Indian Journal of Pure & Applied Physics
Vol. 46, August 2008, pp. 561-564

Synthesis and characterization of CdO and CdS nanoparticles

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Received 5 July 2007; revised 5 March 2008; accepted 13 May 2008

Cadmium oxide and cadmium sulphide particles in the nanometer size regime have been synthesized using chemical routes. CdO nanoparticles are prepared by using ethylene glycol as a capping agent and CdS nanoparticles were prepared with H_2S gas. Variety of techniques like X-ray diffraction (XRD), UV-Vis absorption spectroscopy and Scanning Electron Microscopy (SEM) are used to carry out structural characterization of the nanoparticles. The optical band gap of these materials has been determined in order to establish a relationship between energy band gap of bulk and nanomaterials.

Keywords: Nanoparticles, Cadmium oxide, Cadmium sulphide

1 Introduction

The synthesis of binary chalcogenides of group II-VI semiconductor in a nanopowder form has been a rapidly growing area of research due to their important optical, physical and chemical properties. These II-VI semiconductor nanoparticles are presently of great interest for their physical applications such as zero-dimensional quantum confined materials and for their applications in optoelectronics[13]. Semiconductor nanoparticles belong to state of matter in the transition region between molecules and solids[12].The physical and chemical properties of these nanomaterials are found to be size dependent. Large scale synthesis of semiconductor nanoparticles such as solid powder is critically important not only for the study of their physical properties but also for industrial applications in the area of catalysis, photocatalysis and microelectronics[10].

Cadmium oxide is attracting tremendous attention due to its interesting properties like direct band gap of 2.3 eV. It is widely used in the applications like the preparation of cadmium-coated baths and manufacture of paint pigments. Cadmium sulphide is one of the most studied materials with a band gap of 2.43eV. It is primarily used in solar cell and a variety of electronic devices. The photoconductive and electroluminescent properties of cadmium sulphide have been applied in manufacturing a variety of consumer goods.

In the present paper, synthesis and characterization of cadmium oxide and cadmium sulphide nano-particles has been studied.

2 Experimental Details

Samples of CdO and CdS materials have been prepared by chemical method.

2.1 CdO nanoparticle

Chemical synthesis of CdO nanoparticles has been done in alcoholic media like ethanol, methanol or propanol. In alcoholic media, growth of oxide particle is slow and controllable.

Different solutions were prepared by dissolving 0.1M of $CdCl_2$ (20ml), 0.1M of NaOH (100ml) and X ml ethylene glycol with methanol. Ethylene glycol solution was added to NaOH solution while it was continuously stirred. The resulting solution was stirred for one hour before adding $CdCl_2$ solution to it. After three hours of constant stirring a milky white solution was obtained. Size selective precipitation was carried out using acetone as a non-solvent. The precipitate was washed in methanol and methanol was allowed to evaporate at room temperature to obtain cadmium hydroxide nanoparticles in white powder form.

Cadmium hydroxide nanoparticles are then placed in the furnace and heated to 250ºC for five hours. After five hours we get the cadmium oxide powder which is in brown color. By changing the ethylene glycol concentration (0.1 and 0.01ml), we could vary the particle size.

2.2 CdS nanoparticle

Sample CdS materials have been prepared by precipitation method using cadmium chloride, NaOH

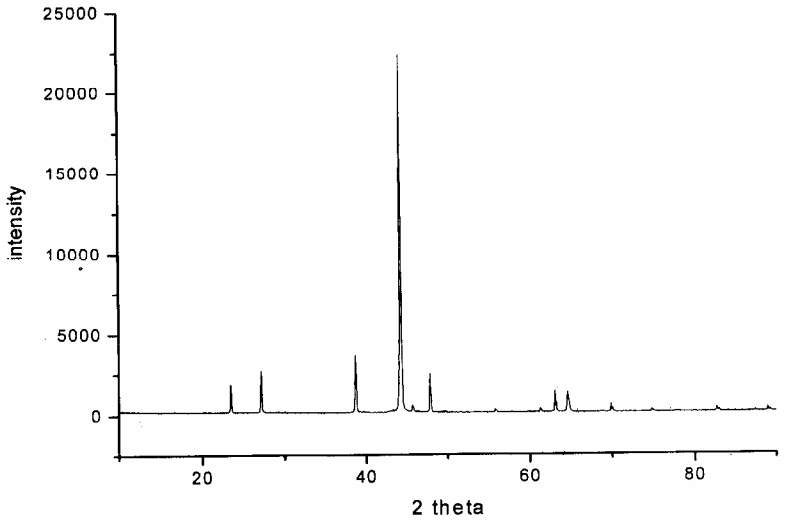

Fig. 1 — XRD of CdO-1

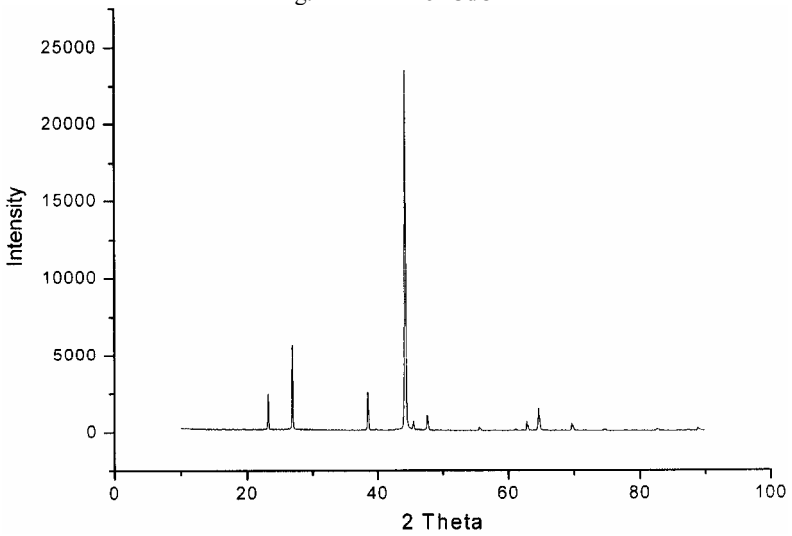

Fig. 2 — XRD of CdO-2

and H_2S. In this method aqueous solutions of 0.1M of $CdCl_2$ (20ml) and 0.1M of NaOH (100ml) were prepared separately. NaOH solution was slowly added to methanol and H_2S gas was liberated into the solution. The resulting solution was stirred for one hour before adding $CdCl_2$ solution in it. After three hours of constant stirring a yellow solution was obtained. Selective precipitation was carried out using acetone as a non-solvent. The precipitate was allowed to evaporate at room temperature to obtain CdS nanoparticles in orange powder form.

3 Results and Discussion

3.1 CdO nanoparticles

In the present work, we have synthesized CdO nanoparticles in the quantum confinement regime. The prepared materials CdO-1(0.1 ml EG) and CdO-2(0.01 ml EG) were characterized by using X-Ray Diffraction. Particle size was determined from the width of XRD peaks using Scherrer's formula[12]:

$$d = (0.94\ \lambda) / (\beta \cos \theta)$$

where β is the full width half maximum (FWHM), θ is the diffraction angle, d is the average crystallite grain size and λ is the wavelength of X-rays. Diffractogram of powder of samples CdO-1 and CdO-2 are shown in Figs 1 and 2. Fig. 1 shows the grain size of CdO-1 sample (38.9nm) obtained from the FWHM of peak corresponding to 2θ=44.228º. Fig. 2 shows the estimated X-ray grain size of this sample (34.4nm) obtained from the FWHM of peak corresponding to 2θ =44.228º. From this, it can be seen that CdO-1 has

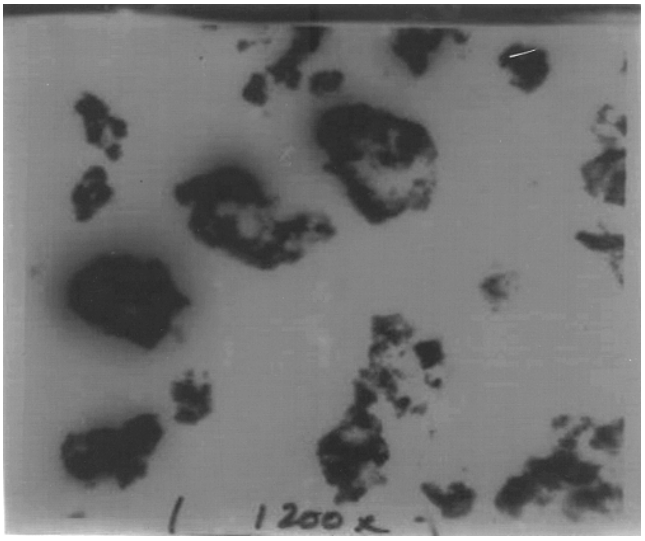

Fig. 3 — SEM image of CdO-1 with 1200 magnification.

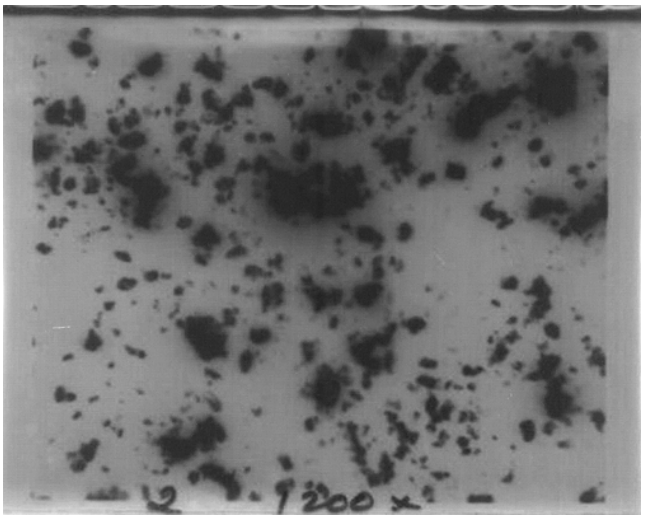

Fig. 4 — SEM image of CdO-2 with 1200 magnification

strong bonding between Cd and O than CdO-2 sample.

The SEM images of CdO-1 and CdO-2 are shown in the Figs 3 and 4. The SEM image of CdO-1 in Fig. 3 shows the particle size from few micron ranges to nanometer range. Fig. 4 shows the particle size of CdO-2 in the nanometer range.

The absorption spectra of the CdO sample are shown in the Fig 5. The energy band gap of these materials was estimated using the Tauc relation[12].

$$\alpha h\upsilon = A\,(h\upsilon - E_g)^n$$

where α absorption coefficient, $h\upsilon$ the photon energy, E_g the band gap n =1/2 for the direct transitions.

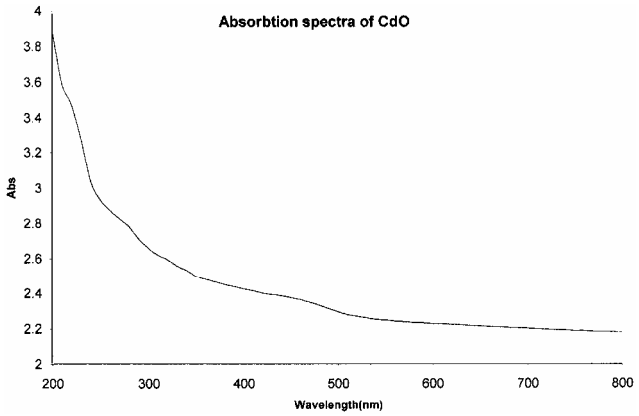

Fig. 5 — Absorption spectra of CdO

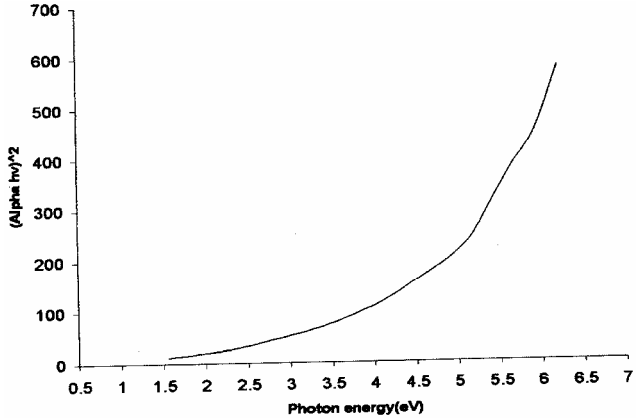

Fig. 6 — Energy band gap determination of CdO

Table 1—Band gap for bulk and nanomaterials

Samples	Band gap (eV) (bulk)	Band gap (eV) (nano)
CdO	2.3	3.4
CdS	2.42	3.25

The energy band gap is measured with the help of absorption spectra and a graph of $(\alpha h\upsilon)^2$ versus $h\upsilon$ is plotted (Fig. 6). The extrapolation of the straight line to $(\alpha h\upsilon)^2 = 0$ gives the value of the energy band gap of prepared materials. The energy band gaps for bulk and nanomaterials are given in the Table 1.

3.2 CdS nanoparticles

XRD pattern of CdS sample is shown in Fig. 7. The XRD peaks are found to be very broad which indicate the very fine size of the grain. The XRD pattern exhibit the prominent broad peaks at 2θ values of 26.778, 43.928 and 51.678°.The estimated grain size of the sample is 1.5 nm from the FWHM of most intense peak.

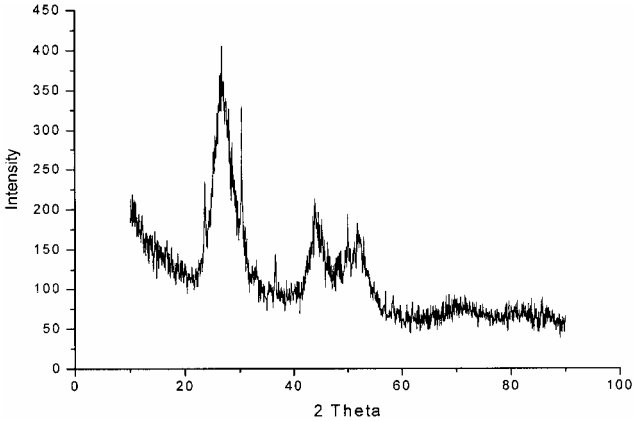

Fig. 7 — XRD of CdS

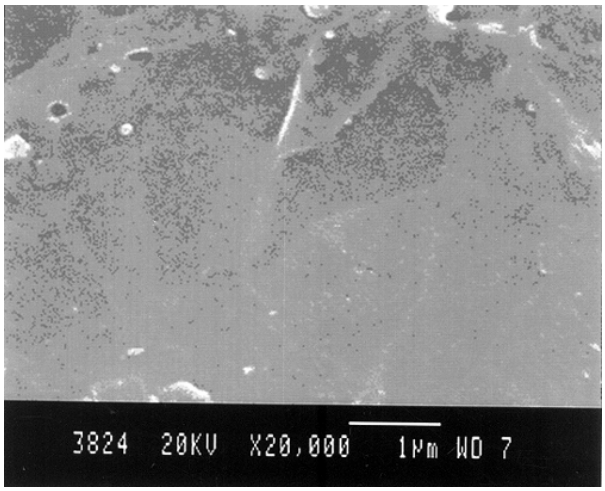

Fig. 8 — SEM image of CdS with 20,000 magnification

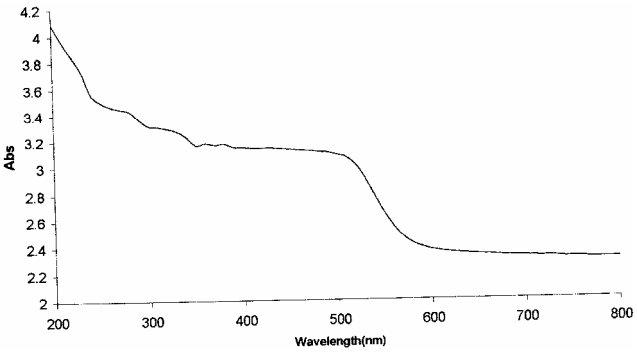

Fig. 9 — Absorption spectra of CdS

The SEM image of CdS nanoparticles is shown in the Fig. 8. It shows that the particle is in cubic structure and in the nanometer range. UV-Visible absorption spectra of CdS is shown in the Fig. 9. The energy band gap of determination of CdS is shown in the Fig. 10. The energy band gap of bulk CdS is compared with CdS nanomaterials (Table 1).

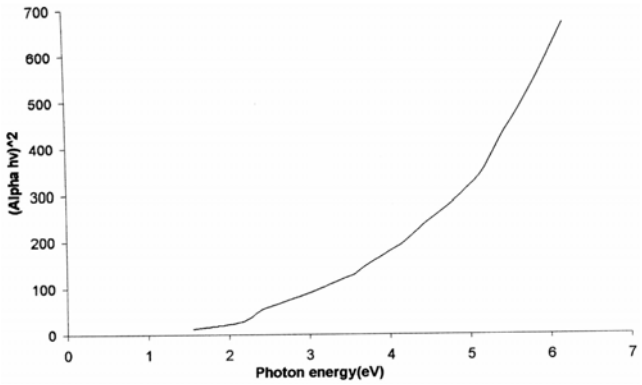

Fig.10 — Energy band gap determination of CdS

4 Conclusions

The present study indicates that the precipitation method can be successfully employed for the preparation of CdO and CdS materials. XRD and optical band gap have been obtained to confirm the nanosize of the materials. From XRD and SEM, the size of the particle increases as the concentration of capping agent increases. An increase in the band gap is observed due to the quantum confinement effects in the nanoparticles.

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