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Influence of Laser Energy and Annealing on Structural and Optical Properties of CdS Films Prepared by Laser Induced Plasma

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Abstract

The current study was achieved on the effects of laser energy and annealing temperature on x-ray structural and optical properties, such as the UV-Visible spectra of cadmium sulfide (CdS). The films were prepared using pules laser deposition technique (PLD) under vacuum at a pressure of 2.5×10^{-2} mbar with different laser energies (500-800 mJ) and annealing at a temperature of 473K. X-ray diffraction patterns and intensity curves for the CdS showed that the formation of CdS multi-crystallization films at all laser energies. The optical properties of the films were studied and the variables affecting them were investigated in relation to laser energy and changes in temperature.

Keywords: Pulsed laser deposition (PLD), CdS thin films , Structural and optical properties .

تأثير طاقة الليزر ودرجة الحرارة على الخواص التركيبية والبصرية للاغشية الرقيقة CdS النانوية المحضرة بواسطة البلازما المستحثة بالليزر

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الخلاصة

أجريت الدراسة الحالية حول تأثير طاقات الليزر ودرجة حرارة التلدين على الخصائص التركيبية والبصرية للأغشية الرقيقة (CdS) المحضرة باستخدام تقنية الليزر النبضي (PLD) تحت الفراغ عند الضغط مساوي 2.5×10^{-2} mbar باستخدام طاقات ليزر مختلفة mJ (500–800) و تليين عند درجة حرارة 473K. فقد بينت انماط الحيود للأشعة السينية (x–ray) ومنحنيات الشدة للأغشية الرقيقة CdS بانها متعددة التبلور عند جميع الطاقات. وقد تم حساب الخواص البصرية للأفلام ودراسة المتغيرات المؤثرة عليها من طاقات ليزر وتغير درجة الحرارة .

Introduction

Cadmium Sulfide is classified within the composite semiconductors II-VI , which possess an energy gap estimated at 2.42eV at R.T [1]. CdS is considered to be one of the materials used in many applications such as solar cells, optical reagents and optoelectronic devices [2, 3]. In addition, the n type CdS is utilized as a window layer in the non-homogeneous solar cells [4]. There are several techniques that can be used for the purpose of sedimentation, including chemical bath deposition

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(CBD), magnetron sputtering (MS), chemical vapor deposition (CVD), and pulsed laser deposition (PLD) [5-7]. Among the techniques listed above, PLD was used for the deposition CdS films .Thin film growth is achieved by directing the laser on the target (pellet), which leads to the evaporation of the material and its growth on the substrate. The laser used for the growth method of films is Nd: YAG laser with a wavelength of 1064 nm. The evaporation process depends on laser parameters such as laser energies and pulses duration [8]. X-ray diffraction (XRD) was used to calculate the crystalline structure and grain size of the CdS films prepared by PLD techniques. The grain size (D) was calculated by using Scherer's equation [9].

$$D = \frac{k\lambda}{\beta cos\theta} \quad (1)$$

Where k is a constant taken to be 0.94, λ is the wavelength of X-ray 1.54Å, β is full width at half maximum (FWHM), and θ is Bragg's angle [10] .

The optical properties were studied using a double beam UV-Vis spectrophotometer (Metertech SP8001, Taiwan). The absorption spectra of the prepared NPs at different conditions were examined within the spectral range of 100 -1100. The optical band gap was estimated graphically by applying Tauc's relation for direct transition [11].

$$(\alpha hv)^{\frac{1}{n}} = A(hv - E_g) \quad (2)$$

where α is the absorption coefficient, A is constant, h is plank's constant, υ is the incident photon frequency, E_g is optical energy gap, and n is a constant depending on the nature of transition.

Experimental

In this work , the hydraulic piston was used for the purpose of preparing a target of cadmium sulfide powder, where 3 g of the material was pressed at a pressure of 6 ton for 10 minutes. Also, pulse laser deposition technique (PLD) was used to prepare CdS films where the films were prepared using different laser energies (500 to 800 mJ), with 200 pulses per energy under a pressure of P = 2.5 × 10^{-2} mbar using the Varian DS219 Rotary pump. Nd: YAG laser with a fundamental wavelength of 1064nm and frequency of 6 Hz was used as a source of PLD. The laser was shed on the target at an angle of 45^0 for the purpose of depositing the material on the substrate which was placed on a distance of 2.5 cm from the target, as shown in the Figure-1. Finally, thin films were treated thermally at a temperature of 473 K for one hour using an electric oven.

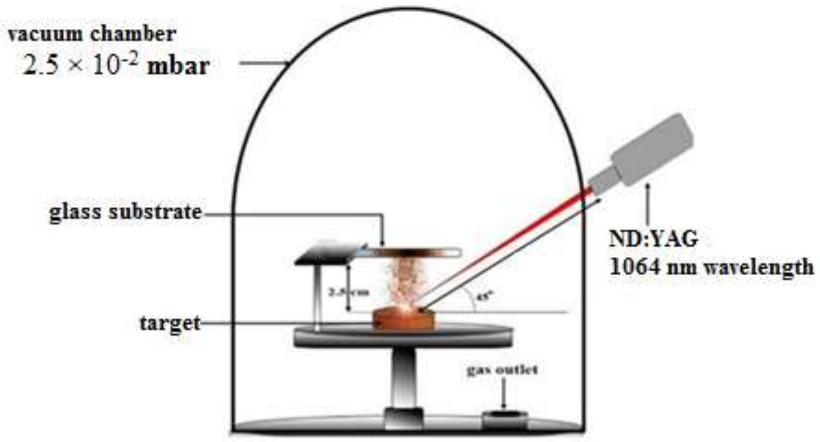

Figure 1-Schematic diagram of pules laser deposition (PLD) experiment

Results and Discussion

Figure-2 shows the XRD patterns for the CdS powder, from which it can be deduced that CdS has a cubic structure with diffraction peaks at crystalline 111, 200, 311 and 331 corresponding to 2θ of 26.5744, 43.7370, 52.0415 and 70.8651, respectively. The values are in good agreement with the standard values of the reported data (JCPDS No. 96-900-8840). Table-1 shows the structural parameters for the CdS powder which include the Bragg angle (2θ), full width half maxima (FMHM), experimental inter-plane spacing, and crystalline size as calculated by Scherrer's equation.

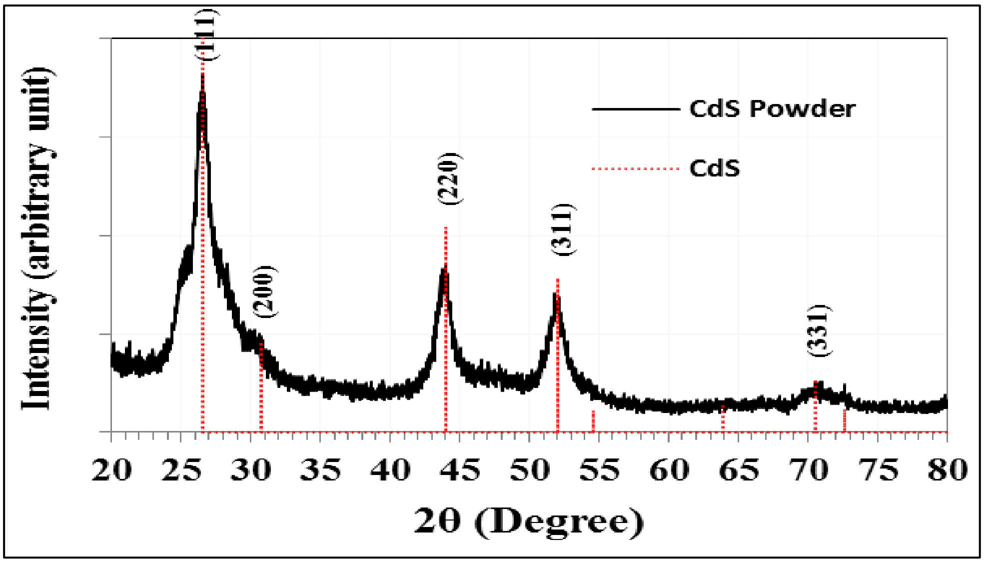

Figure 2-X-ray pattern of CdS Powder.

Table 1-XRD for the CdS powder in comparison with the standard

2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	G.S (nm)	d_{hkl} Std.(Å)	Phase	hkl	card No.
26.5744	2.4914	3.3516	3.3	3.3590	Cub.CdS	(111)	96-900-8840
43.7370	1.1765	2.0680	7.3	2.0570	Cub.CdS	(220)	96-900-8840
52.0415	1.3841	1.7559	6.4	1.7542	Cub.CdS	(311)	96-900-8840
70.8651	1.7301	1.3287	5.6	1.3347	Cub.CdS	(331)	96-900-8840

Figures-(3, 4) show the effects of laser energy on the structural properties of the CdS films. XRD results show that all the spectra have a polycrystalline structure and that the main phase of the thin films is a hexagonal phase. The results also demonstrated a continuous increase in intensity with increasing laser energy from 500 to 800 mJ, which was also associated with increased grain size. Also the effect of temperature change was evident as the grain size was increased after annealing, while the FWHM was decreased with annealing. This implies that crystalline films have been improved due to system regularity and reduced defects.

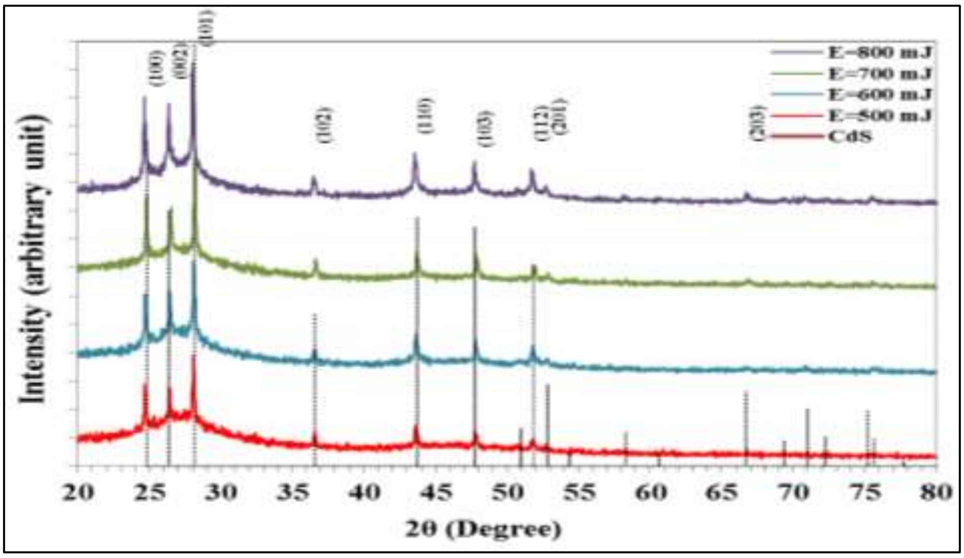

Figure 3-X-ray diffraction patterns of CdS films at R.T.

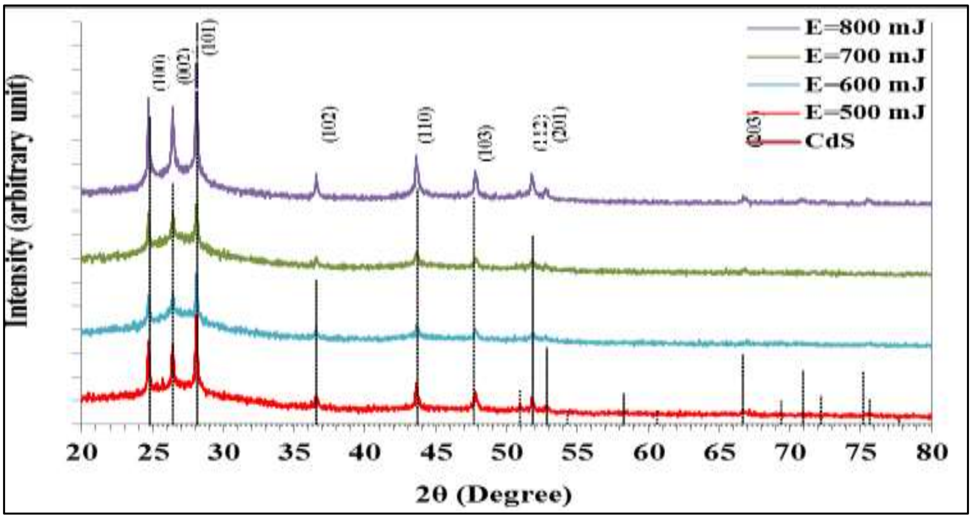

Figure 4-X-ray diffraction patterns of CdS films at 473 K.

From Figures-(5, 6), we can notice the decrease in absorbance with increasing the λ for all samples. The absorbance spectral characteristics are affected by increasing laser energy, as observed with the absorbance intensity which was increased with increasing laser energy. The absorption peak intensity values of the samples deposited with annealing temperature of 473 K were lower than the values than those for the samples deposited at R.T.

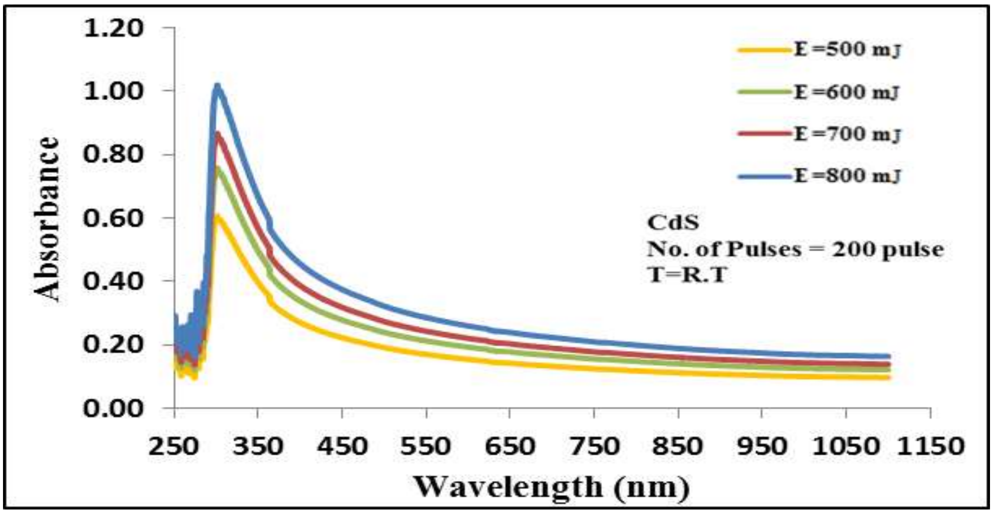

Figure 5-Absorbance spectrum of CdS films prepared by PLD at different laser energy

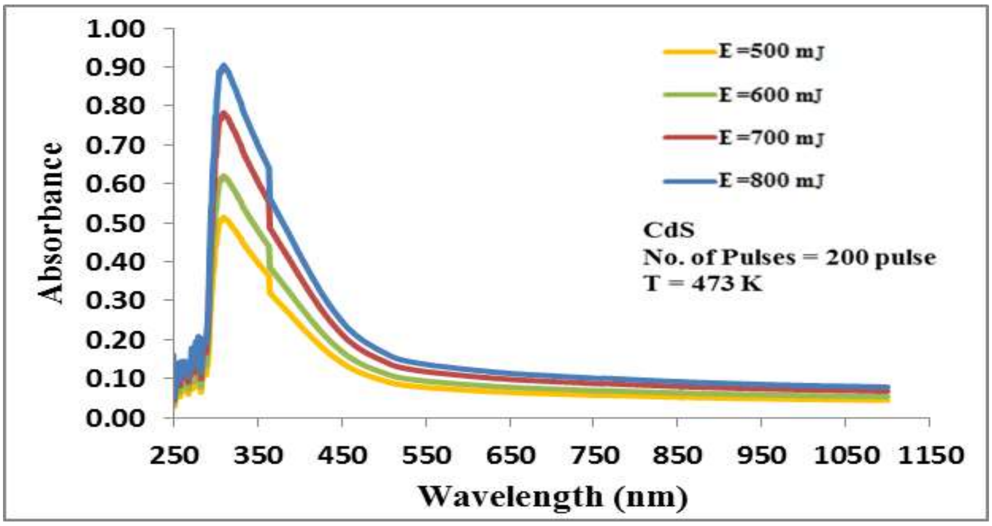

Figure 6-Absorbance spectrum of CdS films prepared by PLD at different laser energy

Figures- (7, 8) show the energy gap of CdS thin films deposition by PLD at R.T and annealing at 473K. From this figures, it can be observed that the energy gap value was decreased with increasing laser energies. The effect of temperature change was evident in two cases, where the energy gap values were increased by increasing temperatures, the values show in the Table-2.

Table 2-The values of energy gap of CdS thin films

E(mJ)	E_g(eV)	E_g(eV) at T= 473 K
500	2.9	3
600	2.8	2.95
700	2.7	2.9
800	2.6	2.8

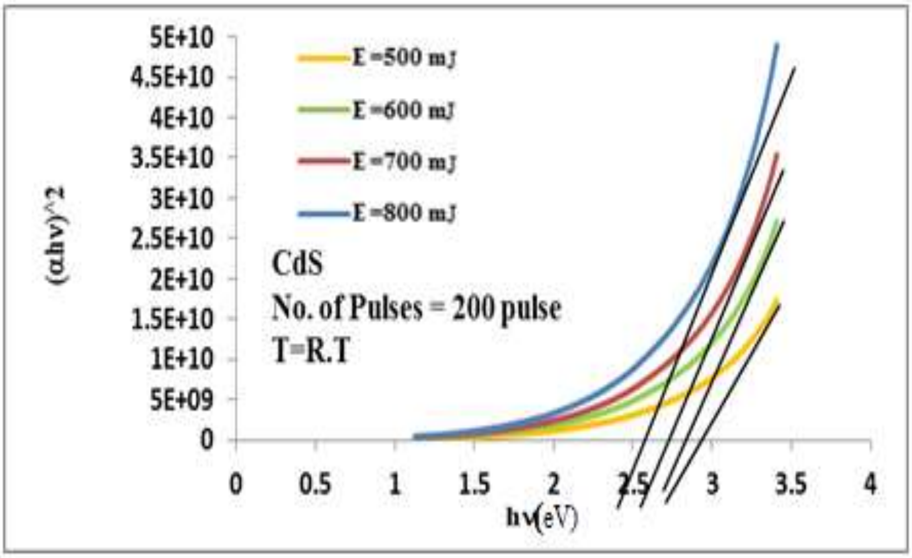

Figure 7-Direct transition of CdS prepared by PLD at different laser energies.

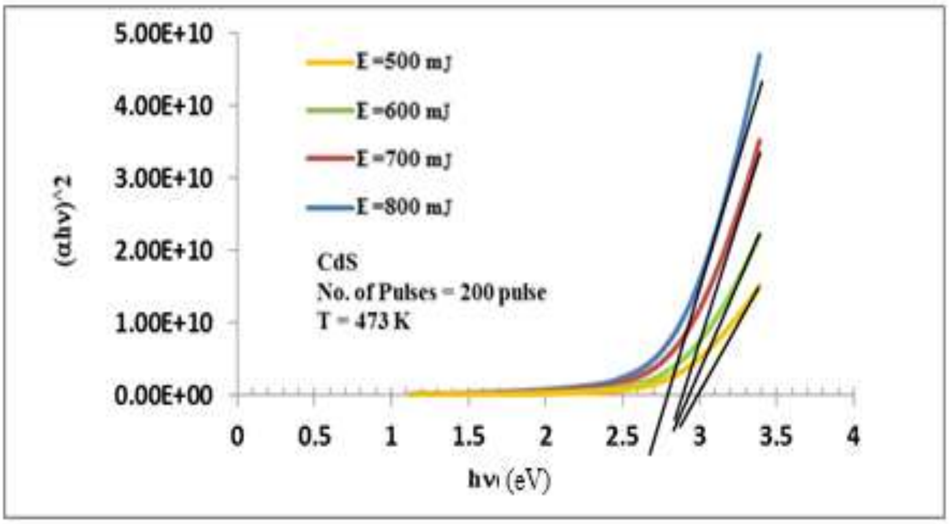

Figure 8-Direct transition of CdS prepared by PLD at different laser energies.

Conclusions

CdS thin films were deposited on a glass substrate using PLD technology with different laser energies under vacuum, where the films were heat treated at 437 k for one hour. Based on the results, it can be seen that the structure of CdS films is a polycrystalline structure and the preferred orientations are of 101 levels for all films. The optical properties of films exhibited a strong dependence on the ambient conditions, as for the increase in absorption with increasing laser energy. While, decreasing the value of the energy gap under the same conditions of growth temperature played an important role in changing the crystal structural and optical properties of CdS thin films. The values of energy gap for the annealed films were greater than those for the films deposited at room temperature.

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