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Journal of Crystal Growth 284 (2005) 142–148
JOURNAL OF CRYSTAL GROWTH
www.elsevier.com/locate/jcrysgro

Radial spherical ZnO structures with nanorods grown on both sides of a hollow sphere-like core

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Received 8 March 2005; received in revised form 15 June 2005; accepted 1 July 2005
Available online 15 August 2005
Communicated by R. Fornari

Abstract

Radial spherical ZnO structures with nanorods grown on both inside and outside of a hollow sphere-like core along the *c*-axis direction have been produced by thermal evaporation of Zn powder in the absence of catalysts. Scanning electron microscopy and X-ray diffraction investigation show that the radial spherical ZnO structures are of high purity nanocrystal with a wurtzite structure. It is found that the formation of the sphere-shaped liquid Zn droplets before adding oxygen is a key factor to control the morphology of the radial spherical ZnO structures. The radial spherical structures could possibly be used as a building block and open up new opportunities for the self-assembly of functional nanodevices.

PACS: 81.05; 81.15.G; 68.65

Keywords: A1. Nanostructures; A3. Chemical vapor deposition processes; B1. ZnO; B2. Semiconducting materials

1. Introduction

Nanostructures exhibit peculiar and fascinating properties compared with their bulk counterparts due to the minuscule structures. Since it is very important for future nanotechnology to synthesize nanostructures of different shapes, which could be the building blocks in self-assembled process, and the novel properties of nanostructures depend sensitively on their shape and size, the ability to generate new types of nanostructures and to understand the growth mechanism is essential to nanoscience and nanotechnology development. Recently one-dimensional (1-D) nanostructures,

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0022-0248/$ - see front matter
doi:10.1016/j.jcrysgro.2005.07.003

such as nanowires, nanorods, nanobelts, and nanotubes, draw intense research interest because of their potential applications as building blocks and interconnect integration in self-assembly process and nanodevices [1,2].

Zinc oxide (ZnO) is a versatile wide band-gap (3.37 eV) compound semiconductor material that has potential applications in UV lasers [3,4], field-emission displays [5], sensitive gas sensors [6], hydrogen storage material [7], varistors [8]. It is also a material that has various kinds of nanostructures whose configurations are much richer than any of the known nanomaterials. Except for the nanowires and nanobelts [9], other ZnO materials of varied geometries have been produced, e.g. nanocombs, nanorings, nanosprings [10], tetrapods [11], nanowalls [12] and microcages [13]. Recently, Hollow ZnO structures are of particular interest due to their lower densities with higher surface areas and may find potential applications in filters, coatings, capsule agents for drug delivery, or templates for functional-architectured composite materials [13]. In this paper, we report a radial spherical ZnO (RS-ZnO) structure with a hollow sphere-like core where nanorods are grown both inside and outside, using a simple method of thermal evaporation of Zn powder in the absence of catalysts. The RS-ZnO structures are found really interesting for their core structure which is a hollow sphere-like shell with nanorods grown inside towards the center of the sphere. Although radial structures have been reported before, such as dandelion-like structures with a hollow empty core [14], radial structures with a solid core [15] and needle-like rods whose center core structure is unknown [16], the structures of the core are different from that of our prepared samples. The RS-ZnO structures analogous to biomaterial-like morphology are fully characterized and a possible growth mechanism is discussed based on the experimental conditions.

2. Experimental procedure

The RS-ZnO structures are synthesized in a conventional furnace with a horizontal quartz tube (illustrated in Fig. 1), where the temperature, pressure, and evaporation time can be controlled easily. A little quartz tube loaded with Zn powder (purity: 99.999%) was placed in the high-temperature zone of the tube furnace. Si substrate (10 mm × 10 mm) prepared from P-type Si (1 0 0) wafer was positioned near the open end of the little tube at the downstream side. When the tube furnace was evacuated to 10 Torr by a mechanical pump, the chamber was heated to 650 °C in 25 min with a constant flow of 50 standard cubic centimeters per minute (sccm) of Ar and kept isothermal for 5–15 min. Once the chamber temperature reached 550 °C, a flow of 10 sccm of oxygen was introduced into the quartz tube. After the chamber cooled down to room temperature, the as-synthesized products on substrate were then characterized and analyzed by X-ray diffraction (XRD, MAC science M18X with Cu Kα radiation), scanning electron microscopy (SEM, JEOL-6360LV, equipped with an energy dispersive X-ray spectrometer (EDS)), and transmission electron microscopy (TEM, JEOL-2010).

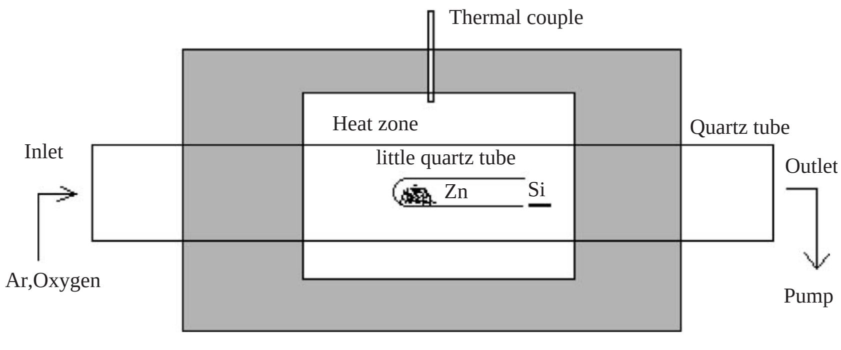

Fig. 1. Experimental set up for the synthesis of RS-ZnO nanostructures.