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TO STUDY THE CADMIUM SULPHIDE THIN FILMS SYNTHESIS BY SIMPLE SPIN COATING METHOD FOR ENERGY APPLICATION†

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The paper examines the properties of CdS thin film, which is used for window material of solar cells and optical devices. The cadmium sulfide (CdS) thin film was prepared by sol-gel method on glass and ITO substrate. Prepared thin film dried in a vacuum oven at 70°C. Thin film and powder of CdS characterized for structural, optical, and electrical properties by X-ray Diffractometer (XRD), UV-Visible spectrometer, and Keithley spectrometer. The average crystallite sizes, micro strain and dislocation density of the samples were calculated by the Debye Scherrer formula. The optical band gap of CdS calculated by the Tauc-plot method and obtained 2.40 and 2.41eV for powder and film. The absorption wavelength of CdS is decreased near 280nm and becomes flat in the higher wavelength region. The FTIR spectrometer is used to identification of unknown materials and bond formation. The bond formation, imperfections and impurities were observed by the PL spectrometer. Keithley spectrometer is used for I-V characteristics and calculates electrical resistivity by Ohms law.
Keywords: *Ultra-Sonication; CdS; XRD; UV-Visible; Electrical Properties*
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1. INTRODUCTION

The cadmium sulphide (CdS) is II-VI group material. This is one of the most investigated semiconductors in the form of thin film. The creation and utilization of energy have been a cornerstone considers the improvement of human development. Sun-powered energy is accessible in the majority of the areas around world and supplies gigantic green energy that can undoubtedly cover world energy requests [1]. Cadmium sulfide (CdS) is the most normally utilized in window layer materials for high-productive cadmium telluride (CdTe) and chalcopyrite polycrystalline thin film of photovoltaic gadgets [2]. Cadmium sulfide (CdS) is a very important material in II–VI group compound semiconductors in optoelectronic devices, and extensive research and development efforts have been undertaken. The utilization of sustainable and non-contaminating energy has acquired for significance on the planet because of the weariness of petroleum products and the elevated degrees of contamination created by non-renewable energy source use. A promising type of perfect and sustainable power is hydrogen, created by the separation of water utilizing sunlight-based energy [3].

Quantum confinement effects in semiconductor nanoparticles are known to make their structural, electrical and optical properties significantly used with different from those of the bulk material [4]. Cadmium telluride has a direct band gap of 1.43 eV that is a good match to the solar spectrum for solar cell applications. The surface recombination velocity for CdTe is large so that a hetero junction structure is better suited for CdTe solar cells. Cadmium sulfide have band gap of 2.43 eV is a tunable window material for a CdS/CdTe heterojunction solar cell [5]. The cadmium (Cd) nuclei 48 and sulphur nuclei contains 16 protons with only single pair of the magic proton number Z = 50 and 20 respectively, so they are providing nuclear properties like the sub shell effect and also provides outstanding test case for nuclear model calculations [6]. Thin films of CdS have used in many devices as electrochemical cells, metal Schottky barrier cells, light emitting diodes (LED), photo sensor detection, semiconductor lasers, thin films transistor, photo detectors, photoluminescence, photosensitization, photo catalytic properties solar cellular and gas sensor [6-9]. CdS used in the bulk as well as in the nano-scale form of thin film and quantum dot. Often CdS semiconductor has been worked for a long time and it has been very a fascinating material due to its band gap value, n-type conductivity and high transparency for optoelectronic device applications. The n-type CdS semiconductor can be utilized as a window layer along with retention layers of CdTe or CIGS to create high-effective sunlight-based cells [10]. Cadmium telluride (CdTe) and CdS based slender film sun-oriented cells have drawn in for overall exploration consideration throughout recent many years to foster minimal expense and high productivity sun powered chargers appropriate for photovoltaic sun-based energy change. It is a special interesting choice due to its appropriate band gap (2.42 eV) relatively high absorption coefficients, particular optical properties and pattern of fabrication. CdS exhibits n-type semi conduction properties due to sulfur deficiency. The dispersion parameters of the pure and F: CdS films were used to determine the nonlinear optical susceptibility [12-14]. The highest 1.25% efficiency was obtained from inexpensive materials in this used porous CdS as a photo electrode [15]. Many techniques as spin coating radio frequency, vacuum evaporation, sputtering, electro-deposition, molecular beam

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epitaxial (MBE), metal organic chemical vapor deposition (MOCVD), pulsed laser evaporation, spray pyrolysis deposition (SPD), micelle method, chemical bath deposition (CBD), close-spaced sublimation (CSS) and successive ionic layer adsorption have been used to synthesis thin films for a good quality and long time. These techniques have also been used for the preparation of CdS films [16-17]. The synthesis of nanoparticles for the green approach is favored over traditional methodologies due to environmental concerns [21].

In the present work CdS thin films synthesized by spin coating method. Films dried in vacuum oven at 70°C and 24 hours to analyzed structural, optical and electrical properties of powder and thin films of CdS.

2. Experimental details

2.1. Solution preparation method

Cadmium sulphide (CdS) yellow colour and powder form purchased from Sigmachemie specialty Pvt. Ltd. (Amaranth West, Maharashtra) with 144.47g mol^{-1} molecular weight and 99.9% and above purity. Dichloromethane (CH_2Cl_2) Qualikemes, Propane -2-ol ($(CH_3)_2CHOH$), ans Triton X-100 were also purchased Fine chem. Pvt. Ltd. in liquid form. Cadmium sulphide (CdS), dichloromethane (CH_2Cl_2), propane -2-ol ($(CH_3)_2CHOH$) were used to prepared CdS solution. Dichloromethane (CH_2Cl_2) and propane -2-ol ($(CH_3)_2CHOH$) were taken with 10:1 volume ratio 0.5 wt% CdS powder was dissolved in the mixed co-solvents. The color of the CdS solution was yellow. After that the CdS solution was stirred on the hot plate of magnetic stirrer for 8 hours at room temperature. After stirring a small amount of triton X-100 was added in the solution to make uniform and high-quality surface of CdS thin films.

2.2. Deposition of CdS thin films

The CdS thin film was synthesized on glass and ITO surface by using spin coating method. The glass substrate was first cleaned with acetone and DI water. The CdS precursor solution was spin coated one time on glass and ITO 1×1 cm^2 surface at speeds of 1500 rpm for 60 sec. The prepared CdS films were dried at 70^0C in vacuum oven.

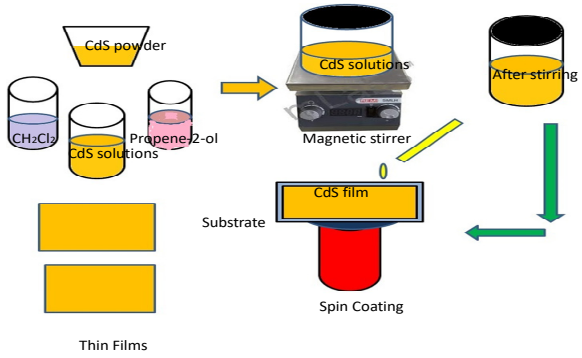


Figure 1. Schematic diagram of CdS thin film deposition process

3. CHARACTERIZATION

The X-ray Diffraction (XRD) spectra have been collected of powder and thin film of CdS sample by using copper (Cu) Kα Bruker AXS Single Crystal X-ray Diffractometer (modal Apex II) in the range (2θ) 10^0-80^0 with step size $1/100^0$. UV-visible and FTIR spectra have collected shimadzu (UV-2600) wave length range 200-900nm, ALPHA Bruker FTIR spectroscopy (ECO-ATR) in the transmittance mode at room temperature in the wave number range 4000-200 cm^{-1}. Horiba FluoroMax-4 spectrometer have used for photoluminescence spectra (PL). Current–voltage curves were obtained by a Keithley M236 source measure unit.

4. Results and discussion

4.1. Structural studies (X-Ray diffraction)

The structural analysis of CdS powder and synthesized CdS thin film was studied using X-ray diffraction pattern. XRD pattern of the CdS illustrated in below Figure 1 which presents the indexed of cubic structure of CdS (JCPDS – file No. 10-0454) with prominent peaks observed corresponding to the reflections at (111), (220), (311) planes at angles 2θ equal to 26.680, 43.570, 52.060 respectively. The sharp peaks of thin film Figure a) indicating transparency of thin film. XRD pattern in Figure b) intensity decreases and FWHM width increases indicating that the difference of particle sizes between film and powder. The d-spacing for both samples can be evaluated from the position of the major peak at about 26.06^0.

The average particle size of the CdS calculated using Scherer formula

$$D = k\lambda / \beta\cos\theta,$$

where, constant k is a shape factor usually = 0.94, D is the average crystalline size, λ is the wavelength of X-ray radiation, β is also a constant define by the full-width at half-maximum (FMWH) of the peak, and θ is the diffraction angle.

The lattice constant of synthesized CdS is found to be equal to a = b = c = 5.86 A°, which is close to reported values of cubic CdS by literature of review [17].

The crystallites size and dislocation density can be found from

$$\delta = 1/ D^2.$$

The lattice strain in the film can be found by,

$$\varepsilon = \frac{\beta \cos\theta}{4}.$$

Table 1. Shows the results of thin film and powder of CdS

S.N.	Sample name	Average particle size (D) (nm)	Dislocation density (δ)	Strain (ε)	Energy Band gap (eV)	Resistivity ($\rho \times 10^{-2}$) (Ω-cm)
1	CdS Thin Film	34.45	0.08426	0.3279	2.41	3.351
2	CdS Powder	26.06	0.01472	0.12639	2.40	4.166

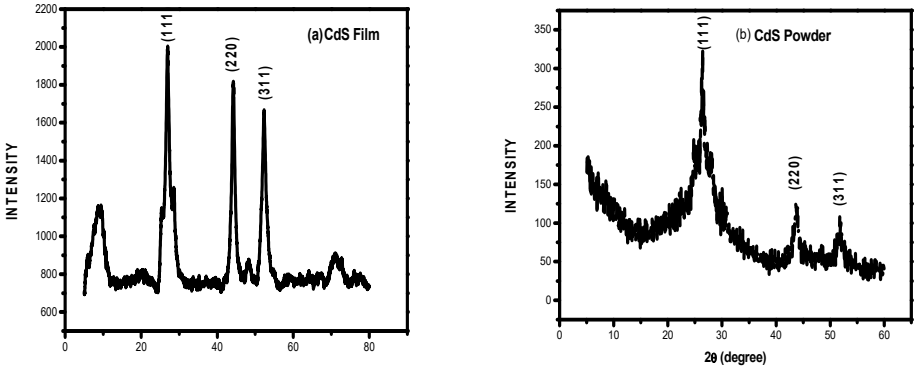


Figure 2. X-Ray diffraction pattern of a) CdS Thin film b) CdS powder

4.2. Scanning electron microscope

SEM microscope produces images of material by scanning of the surface. The SEM measurements were performed of CdS thin films to study their surface morphology with different images. The particle size distribution and corresponding Gaussian curve fitting of sample is show in Figure 3. It has observed that the CdS thin film surface become uniform and particle distribute everywhere but random conformed amorphous shapes. SEM image clarify that the thin film surface was smooth, random distribution of particles and contains spherically formed grains. The surface was enclosed in grains with uniform size. The thin sheets display no cracks or pin prick in the materials [26].

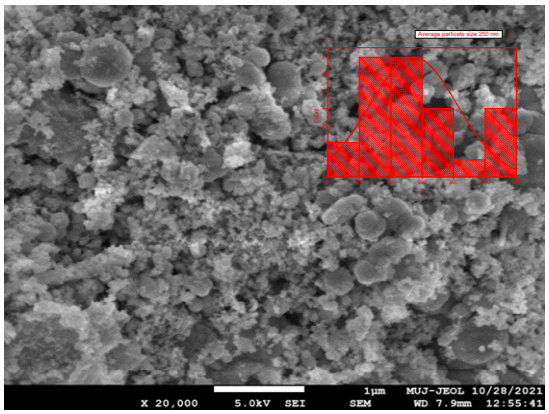


Figure 3. SEM image of CdS thin film

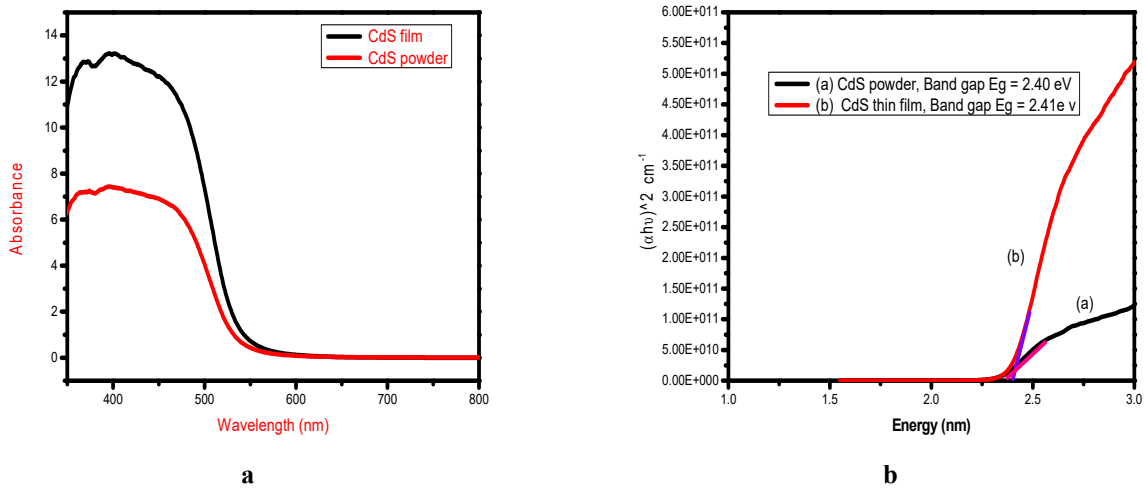
4.3. Optical studies

UV-Visible absorption spectrum of the cadmium sulphide powder and films are show in Figure 4. The optical properties of CdS reflected on the UV-Visible spectral data in the region of 370-400 nm wavelengths with a red shift of absorption wavelength. The results of above analysis are similar to other researcher by literature. A strong absorption in the ultraviolet region was observed at wavelength about 397 nm, 400 nm for film and powder respectively. Which was fairly blue shifted from the absorption edge due to quantum confinement effects [16, 18].

The optical band gap of CdS powder and film calculated using Tauc's plot method. The Tauc's equation

$$\alpha h\nu = B\,(h\nu - Eg)^n \qquad (1)$$

is used, where the absorption coefficient is α, the energy of photon is hν, B is an also constant, Eg is the band gap and n = 1/2 for direct allowed transition. The optical band gap is decided from the boundaries gotten of a straight contraction of the term $(\alpha h\nu)^2$, [27] whose convergence with the x-axis (in α=0) gives the optical band gap. This graphical interpretation starts by replacing the wavelength values to energy level using the equation (1), which comes from: Eg = ch/λ. To obtain absorption coefficient by measured absorbance assume that sample thickness is 1μm which is measured by cross section of SEM micrograph of the Sample α = 2.303A/t, 'A' measured by UV-Visible spectrometer and 't' sample thickness. According to Figure 4 band gap obtained CdS powder 2.40 eV and CdS film 2.41 eV approximately equal.



a **b**

Figure 4. a) Absorption v/s wave length, **4b)** Band gap by Tauc's plot method

4.4. Fourier transforms infrared spectra (FTIR)

Figure 5 shows the Fourier transform infrared (FTIR) spectra of deposited powder and films are recorded on a FTIR spectrometer. The more vibration in powder form and less vibration in film represent good agreement with solvent. The FTIR spectra CdS conforming to the existence of constitutional elements functional group and chemical bonding between Cd and S. FTIR spectra were lies from 400 to 4000 Cm^{-1} at room temperature. The absorption bands of FTIR spectra on wave number 1030-1070 cm^{-1} represents the S = O sulphide group. The sharp bending at the infrared active spectrum due to absorption band 1365cm^{-1}-1465 cm^{-1}, it is indicated by C–H and N–H bonding goes to 1580–1650 cm^{-1}.The prominent 2250 cm^{-1} caused by C≡N. The powder form of CdS shows water molecules stretching O–H between 3000-3550 cm^{-1} due to solvent. The band at 720 cm^{-1} relate to the Cd–S bond which substantiate the formation of CdS particles [22].

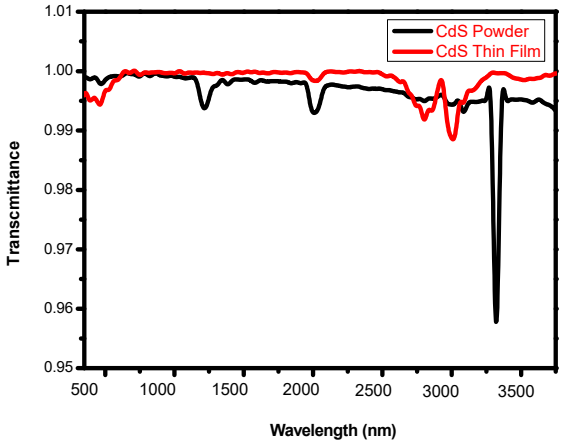


Figure 5. FTIR graphs of powder and film of CdS

4.5. Photoluminescence spectra (PL)

Photoluminescence (PL) spectroscopy has been used to study of the photo luminescence spectra of CdS powder and films with an excitation wavelength of 507 nm. The PL spectra of the deposited CdS powder and films have been recorded the wavelength range between 600 nm – 650 nm (Fig. 6). PL spectra indicate of the CdS exhibited two distinct PL bands but the peak positions and PL intensities of the powder and film were remains same due to different physical condition of cadmium sources [19]. The PL emission peaks centered around 630 nm for powder and film both. CdS shows band to band transition and direct band gap.

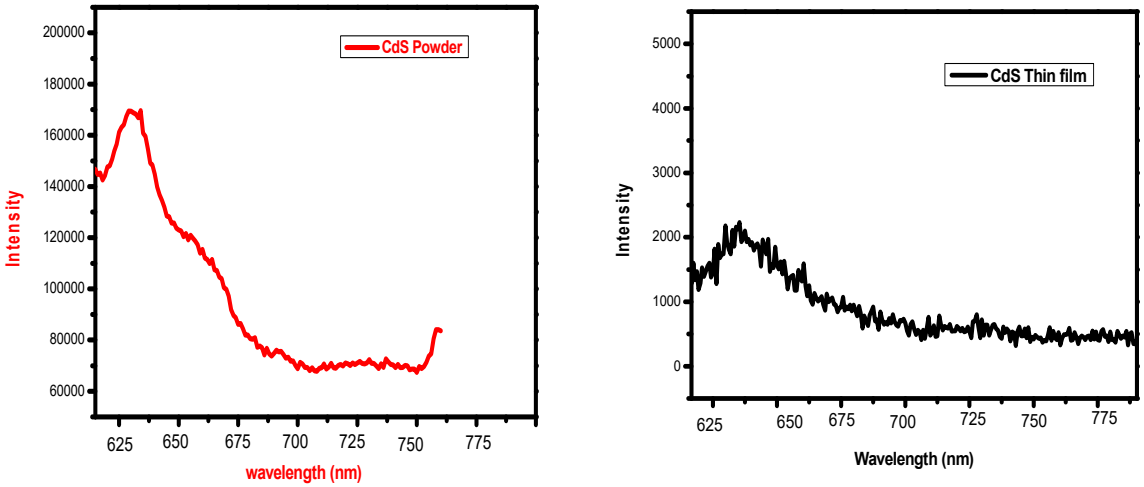


Figure 6. PL graph of powder and thin film CdS

4.6. Electrical studies (V-I Characteristics)

Figure 7 Shows I-V characteristics of the CdS films, were traced out by the Keithley spectrometer. The non Ohmic I-V characteristics can be attributed to the schottky contacts between CdS and metal contacts by silver paste. The current difference ΔI is defined as current Imax - Imin at a specific bias voltage. Imax is the maximum current and Imin is the minimum currents on the linear part of the curve. The electrical resistivity is calculated using $\rho = VA/IL$, where I is the current in mA, L the thickness of the sample (1μm), V the applied voltage, and A is the cross-section area of the sample. The calculated resistivity of film and powder were 3.351 Ω·cm, 4.166 Ω·cm respectively [25, 26].

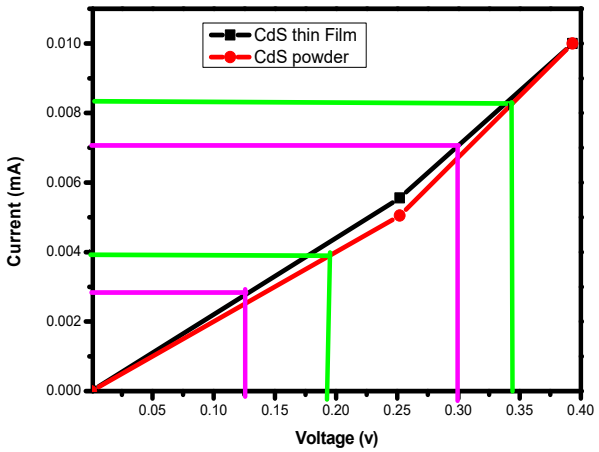


Figure 7. I-V Characteristics of powder and thin film CdS

5. CONCLUSION

In this paper spin coating method is used for CdS thin film. The prepared thin film has a bandgap of 2.41 eV. X-ray diffraction spectra show that film exists in the cubic phase. FTIR spectra confirmed sharp and strong bonding of composition. PL spectra indicate one strong visible emission band at about 630 nm for CdS. Intensity decreases of thin film comparatively to powder form due to bond formation. SEM image shows that particles are distributed randomly on the surface of thin films. The obtained resistivity of the CdS thin film was 3.351 Ω·cm.

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ДОСЛІДЖЕННЯ СИНТЕЗУ ТОНКІХ ПЛІВОК СУЛЬФІДУ КАДМІЮ ОТРИМАНИХ МЕТОДОМ ПРОСТОГО ОБЕРТАННЯ ДЛЯ ЗАСТОСУВАННЯ В ЕНЕРГЕТИЦІ

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У статті досліджено властивості тонкої плівки CdS, яка використовується для виготовлення віконних матеріалів сонячних батарей та оптичних пристроїв. Тонка плівка сульфіду кадмію (CdS), отримана золь-гель методом на склі та підкладці ITO. Підготовлену тонку плівку сушать у вакуумній печі при 70 °C. Тонка плівка та порошок CdS характеризуються структурними, оптичними та електричними властивостями за допомогою рентгенівського дифрактометра (XRD), УФ-видимого спектрометра та спектрометра Кейтлі. Середні розміри кристалітів, мікродеформації та густину дислокацій зразків розраховують за формулою Дебая Шеррера. Ширина забороненої зони CdS, розрахована методом Tauc-plot, становить 2,40 та 2,41 еВ для порошку та плівки. Довжина хвилі поглинання CdS раптово зменшується біля 280 нм і стає плоскою у вищій області довжин хвиль. Спектрометр FTIR використовується для ідентифікації матеріалів і утворення зв'язків. Утворення зв'язків, дефектів та домішок спостерігали на спектрометрі Кейтлі, який використовується для вимірювання ВАХ і обчислення питомого електричного опору за законом Ома.

Ключові слова: *ультразвукова обробка; CdS; XRD; видимий УФ; електричні властивості*