Effect of Pb percentage on optical parameters of $Pb_xCd_{1-x}Se$ thin films

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Abstract

$Pb_xCd_{1-x}Se$ compound with different Pb percentage (i.e. X=0, 0.025, 0.050, 0.075, and 0.1) were prepared successfully. Thin films were deposited by thermal evaporation on glass substrates at film thickness (126) nm. The optical measurements indicated that $Pb_xCd_{1-x}Se$ films have direct optical energy gap. The value of the energy gap decreases with the increase of Pb content from 1.78 eV to 1.49 eV.

Key words
Pb_xCd_{1-x} Se, percentage, optical, parameters.

Article info.
Received: May. 2015
Accepted: Oct. 2015
Published: Apr. 2016

تأثير نسبة اضافة الرصاص على الخصائص البصرية للغشاء الرقيق $Pb_xCd_{1-x}Se$

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الخلاصة

تم تحضير سبائك $Pb_xCd_{1-x}Se$ بنسب مختلفة من الرصاص (i.e. x=0, 0.025, 0.050, 0.075, 0.1) رسبت اغشية رقيقة من هذه المركبات باستعمال تقنية التبخير الحراري وسمك 126nm. اظهرت القياسات البصرية ان الاغشية المحضرة تمتلك فجوة طاقة مباشرة وان فجوة الطاقة البصرية تناقصت بزيادة تركيز الرصاص من 1.78 eV الى 1.49 eV.

Introduction

II – VI compound crystallize in such a manner that each atom of one element is located at the center of a regular tetrahedron, the apices of which are occupied by atom of the other element. Two possible structures can be formed from such tetrahedral [1-3]. CdSe is II-VI a narrow band semiconductor and its band gap energy 1.74 eV, it is semiconductor compound material with potential applications in low cost electronics and optoelectronics devices such as solar cells, photoconductors, thin film transistors, light emitting diodes, biomedical imaging devices and laser diodes [4, 5]. Changing the material composition provides new opportunities for covering injection, radiative recombination, and reabsorption. A change in the material composition results in a change in the energy gap that enables one to modify the potential profile. The wide varieties of semiconductors applications necessities the need to high sensitive material that are easy to fabricate at the same time, they have a broad range of electrical, optical and optoelectronic properties [6]. Solid state solutions based on semiconductors of $A^{IV}B^{VI}$ are classical materials used in optoelectronics .the main advantage of this material is that the electrical and optical properties can be easily controlled through the change of its composition [7]. In this paper, we have studied the effect of Pb percentage of CdSe compound on optical parameter.

Experimental work

In the present work, $Pb_xCd_{1-x}Se$ compound have been synthesized using high purity elemental cadmium, tin and selenium with purity (99.999%), the compound were prepared with different x content where x = 0, 0.025,0.050, 0.075 and 0.1. A quartz ampoule was cleaned carefully with water and alcohol respectively, to remove dust, grease, and other possible contaminants. Stoichiometric amounts of the elements were placed in a quartz ampoule, which was evacuated to a vacuum of 10^{-3}mbar and then sealed. The sealed ampoule was placed in a furnace and then heated in steps up to 900˚C by steps of 200˚C by remaining it at each step for two hours and continuing up to 900˚C and remains it at this temperature for two hours and then allowed to cool slowly to room temperature. $Pb_xCd_{1-x}Se$ compound for all x values deposited onto glass substrates by thermal evaporation technique which are cleaned by distilled water, pure alcohol, and then by ultrasonic vessel and the pressure inside the chamber was better than $2*10^{-5}$ mbar $Pb_xCd_{1-x}Se$ were evaporated thermally with a deposit rate of 8.4 nm/min to get thin films with thickness 126 nm. The optical properties of the prepared thin films deposited on glass slide which includes the transmittance spectra are studied over the wavelength range (300-1100nm). The optical energy gap E_g^{opt} of the $Pb_xCd_{1-x}Se$ thin films prepared at different x was measured throughout plotting $(\alpha h\nu)^n$ and $(h\nu)$ the intercept on $(h\nu)$ axis when $(\alpha h\nu)^{1/r}=0$. The allowed direct transition refers to that transition which occurs between top of the valence band and bottom of the conduction band when the change in the wave vector equal to zero (Δk = 0)

This transition is described by the following relation [8]:

$$\alpha h\nu = \acute{B}(h\nu - E_g)^{1/2} \quad (1)$$

where $\acute{B}$ is inversely proportional to amorphousity the optical energy gap. The optical constants are very important parameters because they describe the optical behavior of the materials. The absorption coefficient of the material is a very strong function of the photon energy and band gap energy. Absorption coefficient represents the attenuation that occurs in incident photon energy on the material for unit thickness, and the main reason for this attenuation is attributed to the absorption processes [9-11]. Optical constants included refractive index (n), extinction coefficient (k), and real (ε_r), and imaginary parts (ε_i) of dielectric constant.

The complex refractive index (n_c) is defined as [12]:

$$n_c = n - ik \quad (2)$$

and it is related to the velocity of propagation (v), and light velocity (c) by:

$$v = c/n_c \quad (3)$$

The refractive index value can be calculated from the formula [11]:

$$n = \left(\frac{4R}{(R-1)^2} - k^2\right)^{\frac{1}{2}} - \frac{(R+1)}{(R-1)} \quad (4)$$

The extinction coefficient, which is related to the exponential decay of the wave as it passes through the medium, is defined as

$$k = \frac{\alpha\lambda}{4\pi} \quad (5)$$

where λ is the wavelength of the incident radiation and $\alpha$is given by [13]:

$$\alpha = 2.303\frac{A}{t} \qquad (6)$$

where A is the absorbance. The real and imaginary part of dielectric constant can be calculated by using the following equations [14]:

$$(n - ik)^2 = \varepsilon_r - i\varepsilon_i \qquad (7)$$

where

$$\varepsilon_r = n^2 - k^2 \qquad (8)$$

and

$$\varepsilon_i = 2nk \qquad (9)$$

Results and discussion
1. Optical studies
1.1The transmittance

The transmittance of the $Pb_xCd_{1-x}Se$ thin films deposited at room temperature for different Pb content x = 0, 0.025, 0.05, 0.075 and 0.1 and different film thicknesses (t = 126, 226 and 284 nm) are shown in Fig. 1. It is observed that the overall transmittance decreases with the increase of film thickness. This is due to the overall increase in the absorbance with the increase of film thickness. Rise and fall in the transmittance spectrum above the absorption edge are observed. These variations have been observed to increase with the increasing of film thickness. This behavior is due to interference of the light transmitted through the thin film and the substrate[15].

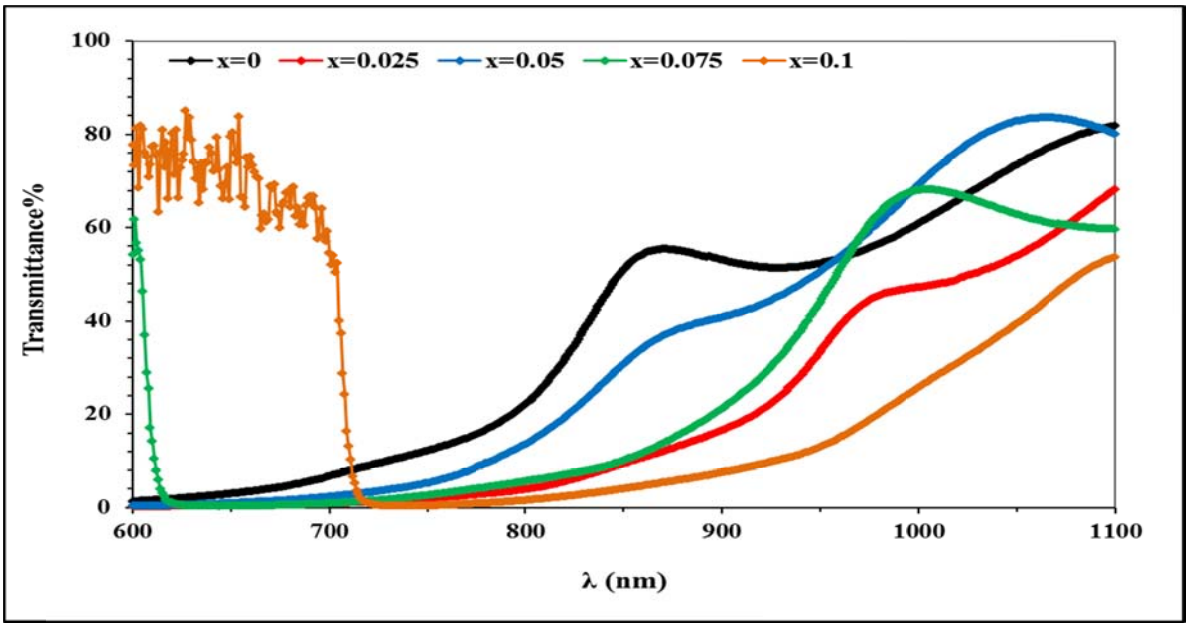

Fig.1: The transmittance spectra versus the wavelength for $Pb_xCd_{1-x}Se$ films with different Pb content at film thickness of 126 nm.

1.2 The Absorption coefficient

Fig. 2 shows the absorption coefficient for $Pb_xCd_{1-x}Se$ films of thickness 126 nm with different Pb content (0, 0.025, 0.05, 0.075, and 0.1) was calculated from Eq. (6). It is observed from this Figure that the absorption coefficient near IR region decrees with increasing x content for all sample, but at visible region the absorption coefficient increase at x=0.075, 0.1 and this is attributed to the variation in the pb concentration and this is confirm by AFM [16]. While decrease near IR.

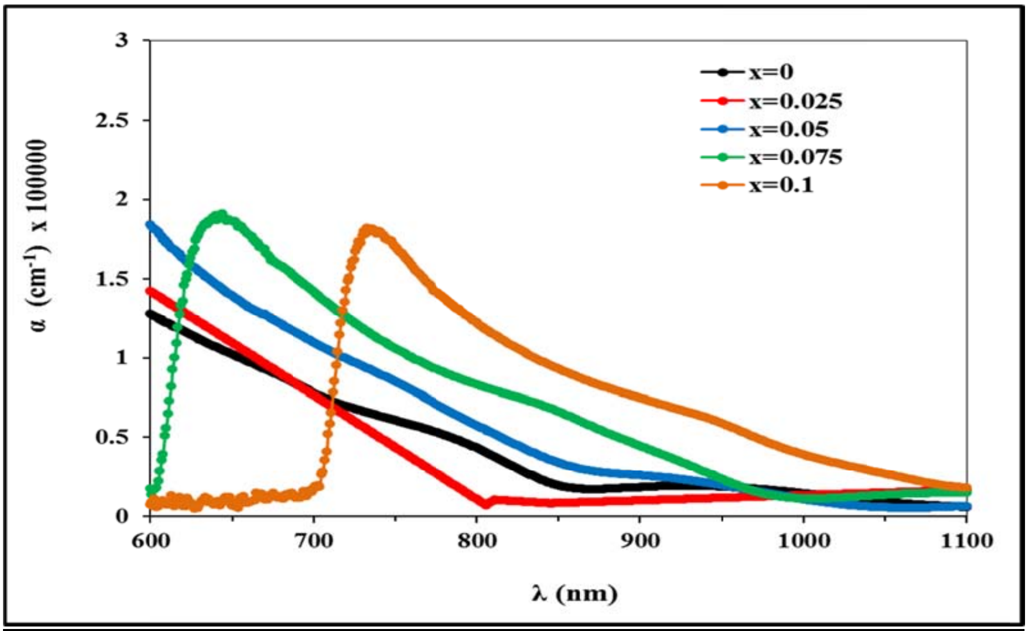

Fig. 2: The absorption coefficient for $Pb_xCd_{1-x}Se$ films with different Pb content at film thickness of 126 nm.

1.3 The optical energy gap

The absorption coefficient α was determined from the region of high absorption at the fundamental absorption edge of the film from Eq. (1). Fig. 3 shows the variation of $(\alpha h\upsilon)^2$ as a function of hυ for different thicknesses. As shown in Figure for different Pb content we observed that the optical energy gap decreases from 1.78 eV to 1.49 eV with the increase of x value. The improved crystal structure of the film is due to segregation of the impurity atoms along the grain boundaries [17, 18]. Also that is due to be localized state inside optical energy gap which leads to decreased energy gap values.

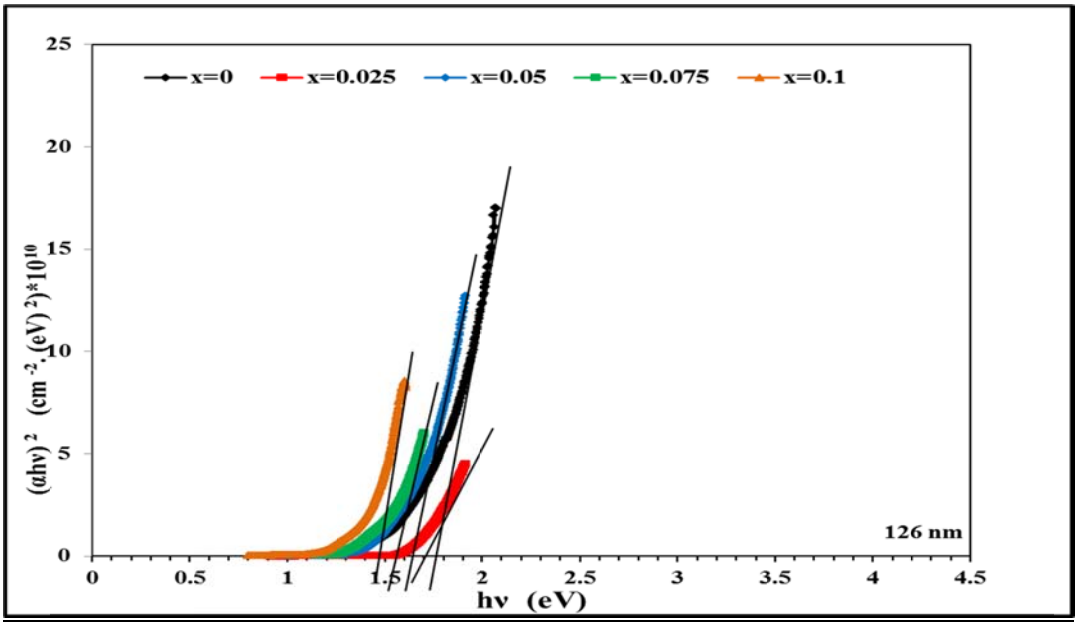

Fig. 3: Variation of $(\alpha h\nu)^2$ vs hν for all Pb content for $Pb_xCd_{1-x}Se$ at film thickness of 126nm.

Table 1: Indicted value of energy gab for all Pb concentration at film thickness of 126 nm for PbxCd1-xSe.

X content	Eg (eV)
0	1.78
0.025	1.7
0.05	1.65
0.075	1.57
0.1	1.49

1.4 Refractive index

The refractive index in the range (300-1100) nm for $Pb_xCd_{1-x}Se$ thin films Fig. 4 shows the variation of the refractive index as a function of the wavelength for $Pb_xCd_{1-x}Se$ thin films at different Pb content was calculated from equation 4. We can see that the refractive index at visible region the refractive index increased at x=0, 0.025, 0.05, while it decreased at x=0.075, 0.1. At rang 790-1100 near IR region at x= 0.025, 0.05 decrease, while it is decrease at x=0, 0.025 and this attributed to the structure.

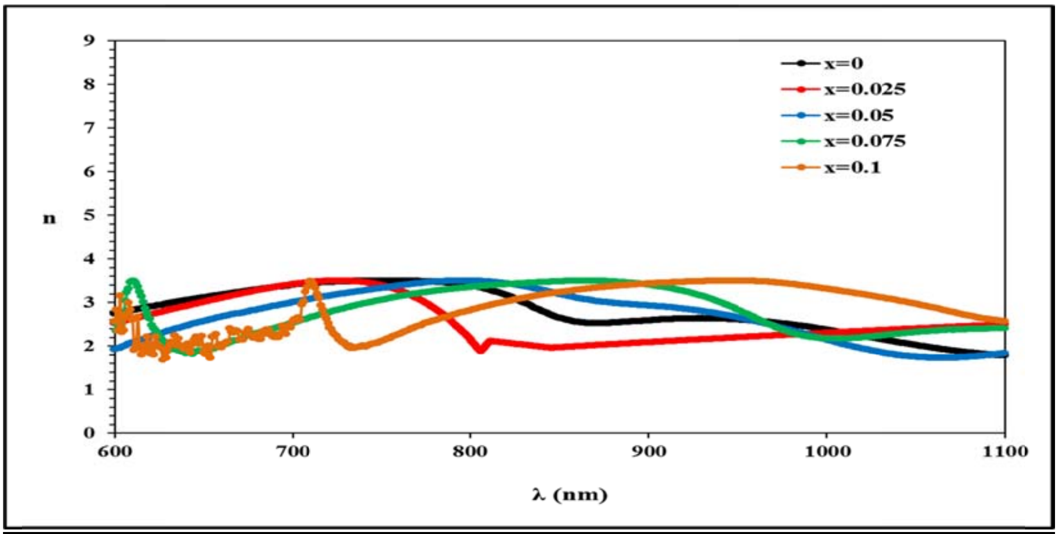

Fig. 4: The Refractive Index n for $Pb_xCd_{1-x}Se$ thin films for all Pb content at film thickness of 126 nm.

1.5 Extinction coefficient

Extinction coefficient was calculated. Fig. 5 shows the variation of extinction coefficient as a function of wavelength for $Pb_xCd_{1-x}Se$ thin films, for all Pb content, was calculated from equation 5. It is observed from this Figure that the Extinction coefficient near IR region decrees with increasing x content for all sample, but at visible region the Extinction coefficient increase at x=0.075, 0.1 and this is attributed to the same reason ,which is mentioned previously in absorption coefficient, while it is decrease at x=0, 0.025, 0.05.

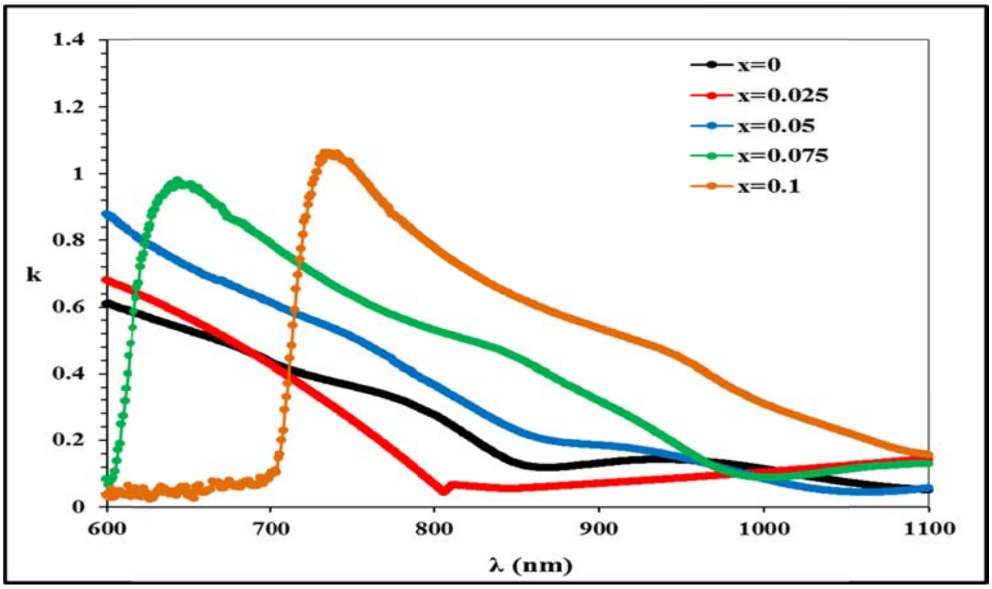

Fig. 5: The extinction coefficient for $Pb_xCd_{1-x}Se$ thin films for all Pb content at film thickness of 126 nm.

1.6. Dielectric constants

Real and imaginary dielectric constants were calculated. Figs. 6 and 7 show the variation of real (ε_r), and imaginary (ε_i) dielectric constants for $Pb_xCd_{1-x}Se$ thin films, at different Pb content were calculated from Eq. 8 and 9. It is observed from the Figures that the behavior of real and imaginary dielectric constants is similar to refractive index because the similar value of k^2 comparison of n^2, while (ε_i) is mainly depend on the k values, which are related to the variation of absorption coefficient.

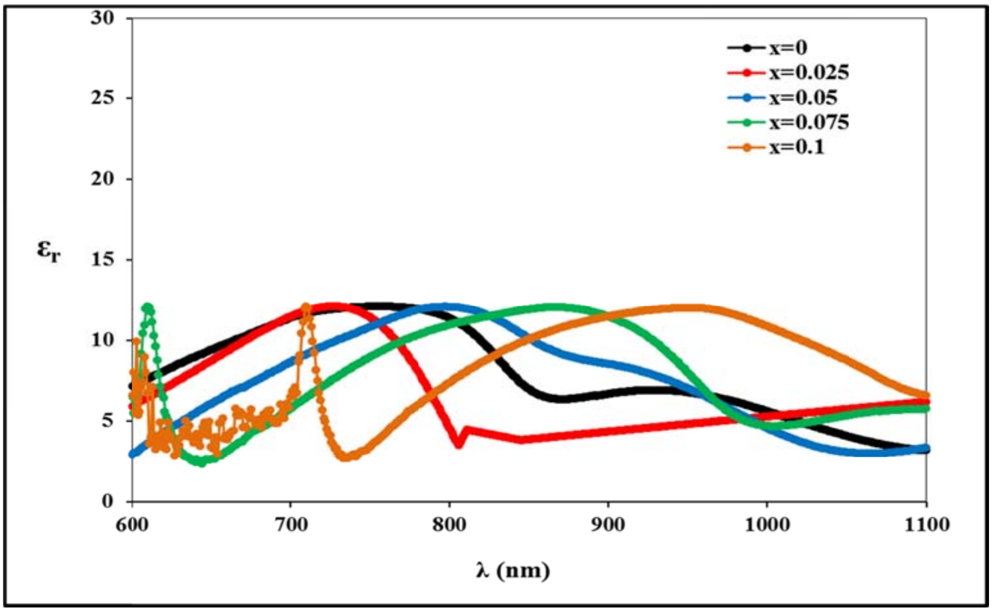

Fig. 6: Real dielectric constant (ε_r) for $Pb_xCd_{1-x}Se$ thin films for all Pb content at film thickness of 126 nm.

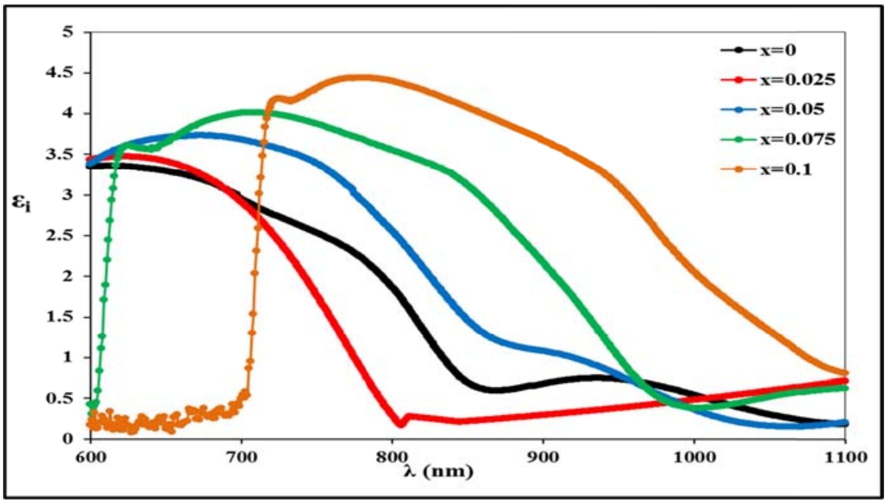

Fig. 7: Imaginary dielectric constant (ε_i) for $Pb_xCd_{1-x}Se$ thin films for all Pb content at film thickness of 126 nm.

Conclusions

$Pb_xCd_{1-x}Se$ compound is prepared successfully. The optical study showed allowed direct type of transition. The optical band gab decreases with increasing Pb content in CdSe alloy.

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