Structural and Optical Properties of Cadimium Selenide Thin Films Prepared via Direct Current Sputtering Technique

Baha'a A.M. Al-Hilli *   Muhammed Khmas Khalaf **   Anwar Abd Alzahra Muhammed *
*Al-Mustansiriyah University /College of Education- Physics Dept.,
**Ministry of Science and Technology /Material Research Directorate- Applied Physics Research Center,
Baghdad-Iraq
E-mail:bahahilli@yahoo.com

Abstract

The influence of preparation condition on the structural and optical properties of Cadmium Selenide (CdSe) thin films deposited onto glass substrates was studied. The structural investigations performed by means of X-ray diffraction (XRD) technique showed that the films have polycrystalline, hexagonal structure, Moreover, the AFM study showed that the film of uniform nano-grain size about 10nm. Transmission spectra in the spectral domain (200-1200nm), were investigated. The values of some important parameters of the studied films (absorption coefficient, optical energy band gap and refractive index) were determined from these spectra. The values of the energy gap, Eg (allowed direct transitions), calculated from the absorption spectra, ranged between 2 and 2.2eV.

Key words: Thin Film, CdSe, DC Sputter, and Optical Energy Band Gap.

الخواص التركيبيه والبصريه لأغشيه الكادميوم سيلينايد المحضره بالترذيذ المستمر

بهاء عبد الرسول مجيد الحلي*، محمد خماس خلف، أنوار عبد الزهرة محمد***
*الجامعة المستنصرية / كليه التربية- قسم الفيزياء
** وزاره العلوم والتكنلوجيا / دائرة بحوث المواد - مركز الفيزياء التطبيقية
بغداد - العراق

الخلاصة

درس في هذا البحث تأثير ظروف التحضير على الخواص التركيبية والبصرية لأغشية كادميوم سيلينايد المرسبة على قواعد زجاجية بطريقة الترذيذ. الخواص التركيبية لهذه الأغشية درست باستخدام فحوص حيود الأشعة السينية (XRD) والتي بينت أن هذه الأغشية لها تركيب متعدد التبلور وبالشكل السداس، وأظهرت نتائج مجهر القوة الذرية AFM أن الأغشية المحضرة ذات سطوح متجانسة وحجم حبيبي بأبعاد نانوية بحدود 10nm، قيس طيف النفاذية للمدى الطيفي (200-1200nm) ومن خلاله حسبت بعض المعلمات المهمة مثل:(معامل الأمتصاص، فجوة الطاقة البصرية ومعامل الأنكسار). وكذلك حسبت فجوة الطاقة (Eg) للانتقال المباشر المسموح من قياس طيف الامتصاص ووجدت ان قيمها تراوحت بين (2-2.2eV).

الكلمات المفتاحيه:ألاغشيه الرقيقه ،الكادميوم -سيلينايد،الترذيذ المستمر و فجوه الطاقه البصريه

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Introduction

Cadmium selenide is a direct band gap semiconductor belonging to the II-IV group. Several physical and chemical techniques are employed for the deposition of CdSe thin films. CdSe thin films have been grown by many deposition methods such as thermal evaporation (Patel *et al.*,2009), chemical path deposition (Gopakumar *et al.*, 2010), pulsed laser deposition(Perna *et al.*, 2004), electrochemical deposition (Athanassopoulou *et al.,* 2012), electron beam evaporation (Suthan *et al* 2012), successive ionic layer adsorption and reaction(SILAR) (Saglam *et al.*, 2012) and DC-sputtering technique (Glew *et al*., 1977).

CdSe as a semiconductor is well studied and found to be promising material for its application in the area of electronic and optoelectronic such as photo detection (Nair *et al*., 1993), gas sensing (Patel *et al.*, 1994), thin film transistor and solar energy conversion (Chanda 2008). It is well known fact that the quality of the device based on CdSe thin films strongly depends on the structural and electronic properties of the films obtained by various experimental conditions. The material has been grown bulk, single crystalline and polycrystalline, and has been used as an efficient photo detector device.

A study was made of the preparation and properties of films sputtered from a CdSe target in a Argon gas.

Sputtering is a method for depositing very thin layers of a material onto a surface by bombarding a source material in a sealed chamber with electrons and other energetic particles to eject atoms of the source as a form of aerosol that then settle onto all surfaces in the chamber. The process can deposit extremely fine layers of films down to the atomic scale, but also tends to be slow and is best used for small surface areas.

The aim was to produce Nano structural films with suitable properties utilizing a DC-sputtering technique.

Materials and Methods

Thin films of CdSe were deposited on chemically and ultrasonically cleaned glass substrates with the help of vacuum coating unit. Stoichiometric CdSe powder having purity around 99.99% was capsulated in a pullet shape of ($\approx 2\times 2 cm^2$) dimension prepared to be as electrode (Target) inside the sputtering chamber.

The attainable films thickness where calculated using “StellarNet’s Thin Film measurement system” by means of optical interference method and found to be around 500nm±5 according to deposition conditions: (2×10^{-2} mbar inside chamber pressure, 2KV supplied voltage between the anode and cathode and 2 hour deposition period).

Results and Discussion

Structural properties

The X-ray diffraction analysis of prepared CdSe thin films have been carried out and the X-ray diffractogram have been shown in Fig.(1) and table (1). The peaks of CdSe samples have been obtained due to diffraction corresponding to (111), (101), (103), (201) reflections which is in a very good agreement with polycrystalline (hexagonal and cubic) CdSe structure, (joint committee on diffraction standards) JCPDS card no. 19-0191, CAS No.1306-24-7. Since the thickness of the films was not sufficiently enough, the intensity of other peaks is almost negligible (very near to the noise line) this can be rectified only after setting up of the grazing angle. Since the grown films possess hexagonal structure.

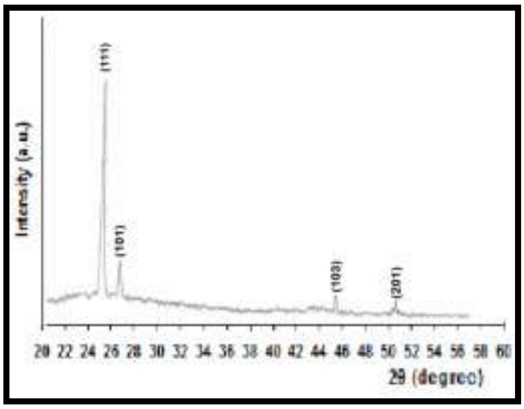


Fig.(1) X-ray Diffraction Pattern of CdSe Thin Film

Table (1) X-ray Diffraction Data for Cd Se Target

Thicknesses nm	2θ (deg)	d (A^0)	hkl
500	**25.414**	**3.5018**	**111**
	26.794	**3.324**	**101**
	45.698	**1.984**	**103**
	50.781	**1.797**	**201**

In order to investigate the surface microstructure and quantifies the surface topography, an atomic force microscopy (AFM) technique are utilized using the instrument type (ATELIESS MAITRE).

The surface morphology of the CdSe thin films observed from the AFM micrograph which confirms that the grains are uniformly distributed within the scanning area (520nm×520nm). An initial visual realization of the deposited films on glass substrate has shown that they are compact and have good adherence to the substrate. All the CdSe films exhibit smooth surface morphology with uniform nanocrystalline CdSe grains of about 10nm and average roughness 0.2nm as shown in figure(2).

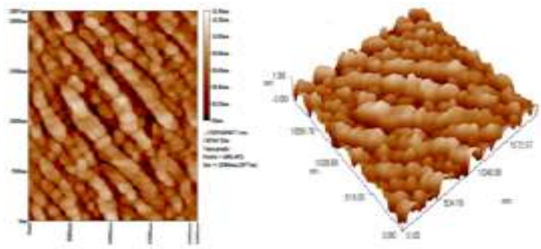


Fig.(2) The AFM Images of CdSe thin film

Optical properties

The optical absorption spectrum of CdSe films have been recorded in the wavelength range (200-1200)nm. The results of these investigations have been used for the calculations of absorption coefficients and other parameters. The calculated absorption coefficient corresponding to the energy of incident radiation has been plotted with respect to the energy of photons. The fundamental absorption, which corresponding to the transition from the valance to the conduction band, can be used to determine the band gap of the material. The relation between α and the incident photon energy (hυ) can be written as :

$$(\propto h\upsilon) = A\left(h\upsilon - E_g\right)^r \ldots\ldots(1)$$

Where A is a constant, Eg is the band-gap of the material and the exponent (r) depends on the type of transition. The parameter (r) may have values:1/2, 2, 3/2, 3 corresponding to the allowed direct, allowed indirect, forbidden direct and forbidden indirect transitions respectively.

The value of Eg is evaluated by extrapolating the straight line portion of $(\alpha h\upsilon)^2$ vs. hυ has been shown in Fig(3). The values of the direct band gap is (>2eV) for the CdSe thin films in present investigations is in good agree ment with the reported data(M.D. Athanasso poulau).

Using absorption spectra, transmission and reflection coefficients have been computed by the equations:

$$T\% = \left(\frac{1}{A}\right) \times 100\% \text{..........(2)}$$

$$R = 1 - (T + A) \text{......... (3)}$$

The variations of A, T, R and α with wavelength have been shown in graphical form in Fig.(4 a,b,c and d respectively). It implies that the absorption and the reflection possess almost the same trend. But the value of absorption in percentile is more than that of reflection.

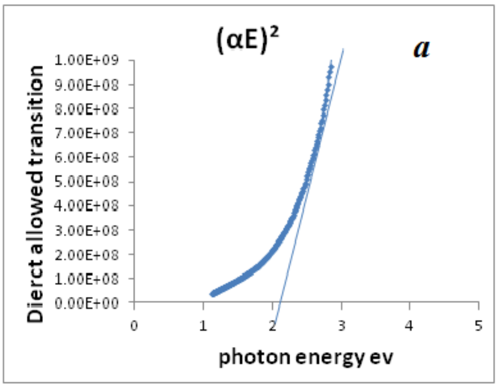
Furthermore, the reflectance (R) and the optical constants like the extinction coefficient (K) and the refractive index (n) at certain constant wavelength (λ) are related through the following equations:

$$k = \frac{\alpha\lambda}{4\pi} \text{.........(4)}$$

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2} \text{.....................(5)}$$

Using these relations, the values of (k) and (n) have been calculated at different input wavelengths from the measurement of T & R.

The relation of the refractive index (n) and the extinction coefficient (k) with wavelength for CdSe thin films are shown in Fig. (4,e and f). The general trend of variation in these parameters is fairly the same for all the materials. For example (k) and (n) values increase gradually up to about 303nm and then decrease sharply again.



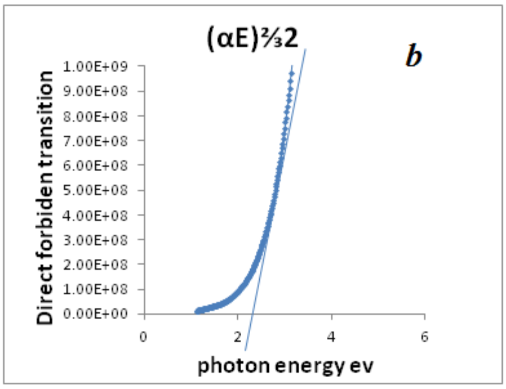
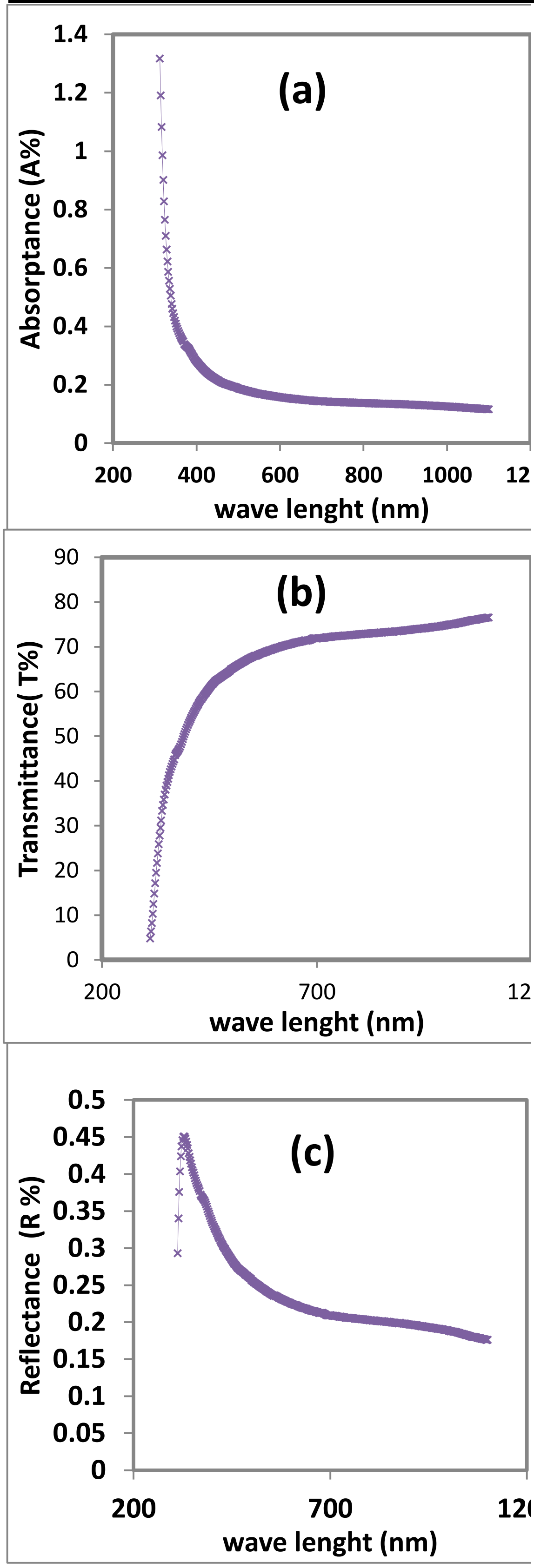
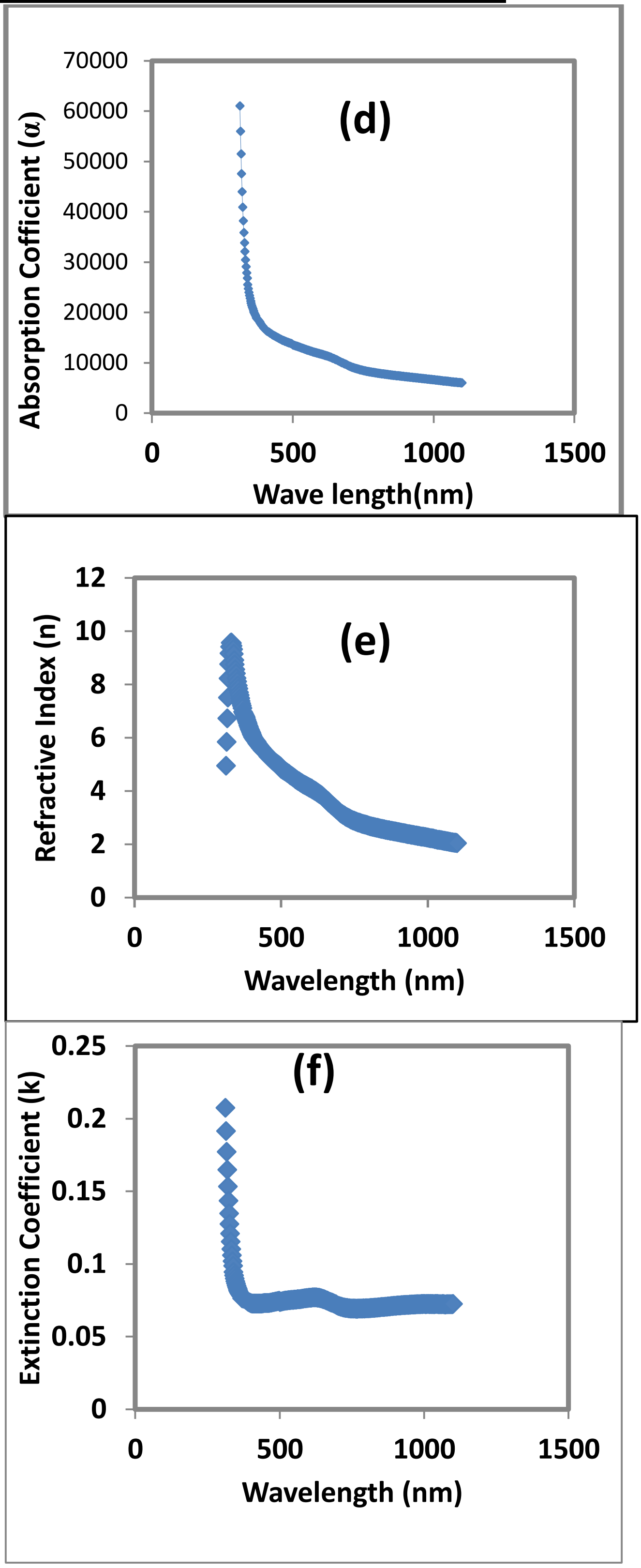


Fig. (3) The Direct Allowed (a) and the Direct Forbidden (b) Transition





Fig(4) (a) absorptance, (b) Transmittance, (d) Reflectance, (d) Absorption Coefficient, (e) Refractive Index and (f) Extinction Coefficient.

Conclusions

A very good quality, stoichiometric and epitaxial like CdSe thin films were grown on to non-conducting glass substrates using DC-sputtering method. From XRD analysis, the structural parameters like crystallite size were calculated. The results are in good agreement with the earlier reported values. From the optical studies, a very sharp absorption at 700nm was observed and the band gap was found to be around (2-2.2)eV, which suggest that sputtering deposited CdSe film is a good candidate for solar cell.

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