Synthesis and Characterizations of ZnO Nanorods Arrays and Mesoporous Films for Device Applications

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ABSTRACT

We present a novel aqueous-solution synthesis technique to obtain uniform ZnO nanorod arrays with good crystalline and mesoporous films. This technique was preferred for reasons related to economical and ecological advantages, low-temperature and the flexibility to tailor the nanorod sizes and shapes, density and properties by doping and solution conditions. Most attention is paid to an aqueous-based solution route that involves the formation of a nanorods by hydrolysis, condensation and complexation reactions of metal salts without any templates and seeds.

Scanning electron microscope (SEM), transmission electron microscope, Rutherford backscattering (RBS), energy dispersive X-ray analysis (EDX), and X-ray diffraction (XRD) were used for materials characterization.

The high sensitivity and stability of sensors made from ZnO nanorods and nano/mesoporous films demonstrate the potential for developing a new class of nanosensors and nanodevices for industrial applications.

Keywords: ZnO, nanorods, mesoporous, nanosensor.

1 INTRODUCTION

The synthesis and characterization of one-dimensional (1-D) nanoarchitectures (nanorods, nanowires and nanotubes) have received tremendous interest due to their unique physiochemical properties and their novel potential applications in novel nanodevices [1-4]. Significant efforts have been concentrated on semiconducting oxides such as SnO_2, TiO_2, WO_3, CeO_2, Cu_2O, ZrO_2, and ZnO. Among them zinc oxides – key functional materials – are especially interesting since they have important applications in a wide area of high-tech applications such as nanoscale electronics, optoelectronics, magnetoelectronics, transducers, sensing systems, and biomedical applications.

The small dimension of the ZnO nanostructures promises increase in device packing density, decrease in power consumption, and an increase in sensitivity in chemical sensing applications. Gas sensing with nanorods and nanowires are performed by monitoring of the electrical resistance change when exposed to a specific gas. 1D nanoarchitectures have very small radii with a larger surface-to-volume ratio that is very susceptible to altered electrophysical properties by chemisorption in the chemical environment. When the diameter becomes compatible to the Debye screening length, chemisorption induced surface states effectively alter the electronic structure of the system.

Synthesis and study of nanorod based solar cells and chemical sensors are quickly directed towards developing alternative, lightweight, flexible nanodevices for wide area of commercial applications [1-6]. Many research papers have been published in recent years, in the area of dye sensitized solid-state solar cells in particular, which is currently the most stable and efficient excitonic solar cell for large-scale solar energy conversion [6-7]. One-dimensional ZnO nanorods, with their high carrier mobility serve as the direct conduction pathways for the excitons. Also it is of importance to synthesize a porous structure with a high interfacial area to allow the creation of a 3-dimensional interpenetrating network between the semiconductor/dye and the solid-state electrolyte.

Much effort has been devoted for the preparation of 1D ZnO nanoarchitectures [1-8] using various methods, including vapor-liquid-solid (VLS), vapor-solid (VS) [9] processes, metal-organic chemical vapor deposition (MOCVD) [2], chemical vapor deposition [10], solution-liquid-solid growth in organic solvents [11], and a template-based method [12].

In this work we present a novel aqueous-solution synthesis technique to obtain size-controllable and uniform dimensional ZnO nanorod arrays with good crystalline and mesoporous films on glass and conducting substrates. The change of the morphology, structure orientation and composition of the ZnO is controlled through solution conditions.

2 EXPERIMENTAL

The conventional method to synthesize ZnO nanorods is undesirable, due to high-energy consumption, complicated and severe conditions. At the same time the use of catalysts or template brings impurities into the final nano-structures, which influence on the adherence and the purity of ZnO nanoarchitecture, on their electrical, light emission and sensitivity properties. Thus, the fabrication of ZnO nanorods with high purity and at low cost requires a simple