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Investigation of tailored planar defects arising from ZnO tetrapods doped with In_2O_3

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ABSTRACT

4 mol% In_2O_3-doped ZnO tetrapods with bamboo shape legs (in terms of planar defects) have been grown controllably by thermal evaporation of Zn and In_2O_3 mixed source. It is found that the indium oxide dopants can get incorporated into the ZnO lattice to form O–In bonds, which are confirmed by X-ray photo-electron-spectroscopy (XPS) and the high resolution transmission electron microscopy (HRTEM). The detailed electron microscopy studies indicate that the structures of In_2O_3-doped ZnO tetrapods have the planar defects such as stacking faults and twins. The formation of the planar defects might be attributed to the high strain in the crystal caused by In_2O_3-insertion.

1. Introduction

ZnO tetrapods have the main advantages such as their multi-terminal nature, the junctions between different terminals and new functionality that may associate with these junctions [1]. Thus, the unique structures of ZnO tetrapods with natural junction attracted vast and persistent attention for a variety of applications, including detecting cathodoluminescence [2], gas sensing [3], ZnO photoanode for dye-sensitized solar cells [4] and microwave absorber [5].

Since defects in the structures of solid state materials are closely related to their physico-chemical properties, a variety of theoretical and experimental methods have been explored to study these interesting phenomena [6,7]. ZnO doped with other elements often affects the planar and point defects [8]. Deng et al. [9] reported that there existed planar defects in Sn-doped ZnO nanobelts and Ding [10] reported the dislocations in ultra-narrow ZnO nanobelts of 6 nm in width. Jeong [11] reported the 2D/3D defects in controlled-growth oxygen-deficient ZnO nanowires. Nevertheless, the tailored planar defects arising from ZnO tetrapods doped with In_2O_3 have seldom been reported.

Herein, lattice defects such as stacking faults and twins arising from ZnO tetrapods doped with In_2O_3 are investigated in detail via HRTEM. Furthermore, we do observe that unambiguously indium ions were incorporated into the ZnO lattice for the first time. The fundamental understanding of the planar defects is still scientifically important and could provide new insights for the formation and growth of dopants in ZnO.

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2. Experiments

For synthesis of In_2O_3-doped ZnO nanostructure, an appropriate amount of high purity Zn (purity, 99.99%) powders and In_2O_3 (purity, 99.99%) were mixed with a given molar ratio 4% and ground in agate mortar for 60 min. Then, the mixed powder in an amount of 2 g was loaded into an alumina boat and placed in a 1.2 m long aluminum tube, which was placed in a horizontal furnace. Initially, the aluminum tube was evacuated to 1 Pa and then it was purged Ar carrier gas at 70 SCCM (Standard Cubic Centimeter per Minute). Then, the furnace temperature was increased to 800 °C with a speed of 15 °C/min in the presence of Ar gas flow. Soon after the growth temperature was obtained, O_2 was added to the aluminum tube at the flowrate of 20 SCCM and the growth process was maintained for 30 min. On cooling to room temperature, a white woolly deposit was observed on the top of the alumina boat.

The typical planar defects arising from ZnO tetrapods doped with In_2O_3 were characterized using HRTEM (JEM-2010). The chemical analysis of In_2O_3-doped ZnO tetrapods was analyzed by XPS (K-ALTHA) measurement.

3. Results and discussions

XPS survey spectra shown in Fig. 1(a) are used to check the surface compositions and confirmed that only In, Zn and O are present in the as-prepared samples. Typical high resolution scans of Zn-2p and In-3d are shown in Fig. 1(b) and (c) respectively. The binding energies of Zn-$2p_{3/2}$ and Zn-$2p_{1/2}$ peaks are observed at 1021.88 eV and 1044.98 eV respectively. The energy difference between these two peaks is 23.1 eV, which agrees well with the

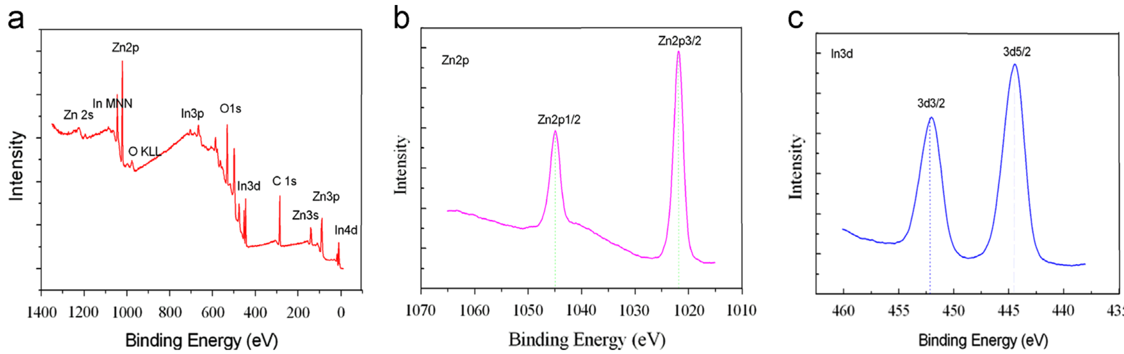

Fig. 1. XPS data for In_2O_3-doped ZnO Nanostructures, including (a)XPS survey spectrum core level, (b)spectrum of Zn 2p, and (c) In 3d.

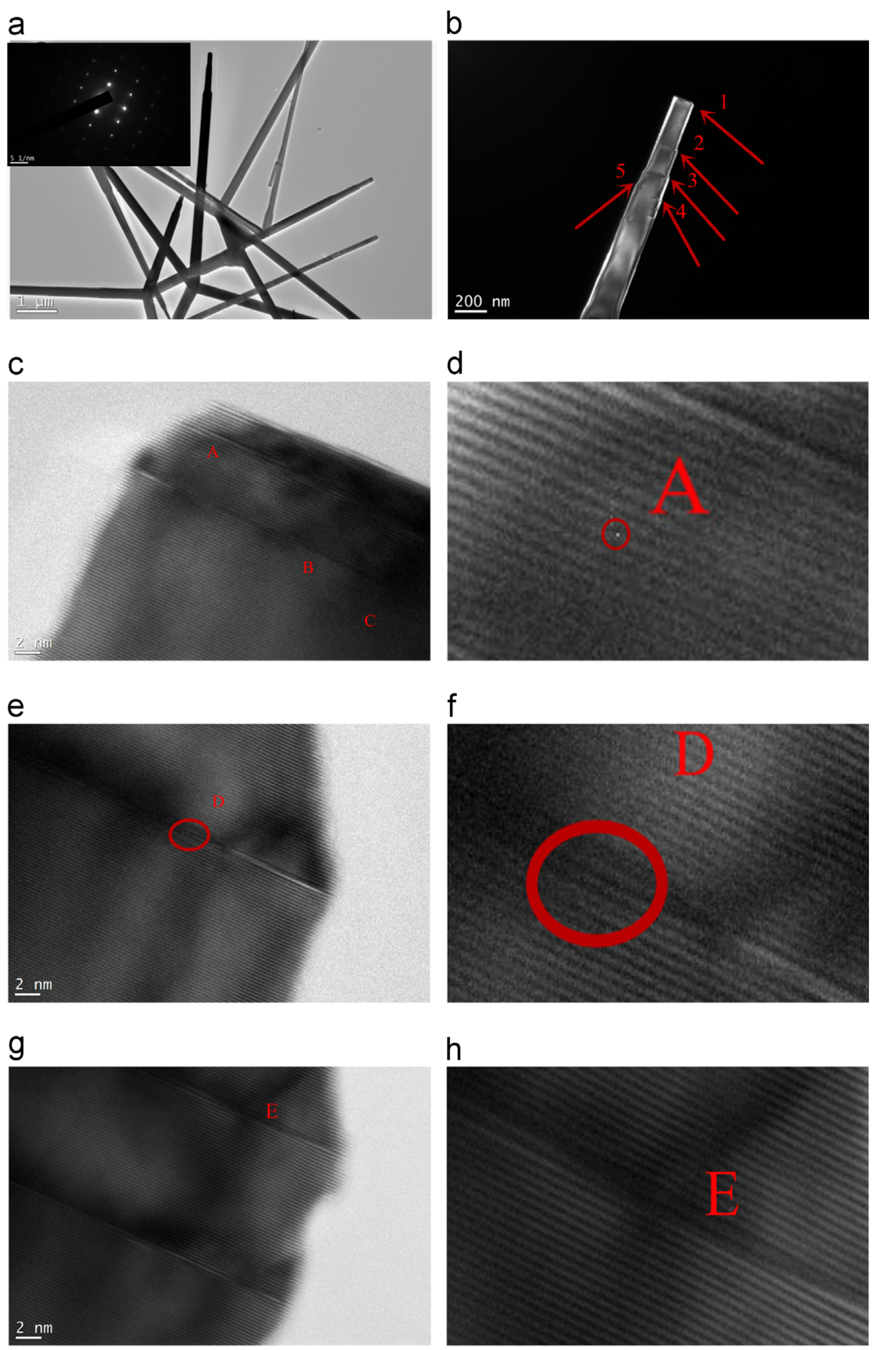

Fig. 2. (a) TEM and the corresponding SAED pattern of the ZnO nanostructure, (b) a typical TEM image of one leg from the tetrapod ZnO, (c, d) low and high HRTEM image for the top of the leg, (e, f) low and high HRTEM image of the stacking faults located on "2" in (b), and (g, h) low and high HRTEM image of the stacking faults located on "3" in (b).