



Influence of Thickness on Structural and optical properties of the CdS single crystal nano structure thin films Deposited Via Thermal evaporation

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<https://doi.org/10.25130/tjps.v24i6.443>

ARTICLE INFO.

Article history:

-Received: 22 / 4 / 2019

-Accepted: 1 / 8 / 2019

-Available online: / / 2019

Keywords: Single crystal CdS thin films, PVD, XRD, FESEM Cross section, AFM.

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ABSTRACT

In this paper, the preparation of the harmful cadmium CdS on glass bases, prepared by thermal evaporation in the vacuum and study of optical and structural properties. The thickness and structural of the films were determined by (FESEM cross section). The results of the X-ray diffraction (XRD) showed that the films had a single crystal the hexagonal structure and the roughness and granular size were studied by using the (AFM) in two dimensions and three dimensions. The surface of the films was formed from clusters of granules called cluster and the roughness rate increased. The optical properties were studied through the (T) permeability spectrum of cadmium sulfide (CdS) prepared in wavelength range (400,650,750) nm. It was noted that the permeability of cadmium sulfide was low and when the permeability decreased, the energy gap increased. And the value of the optical energy gap is (2.6eV) for cadmium sulfide. The optical properties were calculated as a function of the photon energy, which includes the absorption coefficient. The optical properties suggest that the prepared had a direct energy gap of 2.5,2.2,1.95eV where the energy gap was observed by increasing the thickness of the prepared the films was studied for the manufacture of electronic devices such as solar cells. The morphology of the surface was studied through (AFM), and the study of the optical properties of the films by UV-visible, and the CdS of the (PVD) thermal discharge were prepared in vacuum.

Introduction

CdS has been intensively used by the researchers because the 'n-type semiconductor' possesses a widely direct energy band gap within (2.28eV) and (2.45eV) at the room temperature, adequate optical transmittance and less resistivity, also it has found potential applications [1]. The researchers have chiefly concentrated on the study of nanowires, nanotubes and nanostructure, comprising the evolution of synthetic approaches and the investigations on their novel physical characteristics [2-5]. In terms of structure, it has been reported that the CdS can exist in cubic (Zinc blend) phase [6-11], hexagonal phase of the two phases, depending on the method of preparations and the condition synthesis [12,13]. It has different commercial applications, such as solar cell [14], photo detector [15], LED [16], FET [17], pixel electronics and various semiconducting devices [18]. Various approaches were used to deposit the CdS thin films, comprising

evaporation by vacuum [19], and chemical bath deposition (CBD) [20], sol-gel [21] and so on. present study, PVD was used to prepare the CdS thin films. Also, the thickness effect on the structural and optical characteristics of the films was investigated.

Experimental Work

CdS thin films were this word does not come in this context-so check it again please deposited by (Edward 306) PVD technique at a vacuum pressure of (2×10^{-4}) mbar on cleaned glass substrates using high purity CdS powder (Merck) that was vaporized by the used molybdenum boat. The film thickness was measured by (cross section) FESEM method and was found to be three thicknesses ~ (400, 650, and 750) nm. The distance between the pot and the sprite is 10cm. The sedimentation rate is the thickness of each case divide by 5 minutes. The glass bases and check it bases in to(2x2cm)place the glass bases in baker and add it is acetone and use the ethers for ten

minutes to remove the suspended material. The bases are washed with water the ether sonic for ten minutes the bases are then placed in a baker containing ethanol with an ether sonic for ten minutes and in the final stage. From cleaning, the bases are rinsed with distilled water the ether sonic and then dried with nitrogen gas. The X-ray diffraction patterns of CdS thin films were registered by using the XRD apparatus, model (Shimadzu-6000), in the range of 2θ between (10°-80°), using Cu Kα radiations with a wavelength of 1.54060 Å. The surface property measurements were done using atomic force microscopy (AFM), model (AA3000 scanning probe microscope/SPM).

The absorbance spectra were recorded using UV-VIS-NIR spectrometer, model UV-2800 .

Results and Discussion

1. Structure properties

Figure (1). depicts the XRD patterns of the (CdS) film for different thicknesses. The spectrum was found by scanning 2θ in the range 10– 80°. rewrite it again please. that the maximum intensity creases abruptly as shown in the table(1) below 2θ=26.66, and the peak sharpness indicates that the films are individual crystalline possessing a hexagonal structure having (002) plane arrangement in accordance with the International Center for Diffraction Data (ICDD), card no. 00-001-0783.

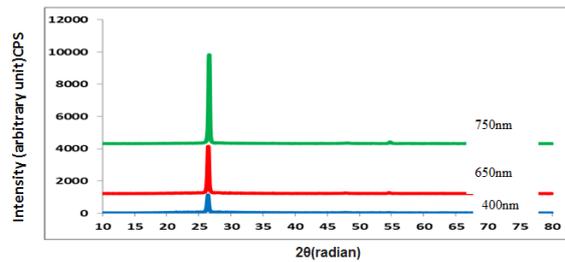


Fig. 1: XRD for CdS thin film for three thicknesses (400, 650 and 750) nm

The crystalline size can be calculated using Scherrers formula [22]:

$$D = \frac{K\lambda}{\beta_{2\theta} \cos \theta} \text{ -----(1)}$$

Where,

K : Constant, which is often approximated to (0.94)

(λ = 1.54 Å): Wavelength of X-ray

2θ: Bragg angle

β_{2θ} : FWHM of diffraction peak(in radian)

The crystalline size value of crystalline increases with the thicknesses, but the size of crystallite has been estimated from the (002) diffraction peak for the CdS films deposited by PVD. The micro strain and dislocation density are calculated by using the equations 2and 3 [23], respectively.

$$\varepsilon = \beta_{2\theta} \cos \theta / 4 \sin \theta \text{ -----(2)}$$

$$\delta = 1 / D^2 \text{ -----(3)}$$

Table 1: The results of XRD analysis

Thickness (nm)	(hkl)	2θ (radian)	Beta (radian)	Crystalline size, D (nm)	Micro strain (x 10 ⁻⁴)	Dislocation (μm) ⁻²
400	(002)	26.44	0.27810	40.66	39	380
650	(002)	26.48	0.23670	60.19	27	270
750	(002)	26.66	0.20960	67.97	21	210

The results of the particle size calculation were included in table 1, which comprise the results of structural tests of the x-ray yields of (400,650,750)nm CdS. Note that the size of the crystalline is increasing with increasing thickness. The size of the granules for each of the peaks of BRAC peaks in figure1. Is calculated using the Debye equation-scherer [64]. The reason for this rise in BRAC peaks to single crystal can be explained by an increase in the internal system of atoms and reduced surface energy of the films, which helped the growth of granules per peak the BRAC peaks. There is a good match between the values of d_(hkl) scientifically produced and their value from the standard cards (ASTM) where it was noted that these reflections are the characteristics of composite (CdS) and this is consistent with the published results[71-72-73]. It was found that 002 reflections are the properties structure is consistent with researchers[6-12-28-31]. And the micro strain decreases with increasing films and the reason for this decrease because it decreased the amount of cluster and increased the percentage of dips in the surface

and decreased the thickness of films relative to the reference to the researcher[74] and it is unclear Dislocation decreases with the increase of films and the reason for that because it decreased the amount of peaks and the amount of decreases relative to the reference to the researcher. The films homogeneity decreases during the interferometry process.

2. Atomic force microscope study

The study examined: Do not use we at all. (AFM) on (CdS) in 3D and 2D at a distance of (10x10)mm and found that the surface of all Films consisted of clusters of granules called cluster, Which showed good homogeneity of the Films (a, b, c) Roughness and RMS root mean square are more valuable and are more likely to be explained by the fact that the crystal line growth of the grains is perpendicular to the surface as shown in Figure2 and table2. The Z axis is the surface thickness, the highest of the grains within the thickness of the films studied. The total granularity on the surface of The films is the least possible in the case of the films.

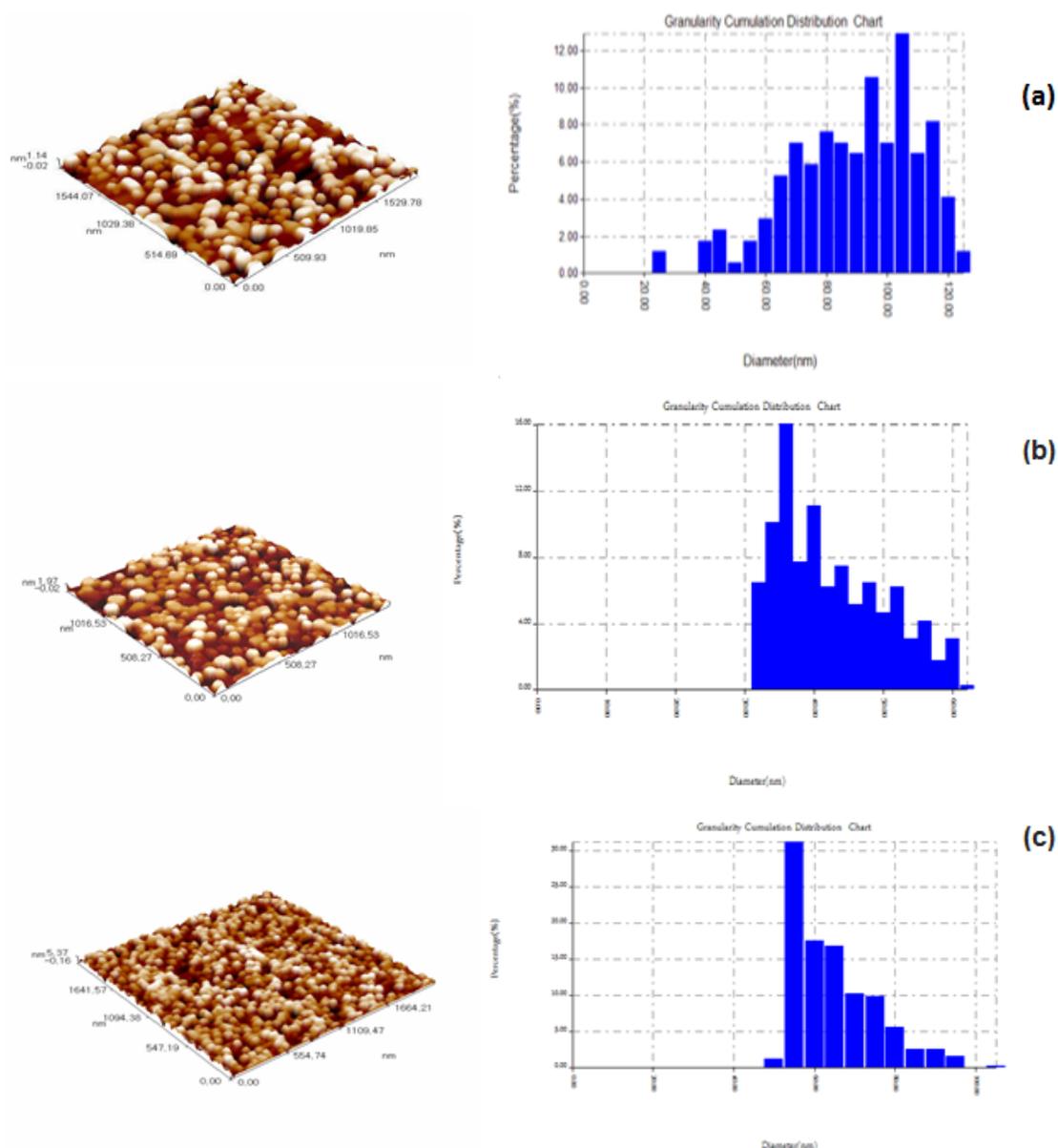


Fig. 2: AFM Analytical Image of (CdS) Films for different thickness (a- 400, b - 650, 750)nm.

Table 2: results of AFM

Thickness	Average particle size	Surface roughness	Square root box	The length of the highest point
400	86.33	1.17	1.38	5.33
650	41.66	6.46	0.534	1.88
750	62.49	1.32	0.332	0.663

The table 2 shows that the topographic surface account of the films with a thickness of (400nm) measured two-dimensional and three-dimensional shows that the particle size by (5.33nm) that surface roughness (1.17nm) and the rate of the square root of the rate (1.38nm) reason that the images shown in figure 2 contains a white tops show. The height of these grains and areas of black mixed colors indicate the percentage of dips in the surface of the films the highest peak. The surface topography was calculated for a thickness of 650nm. The reason for the increase

in this thickness in Table 2 was shown to have affected the parameters and surface of the films. The average particle size decreased to (41.66nm). It was noted that the length of the films surface roughness increased to (6.46nm). The slope decreased to (0.534nm), while the surface dips decreased to the highest peak to (1.88nm). It was clear from the table that the surface topography with a thickness of (750nm) was calculated due to the increase in the thickness. The roughness value decreased to (1.33nm). This indicates that the surface became finite

(0.332nm) and also the peaks and the amount of dips in the surface to (0.663nm) the benefit of these declines is the study of the topography of the surface and to know the amount of dips of summits surface that.

3.Thicknesses measurement

Figure (3) check this again present the cross sectional image of FESEM, which is through it the thicknesses of the films is calculated.

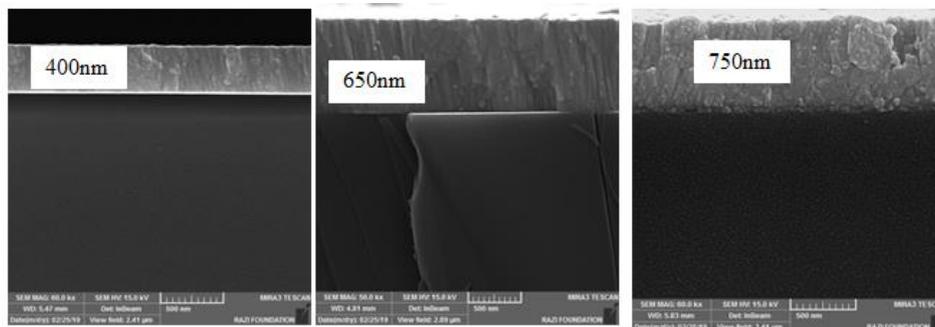


Fig. 3: Cross sectional image of FESEM for CdS- thin films.

4. Optical properties

The optical characteristics of (CdS) thin films were studied using absorbance spectra of the visible-near infrared region (UV-Vis-NIR) within the region (200-1100 nm). The variation of the CdS thin film absorbance with the wavelength for three thicknesses (400, 650 and 750) nm is revealed in Figure4. From this figure, it is noticed that the absorbance decreases as the wavelength increases[25]. Throughout figure(4), omit it. noticed that the band gap of energy reduces from (2.49) to (2eV) with increasing the thickness. The reduction in values of the band gap is owing to large grain size and the quantum size effect [24].

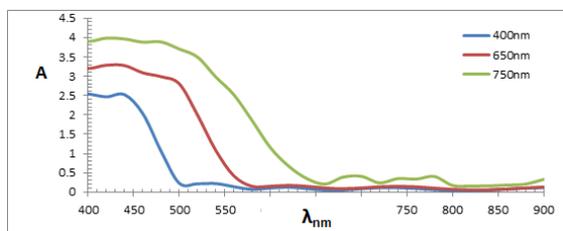


Fig.4: Variation of the CdS thin film absorbance with the wavelength for three value of thicknesses (400, 650 and 750) nm

The optical energy gap of the cadmium sulfide compound by drawing the relationship between $h\nu(eV)$ and $(\alpha h \nu)^2$ external contact is drawn to the high absorption area for the cure to cut the axis of photon energy $(\alpha h \nu)^2=0$ where and junction point axis. The x -value is the value of the optical energy gap instead of the shape that shrinks the optical gap by increasing [27,28 ,29] . The thickness and also reducing the thickness of the films. Low crystalline structural properties and defects [30,31] of the optical energy gap in experimental results compared to with the standard results is due to the formation of particles and the existence of the effect of the quantitative restriction of the prepared [32,33]table 4 illustrates this. If the field rewrite this ohvase of CdS is small, the electron movement and are restricted and appear to be limited, thus increasing the energy

required to prepare the electron in the connection [34,35 ,36] .

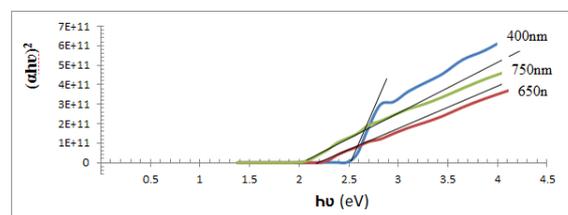


Fig.5: $(\alpha h \nu)^2$ against $h \nu$ for CdS thin films for different thicknesses

Table 4: The energy gap values of CdS thin films for different thickness

Thickness (nm)	Direct energy gap (eV)	Indirect energy gap (eV)
400	2.2	2.4
650	1.5	2
750	1.4	1.4

The optical gap for direct and indirect electron transitions of both allowed and prohibited types of cadmium sulphide was calculated by drawing the relationship between the agnnnen and the outer tangent of the high absorption area of the vector to interrupt the photon $y=0$ energy axis. The former forms that the optical energy gap weak phrase .rewrite it again. It is not clear. decreases with [24-32-29] thickness. The films are also reduced. This can be explained by the improvement of the structural properties and increase the vibrational energy of the atoms. Thus the atoms are aligned and rearranged, thus reducing the crystalline defects. The high value of the optical gap in the experimental results compared to the standard results is due to the formation of nanoparticles and the effect of the prepared.[33-34] if the field is small, the electron movement and the gap are restricted and appear to be limited, thus increasing the rise in the energy required to stimulate the electron in the conduction package [35-36].

Conclusion; without(S)

1. Through the results and practical applications it was observed that the CdS films grew by one crystal by PVD.

2. After conducting the synthetic tests we found that the cadmium sulphide films are crystalline (single crystal line).

3. Cadmium sulphide has energy gap of (2.43 eV) allowed direct transmission and falls within the range of the energy gap values for semiconductors.

References

[1] Morales, A. (2006). Thin films CdS / CdTe solar cells, *Sol Energy*, 80:675–681.

[2] Zhang, Y. and Ijima, S. (1998). Coaxial nano cable: silicon carbide and silicon oxide sheathed with boron nitride and carbon, *Science* 281, 973.

[3] Wang, W. Deng, Z. X. Wu, Y. Y. Sun, X. M. Yu, D. P. and Yang, P. D. *Am. Chem. J.* (2001). Bismuth nanotubes, A rational low temperature synthetic route, *Soc.* 123, 9904.

[4] Lao, S. H. Jo, J. Y. Ren, Z. F. Farrer, R. A. Baldacchini T. and Foukas, J. T. (2003). Field-emission studies on thin films of zinc oxide nanowires, *Appl. Phys. Lett.* 83, 4821.

[5] Wang, Y. W. Meng, G. W. Zhang, L. D. Liang. C., H. and Zhang, *Chem. Mater. J.* (2002). Catalytic Growth of Large-Scale Single-Crystal CdS Nanowires by Physical Evaporation and Their Photoluminescence, 14, 1773.

[6] Khallaf, H. Oladeji, I. O. Chai G. and Chow, L. (2008). Characterization of CdS thin films grown by chemical bath deposition using four different cadmium sources, *Thin Solid Films*, 516, 7306–7312.

[7] Hop, B. X. Trinh, H. V. Dat K. Q. and Bao, P. Q. (2008). Growth of CdS thin films by chemical bath deposition technique, *VNU Journal of Science, Mathematics-Physics*, 24, 119–123.

[8] Al-Hussam, A. M. and Jassim, S. A. (2012). Synthesis, structure, and optical properties of CdS thin films nanoparticles prepared by chemical bath technique, *Journal of the Association of Arab Universities for Basic and Applied Sciences*, 11, 27–31.

[9] Park, W. D. (2012). Optical constants and dispersion parameters of CdS thin film prepared by chemical bath deposition, *Trans. Electr. Electron. Mater.*, 13, 196–199.

[10] Huse, V. R. Mote V. D. and Dole, B. N. (2013). The crystalline graphic and optical studies on cobalt doped CdS nanoparticles, *World Journal of Condensed Matter Physics*, 3, 46–49.

[11] Onwudiwe, D. C. Arfin, T. and Strydom, C. A. (2014). Synthesis characterization, and dielectric properties of N-butyl aniline capped CdS nanoparticles, *Electrochimica Acta*, 116, 217–223.

[12] Lee, J. (2007). Influence of substrates on the structural and optical properties of chemically deposited CdS films, *Thin Solid Films*, 515, 6089–6093.

4. The thickness of the cadmium sulphide crystal if it greatly affects the refractive index, reflectivity and thickness led to increase the blocked energy gap and refractive index, but it led to a decrease in the value of the electric insulation constant and the compliant of laxity.

5. Studying the stability of these films after a period of time by repeating the same measurements on them.

6. Omit numbers use name researcheva.

[13] Ramaiah, R. K. SPilkington Pilkington, D. Hill, A. E. Tomlinson, R. D. and Bhatnagar, A. K. (2001). Structural and optical investigations on CdS thin films grown by chemical bath technique, *Materials Chemistry and Physics*, 68, 22–30.

[14] Tang, J. Kemp, K. W. Hoogland, K. S. Jeong, H. Liu, Levina, L. Furukawa, M. Wang, X. Debnath, R. and Cha, D. (2011). Colloidal quantum dot photo voltaics using atomic ligand passivation, *Nat. Mater.* 10, 765.

[15] Karanjai, M. K. and Dasgupta, D. (1988). Photoconductive properties of dip-deposited CdS: Cu, Cl thin films sensitized in situ, *J. Phys. D: Appl. Phys.* 21, 1769–1772.

[16] Joseph Sharkey, J. Dhanasekaran, V. Chang Woo Lee and John Peter, A. (2011). Microstructural parameters and optical constants of CdS thin films synthesized with various bath temperature *Chemical Physics Letters*, 503, 86–90.

[17] Milind Kale, and Deelip Bhavsar, (2014). Synthesis and Characterization of Nanostructured (CdS)_{0.8}Te_{0.2} Thin Films for Solar Cell Application, *International Journal of Engineering Sciences & Research Technology*, 3(4), 7012–7015.

[18] Talapin, D. V. and Murray, C. B. (2005). PbSe Nano crystal Solids for n- and p-Channel Thin Film Field-Effect Transistors, *Science* 310, 86–89.

[19] Senthil, K. and Mangalaraj, D. (2001). Structural and optical properties of CdS thin films, *Appl. Surf. Sci.* 169–170, 476–479.

[20] Moualkia, H. Hariach, S. SAida, M. Attaf N. and Laifa, E. L. (2009) Growth and physical properties of CdS thin films prepared by chemical bath deposition, *J. Phys. D Appl. Phys.* 42, 135404–135410.

[21] Thambidurai, M. Gilan, S. Muthukumarasamy, N. Murugan, N. and Balasundaraprabhu, R. (2009). Structural Properties of CdS Nanocrystalline thin Films Prepared by Sol-Gel Method, *Int. J. Nanotechnol. Appl.* 3, 29–34.

[22] Cullity, B. D. (1959). *Elements of X-ray Diffraction*, Addison-Wesley Metallurgy Series.

[23] Guinebrière, R. (2007). *X-ray Diffraction by Polycrystalline Materials*, page 230, Published in Great Britain and the United States in by ISTE Ltd.

[24] Tsai, C. T. D. S. Chuu, a. G. L. and Yang, S. L. (1996). Studies of grain size effects in rf sputtered CdS thin films, *J. Appl. Phys.* 79, 12.

[25] Desale, J. Shaikh, S. Siddiqui, F. Ghosh, A. Birajdar, R. Ghule, A. and Sharma, R. (2011). Effect

of annealing on structural and optoelectronic properties of CdS thin films by SILAR method, Advances in Applied Science Research 2, 4, 417-425.

[26] Bhatt, R. Bhaumik, I. Ganesamoorthy, S. Karnal, A. K. Swami, M. K. Patel H. S. and Gupta, P. K. (2012). Urbach tail and bandgap analysis in near stoichiometric LiNbO₃ crystals, Physics Status Solidi A, 209, 1, 176-180 .

[27] AL-Jawad, S.M.H. (2006). Study of Some Physical Properties of CdS Films Prepared by Chemical Bath Deposition, PhD. thesis Applied Science Dep, University of Technology, .

[28] Makhdomi, Kakhaki, Z. Youzbashi1, A. Sangpour, P. Naderi, N. Kazemzadeh, A. (2016). Effects of film thickness and stoichiometric on the electrical, optical and photodetector properties of CdS quantum dots thin films deposited by chemically bath deposition method at different bath temperature" , J Mater Sci: Mater Electron.,

[29] Kavitha, N Chandramohan, R. Valanarasu, S. Vijayan, T. A. Rex Rosario, S. Kathalingam, A. (2015). Effect of film thickness on the solar cell performance of CBD grown CdS/PbS heterostructure, Materials Science Materials in Electronics.

[30] Muthusamy, M.Muthukumar, S. Ashokkumar, M (2014). Composition dependent optical, structural and photoluminescence behavior of CdS:Al thin films

by chemical bath deposition method, Ceramics International Vol. 40pp. 10657-10666.

[31] Mariappan, R. Ponnuswamy, V. Ragavendar , M. Krishnamoorthi , D. Sankar , C (2012). The effect of annealing temperature on structural and optical properties of undoped and Cu doped CdS thin films" Optik Vol.123 pp.1098–1102.

[32] Nanda, K.K. Sarangi, S.N Mohanty, S. and Sahu, S.N, (1998). Thin Solid Films, Vol.322, pp 21 – 27.

[33] Parvathy, N.N. G.(1999) is attributed to presence M. Pajonk, A.V. Rao, J. Mater. Synth. Proc. Vol.7, 221.

[34] Ali Mousa, M. Adawiya, J. Haider. and Selma Hassan Al-Jawad, M. (2011). Optical Properties of Nanostructure in CdS at Different Condition Bath Deposition, Journal of Materials Science and Engineering Vol.5 pp.184-491.

[35] Ruby Das, Suman Pandey, (2011). Comparison of Optical Properties of Bulk and Nano Crystalline Thin Films of CdS Using Different", International Journal of Material Science, Vol.1 , PP.35-40.

[36] Haider, A. Abdulwahid, (2016). Fabrication and Characterization of Nanostructures CdS-Dye Sensitized Solar Cells, M.Sc. Thesis, University of Basrah.

تأثير السمك على الخواص التركيبية والبصرية للأغشية الرقيقة CdS الأنوبية النانوية أحادية البلورية المودعة بواسطة التبخر الحراري

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الملخص

تم في هذا البحث تحضير أغشية كبريتيد الكاديوم (CdS) النقية المحضرة على قواعد زجاجية والمحضرة بطريقة التبخر الحراري في الفراغ ودراسة الخصائص البصرية والتركيبية. تم تحديد سمك وبنية الافلام بواسطة (FESEM cross section)، بينت نتائج حيود الاشعة السينية (XRD) ان الاغشية ذات تركيب احادي التبلور (single crystal) ومن التركيب السداسي (hexagonal) كذلك تم دراسة الخشونة ومعدل الخشونة والحجم الحبيبي بواسطة استعمال مجهر القوة الذرية (AFM) في بعدين وثلاث ابعاد وتبين ان سطح الاغشية يتكون من تجمعات للحبيبات يطلق عليها عنقايد (clusters) وان معدل الخشونة تزداد قيمتها. وتمت دراسة الخصائص البصرية من خلال طيف النفاذية (T) لأغشية كبريتيد الكاديوم (CdS) المحضرة في مدى الاطوال الموجية (400,650,750)nm لوحظ أن نفاذية أغشية كبريتيد الكاديوم تكون قليلة وعندما تقل النفاذية تزداد فجوة الطاقة (Eg) وقد بلغت قيمة فجوة الطاقة البصرية (2.6eV) لكبريتيد الكاديوم. ايضا تم حساب الثوابت البصرية كدالة لطاقة الفوتون والتي تشمل معامل الامتصاص ومعامل الخمود وبينت الخواص البصرية امتلاك الاغشية المحضرة فجوة طاقة مباشرة (2.5 eV, 2.2 eV and 1.95 eV) حيث لوحظ نقصان فجوة الطاقة بزيادة سمك الاغشية كما لوحظ زيادة معامل الانكسار بزيادة سمك الاغشية المحضرة وهذه النتائج اظهرت ملائمة الاغشية لصناعة النانواثر بصرية كالأخلايا الشمسية. وتم دراسة مورفولوجية السطح عن طريق (AFM) ودراسة الخواص البصرية لأغشية عن طريق UV-visible وتم تحضير اغشية (CdS) بتقنية الترغ الحراري (PVD) في الفراغ .