InN nanorods growth: influence of temperature, catalyst, and gas flow rate

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Abstract. One dimensional (1-D) semiconductor nanostructures are attracting lots of attention due to their novel properties different from bulk and their potential application in nanodevices. Indium nitride (InN) is of particular interest for various optoelectronics and electronic applications, especially for field effect transistors due to its large drift velocity. However, the synthesis and characterization of InN nanostructures have not been studied comprehensively. In this work, the growth of InN nanorods was studied. It was found that the morphology of the nanorods was strongly dependent on the NH_3 flow rate and the catalyst used. Based on the obtained results, the possible growth mechanisms of InN nanorods are discussed.

INTRODUCTION

One dimensional (1-D) semiconductor nanostructures, such as nanowires and nanorods, have attracted a great deal of attentions due to their novel properties different from the bulk and their potential application in nanodevices. Among various semiconducting materials, indium nitride (InN) is of great interest for optoelectronic and electronic applications. It represents a good candidate for field effect transistors due to its large drift velocity [1], while InGaN ternary alloys are commonly used in light emitting diodes. However, the synthesis and characterization of InN nanostructures [2-4] have not been studied as comprehensively as other nitrides like GaN or BN. In this work, InN nanorods were synthesized by a chemical vapor deposition method. It was found that the morphology of the resultant nanostructures was strongly dependent on the NH_3 flow rate and the catalyst (e.g. Au, Ag, or In) used. The possible growth mechanisms of InN nanorods are discussed.

EXPERIMENTAL DETAILS

InN nanowires were fabricated on Si substrates by evaporating In at 800 °C in the flow of ammonia gas. In wire (Kurt J. Lesker, 1 mm diameter, 99.99% purity) was placed inside an alumina tube which was placed inside a quartz tube in a horizontal tube furnace. Si substrates coated with catalyst (150 Å of Au, Ag or In) were placed downstream of the In source. After the quartz tube was pumped down to ~10^{-1} Torr, the furnace was ramped up to 800 °C and kept for 30 minutes. Ammonia gas with flow rate of 75-125 sccm was introduced into the system throughout the reaction process, and the pressure was kept at ~10 Torr. After the synthesis, the gas supply was turned off and the furnace was cooled down to room temperature. The nanostructures were characterized by scanning electron microscopy using LEO 1530 FESEM, and energy dispersive X-ray spectroscopy (EDX).

RESULTS AND DISCUSSIONS

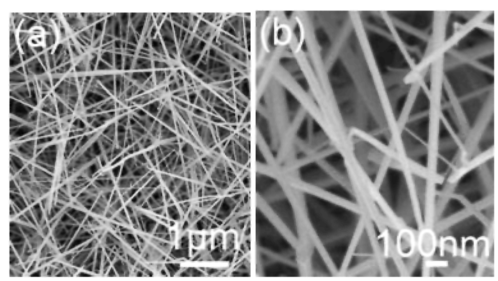

FIGURE 1. SEM images of the InN nanowires fabricated with 150 Å of Au at 400°C substrate temperature (a) Low magnification image (b) High magnification image.

Figure 1 shows the SEM images at different magnifications of InN nanostructures grown at 400°C with NH_3 flow of 125 sccm. The morphologies of the

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obtained nanostructures were found to be strongly dependent on gas flow, substrate temperature, and catalyst used.

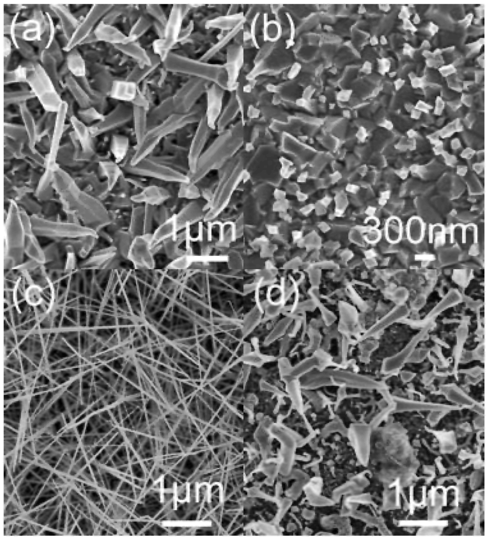

FIGURE 2. SEM images of the InN nanostructures fabricated with different thickness of Au (a) 25 Å at 400°C (b) 25 Å of Au at 550°C (c) 150 Å of Au at 400°C (d) 150 Å of Au at 550°C.

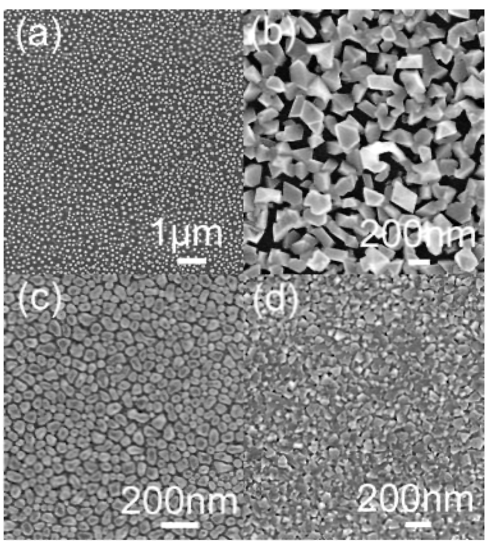

FIGURE 3. SEM images of the InN nanostructures fabricated with different catalysts (a) 150 Å of Ag at 400°C (b) 150 Å of Ag at 550°C (c) 150 Å of In at 400°C (d) 150 Å of In at 550°C.

When the NH_3 flow rate was reduced to 75 sccm, no growth was obtained. The morphology was also strongly dependent not only on the catalyst material but also on the catalyst thickness, as shown in Fig. 2 which gives a comparison of InN morphologies at two different substrate temperatures for Au thickness of 15 nm and 2.5 nm. When the catalyst is changed to Ag or In, significant differences are obtained as shown in Fig. 3. Although self-catalyzed growth of InN has been reported [4], strong dependence on the catalyst type and thickness indicates that InN nanostructures grow by vapor-liquid-solid mechanism, in agreement with previous results for InN nanorods [3] and nanowires [2]. Differences in InN nanostructure growth among different studies can be attributed to different experimental setups and different fabrication conditions. Since the obtained morphology is highly sensitive on fabrication conditions, differences for various fabrication methods are expected. Gold was found to be the most suitable catalyst for InN nanorods. It has been proposed that residual oxygen in the tube plays a role in the growth of InN nanorods due to low miscibility of Au and N [3]. Thus, it can be concluded that successful growth of InN nanostructures requires careful tuning of the growth conditions since successful results can be obtained only for certain catalyst materials and thickness, and in a narrow range of temperatures and gas flow rates.

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CONCLUSIONS

There is a very narrow growth window (in terms of temperature and gas flow) for successful fabrication of InN nanostructures. Out of the catalysts investigated, the best results are obtained from Au, while Ag results in inferior morphology and In results in no nanowire/nanorod growth.

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