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Preparation, structure and photoluminescence properties of SiO_2/ZnO nanocables via electrospinning and vapor transport deposition

X.H. Li [a], C.L. Shao [a], Y.C. Liu [a,*], X.T. Zhang [b], S.K. Hark [b,*]

[a] Center for Advanced Optoelectronic Functional Materials Research, Northeast Normal University, 5268 Renmin Street, Changchun 130024, People's Republic of China
[b] Department of Physics, The Chinese University of Hong Kong, Shatin, Hong Kong, People's Republic of China

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Abstract

SiO_2/ZnO nanocables were prepared by the combination of electrospinning technology and vapor transport deposition procedure. X-ray diffraction patterns indicated that ZnO with wurtzite structure was deposited on SiO_2 nanofibers templates successfully. Field emission scanning electron microscopy and transmission electron microscopy showed that the products were core/shell nanocables with a narrow distribution of the core/shell diameters. The nanocables showed a strong near band edge emission in ultraviolet region and a weak deep level emission at room temperature in their photoluminescence (PL) spectra. The anomalous temperature characteristic of integrated PL intensity in temperature-dependent PL spectra was discussed by considering carrier injection across the interface of SiO_2/ZnO nanocables.

Keywords: Nanocomposites; Luminescence; Electrospinning; Vapor transport deposition

1. Introduction

ZnO is a II–VI semiconductor of great interest due to its direct wide band gap (3.3 eV) and large exciton binding energy (about 60 meV) [1]. As an excellent ultraviolet light emitting material, optical properties of ZnO have been widely studied, in particular their photoluminescence (PL) properties [2]. One dimensional ZnO nanostructures such as ZnO nanorods, nanowires etc. have been well studied as they can be used in electronic or optoelectronic nanodevices [3], chemical sensors [4], and field emitters [5,6] etc. As it is well known, vapor transport deposition is a very simple and low cost method for fabricating one dimensional nanostructures such as nanowires, nanobelts, nanotubes [7,8] etc. The ZnO nanostructures prepared by vapor transport deposition usually have good ultraviolet emitting properties due to their high crystal qualities.

In this work, SiO_2 nanofibers prepared by electrospinning were used as templates for the vapor transport deposition process of zinc oxide. Electrospinning is a versatile method to prepare nanofibers [9] of organic polymer, inorganic oxide, and nanocomposites. Nano- to microscale fibers could be obtained by varying the parameters of electrospinning. Several methods, such as a rotating collector [10], grounded conductive substrates [11], and specially designed electrodes to control the electrostatic field [12], have been introduced to electrospin aligned nanofibers which could make them useful in electronic and optical devices. Compared to organic polymer nanofibers, SiO_2 nanofibers prepared by electrospinning are chemically and thermally stable. They are outstanding carriers for functional nanostructure composites.

2. Experiments

In our experiments, SiO_2 nanofibers were prepared by calcining the nanofibers of poly(vinyl alcohol)/silica precursor. Pure zinc powders (99.999%) were used in vapor transport deposition. SiO_2 nanofiber mats were placed in two ceramic boats at the distances about 5–10 cm and 20–25 cm from zinc source at the end of a horizontal quartz tube. Normal N_2 gas was used as carrier gas at a

* Corresponding authors. Tel./fax: +86 431 85099168.
E-mail addresses: ycliu@nenu.edu.cn (Y.C. Liu), skhark@phy.cuhk.edu.hk (S.K. Hark).

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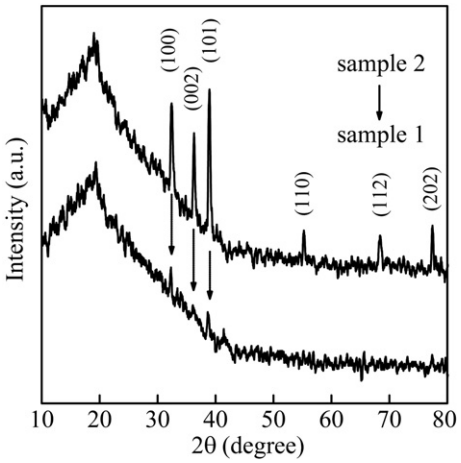

Fig. 1. XRD patterns of sample 1 and sample 2.

flux of 2 L/min. The deposition temperature was kept at 600 °C for 2 h. The products were named as sample 1 (5–10 cm) and sample 2 (20–25 cm) in the following discussions.

Field emission scanning electron microscopy (FESEM) was used to characterize the surface morphologies of the products while the cross sections were characterized by TEM (Hitachi 600). The X-ray diffraction (XRD) measurements were carried out using a D/max-RA X-ray diffraction spectrometer (Rigaku) with Cu Kα line of 0.1541 nm. PL spectra were collected with a Jobin-Yvon HR800 micro-Raman spectrometer using the 325 nm line of a He–Cd laser as the excitation source.

3. Results and discussion

XRD patterns of samples 1 and 2 are shown in Fig. 1. A broad peak around $2\theta = 22°$ origins from the amorphous SiO_2 nanofiber templates. The diffraction peaks of (100), (002), (101), (110), (112) and (202) in the spectra could be indexed to be hexagonal wurtzite structure of zinc oxide [13]. The diffraction peaks of (100), (002) and (101) from sample 1 are much weaker than that of the sample 2. The XRD results prove that ZnO has been deposited on the templates of SiO_2 nanofibers successfully.

Fig. 2(a) shows FESEM images of SiO_2 nanofibers. The nanofibers with average diameter about 200 nm are extremely long in length. After the deposition process, FESEM images of the products (not shown) do

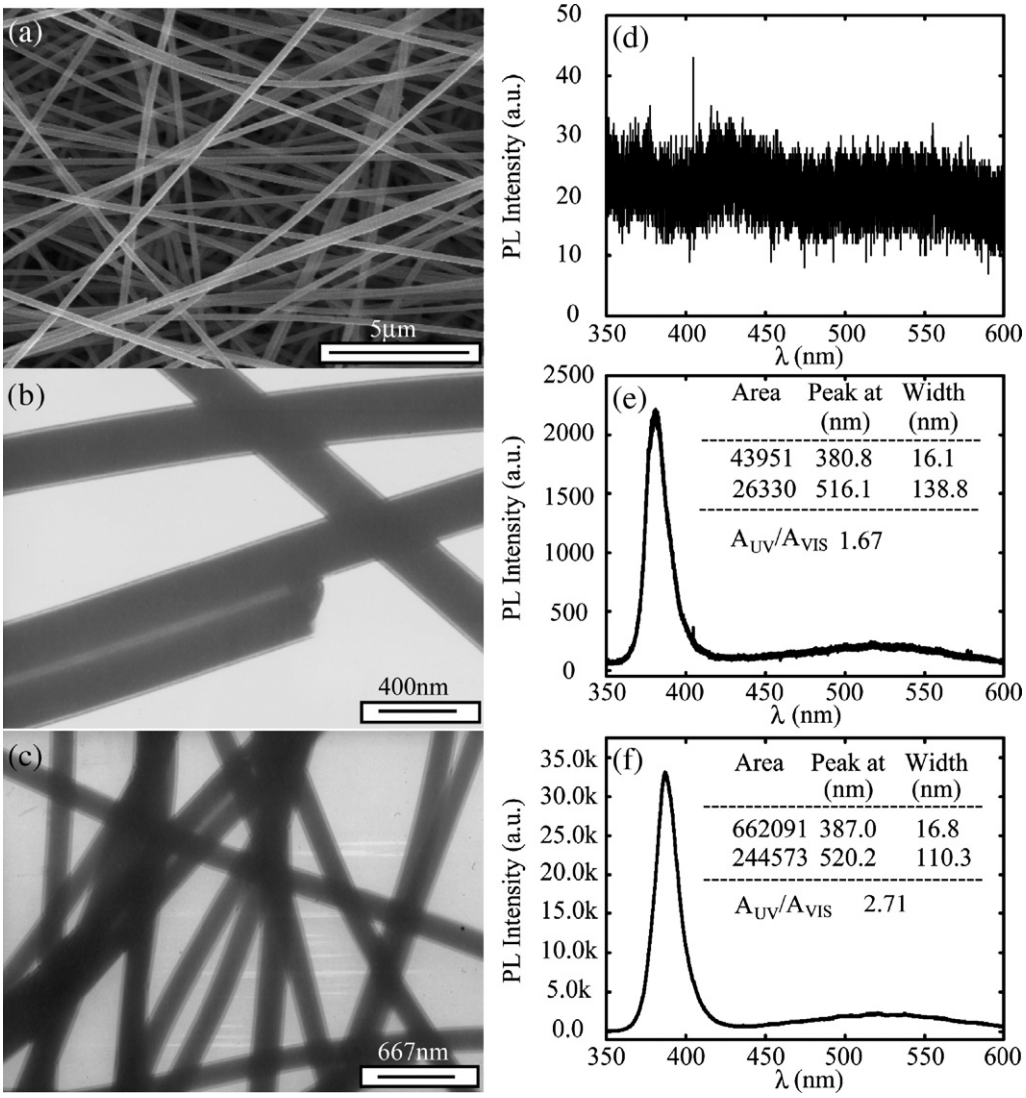

Fig. 2. FESEM images of SiO_2 nanofibers (a), TEM images of sample 1 (b) and sample 2 (c); PL spectrum of SiO_2 nanofibers (d), sample 1 (e) and sample 2 (f).