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Synthesis and room temperature photoluminescence of ZnO/CTAB ordered layered nanocomposite with flake-like architecture

Y.D. Wang[a,*], S. Zhang[a], C.L. Ma[b], H.D. Li[b]

[a]Department of Materials Science and Engineering, Yunnan University, 650091 Kunming, PR China
[b]Department of Materials Science and Engineering, Tsinghua University, 100084 Beijing, PR China

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Abstract

Flake-like ZnO/surfactant ordered layered nanocomposite has been synthesized by self-assembly at room temperature with the presence of cetyltrimethylammonium bromide (CTAB, $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$) surfactant. The procedure described in this study is attractive since it gives high yields of ordered layered nanocomposite with flake-like architecture. XRD results showed the formation of a layered structure with two layered spacings ca. 18.56 Å. SEM and FT-IR spectroscopy were used to further characterize ZnO/CTAB nanolayered composite. The ZnO/CTAB-ordered layered nanocomposite exhibits the room temperature photoluminescence (RTPL) characteristics. It is inferred that the RTPL of ZnO/CTAB-layered nanocomposite might be induced by the interfacial effect between the ZnO and the surfactant.

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Keywords: Nanocomposite; Ordered layered structure; Self-assembly; Room temperature photoluminescence

1. Introduction

One- and two-dimensional nanostructured materials with diverse morphologies, such as nanowires, nanorods, nanosheets, nanobelts, nanoribbon and so on, have been extensively studied due to their novel physical properties and potential applications. Nanosheets with different compositions have been explored using various methods including the vapor–liqiud–solid (VLS) process [1], vapor–solid (VS) process [2,3], a template-based method [4], solution [5,6], and the Langmuir–Blodgett (LB) technique [7].

ZnO is a promising luminescent semiconductor material with wide a band gap (3.37 eV), large exciton binding energy (60 meV) and used for various applications such as vacuum fluorescent displays due to its non-linear optical property and room temperature ultraviolet emission. Although needle crystal and large whiskers have been previously reported [8–10], most of the ZnO nanomaterials studied are in the form of nanoparticles. Polycrystalline ZnO nanowires [11], ZnO cluster and thin films have been prepared and shown to exhibit room temperature UV-lasing properties [12–14]. However, to our knowledge, preparation of the ZnO nanosheets and relative to its properties of room temperature photoluminescence (RTPL) has rarely been mentioned. For the inorganic materials, a large part of the nanosheets has been focused on semiconductor materials such as Pt [15], Ga_2O_3 [3], ZnS [4–6], MgO [2], TiO_2 [7,16] and Ag–GO [17] in the literature. In this paper, we report the synthesis and characterization of ZnO/CTAB ordered layered nanocomposite, of which morphology appears to be distinctively different from the ones reported in the literature. A simple method to synthesize nanosheets of zinc oxide has been developed.

2. Experimental

2.1. Reagents and materials

All the chemical reagents used in the experiments were obtained from commercial sources as guaranteed-grade

*Corresponding author. Tel.: +86 871 5031410; fax: +86 871 5153832.
E-mail address: ydwang@ynu.edu.cn (Y.D. Wang).

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reagents and used without further purification and treatment. All the chemicals were analytical grad.

The synthesis method was based on using a cationic surfactant cetyltrimethylammonium bromide (CTAB): $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$), as structure directing agent, and the simple chemical materials $ZnCl_2$ and NH_4OH as inorganic precursor and counter ions, respectively. Reaction was performed at room temperature. The synthetic procedure was as follows: (1) 5.47 g CTAB was mixed with 60 ml distilled deionized water with stirring until a homogenous solution was obtained, (2) 4 ml of NH_4OH (25 wt% solution) was mixed with 16 ml distilled deionized water, (3) the solution of diluted NH_4OH was then added into the CTAB solution with stirring, (4) when the mixing solution became homogenous, a Zn^{2+} solution of 1.36 g $ZnCl_2$ diluted with 25 ml distilled deionized water was introduced, producing a white slurry, (5) after stirring for 2 h, the product was aged at room temperature for 450 h, and (6) the resulting product was filtered, washed with distilled water and dried at ambient temperature.

2.2. Instrumentation

The as-synthesized products are flake like with a white color. The structure was analyzed and characterized by X-ray diffraction (XRD, Rigaku D/max-RB diffractometer with Cu-K_α radiation, $\lambda = 1.5418$ Å) operated at 150 mA and 45 kV, scanning electron microscopy (SEM, JSM 6301F), transmission electron microscopy (TEM) (200CX at 200 kV). Thermogravimetric analysis (TGA) curve was obtained in flowing air on TGA2050 with a temperature increasing rate of 10 °C/min. Photoluminescence (PL) measurements were carried out at room temperature using 345 nm wavelength as the excitation wavelength with a HITACHI 850 type visible-ultraviolet spectrometer with a Xe laser as the excitation source.

3. Results and discussion

XRD patterns of different products are shown in Fig. 1. The pattern of zinc oxide/surfactant composite contains only a series of low angle peaks in the range of 1–23° (Fig. 1a). These equidistant diffraction peaks have been recognized to arise from a layered nanostructure. On the basis of the XRD results, the interlayer distance of the zinc oxide/surfactant composite ordered layered nanostructure is determined to be 18.56 Å. Energy dispersive X-ray (EDX) analysis of the nanolayered zinc oxide/surfactant composite gave a great deal of Zn and O, indicating that this oxide had the expected composition. In addition, both N and C singles were detected in the EDX spectrum. In contrast, after removing the CTAB template, no N signal was detected in the EDX spectrum.

Thermogravimetric analysis (TGA) of the as-synthesized sample under air shows three apparent decreases in specimen weight (Fig. 2). The first is over the temperature range from room temperature to ca. 177 °C, the second is over the temperature range from 177 °C to ca. 249 °C, and the third is from 249 to 500 °C. The loss of water is below 180 °C and surfactant loss started at 180 °C and was completely removed at about 500 °C. The analysis of the as-synthesized sample reveals ~29% total weight loss on heating to 500 °C. Based on the mass loss, the product of the starting material is $(ZnO)_{14.1} \cdot (H_2O)_{5.5} \cdot$ CTAB. Presumably, the first effect is attributed to the release of

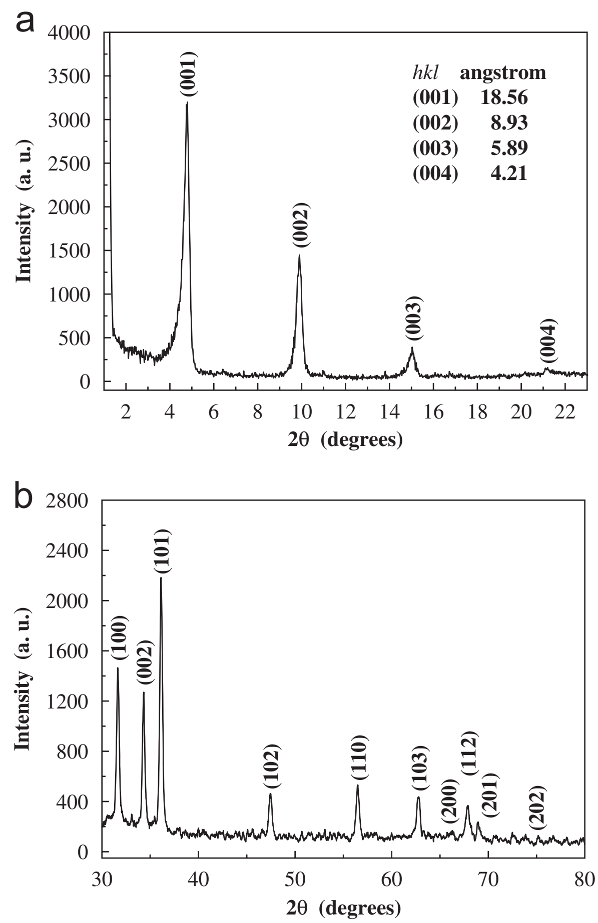

Fig. 1. XRD pattern of the result products: (a) a nanolayered as-synthesized product obtained by self assembly of $ZnCl_2$ and surfactant CTAB and (b) calcined at 500 °C for 2 h.

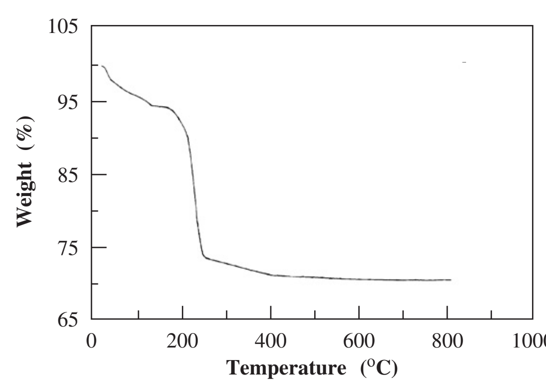

Fig. 2. TGA trace recorded for the as-synthesized layered nanocomposite sample.