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Short communication

Co-synthesis of ZnO/SnO_2 mixed nanowires via a single-step carbothermal reduction method

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Abstract

ZnO/SnO_2 mixed nanowires are fabricated by a single-step in-situ carbothermal reduction of mixed ZnO and SnO_2 powders with activated carbon under atmospheric pressure on a gold (Au) coated alumina substrate. Morphology and structural properties of the mixed nanowires are studied by field emission scanning electron microscopy (FESEM), X-ray diffraction (XRD) and transmission electron microscopy (TEM). FESEM investigation reveals the presence of uniform straight nanowires and branched hierarchical nanowires. The mixed nanowires have a diameter of about 15–80 nm and length ranging from two to several tens of micrometers, and thus having an aspect ratio above 1000. X-ray diffraction patterns show the crystalline nature of the ZnO/SnO_2 mixed nanowires. Elemental mapping in a TEM suggests that the ZnO and SnO_2 phases are mixed uniformly in the nanowire.

Keywords: B. Electron microscopy; ZnO/SnO_2 mixed nanowire; Hierarchical nanostructure; Carbothermal reduction

1. Introduction

One-dimensional metal oxide semiconductor nanostructures have attracted noteworthy attention from researchers because of their electrical, chemical and optical properties [1,2] which lead to potential applications in catalysis [3], chemical and biological sensors [3,4], photodetectors [5], and lithium-ion batteries [6]. Mixed oxide nanowires with hierarchical and core–shell structures have received considerable attention as they can offer improved electrical properties, such as carrier concentration and conductivity, suitable for photovoltaic (PV) energy conversion and chemical sensing [7]. Hybrid one-dimensional nanostructures of mixed metal oxide semiconductors, such as $SnO_2/W_{18}O_{49}$ [7], ZnO/SnO_2 [8–11], CeO_2/TiO_2 [12], TiO_2/ZnO [13], α-Fe_2O_3/SnO_2 [14], and α-Fe_2O_3/ZnO [15] have been synthesized by a variety of methods and they have shown better photovoltaic and chemical sensing properties compared to single oxide 1D structures. Among these oxides, ZnO ($E_g \sim 3.37$ eV) and SnO_2 ($E_g \sim 3.6$ eV) are wide band gap and key functional materials, which have been widely studied [16–19]. Recently, ZnO/SnO_2 mixed nanowires have been synthesized by a number of techniques, such as, vapor phase transport processes [20,21], the two-step carbon assisted thermal evaporation method [8,22], electrospinning [9,10], chemical vapor transport and condensation [23], and the hydrothermal method [20,24]. Until now, most of the ZnO/SnO_2 mixed nanostructures have been reported to be produced by a two-step method at low pressure, where each oxide is synthesized by the carbothermal reduction method sequentially. For example, Hwang et al. [8] synthesized ZnO/SnO_2 core–shell nanowires via a two-step carbothermal reduction method with pressure inside the system maintained around 10^{-2} Torr, while Lan et al. [22] produced hierarchical nanostructures at a pressure of 1 Pa.

This paper reports ZnO/SnO_2 nanowires synthesized by a single-step carbothermal reduction, which is a relatively facile method compared to the above mentioned techniques. All these methods except electrospinning and hydrothermal, are either governed by the vapour–solid (VS) mechanism or the catalyst assisted vapour-liquid-solid (VLS) mechanism. The work reported here employs the catalyst assisted VLS

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