Journal of Quantitative Spectroscopy & Radiative Transfer 112 (2011) 1792–1795

Contents lists available at ScienceDirect

Journal of Quantitative Spectroscopy & Radiative Transfer

journal homepage: www.elsevier.com/locate/jqsrt

Optical measurements of ZnS nanoparticles aqueous solution

M. Moussaoui [a,*], R. Saoudi [a], I.V. Lesnichiy [b], A.V. Tishchenko [a]

[a] Université de Lyon, Université Jean Monnet, Laboratoire Hubert Curien CNRS UMR5516, 18 rue du Professeur Benoît Lauras, 42000 Saint-Etienne, France
[b] Moscow Institute of Physics and Technology, Institutsky Str. 9, 141701 Dolgoprudny, Russia

ARTICLE INFO

Available online 20 February 2011

Keywords:
ZnS nanoparticles
Nanopowder water suspension
Refractive index measurement

ABSTRACT

We synthesized zinc sulfide (ZnS) nanopowders with size ranging from 2 to 100 nm by a simple, low-cost, and mass production chemical method. The nanoparticles (NPs) were characterized by X-ray powder diffraction (XRD), atomic force microscopy (AFM), transmission electron microscopy (TEM), and UV–vis absorption spectroscopy. Our study concerns also the change in the refractive index of deionized water in presence of ZnS nanospheres. We present experimental results on effective index variation of water dispersed ZnS NPs at different wavelengths in visible spectrum.

1. Introduction

Optical properties of semiconductor nanoparticles (NPs) are of fundamental and practical interest and many researches have been performed on them [1,2]. Their studies are mainly concerned with the quantum size effect. When the size of semiconductor particles is reduced to nanometer scale their physical properties differ noticeably from those of the corresponding bulk material and depend on the size and the morphology of the studied structures [3,4]. The extremely small size of the NPs results in quantum confinement of the photogenerated electron–hole pair. When the radius of the particle approaches the Bohr radius of the exciton, the quantum size effect becomes apparent: the energy gap increases with decreasing the grain size, which leads to a blueshift of the optical absorption edge with respect to the bulk material [5]. In order to exploit such size-tuneable properties, many works have been devoted to the development of simple methods for synthesizing semiconductor particles of various sizes in a controllable manner [6]. Optical properties such as optical absorption and refractive index changes have great potential for device applications in photodetectors, optical modulators, and semiconductor optical amplifiers [7,8].

Among the II–VI materials, zinc sulfide (ZnS) is a non-toxic semiconductor with an important direct wide band gap (E_g=3.6 eV at 300 K), and relatively high refractive index [9]. It is a suitable material for numerous applications such as ultraviolet-light-emitting diodes, electroluminescent devices, flat-panel displays, sensors and injection lasers [10].

In this work, ZnS nanoparticles with size ranging from 2 to 100 nm were prepared by chemical process [11]. The synthesis of ZnS NPs was based on the reaction of zinc acetate and thioacetamide as starting materials. The resulting mixture was treated thermally at different temperatures. The resulting product was collected by centrifuging to select the size distribution. The NPs were characterized by X-ray powder diffraction (XRD), atomic force microscopy (AFM), transmission electron microscopy (TEM), and UV–vis absorption spectroscopy.

We also investigate the refractive index of ZnS NPs dispersed in deionized water. The critical angle measurement [12] is employed because of its convenience and high precision.

2. Material and methods

All chemicals used in this work were obtained from Sigma Aldrich company commercial sources with no additional purification.

* Corresponding author. Tel.: +330477915824; fax: +330477915781.
E-mail address: myriam.moussaoui@univ-st-etienne.fr (M. Moussaoui).

0022-4073/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jqsrt.2011.02.006

XRD patterns were acquired on a Bruker D8 Advance instrument using Cu Kα radiation (λ=1.5418 Å). The nanocrystallite powder was pressed inside the sample holder. The TEM images are taken with a TOPCON EM002B transmission electron microscope operating at 200 kV. Samples for the TEM measurement are supported on a carbon-coated copper grid. ZnS nanopowders were also examined by atomic force microscopy with an Agilent 5500 AFM system in tapping mode. The absorption spectra in the UV and visible ranges were recorded with a lambda 900 Perkin-Elmer spectrophotometer in between wavelength range 300–600 nm.

3. Results and discussion

The XRD pattern of the ZnS NP is shown in Fig. 1. The spectrum demonstrates that ZnS is in pure cubic phase. The diffraction peaks at 28.3°, 33.2°, 47.5°, 56.6° correspond to crystal planes (1 1 1), (2 0 0), (2 2 0) and (3 1 1), respectively. An average crystallite size of about 3 nm was estimated according to the line width analysis of the (1 1 1) diffraction peak based on the Scherrer formula [13].

From the AFM picture (Fig. 2) we observe for the selected scan area that the ZnS NPs are almost spherical and have diameter ranging from 20 to 100 nm. Fig. 3 shows the TEM image of the prepared nanopowders. It can be seen that ZnS NPs have almost spherical shape and an average size of less than 10 nm (about 3–6 nm in diameter) which is consistent with the particle size determined by using XRD analysis.

Formation of ZnS NPs has been also confirmed using UV–visible spectroscopy. Absorption spectra were measured in matched quartz cells of 1 cm path length between 300 and 600 nm. Fig. 4 presents the UV–vis absorption spectrum of the prepared ZnS NPs which was recorded after the powder sample being dispersed in deionized water. It shows an absorption peak at 323 nm (E=3.84 eV) which is considerably blue-shifted from 340 nm (E=3.65 eV) for bulk zinc-blende ZnS because of quantum size effect [14].

The direct allowed optical band gap of the ZnS NPs was estimated from the Tauc plot [15] according to the following relation:

$$(\alpha h\nu)^2 = C(h\nu - E_g) \tag{1}$$

where α, ν, C, and E_g are the molar absorption coefficient, light frequency, an arbitrary constant, and the band gap of the nanoparticles, respectively. As shown in the inset of

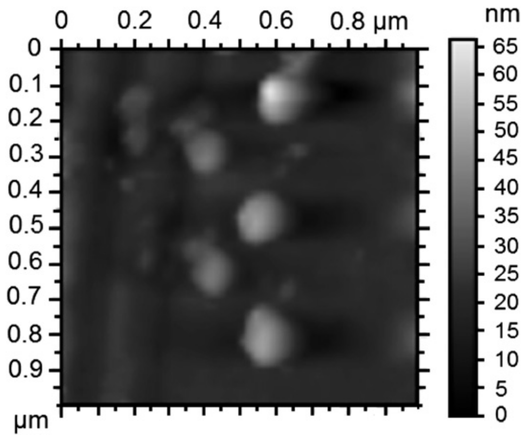

Fig. 2. Typical AFM image of the prepared ZnS NPs.

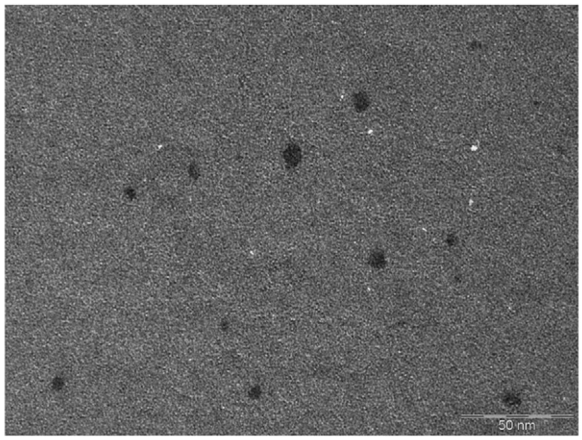

Fig. 3. TEM image of the prepared ZnS NPs.

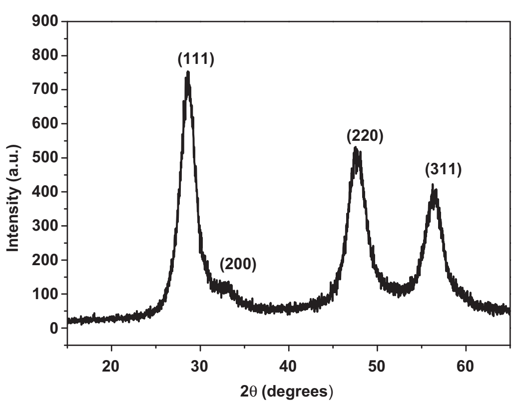

Fig. 1. X-ray diffraction pattern of ZnS NPs.

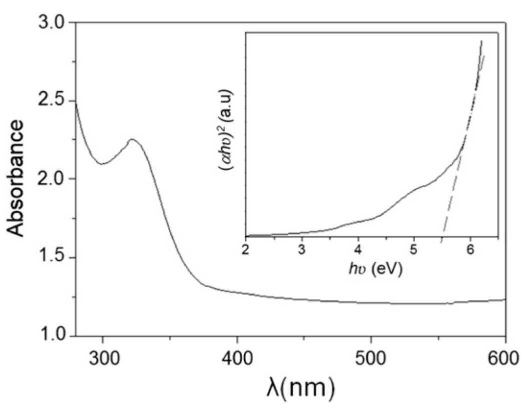

Fig. 4. UV–vis absorption spectrum of the ZnS NPs.