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Synthesis, Structural, Optical and Electrical Properties of Cadmium sulphide Thin Films by Chemical Bath Deposition Method

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Abstract: Cadmium sulphide (CdS) a wide energy gap semiconductor has emerged as an important material due to its applications in photovoltaic cell as window layers, optical filters and multilayer light emitting diodes, photo detectors, thin film field effect transistors, gas sensors and transparent conducting semiconductor for optoelectronic devices. In this work we report synthesis, optical and electrical characterization of CdS thin films coated on glass substrate. The films were deposited using chemical bath deposition method. The X-ray diffraction (XRD) analysis shows that the prepared samples are polycrystalline with cubic structure. Scanning electron microscopy (SEM) reveals that the grains are more uniformly distributed over the surface of the substrate for the CdS films. Optical studies were done using UV-Visible spectroscopy. The band gap energy of the sample is calculated and it is found to be 2.40 eV. Electrical conductivity measurements are carried out on CdS Thin films.
Key words: CdS, XRD, SEM, Solar Cells.

1. Introduction

Energy technology is one of the mainly significant technologies. In the 21st century, technology has dominated people's life and people's consumption for energy will significantly rise. Studies of the production of clean, sustainable and low-cost energy has gained speed because of the reasons such as limitation of fossil fuel resources and increasing the amount of money to be paid to purchase this energy category. The battery usually combines three separate layers such as semiconductor, dye and electrode. Polymers, dyes, pigments and liquid crystals are incorporated in the organic materials used in solar cells. The demand for clean energy technologies has spurred academic interest in new and efficient ways to capture and store sunlight. Concerted efforts are now being directed toward both the design of light harvesting assemblies, construction of economically viable solar cells, and the development of efficient energy storage devices. Even in the age of nanotechnology, century-old liquid junction electrochemical cells play a pivotal role in our daily lives by delivering portable energy to everything from mobile phones to automobiles. In recent years, the concept of utilizing nanomaterial-based architectures in light energy conversion devices has emerged as an alternative to single-crystalline based photovoltaic devices. Thin films of semiconducting nanoparticles have remarkable applications in electronics industry, solar cells and gas sensors. Thin films of CdS are of considerable interest owing to their use in the fabrication of heterojunction solar cells and other optoelectronic devices [1, 2]. Although, there exist various film deposition techniques chemical bath deposition (CBD) is often preferred for its simplicity. Chemical bath deposition method is relatively simple and low cost method and suitable for large

are deposition. Several researchers have shown [3,4] that the efficiency of many solar cells depends strongly on properties of CdS buffer layer and that chemically deposited method is the most convenient way to deposit these layers. The deposition of CdS film has been explored by various techniques, such as thermal evaporation [5], sputtering [6], molecular beam epitaxy [7], spray pyrolysis [8], chemical bath deposition [9]. Chemical bath deposition is a method of growing thin films of certain materials on a substrate immersed in an aqueous bath containing appropriate reagents at temperatures ranging from room temperature to 100°C. It has been identified as a low process suitable for the preparation of large area thin films [10]. In this study, we report the preparation of CdS thin films onto microscope glass slides by CBD method. The structural, morphological, optical and electrical properties of the as-prepared CdS thin films are investigated.

2. Experimental Procedure

The CdS thin films were deposited from a solution of cadmium nitrate and thiourea in an alkaline solution of ammonia and distilled water. Commercial glass slides used as substrates were cleaned in acetone ultrasonically. The glass slides were kept vertically in a closed beaker. In a beaker containing distilled water, cadmium nitrate was added and liquid Ammonia was added to it. Mixture was then stirred for a particular time and thiourea was added to it. The process of stirring was continued. Glass substrate was mounted vertically on the beaker containing the solution. After the deposition was complete, the substrates were removed from the bath and were allowed to dry in air. The dried samples were rinsed with acetone and finally dried.

3. Results and Discussion

3.1 Structural characterization

In order to determine the size and to study the structural properties of the synthesized CdS thin films, the powder XRD analysis was performed. Structural identification of CdS films was carried out with X-ray diffraction in the range of angle 2θ between 0º to 80º. Fig. 1 shows the XRD patterns for CdS thin films, which were nanocrystalline in nature. The observed broad hump in XRD pattern is due to amorphous glass substrate. The well defined (111), (220), (311), and (420) peaks were observed in the XRD patterns. The (111) peak corresponds to phase of polycrystalline structure of CdS. The strong and sharp diffraction peaks indicate the formation of well crystallized sample. It can be seen that the major peak (111) is strongly dominating the other peaks. The structure of CdS deposited is predominantly cubic and reasonably crystalline.

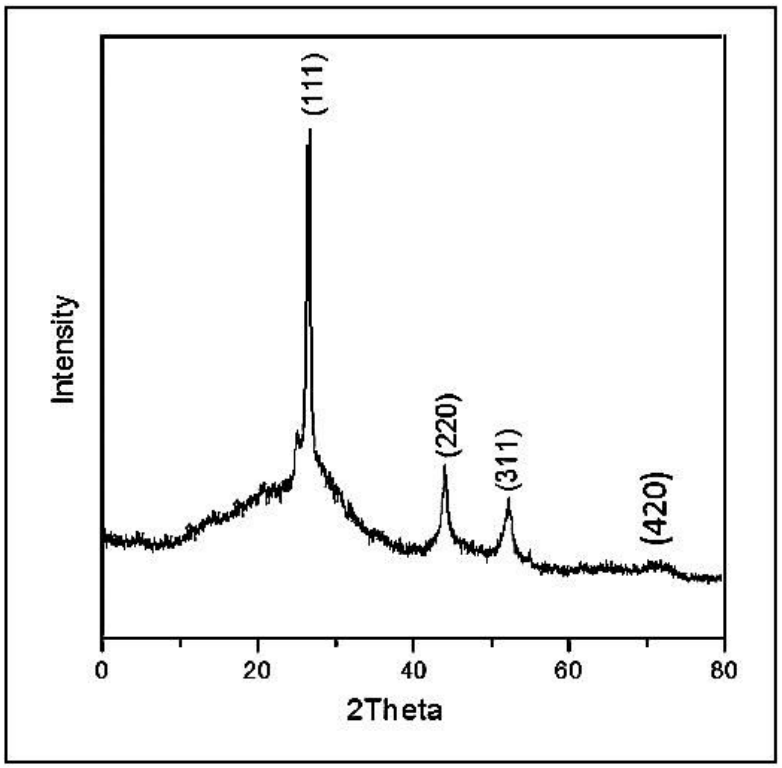

Fig.1.XRD spectrum of CdS thin films

3.2 Surface morphology

Scanning electron microscope (SEM) was used for the morphological study of CdS thin films. Fig. 2 shows the SEM images of the CdS thin films. The CdS thin films formed were highly agglomerated. In this image spherical shape of CdS nanoparticles deposited are confirmed. The spherical shaped particles which have a mean particle size of ~ 15 nm are visible through the SEM analysis.

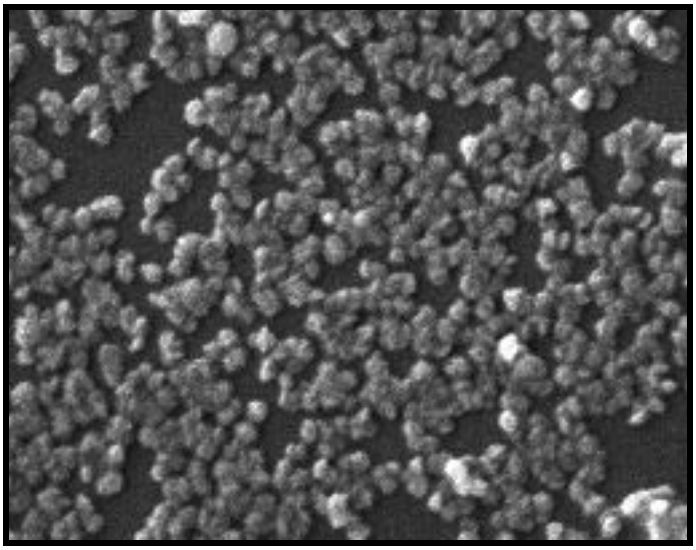

Fig.2 SEM micrograph of chemical bath deposition of CdS thin film

3.3 Optical Properties

The study of optical properties of CdS thin films has special significance in the world of science, technology and industry for the development of new optical devices. Optical absorption study of materials provides useful information to analyze some features concerning the band structure of materials. The optical band gap energy of the semiconductor is an important parameter that plays a major role in the construction of photovoltaic cells. In present report optical properties of the CdS deposited on glass substrate was studied from the absorption spectrum measured by a UV–Visspectrophotometer lambda 25 in the wavelength range 300 to 900 nm. The variation of absorbance (αt) with wavelength (nm) for CdS thin film is shown in Fig.3. The sharp absorption edge observed confirms the good optical band edge property of the CdS thin film. The fundamental absorption, which corresponds to electron excitation from the valance band to conduction band, can be used to determine the nature and value of the optical band gap. The nature of transition is determined by using the relation,

$$\alpha h\nu = A(h\nu - E_g)^n \qquad (1)$$

Where A is constant, hυ is photon energy and E_g is the optical band gap. The exponent *n* depends on the nature of the transition, n=1/2, 2, 3/2 or 3 for allowed direct, allowed indirect, forbidden direct or forbidden indirect transitions, respectively. For determination whether the film has direct or indirect band gap, a plot of $(\alpha h\upsilon)^2$ vs.hυ is plotted (Fig.4), where α is the optical absorption coefficient and hυ is the photon energy. By extrapolating the linear portion of the curve to photon energy axis for zero absorption coefficients, the intercept of the curve i.e. the optical band gap of CdS thin film estimated and found to be 2.40 eV. It is well known that the band gap energy depends upon the films composition, crystal structure, particle size and strain in the film.

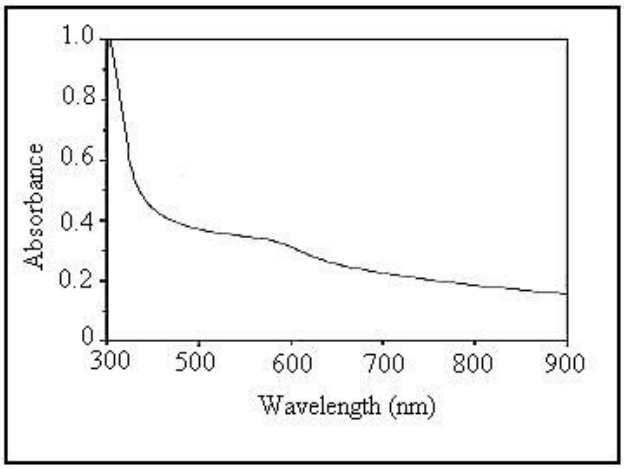

Fig.3 Absorption spectrum of CdS thin films

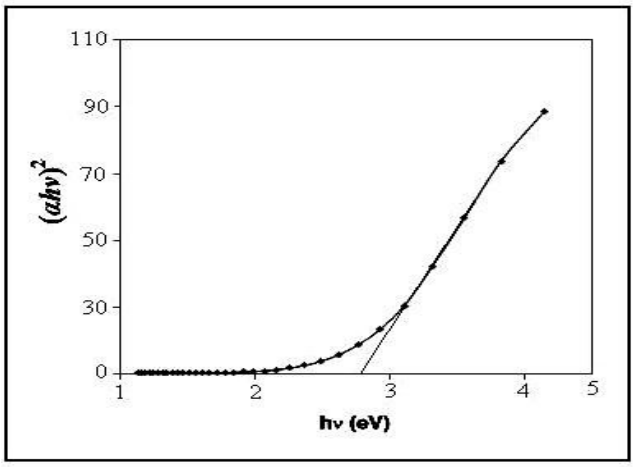

Fig.4 Plot of $(\alpha h\nu)^2$ *V*s photon energy

3.4 *Electrical Properties*

The conductivity measurements were carried out for the CdS thin film using the conventional two-probe technique at different temperatures ranging from 308 to 368 K. The *dc* electrical conductivity (σ_{dc}) of the crystal was calculated using the relation,

$$\sigma_{dc} = t/RA \quad (2)$$

where R is the measured resistance, t is the thickness of the sample and A is the area of face in contact with the electrode. The σdc values were fitted into the equation

$$\sigma_{dc} = \sigma_o \exp(-E_d/kT) \quad (3)$$

The conduction region considered in the present study seems to be connected to mobility of vacancies. The activation energy estimated from the resistivity plot is found to be 0.040 eV for as-deposited CdS thin film.

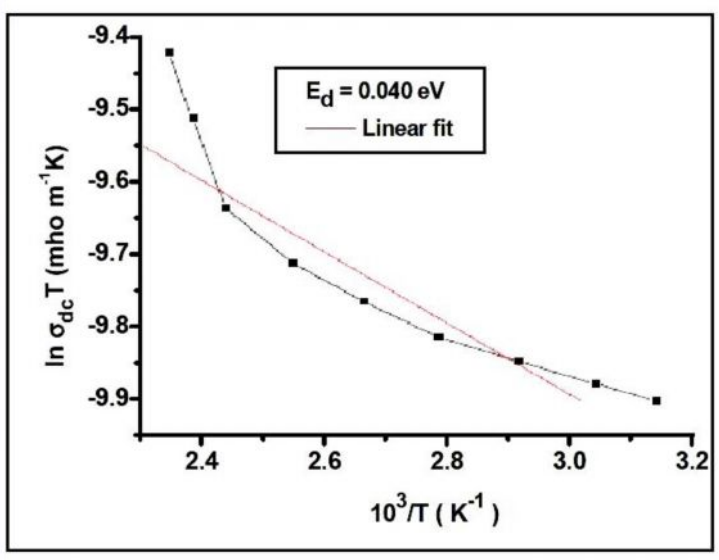

Fig.5. Plot of ln(σ_{dc}) versus 1000/T for CdS thin films

4. Conclusion

The CdS thin film was successfully deposited on glass substrate using chemical bath deposition (CBD) technique. The XRD studies show that, films prepared are in nanocrystalline range and also diffraction peaks are found. The size and morphology of the CdS thin films were characterized using scanning electron microscopy (SEM). The optical band gap is measured to be 2.40 eV. The activation energy of the sample is calculated by *dc* conductivity studies.

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