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Facile synthesis and optical properties of Co_3O_4 nanostructures by the microwave route

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ABSTRACT

Cobalt oxide (Co_3O_4) nanoplatelet shape like nanostructures have been successfully synthesized through a simple microwave route for the first time using cobalt acetate, NaOH and citric acid at 200 °C for 30 min. The structure and morphology of as-prepared Co_3O_4 nanoplatelets are characterized by means of powder X-ray diffraction (XRD), Fourier transform infrared spectrum (FTIR), and scanning electron microscope (SEM). XRD measurements indicate that the product has a perfect crystalline cubic phase of Co_3O_4 with a lattice constant $a = 8.082$ Å. The SEM images show that the obtained Co_3O_4 nanopowder consists of nanoplatelets with diameter 125 nm and thickness 20 nm. Energy-dispersive X-ray spectroscopy (EDS) show that the composition of Co_3O_4 is stoichiometric. Room temperature photoluminescence measurement is exhibited by a strong UV emission and a suppressed green emission, confirming the good optical properties for the as-prepared Co_3O_4 nanoplatelets.

1. Introduction

Recently, nanostructure metal oxide semiconductors have attracted much attention due to their technological applications and intriguing properties [1]. The unique physical properties of nanoparticles, due to surface or quantum-size effects, have recently been the subject of intense research, in terms of both scientific interest and industrial application and present new challenges

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for the chemist [1,2]. The advantages of the microwave-assisted hydrothermal process over the conventional hydrothermal method are (a) extremely rapid kinetics of crystallization, (b) very rapid heating to the required temperature and (c) possible formation of new meta-stable phases [3]. Recently, one and/or two dimensional nanostructures have pulled a great attention towards itself due to their exotic, tremendous and marvelous qualities in the electrical, optical, thermal, and mechanical properties as compared to their bulk materials. It is pivotal for the preparation of materials in order to obtain excellent quality. For this reason, a wide variety of chemical and physical methods have been used for the production of Co_3O_4 nanoparticles such as polymer combustion [4], sol–gel [5], co-precipitation [6], ball milling [7], chemical vapor deposition (CVD) and others. Transition metal oxides find many applications because of the interesting properties arising due to the variable oxidation state of the transition metals. Another major implication of imposing nanoscale structural morphology upon transition metal oxides is the alteration of magnetic properties. It is well known that Co_3O_4 has a normal spinel structure and bulk Co_3O_4 exhibits anti-ferromagnetism with the Neel temperature at around 30 K [8]. Cobalt oxide (Co_3O_4) belong to the family of transition metal oxides and the most stable phase Co_3O_4 is an intrinsic p-type semiconductor (direct optical band gap at 1.48 and 2.19 eV) [9]. It is very important because of its application as excellent catalyzing material with high temperature stable up to 800 °C in air, gas sensing, magnetic materials, electro-chromic devices [10], electrochemical systems [11], and high-temperature solar selective absorbers [12], field emitters, electrode material (anode) for lithium-ion batteries, gas sensor, and so on. Hence, the preparation of nanosize Co_3O_4 particles is significant. Therefore the preparation of pure nanosize substances is very important not only for the study of their properties but also for their applications. To our knowledge, there is no report on the preparation and study of pure Co_3O_4 nanoparticles synthesized by microwave route. In this paper, we present the synthesis of Co_3O_4 nanoplatelets prepared simply through microwave route. The structure and morphology of as-prepared Co_3O_4 nanoplatelets were characterized by powder X-ray diffraction (XRD), Fourier transform infrared spectrum (FTIR), and scanning electron microscope (SEM). The optical properties of Co_3O_4 nanoplatelets were examined, too.

2. Experimental

2.1. Synthesis of Co_3O_4 nanoplatelets

For the synthesis of Co_3O_4 nanosheets, analytical grade cobalt acetate ($C_4H_6CoO_4$) (Aldrich), sodium hydroxide (NaOH) (Aldrich), citric acid were used as received without further purification. In a typical reaction process for the growth of Co_3O_4, 0.11 mol of cobalt acetate was dissolved in 100 ml distilled water and stirred for 30 min at room temperature. Simultaneously, a 15 ml NaOH (5 mol) was added drop wise into this aqueous cobalt acetate solution under vigorous stirring for 30 min with control pH $=$ 10. In addition, 1 g of citric acid was used as a capping agent. All the above solutions were placed in a microwave hydrothermal Teflon cell; the temperature was increased from room temperature to 200 °C for 10 min and maintained at the final temperature for 30 min. The system was then allowed to cool to room temperature. Microwave power was 1000 W. The products deposited at the bottom of the vessel. The resulting powder was washed with distilled water several times and then filtered with water, and subsequently left to dry in open air. In the end, the cobalt oxide (Co_3O_4) nanoplatelets can be obtained.

2.2. Instrumentation

The X-ray measurements were performed using Philips X'pert diffractometer supplied with copper X-ray tube ($\lambda_{k\alpha 1} = 1.5406$ Å), nickel filter, graphite crystal monochromator, proportional counter detector, divergence slit 1° and 0.1 mm receiving slit. The working conditions were 40 kV and 30 mA for the X-ray tube, scan speed 0.05° and 2 s measuring time per step. For each measurement, a complete scan was made between 10° and 70° (2θ°). To calibrate the measured Bragg 2θ-angles, a standard reference material (SRM 640a) of pure Si powder was used.