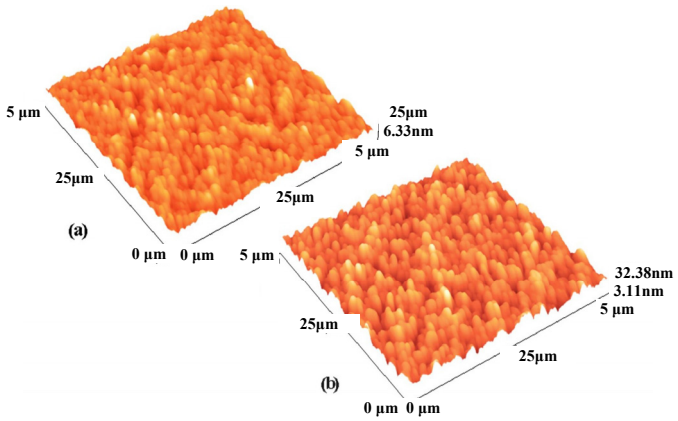

Fig. 2. Taping mode AFM images of InN/AlN/kapton films deposited at 0.6 (a) and 0.8 Pa (b).

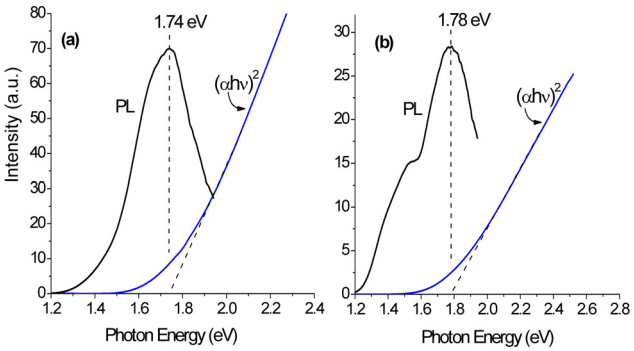

Fig. 3. Band gap estimation from PL spectra and Tauc's plot of InN films deposited at 0.6 (a) and 0.8 Pa (b)

The absorption coefficient was estimated based on the αd = ln((1-R)/T) relationship, where T and R are the measured transmittance and reflectance spectra and d is the film thickness.

The simultaneous observations of the absorption edge and the PL at essentially the same energy indicate that this energy position corresponds to the transition across the fundamental band gap of InN.

4. Summary and conclusions

Indium nitride thin films have been deposited on kapton polyimide flexible substrates with AlN nucleation-buffer by reactive RF magnetron sputtering method. The films are primarily polycrystalline with a columnar wurtzite structure with preferred (002) orientation. The band gap was estimated at 1.74-1.78 eV.

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