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Effects of initial precursor and microwave irradiation on step-by-step synthesis of zinc oxide nano-architectures

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ABSTRACT

ZnO nano-architectures were produced with the aid of a fast, simple and low cost microwave-assisted synthesis method. Solid semispherical ZnO nanoparticles on the order of 600 nm in diameter along with rice-like ZnO nanorods 95 nm thick were produced from butanol, triethanolamine (TEA), and zinc acetate dihydrate. Solid spherical ZnO nano-architectures with an average diameter of 250 nm were produced from the same starting materials in addition to NaOH. X-ray diffraction, scanning electron microscopy, and transmission electron microscopy were used to characterize the ZnO nano-architectures as well as the precursor. This method is cheap, fast and simple; capable of producing large quantities of each ZnO nanostructure. Investigation of the step-by-step formation mechanism for each ZnO nanostructure was conducted.

1. Introduction

As an important wide-band-gap semiconductor, ZnO has a variety of applications including varistors, transparent conductors, transparent UV-protection films, chemical sensors, and so on [1–4]. Recently, synthesis of ZnO nanostructures has attracted considerable interest due to the potential applications. Up to now, much work has been published on synthesis and characterization of different ZnO nanostructure materials. However, during synthesis, complex conditions and long synthesis time were required for these technologies. Microwave treatment is a special heating method by which microwave radiation is used as a heat treatment; it has been used to synthesize various materials [5–8]. Compared with the conventional heating, microwave heating has unique effects such as rapid homogenous volumetric heating, high reaction rate, short reaction time, enhanced reaction selectivity and is energy efficient. Since the first report of microwave-assisted synthesis in 1986 [9,10], the application of microwave heating for the synthesis of inorganic materials has been rapidly growing [11,12]. In this present work, we investigate step-by-step fabrication process of two ZnO nano-architectures via microwave heating. Reaching this goal, we have studied the effects of NaOH as an additive in addition to microwave heating of the precursor on the obtained ZnO nanostructures and have presented probably formation mechanisms.

2. Experimental details

In this work, different ZnO nanostructures were synthesized through a simple, fast solution chemical and microwave assisted route. Synthesis was carried out at room temperature using butanol ($C_4H_{10}O$), triethanolamine (TEA) [$N(CH_2CH_2OH)_3$], zinc acetate dihydrate [$Zn(CH_3COO)_2.2H_2O$], and NaOH as the initial materials. All reagents were used as received without further purification and purchased from MERCK Chemical Co. Ltd. Deionized water was employed both in solutions preparation and cleaning procedures. In a typical procedure synthesis route, 10 ml triethanolamine (TEA) was dissolved in 100 ml butanol and 10 ml H_2O while stirring vigorously at room temperature. The initial pH of this solution was measured to be about 10.75. Following this step, zinc acetate dihydrate crystals were added gradually to the solution under rapid stirring until the final pH was adjusted to 8. A milky, white solution was obtained from this step which was termed the precursor. The obtained white precursor was divided into three parts. The first part was centrifuged, and the settled white precipitate was separated, washed with acetone and deionized water several times and dried in oven at 55 °C for 16 h (sample I). The second part was heated in a microwave oven (2.45 GHz, single mode, Tecnokit3610) for 40 s reaching the temperature 110 °C, and the obtained white powder washed with acetone several times and dried in oven (sample II). NaOH pellets were gradually added to the third part of the precursor until a pH of 10 was obtained. This solution was then heated by microwave oven for 60 s and the viscous, white solution was washed and dried in an oven (sample III). Each reaction resulted in the production of a crystalline powder with each examined in terms of their morphology and chemical property. Chemical analysis was

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