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Synthesis, characterization and photoluminescence properties of Sn doped ZnO nanonails

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ABSTRACT

Vertically aligned undoped ZnO nanowires and Sn doped ZnO nanonails are synthesized on a silicon substrate using vapor–solid technique, without using a catalyst or predeposited buffer layers. The structure and morphology of the as-synthesized nanonails and nanowires are characterized using X-ray diffraction, scanning electron microscopy, transmission electron microscopy, selected area electron diffraction, and electron dispersive X-ray spectroscopy. The results showed that the use of $SnCl_2$ is critical for the formation of nanonails. Without it, only ZnO nanowires can be obtained. The photoluminescence properties are also investigated at room temperature. The UV peaks of undoped ZnO nanowires and doped nanonails are located at 379.5 and 385.4 nm, respectively. This red shift of 6 nm in the Sn doped samples indicates a reduction of the ZnO band gap caused by the Sn doping. The dominance of the green emission in the nanowires sample indicates that it exhibits a much higher defect concentration than the nanonails.

1. Introduction

Vertically aligned one-dimensional (1D) semiconductor nanowires represent a great promise for sensing applications [1], light-emitting diodes [2], lasers [3], photodetectors [4], and field-effect transistors [5]. Many physical and chemical synthesis methods have been developed to synthesize ZnO based nanomaterials with tailored morphologies and properties [6].The vapor–liquid–solid (VLS) process is widely used as the mechanism for growing one-dimensional structure, such as nanowires and nanorods [7–9]. In this process Zn vapor forms liquid-phase eutectic alloys with the catalytically particles and then condenses out as ZnO nanowires after reaching the supersaturating level. The disadvantage of the VLS route is that the catalyst often diffuses into the ZnO matrix during growth, creating deep traps within the band gap. On the other hand, the vapor–solid (VS) route requires no catalyst and appears to be more versatile [10,11]. The VS growth can produce a wide range of fascinating nanostructures, such as tetrapods, nanohelices, nanorings, nanocombs, and so forth [12]. It is noteworthy that many of these hierarchical nanostructures are created using a simple template-free vapor transport method. However, the formation mechanisms could be quite complex and often involves correlated factors such as intrinsic surface polarity, defect propagation, surface-dependent oxidation, and orientation-dependent growth speed [13–16].

Herein, we report the synthesis of Sn doped ZnO nanostructures that exhibit nanonails morphology. With most of the previous works concentrating on undoped ZnO, there have been more efforts devoted to investigate the doped counterparts [17–23]. For semiconductors, doping is a powerful tool to tailor the electrical and optical properties, facilitating the construction of many electronic and optoelectronic devices. Sn doping modifies the photoluminescence (PL) transitions in ZnO by creating localized impurity levels [24]. Additionally, Sn behaves as an acceptor in ZnO with its energy level locating at 0.1 eV below the bottom of the conduction band, making itself a good candidate for creating a p-type ZnO [25].

2. Experimental

2.1. Samples preparation

A schematic drawing of the experimental setup is shown in Fig. 1. Zn and $SnCl_2$ powders are chosen as source materials due to their low melting points (Zn 419 °C; $SnCl_2$ 247 °C). Both the Zn (0.5 g) and the tin chloride (0.05 g) powders were mixed carefully and ground for 30 min. The resulting source powder was then inserted into the bottom of a one-end sealed quartz tube with a diameter of 12 mm. The aim of this quartz tube is to concentrate the source vapor, which is critical for the formation of nanonails. Before the growth, this quartz tube was put into the center area of a horizontal furnace tube with the opening facing the direction of

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