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Growth and characterization of the InN film ammonification technique

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Abstract

InN film was synthesized by ammoniating indium film on Si(1 1 1) substrates. The samples were analyzed by X-ray diffraction (XRD), X-ray photo-electron spectroscopy (XPS), atomic force microscopy (AFM) and transmission electron microscopy (TEM). The XRD and TEM show that nanoparticles were hexagonal InN single crystals.

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Keywords: InN; Ammoniating; Single crystal

1. Introduction

Indium nitride is one of the III–V nitride semiconductors with a direct band gap of 0.7 eV [1]. It has the smallest effective electron mass of all the group-III nitrides, which leads to high mobility and high saturation velocity, and a large drift velocity at room temperature [2–5]. Due to these properties of InN, it has potential applications in optoelectronic devices, such as LDs and high efficiency solar cells, as well as high frequency (high power) electronic devices. In recent years, much effort has been made to grow InN film by various methods such as metal organic chemical vapor deposition (MOCVD) [6,7], molecular beam epitaxy (MBE) [8,9], and reactive sputtering. In this letter, we report the synthesis of InN film by ammoniating In/Si thin film with radio frequency magnetron sputtering.

2. Experimental

The In film was deposited on Si(1 1 1) using a JCK-500A r.f. magnetron sputtering system. The conditions of sputtering were as follows: the background pressure was 4.0×10^{-4} Pa, the distance between targets and substrates was 8 cm and the pressure of Ar (99.999%) was 3 Pa. After 30 s, N_2 (99.999%) instead of Ar was introduced to the chamber. The pressure of N_2 was 3 Pa. The In film was grown by sputtering an indium (99.99%) target with r.f. power of 150 W for 15 min.

The InN thin film was synthesized by ammoniating the In thin film in an open quartz tube inside a horizontal quartz tube. Firstly, the samples were placed into the reaction system when the temperature of the system was increased to 700 °C. Secondly, N_2 was introduced into the system for 5 min to expel air and then NH_3 of 500 ml/min (99.999%) was introduced into the system for 2 h. After nitridation, the samples were quickly cooled down to room temperature in the flow of super pure N_2 gas (99.999%).

Structural and compositional characterizations were performed using X-ray diffraction (XRD; Rigaku D/max-rB Cu Kα), atomic force microscopy (AFM; Park),

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transmission electron microscopy (TEM; HitachiH-800) and X-ray photo-electron spectroscopy (XPS; MICRO-LAB MK II).

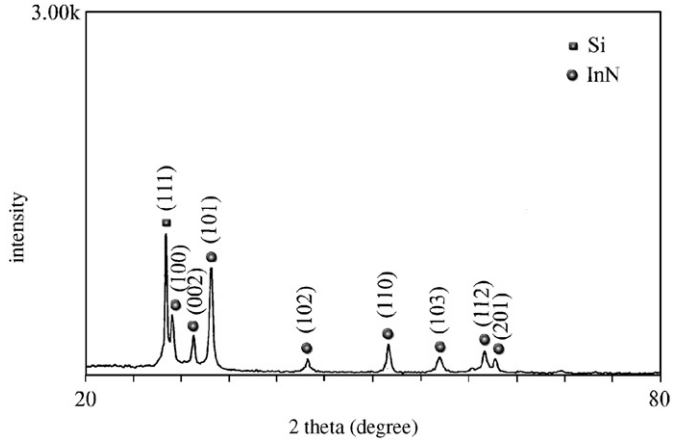

Fig. 1. XRD pattern of the sample.

3. Results and discussion

3.1. XRD analysis

The XRD pattern of the sample, which was tested by the lab assistant of Shandong Provincial Analysis and Test Center, is depicted in Fig. 1. Peaks were found at $2\theta = 29.06^\circ$, 31.28°, 33.14°, 43.24°, 51.58°, 56.92°, 61.60° and 62.76° in correspondence with the hexagonal InN (lattice constants $a = 0.354$ nm and $c = 0.5705$ nm). They are due to the (1 0 0), (0 0 2), (1 0 1), (1 0 2), (1 1 0), (1 0 3), (1 1 2) and (2 0 1) diffraction peaks of hexagonal InN. A peak at $2\theta = 28.40^\circ$ is attributed to Si(1 1 1). As a result of disappearance of diffraction peaks of In (the strong peaks are expected at $2\theta = 33.00^\circ$, 36.38°, 39.20° and 54.48°), it is thought that In was turned completely into InN.

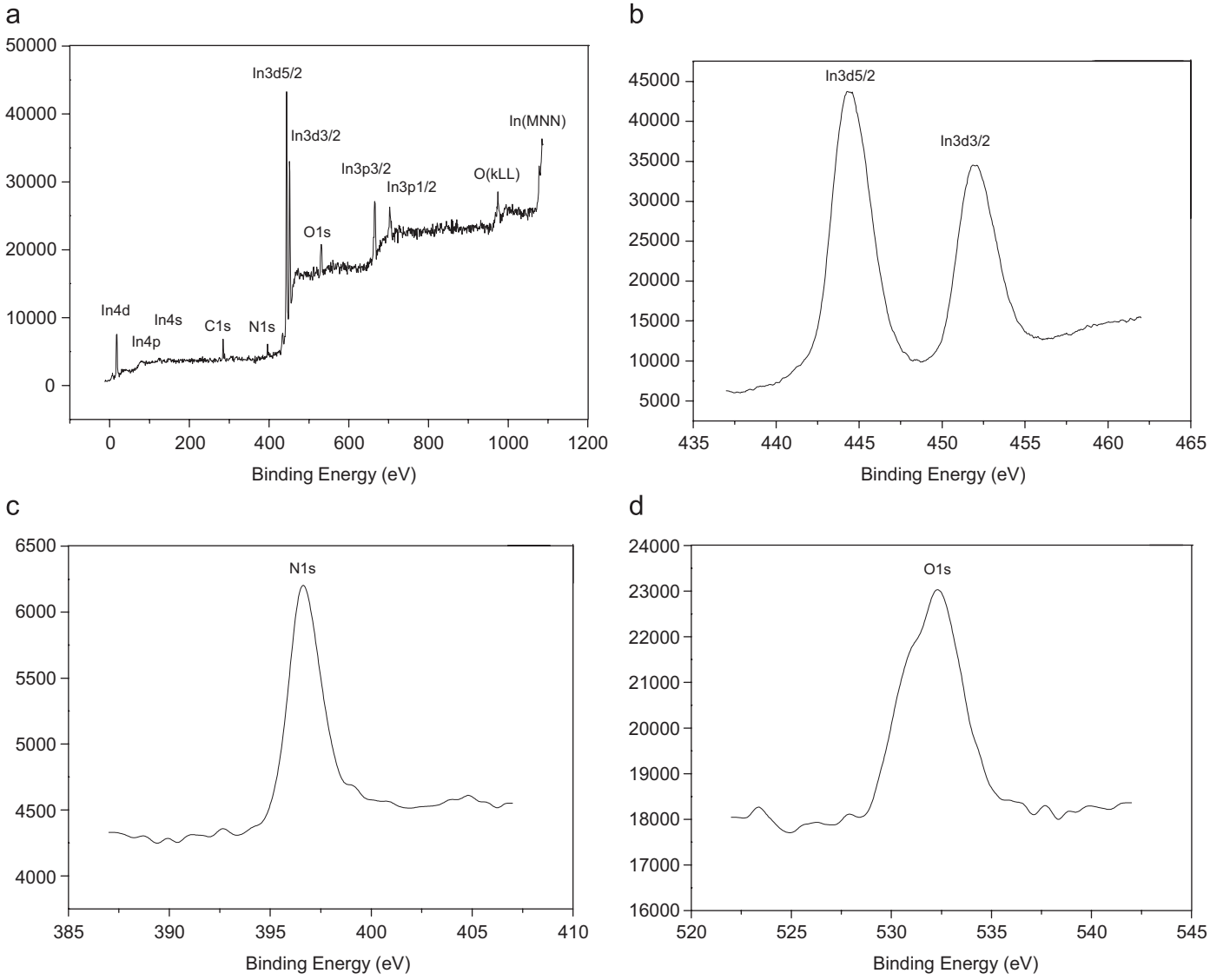

Fig. 2. XPS spectra of the sample.