

Temperature-induced Morphological Evolution of Indium Nitride

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1. Introduction

Recently, significant progress has been made in the nitrogen RF plasma-assisted epitaxy of InN [1,2], inspired by the re-evaluation of the InN bandgap from 1.9 to ~0.7 eV [3]. However, the InN material quality is still inadequate for device applications and many aspects of the growth process and the material properties are not clear. Earlier works have revealed, for example, important differences in the growth and thermal stability of In-face and N-face InN (0001) [4,5]. The fabrication of group-III nitride one-dimensional (1D) nanostructures has become the focus of materials research because their wide-range bandgaps make them suitable for optoelectronic applications such as near-IR/near-UV devices. Several research groups reported synthesis and characterization of 1D InN nanostructures via vapor-liquid-solid (VLS) process [6] or vapor-solid (VS) process [7]. Dingman et al. reported that InN nanowires from azido-indium precursor based on the vapor-liquid-solid (VLS) process under low temperature [6]. Also, Zhang et al. reported an efficient route to the single-crystalline InN nanowires by vapor-solid (VS) method.[7]

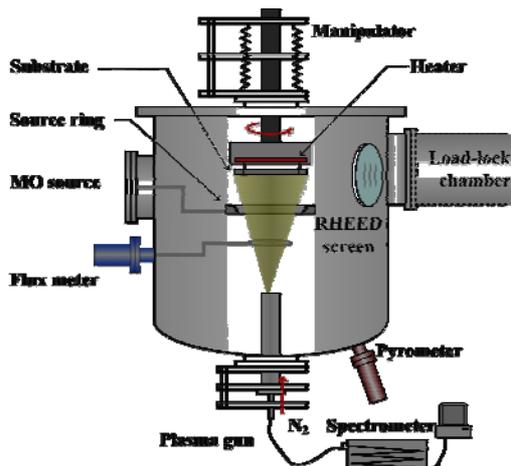


Fig. 1 Schematic diagram of RF-MOMBE epitaxial system.

In this work, we established a RF-radical source metalorganic molecular beam epitaxy (RF-MOMBE) to fabricate InN thin film and characterize its crystallinity and surface morphology. X-ray diffraction (XRD, Siemens D5000) analyses were conducted using Cu-K α radiation to determine the crystallinity of the InN films. The diffrac-

tion angle 2θ was scanned from 20° to 80° at 0.05° per second. In addition, the surface morphology was examined by atomic force microscopy (AFM), and the shape and structural properties of the ZnO nanostructures were determined using Hitachi S-4300 field-emission scanning electron microscope (FESEM) attached with energy-dispersive X-ray fluorescence spectroscopy (EDS) for composition analysis. Meanwhile, room-temperature photoluminescence (PL) emission at around 0.7 eV was observed. Our experimental results show the influence of growth temperature on surface morphology of InN films, and proposed growth mechanism will be discussed.

2. Experimental details

InN films were grown on nitridated c-sapphire substrates with AlN buffer layers by self-designed RF-MOMBE (as shown in Fig. 1), which consist of a load lock and a growth chamber with a base pressure of $\sim 10^{-9}$ Torr. Trimethylaluminum, trimethylindium and atomic nitrogen generated by radio frequency plasma, were used as the group-III precursor and N source. Prior to the growth of InN, the substrate was heated to 950 °C and then exposed to nitrogen plasma for 10 min in order to clean the surface and also form a thin nitridated layer. After growth of an AlN buffer layer at 750 °C, the substrate temperature is decreased at 500-600 °C, and InN is grown then. During the deposition, the substrate temperature was monitored by a thermocouple and IR pyrometer with a PID-programmable heater.

Figure 2 shows the XRD patterns of InN films grown at various growth temperatures. At the growth temperature of 500 °C, two diffraction peaks which correspond to InN (0002) and sapphire (0006) are observed as indicated in Fig. 2(b) at approximately 31.4° and 41.8°, respectively. This implies that the growth of highly c-axis oriented InN films on c-sapphire has been achieved. While the growth temperature is increased, it should be note that the intensity of the diffraction peak at 31.4° increase with the growth temperatures. In particular, the "anomalous" 33° peak shown in Fig. 3(c) is in fact the (01-11) diffraction peak of InN rather than metallic In.[8]

The cross-sectional SEM images of the InN films grown at 500 °C, 550 °C and 600 °C are shown in Fig. 3(a)-(c). The observation reveals that the InN films exhibit a pronounced two-dimensional growth mode at low growth

temperature of 500 °C. While increasing growth temperature, the three-dimensional growth mode would be enhanced due to higher desorption rate of indium nitride and formation of nanorods and nanonail can be observed clearly from the SEM images.

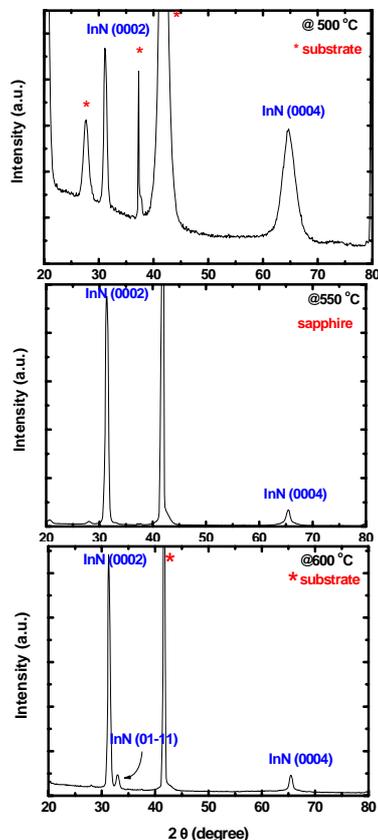


Fig. 2 XRD spectrum of InN grown at (a) 500 °C, (b) 550 °C and (c) 600 °C.

3. Conclusions

InN thin films were grown on the c-axis sapphire substrate by RF-MOMBE system. Using an AlN buffer layer can significantly improve the structural and electrical properties of InN. Growth temperature plays an important role in the InN morphology. For example, the InN showed a pronounced two-dimensional mode as the growth temperature is below 500 °C. On the other hand, 1D nanorods and nanonails formed in the high temperature region. The formation of InN nanonail might result from high desorption rate of InN material at high temperature. Accordingly, growth temperature can be used for engineering the self-organized growth of InN nanostructures. The technique appears potential applications in nanoelectronics, nanocomposites, optoelectronic etc..

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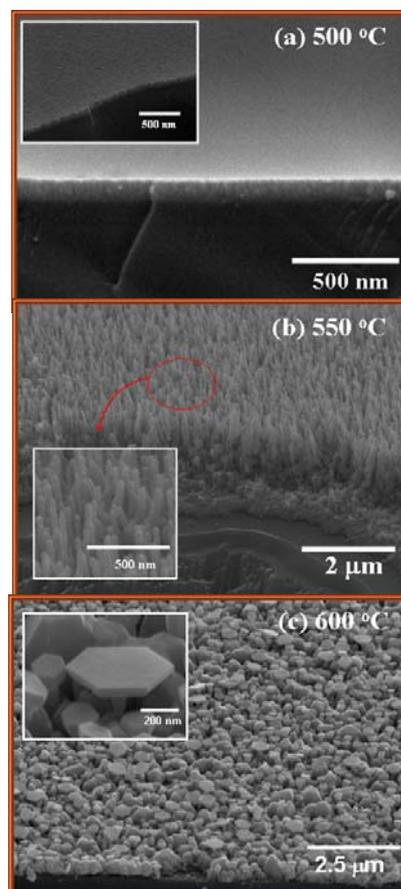


Fig. 3 SEM images of InN films grown at (a) 500 °C, (b) 550 °C and (c) 600 °C

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