Soft-chemical Synthesis and Optical Properties of Zinc Oxide Nanofibers

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Abstract

A simple soft-chemical synthesis protocol has been developed to synthesize ZnO nanostructures. The FESEM study revealed the formation of ultra-long ZnO nanofibers of length 1 μm and diameter ~ 50 nm. Low absorption was observed in the visible region indicating the high level of transparency of the material in the visible region. The synthesized ZnO nanofibers exhibit strong photoluminescence emission at 425 nm owing to recombination of electrons at zinc interstitials and holes in the valence band.

Keywords: Soft-chemical; ZnO; Nanofibers, Absorption; Photoluminescence.

1. Introduction

Zinc Oxide is a very interesting and multifunctional semiconducting materials being widely used in various application from optoelectronics to cosmetics [1]. It is very unique as a semiconductor due to its wide and direct band gap of 3.37 eV and large excitonic binding energy of 60 meV [2]. Such electronic structure enables its potential applications in fabricating ZnO based UV laser. It exhibits photoluminescence over a wide range of electromagnetic spectrum ranging from UV to visible region [3, 4]. Therefore, it can be used in the fabrication of various visible light sources and detectors. Being optically transparent and conducting, it is also being used as transparent electrode in solar-cells. ZnO has hexagonal unit cell stricture with a lack of center of symmetry. Therefore, it has uncompensated charges along the c-axis which give rise to the development pf piezoelectric property [5]. Therefore, it is a potential material for piezoelectric energy generation. Defects plays an important role in in optical emission and electrical conductivity of ZnO. Several kinds of defects such as interstitials, antisites, vacancies (Zn and O) are observed in ZnO nanostructures grown at low temperatures [6]. A proper understanding of the defects dynamics is very essential for proper understanding the optical and electrical properties of ZnO nanostructures. Several methods have been reported in the literature for synthesizing variety of ZnO nanostructures. Amongst them, chemical synthesis method has become very popular because of its simplicity. Besides, it is a cost-effective method quite suitable to adopt in the laboratory without much infrastructure. Additionally, it does not require the maintenance of rigorous experimental conditions such as high temperature, low pressure and floe of carrier gases.

Here, in this paper, we report a soft-chemical synthesis of ZnO nanostructures followed by typical morphological analysis. Besides, optical property has been analyzed for detail understanding of the energy states of the carriers in ZnO nanocrystals.

2. Experimental

We followed a simple soft chemical synthesis protocol to synthesize ZnO nanofibers. In a typical synthesis process 0.2 M aquash solution of zinc acetate (50 ml) was mixed with 1.0 M of NaOH aquash solution (50 ml) and the stirring was continued for 2 hr. At the end of the reaction, the white precipitate was filtered and dried in an ordinary furnace for further characterization.

The surface topography of the synthesized ZnO nanostructure was observed in a ZEISS field emission scanning electron microscope (FESEM) that was operated at 10 kV. The UV-visible (UV-VIS) spectroscopic absorption data were collected in a Perkin Elmer LS-55 spectrophotometer in the wavelength range 200-800 nm. The room temperature photoluminescence (PL) data were collected in a Perkin Elmer LS-45 spectrophotometer that uses a xenon lamp as a source of excitation.

3. Results and discussions

Typical FESEM images of the synthesized ZnO nano powder is shown in Fig.-1. Nanofibers are found to form in the chemical synthesis process. The nanofibers are very long ~ 1 μm and have average diameters ~ 50 nm. The nanofibers are well separated as can be observed from the figure.

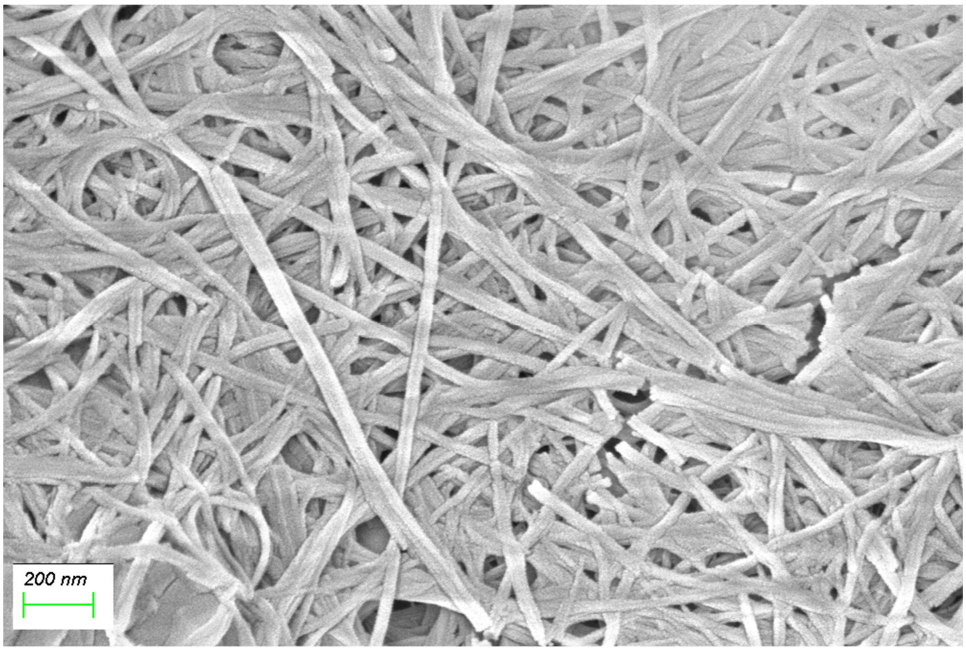

Figure 1: Typical FESEM image of the synthesized ZnO nanofibers.

UV-visible absorption spectroscopy is an essential tool to investigate the optical absorption of the material. Typical optical absorption spectrum of the synthesized ZnO nanofibers is shown in Fig. 2. The nanofibers exhibit strong absorption in the visible region and therefore can have potential applications in visible light absorber and sensors.

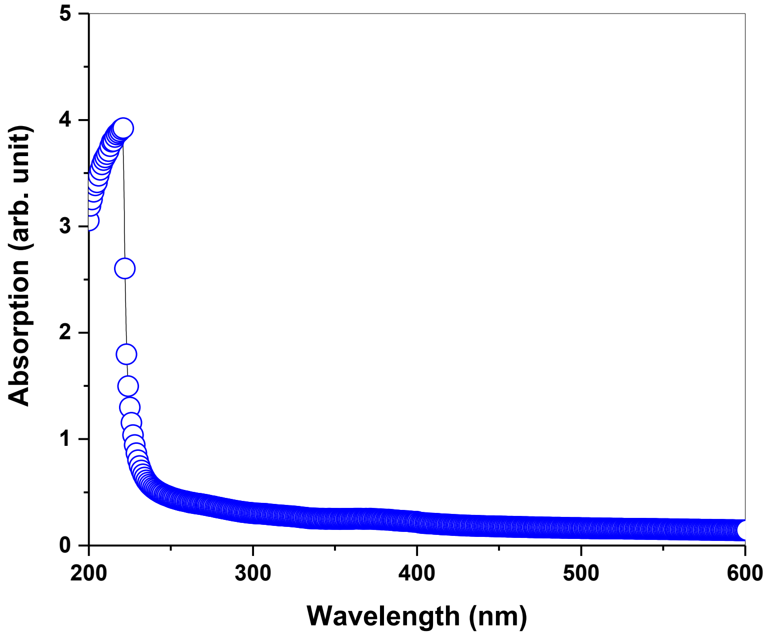

Figure 2: Typical UV-visible spectrum of ZnO nanofibers.

Optical emission property of a material can be investigated by studying its photoluminescence spectra. Typical room temperature photoluminescence (PL) spectrum of the synthesized ZnO nanofibers is shown in Fig. 3. Two strong peak was observed at 425 nm and 620 nm . The Peak at 620 nm is the second harmonic peak of the excitation source (310 nm). The PL emission peak of the synthesized ZnO nanofibers appears at 425 nm. The defects energy levels of ZnO have been calculated by many researchers using full-potential linear Muffin-Tin orbital method and the calculated energy states are shown in Fig. 4 [7]. From Fig. 4, the PL emission from ZnO nanofiber at 425 nm can be assigned due to recombination of electrons at zinc interstitials and holes in the valence band [8].

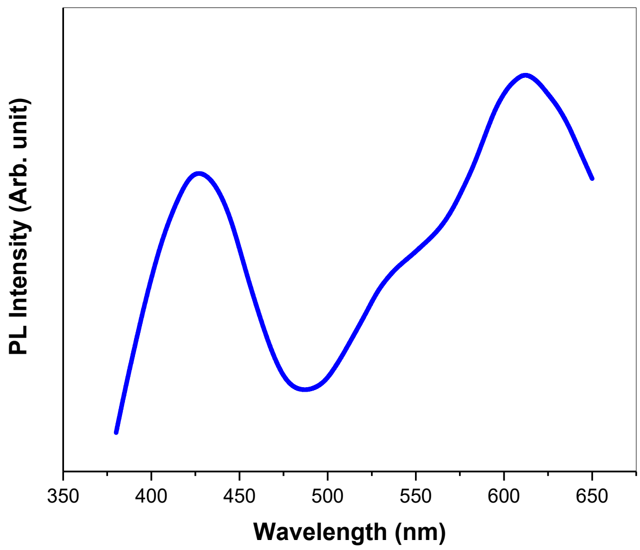

Figure 3: Room-temperature PL spectrum of ZnO nanofibers.

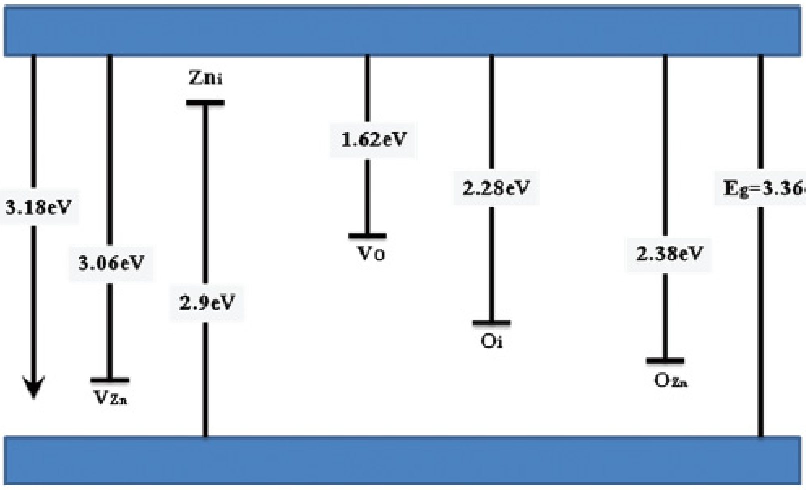

Figure 4: Defect energy states of ZnO.

4. Conclusions

In conclusion, we have successfully grown ZnO nanofibers of high aspect ratio. The fibers are stand alone. The synthesized nanofibers have absorption in the visible range of spectrum. The ZnO nanofibers exhibit PL emission in the violet emission owing recombination electron in zinc interstitials and holes in the valence band.

References

[1] W. J. E. Beek, M. M. Wienk, and R. A. J. Janssen, Adv. Funct. Mater. 16, 1112 (2006).
[2] M. H. Huang, S. Mao, H. Feick, H. Yan, Y. Wu, H. Kind, E. Weber, R. Russo, and P. Yang, Science 292, 1897 (2001).
[3] P. K. Samanta, S. K. Patra, and P. Roy Chaudhuri, Physica E 41, 664 (2009).
[4] B. Tang, H. Deng, Z. W. Shui, and Q. Zhang, J. Nanosci. Nanotechnol. 10, 1842 (2010).
[5] X. Y. Kong and Z. L. Wang, Nano Lett. 3, 1625 (2003).
[6] C. Wu, X. Qiao, J. Chen, H. Wang, F. Tan, and S. Li, Mater. Lett. 60, 1828 (2006).
[7] B. Lin, Z. Fu, and Y. Jia, Appl. Phys. Lett. 79, 943 (2001).
[8] P. S. Xu, Y. M. Sun, C. S. Shi, F. Q. Xu, and H. B. Pan, Nucl. Instrum. Methods Phys. Res. B 199, 286 (2003).