RESEARCH PAPER

Synthesis and Characterization of Nanostructural Cds Thin Film Using Spin Coating Technique for Photodetector Application

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ABSTRACT

This article, thin films of cadmium sulfide nanocrystals (CdS) were prepared by "Spin Coating" technology deposited on the glass substrates with various concentrations of Cd and S (0.5, 0.75, 1, 1.25) M. The structural characteristics of the prepared film were characterized using the X-ray diffraction "XRD", The Scanning electron microscope with field emission (FE-SEM)", the atomic force microscope (AFM), and the optical properties with UV-Visible measurement . The thin film with a concentration of (1M) has good structural and optical properties that reveal desirable for photovoltaic applications. The "XRD" revealed that all films have a cubic phase structure, with diffraction peaks of (111), (220), and (311), respectively, at 2 = 26, 43, and 51 for the deposit) the preferred orientation of its peak (111) at 2 =26.In addition, high intensities of peaks in film concentration of 0.75 M have been observed due to high crystallinity, low crystalline size, and roughness. However, The 1 M film concentration exhibits a lower crystallinity, a small crystalline size, and a high roughness. According to the FE-SEM, The nanospheres uniformly shape the structure that has been formed throughout the whole substrate surface, and There are no fractures or pinholes in any of the Cadmium-Sulfide films, and they are uniform and neatly wrapped around the substrate. A thin layer (1 M) with a uniform absorption spectrum for all visible wavelengths has a high absorption spectrum, according to the optical characteristics. The absorption values of the thin sheet (1M) are substantial. In the viewable range, all films are transparent, according to this study. The energygap increases with the decreases in molarity, and the measured energy gap is in good agreement with the energy-gap bulk.

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INTRODUCTION

Cadmium sulfide (CdS) is a semiconducting material with several applications. The physical, electrical, mechanical, and chemical properties of semiconductor nanostructures have piqued interest in recent decades due to their uniqueness. Because of their essential nonlinear optical characteristics, binary metal chalcogenides of group II-VI semiconductors in nanocrystalline form are a rapidly expanding research topic. [1], as well as luminous characteristics, the quantum size effect, as well as other important physical and chemical properties [2]. Cadmium sulfide (CdS) is a remarkable semiconductor with a massive band

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gap of 2.4 eV (in bulk) [3]. Has been studied for decades. Because of its uses in electrical devices such as field-effect transistors, [4,5], optical thin films filters, nonlinear integrated optical devices, (LEDs)light emitting diodes, solar cells, photoconductors, and laser heterostructures for visible spectrum emission, extensive research has been conducted in recent decades. Sol-gel Spin-Coating [6], metal organic chemical vapour deposition, RF sputtering, [7], electro deposition [8], chemical bath deposition, screen printing spray pyrolysis, thermal evaporation [9], sequential ionic layer adsorption reaction molecular beam epitaxy [10] have all been used to create CdS films. The "Sol-Gel" spin coating process is the most frequently utilized approach for cadmium sulfide thin film deposition. The simplicity, cheap cost, and capacity to produce homogenous films with high adhesion and repeatability are the major advantages of the sol-gel technique [4].

MATERIALS AND METHODS

The sol-gel method was used to create cadmium sulphide nanoparticles (CdS) films on the glass substrates at the various concentrations (X=0.5, 0.75, 1, and 1.25) M. The spin coating technique was used to make the cadmium sulfide thin films nanostructures at room temperature. Polyethylene glycol200 [$C_{2n}H_{4n}+2O_{n+1}$] For 1hour, 0.6ml of PEG, 0.5ml of Acetic-Acid [CH_3COOH], and 8.9ml of ethanol [C_2H_5OH] were stirred together. To make a solution, combine 15mL of ethanol, (X) Mol/L of thiourea extremely pure (CH_4N_2S) as a source of S and (X) Mol/L of Cadmium-Nitrate $Cd(NO_3)_2.4H_2O$ as a source of Cd, This solution was gradually added to the SOL. PEG while rapidly stirring for 2 hours, until a homogeneous solution was created. As the reaction continued, the reaction system gradually transformed from clear to brilliant yellow. To verify that all components were properly mixed, The final ideal solution was maintained at room temperature for at least 20 hours. Acetic acid and ethanol were used to clean glass substrates. the generated solution was spin coated for 30 seconds at a spinning speed of 2000 RPM on glass substrates. At this point, the precipitate was dried on a hot plate at 100 degrees Celsius. The CdS thin film nanostructure was described using XRD, FE-SEM, AFM and (UV–vis) .The "x'pert" high score application was used to analyse the "XRD" data.

RESULTS AND DISCUSSION

Characterization of Structure and Morphology

Despite the fact that several strategies for creating these nanocrystalline thin films with controlled size , shape ', and crystallinity are being researched, different factors impacting the size and form of these materials have yet to be discovered [5],.By changing the detector's angle 2, the "Bragg" peak may be discovered.

$$2d \sin \theta = n\lambda \qquad (1)$$

where n is an integer. "Scherer's" formula is used to calculate the grain size (D) in a polycrystalline film. [6]:

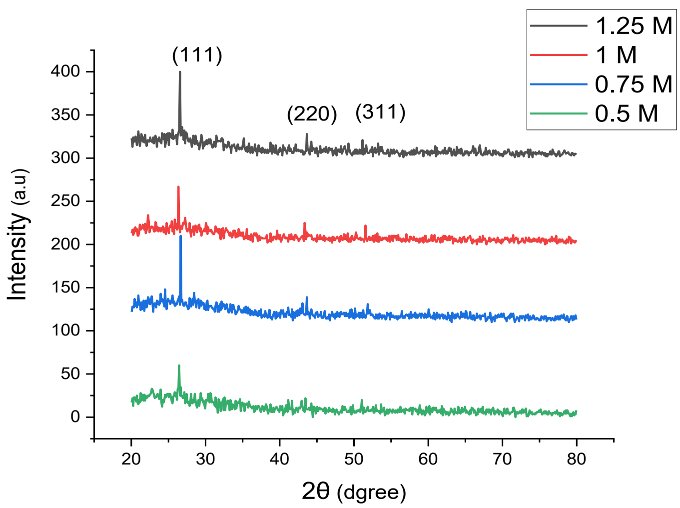

Fig. 1. XRD of Cadmium_Sulfide thin films

Table 1. Cadmium Sulfide thin film structural parameters.

				CdS			
M	2θ	Hkl	β	D	a,b,c	ϵ	δ *E-3
0.5	26.5	111	0.3936	36	5.7	0.095	0. 7
0.75	26.6	111	0.1034	137	5.8	0.025	0. 05
1	26.3	111	0.2214	64	5.7	0.053	0. 24
1.25	26.5	111	0.0266	535	5.85	0.0055	0. 0034

$$D=\frac{K\lambda}{\beta\cos\theta} \qquad (2)$$

β where is the peak's entire width at half-maximum (in radians), k = 0.94, and is the Bragg angle . Cu (k) was used as the radiation source, with a wavelength of 1.5406A.The dislocation density, which is a measure of crystallite defects [7],was calculated using Williamson and Smallman's formula.

$$\delta=\frac{n}{D^2} \qquad (3)$$

$$\mathcal{E}=\beta\cos\Theta/4 \qquad (4)$$

where D denotes the average crystallite size and n denotes the maximum dislocation density when equal to one.This section contains X-Ray-diffraction patterns for S0L-GEL ((CdS)) thin films on the glass substrates at various concentrations. The X-ray characterisation of materials is summarized in Table 1. The average grain diameters of the nanocrystallites D, dislocation density (δ), and film strain (Ɛ) were calculated using the Debye-Scherrer equation from the FWHM (full-width at half-maximum) of the (111) diffraction peaks and are shown in Table 1. [8]. illustrate the XRD-patterns of the cadmium sulfide thin film (Fig. 1), a deposit that was discovered

Atomic force microscopy (AFM)

AFM is an abbreviation for Atomic Force Microscopy. The surface morphology of Cadmium sulfide thin film deposition on glass substrates at different concentrations was studied using AFM, as shown in the picture (Fig. 2). It was revealed that crystallization influences the roughness (R) of Cadmium sulfide thin films. With the highest intensity for film concentration 0.75 M, resulting in a film with high crystallinity and low average roughness, and the lowest intensity for film concentration 1 M, resulting in a film with low crystallinity and high average roughness. Table 2. shows that the greatest crystallinity and the least surface roughness, as well as the lowest Root Mean Square and the smallest particle size, have an inverse relationship.

Scanning electron microscope with field emission (FE-SEM)

A " FE-SEM" is an analytical instrument that uses a beam of electrons to raster scan across surface, whole, or fractioned nanoscale objects to detect topographic features. The "FE-SEM" images of the cadmium sulphide CdS reveals that the cauliflower's spherical particles contain clusters. These clusters consist of clusters of grapes that are separated from each other. This shape assistant to absorb wavelengths. Nucleation within growth gives superior absorption[9]. The average spherical diameters of the nanofilms range from 5.6 nm to 22.7 nm. Fig. 3. depicts the structure of the thin film. We can see from the FE-SEM image that the concentration (0.5 M) is in the form of spherical morphology of CdS nanoparticles with grain size 16.7 nm that are regularly scattered on the surface, and we can see that as the concentration increases, the growth of granules increases, as evidenced by the XRD examination. Nanoparticles having a grain size of 22.7 nm and regular diffusion The form of the installation is denser with the increase in concentration to (1M), and the cauliflower's spherical particles include clusters and smaller volumes than the concentration (0.75 M), as demonstrated in the inspection. XRD shows that when the concentration of nanoparticles with a grain size of 5.6 nm increases, the surface becomes highly dense aggregates, as seen in Fig. 3D during inspection (AFM). The coating contains nanoparticles with a grain size of 6.8 nm, ensuring that the elements are protected. The structure

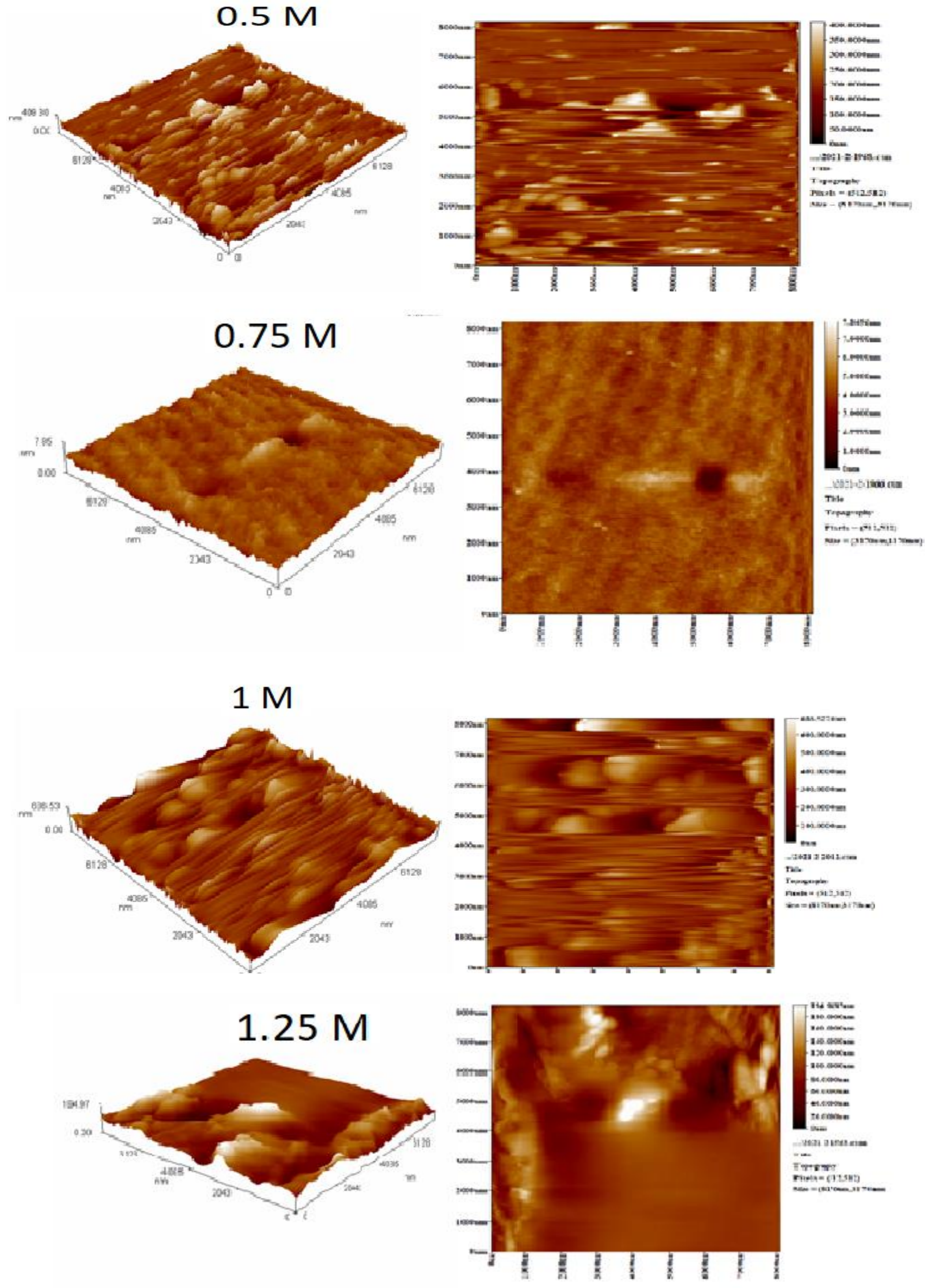

Fig. 2. shows 2D and 3D using (AFM) of Cadmium sulfide thin film with various concentrations

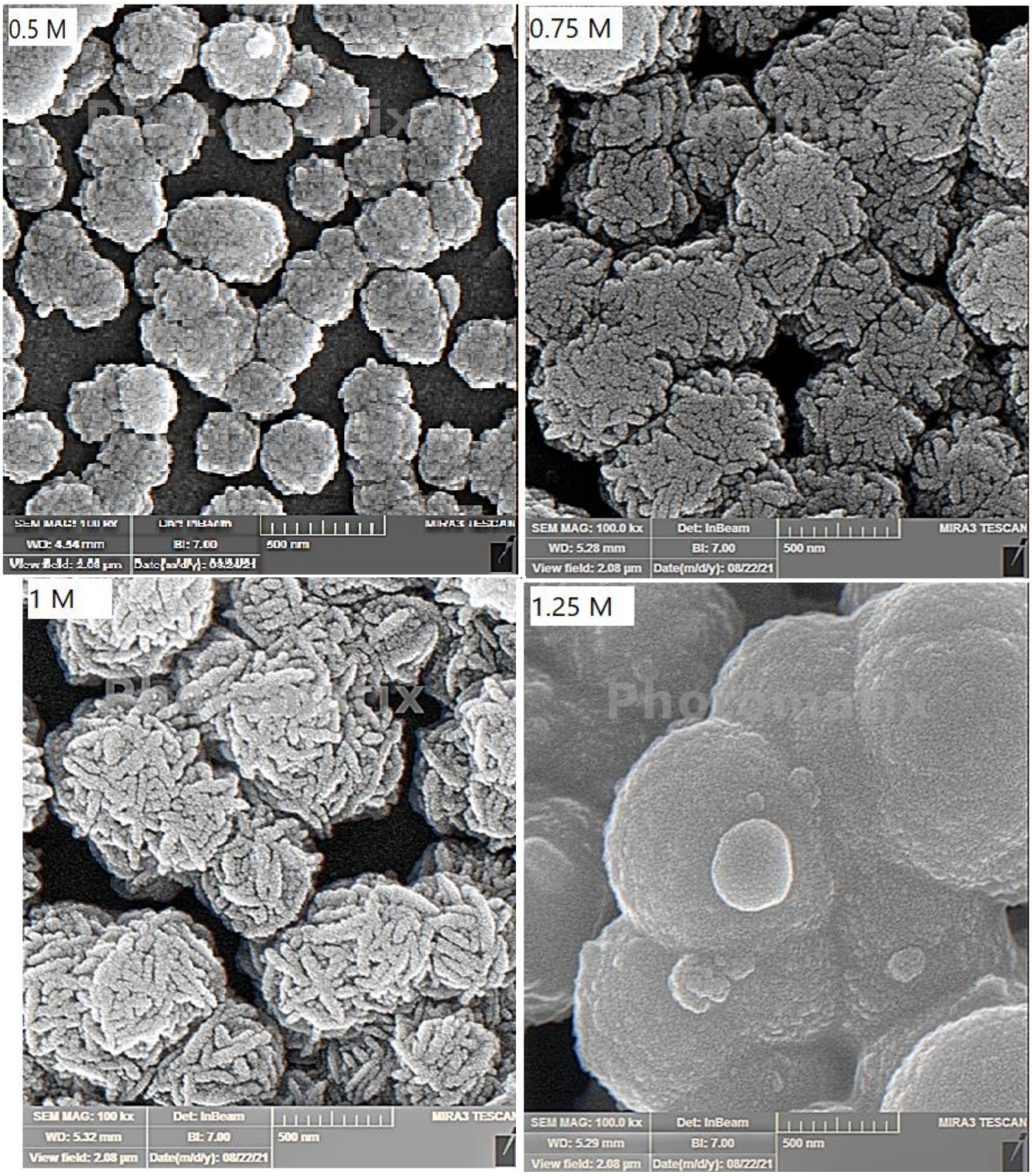

Fig. 3. The SEM image of the CdS structure (images process Using PHOTOMATIX to convert HDR. (High Dynamic Range Image) to JPG).

grew consistently throughout the whole surface of the substrate thanks to nanospheres, implying that the CdS films are tightly wrapped around the substrate and are homogenous There were no flaws or pinholes in any of the Cadmium sulfide films.

Optical Properties

Grasp semiconductor nanocrystal behavior demands a detailed understanding of optical characteristics such as absorption, transmission, and energygap (Eg). The difference in energy between the empty conduction band and the full valence band is a fundamental feature of semiconductors.Electrons traveling through the energy gap are not allowed to be photoexcited.

Table 2. roughness and RMS of the CdS thin films

Concentration	Roughness	Root mean square
0.5	47.7	31.3
0.75	0.35	0.487
1	52.3	72.3
1.25	16.7	24.3

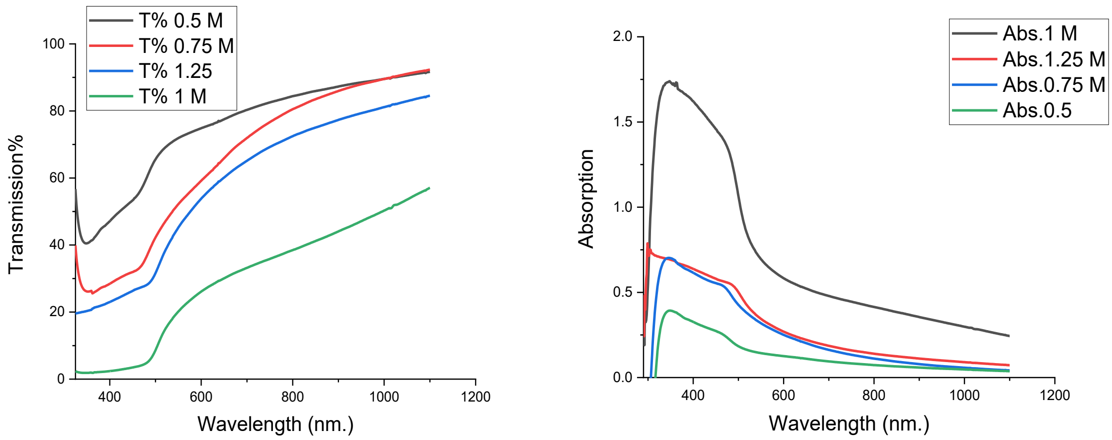

Fig . 4. UV -transmittance and UV-absorption spectra of CdS thin films at various concentrations

Table 3. Energy-bandgap and particle size of CdS thin films

Concentration	Energy bandgap	Grain size
0.5	2.50	16
0.75	2.38	25
1	2.32	35
1.25	2.30	23

In the visible-near infrared region, films with the lowest concentration have better transmittance, whereas those with larger concentrations have lower transmittance.[10,11] As seen in Fig. 4, the quantity of absorption varies depending on the molarity, with the optimum absorption spectrum being obtained by a thin film (1 M) with a uniform absorption spectrum for all visible wavelengths. The thin film has a high absorption rate (1M).

When it comes to optical properties, the surface

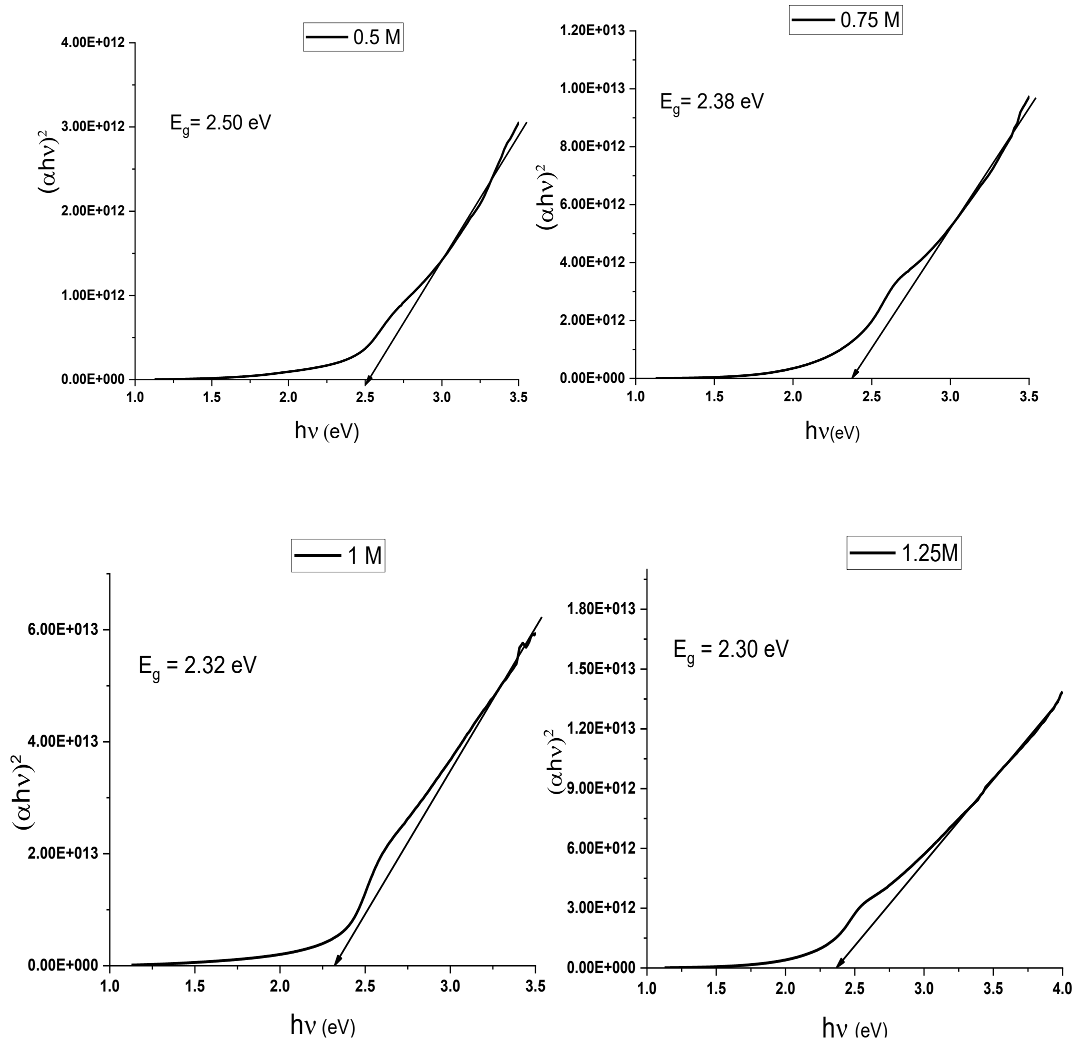

Fig. 5. The energy gap of the CdS films at various concentrations

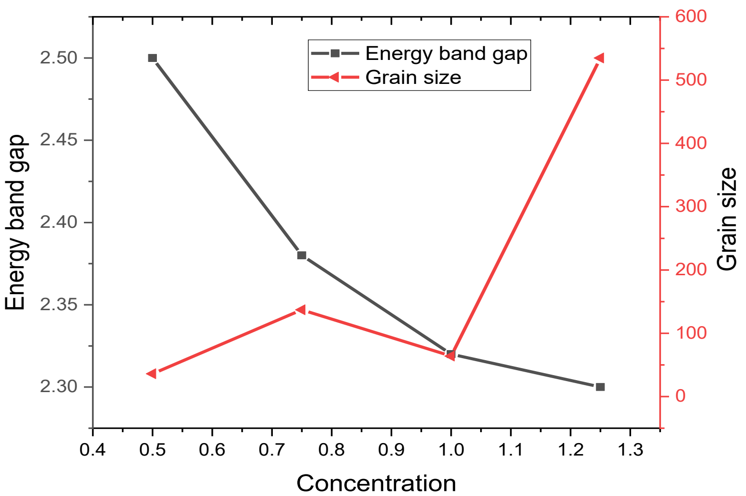

Fig.. 6. The grain size and energy gap of CdS films as a function of concentration roughness of a material may have a role. Using the energy gap development curves, the energy gap of the CdS thin films was estimated. The energy gaps were approximated from the absorption peak and found to be between 2.30 and 2.5 eV Eg..as shown in and Fig. 5, and Table 2. results were in good agreement with those reported[12,13,14].

CdS thin films have an energy bandgap in the region of 2.30–2.45 eV. According to Table 3. and Figs. 6 [11,12,15], the energy gap of the films diminishes as concentration molarity rises. Due of the quantum confinement effect, the energy-gap" of the films increases with decreasing grain size [13,15]and The point of intersection of the two columns (particle size and energy gap) represents the optimization molarity that can be chosen to make photodetector. The observed energy-gap agrees well with the energy gap bulk. As a result, it is widely understood that the bandgap energy is affected by particle size, crystal structure, and strain [16,17].

CONCLUSION

The Spin-Coating process was used to deposit cadmium sulfide CdS nanostructured thin films on the glass substrates in various concentrations (X=0.5,0.75,1, 1.25) M. As molarity diminishes, so does the energy gap. which discovered that the greatest absorption spectrum has been recorded of a thin sheet (1 M) with a uniform absorption spectrum for all visible wavelengths We found that thin films with high absorption values (1M) are transparent in the visible range and have a high average roughness. based on FESEM study The presence of nanoparticles with grain sizes of 6.8 nm in the form of Nanospheres shape forms, The structure formed uniformly throughout the whole surface of the substrate, demonstrating that the cadmium sulfide coatings are homogeneous and securely wrapped to the substrate, with no cracks or pinholes. Cadmium sulfide thin film (1M) shows promise in optoelectronic applications.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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