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A rapid hydrothermal synthesis of rutile SnO_2 nanowires

O. Lupan[a,b,*], L. Chow[a], G. Chai[c], A. Schulte[a], S. Park[a], H. Heinrich[a,d]

[a] Department of Physics, University of Central Florida, PO Box 162385, Orlando, FL 32816-2385, USA
[b] Department of Microelectronics and Semiconductor Devices, Technical University of Moldova, Stefan cel Mare Blvd. 168, Chisinau MD-2004, Republic of Moldova
[c] Apollo Technologies, Inc. 205 Waymont Court, S111, Lake Mary, FL 32746, USA
[d] Advanced Materials Processing and Analysis Center, and Department of Mechanical, Materials, and Aerospace Engineering, University of Central Florida, Orlando, FL 32816, USA

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ABSTRACT

Tin oxide (SnO_2) nanowires with rutile structure have been synthesized by a facile hydrothermal method at 98 °C. The morphologies and structural properties of the as-grown nanowires/nanoneedles were characterized by scanning electron microscopy (SEM), transmission electron microscopy (TEM), selected area electron diffraction, X-ray diffraction and Raman spectroscopy. The SEM images reveal tetragonal nanowires of about 10–100 μm in length and 50–100 nm in radius. The Raman scattering peaks indicate a typical rutile phase of the SnO_2. The effects of molar ratio of $SnCl_4$ to NH_4OH on the growth mechanism are discussed.

1. Introduction

A new generation of one-dimensional (1D) nanoarchitectures, such as nanowires, nanorods and nanoneedles has been produced and attracted considerable attention in the materials research community [1]. The interest is motivated by the physical and chemical properties, which are highly dependent on the aspect ratio and shape [1,2]. Extensive efforts have been made on developing new methods to synthesize, manipulate and tailoring functionalities of a variety of 1D nanostructured materials (SnO_2, ZnO, CdS, In_2O_3, etc.) [1–3]. Among them, rutile SnO_2, an n-type semiconductor with a wide band gap (Eg = 3.62 eV at 300 K), and excellent optical and electrical properties, is a strategic material for a range of technological applications [4]. Its practical uses include ultrasensitive gas sensors [5], optoelectronic devices [6], electrodes for solar cells [4] and anode material for lithium batteries [7].

SnO_2 nanoarchitectures have been synthesized by the self-catalytic vapor–liquid–solid (VLS) method [6], calcination process [7], chemical vapor deposition [8], thermal evaporation [1], hydrothermal [9], laser ablation technique [10], solvothermal [11] and carbothermal reduction [12]. These techniques all require a growth temperature of 900 °C or higher, which makes them difficult for certain device applications and which are often difficult to control reproducibly [13]. Guo et al. [14] has reported a low-temperature hydrothermal synthesis of SnO_2 nanorods at 160 °C, but the process requires at least 12 h. Vayssieres and Graetzel [15] reported SnO_2 nanorods arrays grown on F-SnO_2 glass substrates by aqueous thermohydrolysis at 95 °C.

This paper presents an inexpensive and rapid fabrication technique for one-dimensional (1D) tin oxide (SnO_2) nanowires with rutile structure synthesized by a facile hydrothermal method at 95–98 °C for 15 min. It permits rapid and controlled growth of tin oxide nanowires without the use of templates or seeds. The obtained tin oxide nanowires are distributed on the surface of Si/SiO_2 substrates and individual nanowires can be easily transferred to other substrates which are decisive factor for single nanowire ultrasensitive sensors fabrication.

Our technique is faster and cost-effective, which is important for large scale applications in nanoelectronics/nanotechnologies and can find a wide range of applications.

2. Experimental

Rutile-structured SnO_2 nanowires/nanoneedles were synthesized at a low temperature by a hydrothermal method without any other seeds, templates or surfactant. A solution containing tin chloride [$SnCl_4 \cdot 5H_2O$, 0.01–0.03 M] (purity 99.5%) and ammonia [$NH_4(OH)$, 29.5%] (Fisher Scientific) was employed for growth of tin oxide nanowires and nanoneedles. Both reagents were used in the received form without further purification. A hydrothermal reactor [3] with a cap was filled with aqueous solution. In a typical procedure, Si wafers and glass substrates were cleaned according to

* Corresponding author at: Department of Physics, University of Central Florida, PO Box 162385, Orlando, FL 32816-2385, USA. Tel.: +1 407 823 2333; fax: +1 407 823 5112.
E-mail addresses: lupan@physics.ucf.edu, lupanoleg@yahoo.com (O. Lupan).

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