Absorption Spectroscopic Study of Chemically Synthesized CdS Nanostructures

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Abstract

A simple wet chemical method has been used to synthesize CdS nanostructures. Optical properties of the synthesized material were investigated through UV-visible absorption spectroscopy. Significant variation of the transmittance and absorption and extinction coefficient were observed from UV to visible region. The band gap of the synthesizes CdS was calculated to be 2.16 eV. This material with direct band gap will have potential applications in optoelectronics.

Keywords: Cadmium sulfide (CdS), Wet-chemical, Absorption, Extinction-coefficient, Band gap.

1. INTRODUCTION

Compound semiconductors are of potential interests in the modern research because of their unique tunable optical and electrical properties. Zinc oxide (ZnO), copper oxide (CuO), zinc sulphide (ZnS) and cadmium sulphide (CdS) are very popular semiconductors being studied widely in the recent decade [1-5]. CdS is known for its unique optical properties, including direct bandgap that makes it suitable for optoelectronic applications like solar cells, photo sensors and light emitting diodes [6]. It has a band gap of 2.4 eV that can be tuned by adjusting the size and shape of the nanostructures [7]. Petrus and coworkers have fabricated CdS thin films using high-frequency magnetron sputtering and obtained a band gap of 2.39 eV [8]. CdS nanostructures have been explored for photocatalytic applications, such as the degradation of organic pollutants and water splitting for hydrogen production [9]. It is also used in thin-film solar cells as a buffer layer to improve the efficiency of light absorption and electron transport [10]. CdS nanostructures have been employed in sensors for detecting gases, chemicals and various analytes due to their sensitivity to changes in the surrounding environment [11]. Several methods such as hydrothermal methods, sputtering, spray-pyrolysis, chemical bath deposition have been appeared in the literature to synthesize nanostructured materials. However, wet-chemical method provides a simple and cost-effective way to synthesize nanomaterials with high production yield [12, 13]. Here, in this paper, we report a simple wet-chemical method to synthesize CdS nanostructures followed by typical optical characterization for optoelectronic applications.

2. EXPERIMENTAL

All the chemicals used in this synthesis were of analytical grade and was used as purchased without any purification. In a typical synthesis process, 0.2 M cadmium acetate dihydrate aqueous solution was mixed with 0.6 M of sodium sulfide aqueous solution. We used thioglycerol (TG) of 0.1 M as a capping agent. The magnetic stirring was continued for 2 hr. At the end of the reaction, the precipitate was filtered and dried in a hot air furnace at 110 °C for further characterization. UV-visible spectroscopic data were collected in Perkin-Elmer UV-visible (UV-Vis) spectrophotometer (Model No. Lambda 365) in the wavelength range 200-700 nm. The reaction and the measurements were performed at 32 °C.

3. Results and discussions

Typical UV-Vis spectrum of the synthesized CdS nanostructure is shown in Fig.1. The transmittance suddenly falls off from 260 nm and remains almost constant up to 450 nm and then slowly decreases. Beer-Lambert law was used to calculate the absorption coefficient of the material.

$$I_t = I_0 e^{-\alpha x}$$
$$\alpha = \frac{1}{x}\ln\frac{I_0}{I_t}$$

Where, I_0 and I_t are the intensities of the light beam before and after transmittance through the sample of thickness x. The variation of the absorption coefficient (α) with the wavelength of the incident photon is shown in Fig. 2.

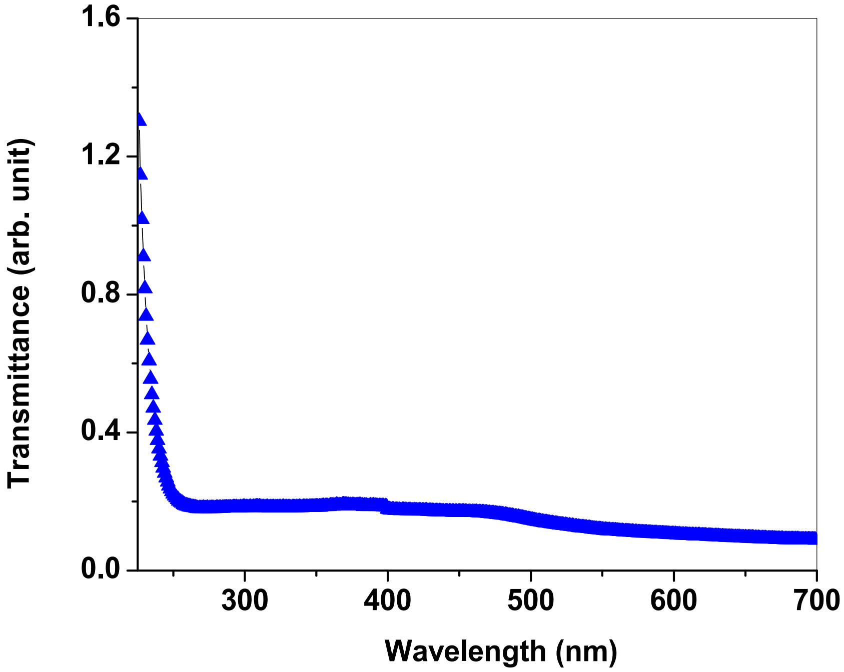

Figure-1: UV-Vis transmittance spectrum of CdS nanostructures.

Extinction coefficient (k) is another important parameter in understanding the optical properties of a material and is defined as-

$$k = \frac{\alpha\lambda}{4\pi}$$

The variation of the extinction coefficient with the wavelength of the incident photon is shown in Fig. 3.

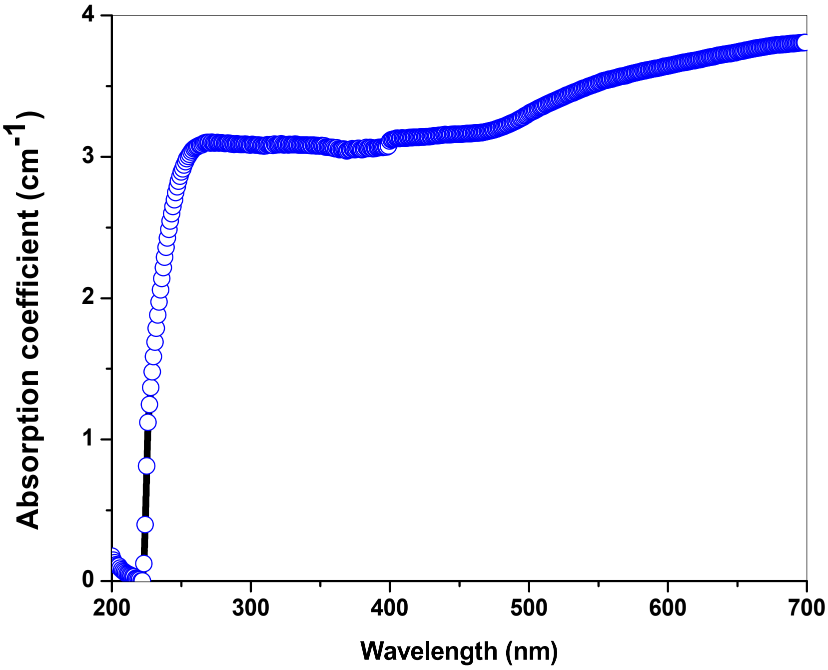

Figure-2: Variation of absorption coefficient with the wavelength of the incident photon.

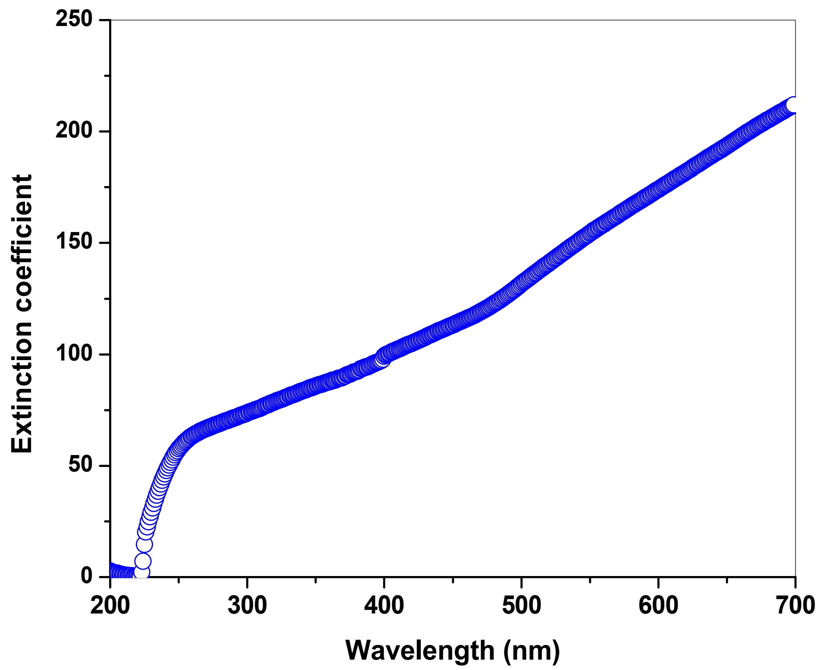

Figure-3: Variation of extinction coefficient with the wavelength of the incident photon.

The optical absorbance of a semiconductor material depends on the frequency (ν) of the incident radiation and can be expressed by Tauc's equation:

$$[\alpha(\nu)h\nu]^{1/n} = D(h\nu - E_g)$$

Where, D is an energy independent constant, $n = 1/2$ for allowed transition for direct band gap and $n = 2$ for allowed indirect band gap. There are also other two types of transition: direct forbidden transition ($n = 3/2$) and indirect forbidden transitions ($n = 3$). Since CdS is a direct semiconductor, the plot of $[\alpha(\nu)h\nu]^2$ vs the photon energy ($h\nu$) is shown in Fig. 4. The intercept of the curve in the high absorption region with $h\nu = 0$ axis will give the band gap of the material. The band gap was calculated to be 2.16 nm which is close to various reported value of 2.4 eV [14]. This direct band gap CdS has potential application in optical detectors and solar cells.

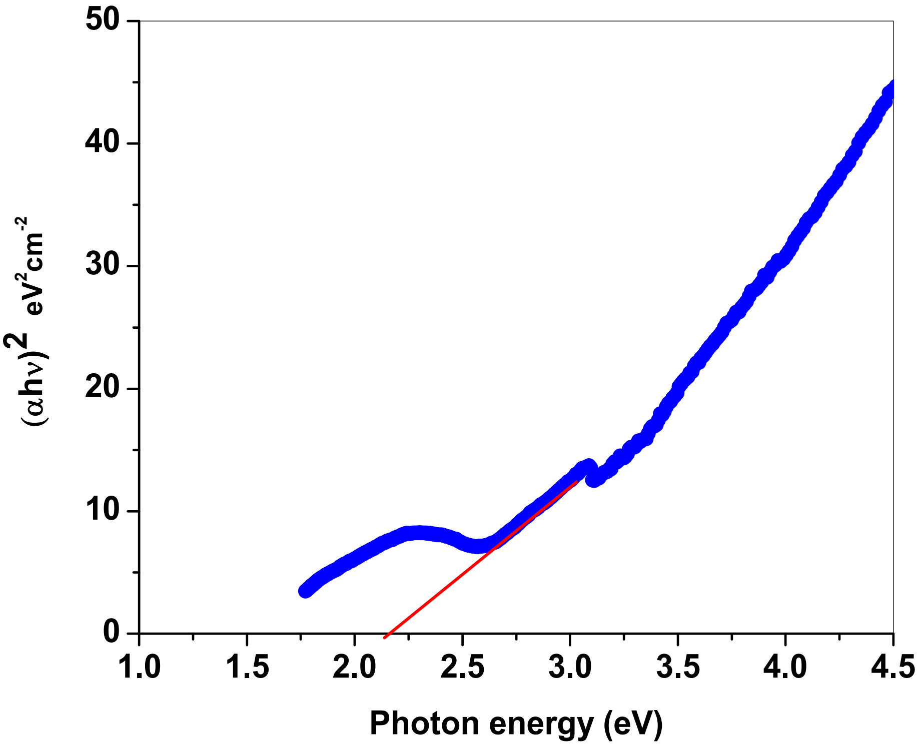

Figure-4: Tauc plot to calculate the band gap.

3. CONCLUSIONS

In conclusion, a simple wet-chemical method has been successfully implemented to synthesize CdS nanostructures. UV-visible spectroscopy was used to explore optical absorption properties of the synthesized CdS nanostructures. Wavelength dependent absorption and extinction coefficient was observed. The transmission was found to remain constant in the UV as well as a part of the visible region of the electromagnetic spectrum. The Band gap of the synthesized nanostructure was also calculated which is consistent with the existing reports.

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