Non-catalytic growth of high-aspect-ratio Sb-doped ZnO nanowires by simple thermal evaporation process: Structural and optical properties

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Well-crystallized high-aspect-ratio antimony (Sb)-doped ZnO nanowires have been successfully synthesized on Si(1 0 0) substrates in a large-quantity via simple thermal evaporation process by using metallic zinc and Sb powders in the presence of oxygen. It is observed from the detailed structural characterizations that the grown nanowires are well-crystallized with the wurtzite hexagonal phase and preferentially grown along the [0 0 0 1] direction. It was clearly seen from the high-resolution TEM images that the Sb-atom are successfully doped into the lattices of ZnO nanowires. The room-temperature photoluminescence (PL) spectrum exhibited a broad band in the visible region with a suppressed UV emission, indicating the presence of structural defects due to insertion of Sb-atoms in the lattices of as-grown nanowires. Due to the enhancement of green emission in the formed nanowires, these structures show great interest for typical applications of ZnO-based phosphors, such as field emissive display technology, etc.

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1. Introduction

Zinc oxide (ZnO), a II–VI wide band gap semiconductor with the wurtzite hexagonal phase, has received a great attention in recent years due to its exotic physical and chemical properties and various applications. The various extraordinary properties of ZnO include its direct and wide band gap (\textsim 3.37 eV), larger-exciton binding energy (60 meV) more than other semiconductor materials such as ZnSe (22 meV) and GaN (25 meV), high-break down strength, piezoelectric and pyroelectric properties, biocompatibility, easy and low-cost fabrication and so on. Due to its multifarious properties, it has been used in a variety of high-technological applications for the fabrication of various high-performance devices such as surface acoustic wave filters, photonic crystals, photodetectors, photodiodes, optical modulator, gas sensors, chemical and bio-sensors, varistors, solar cells, and etc. [1–11]. ZnO possess variety of morphologies, hence it is believed that it has highest family of nanostructures. Among diverse morphologies of ZnO, the 1D nanostructures of ZnO received special attention as these nanostructures are the ideal system for studying the transport process in one-dimensionally confined objects which are important for the development of high-performance nanodevices. Moreover, the high surface to volume ratio of these nanostructures makes them a promising candidate for the fabrication of novel and efficient nanodevices from electro-optical devices to sensors. Recently, the doping in ZnO nanostructures received a great attention, as by doping the properties (electrical and optical) of ZnO nanostructures can be tailored for specific and desired applications. To tailor the properties of ZnO nanostructures several doping elements have been used and reported in the literature such as Ga, In, P, Sn and etc. [1–12]. The p-type doping in ZnO is of particular interest these days. It is reported that p-type ZnO films can be achieved by Sb-doping [13,14]. There are very few reports in the literature which demonstrating the growth of Sb-doped ZnO nanowires [15]. Recently Zang et al. reported the growth of Sb-doped ZnO nanowires by using Zn and Sb2O3 powders in the presence of oxygen at 700°C [15]. In this work, a very simple, cost effective, non-catalytic growth method is presented for the synthesis of well-crystallized Sb-doped ZnO nanowires in a large-quantity. The nanowires were grown onto the silicon substrates at 650–700°C simply by using metallic zinc and Sb powders in the presence of oxygen. Importantly, the as-grown nanowires are straight and exhibited high-aspect-ratio which is important to utilize the grown nanowires for the construction of high-performance electronic and photonic nanodevices. The as-grown nanowires were characterized in terms of their structural and optical properties.

2. Experimental details

Well-crystallized Sb-doped ZnO nanowires were grown in a high-density on Si(1 0 0) substrate by non-catalytic simple thermal evaporation process by using metallic zinc and Sb powders in the presence of oxygen. In a typical reaction