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Self-assembly of ZnO nanoparticles and subsequent formation of hollow microspheres

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Abstract

Nanostructure ZnO hollow microspheres with average crystallite size of about 15 nm, and average diameter of about 1 μm, were successfully fabricated through a novel hydrothermal method. Hollow microspheres were formed due to self-assembly of ZnO oblong nanoparticles, which resulted in formation of a protrusive surface nanostructure. The obtained material was characterized with X-ray diffraction pattern (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and photoluminescence (PL) investigations. The photoluminescence characterization of the nanostructure microspheres exhibited a UV irradiation at around 380 nm and a broad visible emission band centered at green region.

Keywords: Nanostructured materials; Oxide materials; Chemical synthesis; Nanofabrication; Optical properties

1. Introduction

Due to its direct and wide band gap (3.37 eV) and large exciton binding energy (60 meV) [1], zinc oxide (ZnO) is a versatile semiconducting material with efficient excitonic emission at room temperature and unique acoustic [2], electronic [3], catalytic [4] and photocatalytic properties [5], which make it an appropriate material for various applications such as sensors [6], solar cells [7], varistors [1], electroluminescent [8] and optoelectric devices [9]. Among various morphologies which were reported previously for ZnO nanostructures (i.e. nanotubes [10], nanowires [11], nanorods [12] and flowerlike nanoarchitectures [13]) hollow structures have attracted researchers due to their considerable low densities, high surface areas, biocompatibility [14] and unique optical, electrical and surface properties [15], which make them potentially applicable in electronics, optoelectronics, complex hierarchical assemblies [16] and drug delivery systems [17]. Hollow micro- and nanostructures can be produced either with the help of removable or sacrificial templates [18–20] or through self-assembly mechanisms such as Kirkendall effect [21], Ostwald ripening [22] and hydrophobic interactions [23].

Self-assembly of nanoparticles and subsequent formation of well-defined nanostructures has very interesting applications in nanosciences and nanotechnology [24,25]. Such a mechanism relies on weak non-covalent bonds, such as hydrogen and ionic bonds, or van der Waals and hydrophobic interactions [26], and can be applied to fabricate various complex micro- and nanostructures, such as micelles, films, membranes, tubes, rods, mesophases, particles [27,28] and hollow structures [29,30].

In this paper, we introduce a facile template-free hydrothermal route for fabrication of nanostructure hollow microspheres through self-assembly of ZnO nanoparticles and have utilized room temperature photoluminescence spectroscopy to characterize their structural properties.

2. Experimental procedure

All the materials were of analytical grade and were purchased from Merck, Germany. In a typical procedure, a mixture of 100 ml ethanol (C_2H_5OH) and 10 vol.% of triethanolamine (TEA, $C_6H_{15}NO_3$) was prepared. Zinc acetate dehydrate [$Zn(CH_3COO)_2 \cdot 2H_2O$] crystals were added to the initial solution under

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