

Growth of CdS nanoparticles by chemical method and its characterization

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Abstract. In the present work a simple chemical reduction method is followed to grow CdS nanoparticles at room temperature. The grown sample is ultrasonicated in acetone. The dispersed sample is characterized using electron diffraction technique. Simultaneously optical absorption of this sample is studied in the range of 400–700 nm. The photoluminescence spectrum of the sample is also studied. Results show the formation of nanoparticles. Hence an increase in band gap compared to bulk CdS and the as-prepared CdS nanoparticles have surface sulphur vacancies.

Keywords. CdS nanoparticles; chemical synthesis; crystal structures and symmetry; optical properties.

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1. Introduction

The semiconductor nanoparticles exhibit structural, electronic, optical, luminescence and photoconducting properties [1–6] very different from their bulk properties. It is also very attractive because of their possible application in solar cell, photodetector, laser, LED, high-density magnetic information storage and many others in semiconductor industries [7–12]. Gr.II–Gr.VI semiconductor nanoparticles play an important role having applications in optical devices. Their growth techniques are relatively cheap. Cadmium sulphide (bulk band gap 2.42 eV at 300 K) has huge potential in this aspect. Their growth techniques are relatively cheap. Their characteristic absorption of light is in the visible range. There are various methods [13–19] to prepare CdS nanoparticles. Some of the above-mentioned methods have some drawbacks. Used precursors are unstable causing environmental hazards and require very high temperature. These methods are not cost effective also. In the present work a chemical method [20] is followed at room temperature. Sodium borohydride is used to initiate the reaction between CdCl₂ and sulphur at room temperature.

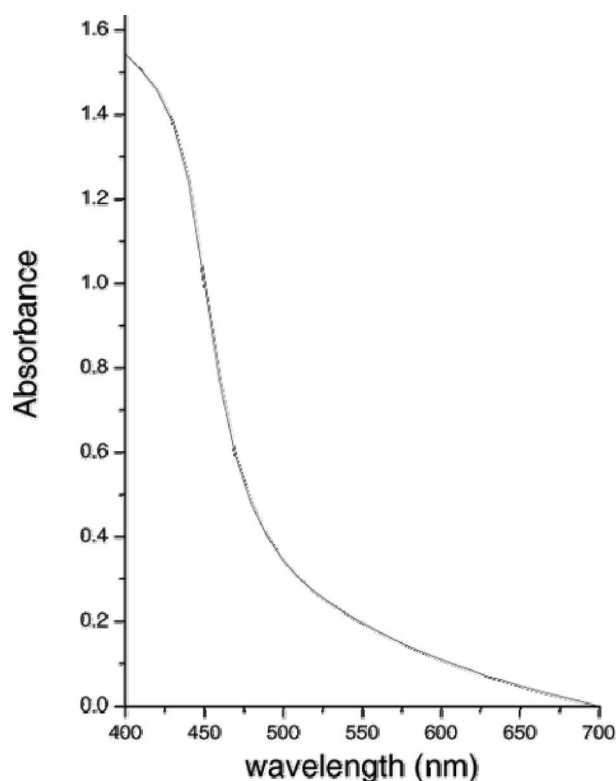


Figure 1. The optical absorption spectra of the as-prepared CdS nanoparticles.

2. Experimental section

Anhydrous CdCl_2 (320 mg), sulphur powder (50 mg) and a stoichiometric amount of sodium borohydride were taken. Tetrahydrofuran was taken as solvent. Sodium borohydride was taken to initiate the reaction at room temperature. The reaction was carried out at 27°C . The stirring was continued for 16 h at a particular speed.

Optical absorption measurements were performed using Shimadzu Pharmaspec 1700 UV-VIS spectrometer. Optical absorption has been studied in the range of 400–700 nm.

For TEM and TED measurements, the as-prepared CdS nanoparticles were dispersed in acetone by ultrasonification. A small drop of this was placed on a thin carbon film supported on the copper grid and was kept for some time for drying. Transmission electron micrographs of the prepared nanoparticles were acquired using Philips CM12 transmission electron microscope operating at 100 kV.

Photoluminescence spectra of the as-prepared sample were obtained using 325 nm He–Cd laser (power 50 mW) as a light excitation source, a Triax320 monochromator was used and detected by PMT.

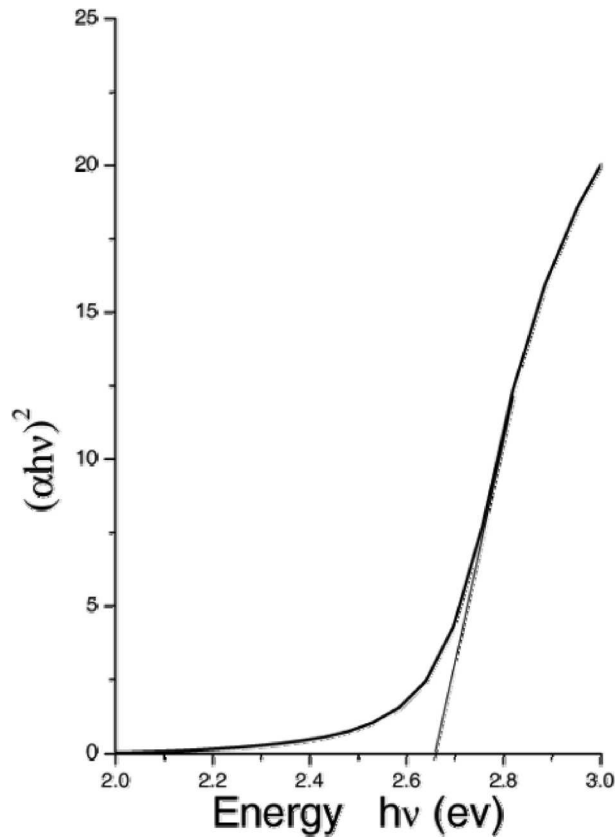


Figure 2. The band gap determination of as-prepared CdS nanoparticles.

3. Results and discussion

Figure 1 displays the variation of optical absorbance with wavelength of the as-prepared nanoparticles. Optical absorption coefficient has been calculated in the wavelength region of 400–700 nm. The band gap of the as-prepared nanoparticles is determined from the relation $(\alpha h\nu) = C(h\nu - \Delta E_g)^{1/2}$ where C is a constant, ΔE_g is the band gap of the material and α is the absorption coefficient. A plot of $(\alpha h\nu)^2$ vs. energy ($h\nu$) is shown in figure 2 and the linear portion of the curve is extrapolated to $h\nu$ axis to determine the band gap. The band gap is found to be $\Delta E_g = 2.67$ eV whereas the bulk band gap is 2.42 eV. It confirms that the absorption peak is shifted from their bulk edge (510 nm). This is due to quantum confinement effect. Wang *et al* obtained CdS nanoparticles having a band gap of 2.79 eV [21].

TEM image of bright field of CdS nanoparticles and its selected area diffraction pattern are shown in figures 3 and 4 respectively. Particle size is determined to be approximately 10–12 nm.

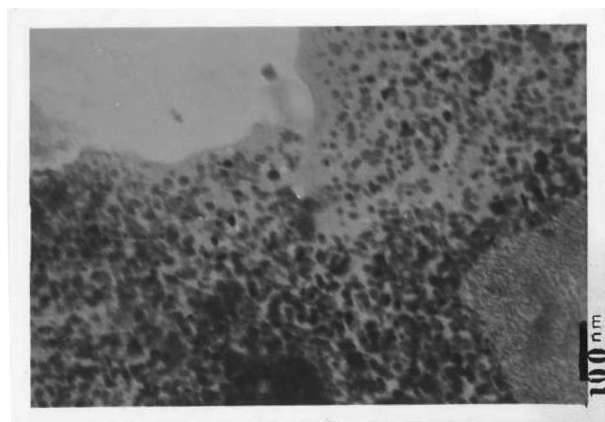


Figure 3. The TEM image of the as-prepared CdS nanoparticles.

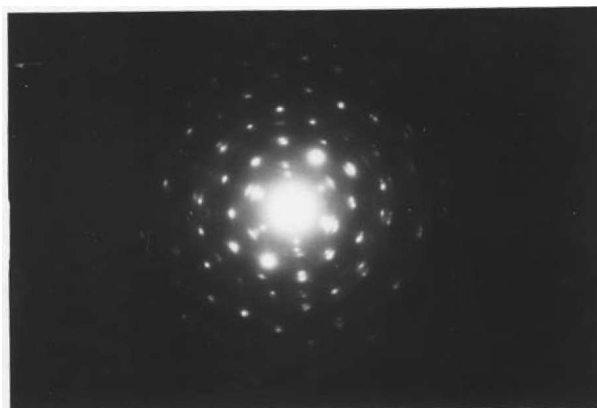


Figure 4. The SAD pattern of the as-prepared CdS nanoparticles.

A clear hexagonal phase of the as-prepared CdS nanoparticle is revealed in ED pattern (figure 4). The interplanar spacing (d) is determined from the SAD pattern. The determined d values are 3.374 Å, 2.048 Å and 1.751 Å for first, second and third rings respectively. The calculated d values match well with ASTM values of 3.385 Å, 2.040 Å and 1.754 Å which correspond to (111), (220) and (311) planes respectively. Gautam *et al* reported TEM studies on 5–10 nm thio-capped nanoparticles [22].

The photoluminescence spectra of the as-prepared CdS nanoparticles is displayed in figure 5. A broad band centered at 650 nm is obtained. This is due to the surface states arising from the deep trap formed due to sulphur vacancy [23,24] whereas the band edge emission is nearly 500 nm. Band edge emission may be due to low-lying dark states of the nanocrystal interior [25]. Cao *et al* reported band edge luminescence at 450 nm and surface trap emission at 600 nm [26]. The solvent tetrahydrofuran has very low dielectric constant ($\epsilon/\epsilon_0 = 7.58$). This notably affects the particle formation. The cadmium ion (Cd^{2+}) and sulphur ions (S^-) are

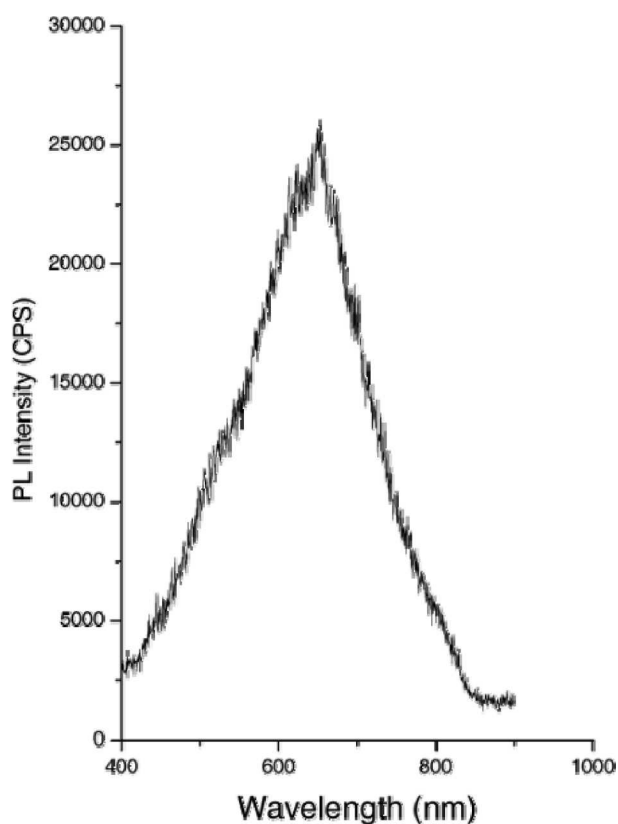


Figure 5. The photoluminescence spectra of the as-prepared CdS nanoparticles.

unstable in reaction medium and nucleate to form CdS nanoparticles due to the large Coulomb force between them.

4. Conclusion

The CdS nanoparticles are synthesized by a simple chemical method at room temperature. The TEM image shows that the size of the nanoparticles is in the range of 10–12 nm. The SAD pattern displays the hexagonal phase of CdS nanoparticles. The optical absorption and photoluminescence spectra are recorded at room temperature. The as-prepared nanoparticles show a blue-shift in optical absorption and the photoluminescence spectrum shows luminescence from trap levels caused by sulphur vacancy.

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References

- [1] A Palivisatos, *Science* **271**, 933 (1996)
- [2] X G Peng, L Manna, W D Yang, J Wickham, E Scher, A Kadavanich and A P Alivisatos, *Nature (London)* **404**, 59 (2000)
- [3] M G Bawendi, M L Steigerwald and L E Brus, *Annu. Rev. Phys. Chem.* **41**, 477 (1990)
- [4] T Trindade, P O'Brien and N L Pickett, *Chem. Mater.* **13**, 3843 (2001)
- [5] M G Bawendi, P J Carroll, W L Wilson and L E Brus, *J. Chem. Phys.* **96**, 1335 (1992)
- [6] V L Colvin, M C Schlamp and A P Alivisatos, *Nature (London)* **370**, 354 (1994)
- [7] A Mews, A Eychmuller, M Giersig, D Shoos and J Weller, *J. Phys. Chem.* **98**, 934 (1994)
- [8] C T Tsai, D S Chou and S L Yang, *J. Appl. Phys.* **79**, 9105 (1996)
- [9] N Tessler, V Medvedev, M Kazes and U Banin, *Science* **295**, 1506 (2002)
- [10] H Mattoussi, L H Radzilowski, B O Dabbousi, E L Thomas, M G Bawendi and M F Rubner, *J. Appl. Phys.* **83**, 7965 (1998)
- [11] T Taguchi, Y Endoh and Y Nozue, *Appl. Phys. Lett.* **56**, 342 (1991)
- [12] S H Sun and C B Murray, *J. Appl. Phys.* **85**, 4325 (1999)
- [13] R Rosseti, J L Ellison, J M Gibson and L E Brus, *J. Chem. Phys.* **80**, 552 (1984)
- [14] Y Wang and N Herron, *J. Phys. Chem.* **95**, 525 (1991)
- [15] T Trindade, P O'Brien and X Zhang, *Chem. Matter* **9**, 523 (1997)
- [16] S Yu, Y Wu, J Yang, Z Han, Y Quan, X Liu and Y Xie, *Chem. Matter* **10**, 2309 (1998)
- [17] C B Murray, D J Norris and M G Bawendi, *J. Am. Chem. Soc.* **115**, 8706 (1993)
- [18] Y D Li, H W Liao, Y T Qian, Y Ding, Y Fan and Y Zhang, *Inorg. Chem.* **38**, 1382 (1999)
- [19] G Henshaw, P Parkin and G Shaw, *J. Mater. Sci. Lett.* **15**, 1741 (1996)
- [20] W Wang, I Germanenko and M S El-Shall, *Chem. Matter* **14**, 3028 (2002)
- [21] S Wang, S Yang, C Yang, Z Li, J Wang and W Ge, *J. Phys. Chem.* **B104**, 11853 (2000)
- [22] U K Gautam, R Seshadri and C N R Rao, *Chem. Phys. Lett.* **375**, 560 (2003)
- [23] S Okamoto, Y Kanemitsu, H Hosokawa, K Murakoshi and S Yanagida, *Solid State Commun.* **105(1)**, 7 (1998)
- [24] N Chestnoy, T D Harris, R Hull and L E Brus, *J. Phys. Chem.* **90**, 3393 (1986)
- [25] A P Alivisatos, *J. Phys. Chem.* **100**, 13226 (1996)
- [26] Y C Cao and J Wang, *J. Am. Chem. Soc.* **126**, 14336 (2004)