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Effects of annealing on optical and dispersion parameters of cobalt doped cadmium oxide thin films

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ABSTRACT

Thin films of Cobalt doped cadmium oxide are deposited on a glass substrate by spray pyrolysis method. UV-Visible spectrophotometer was used in order to determine the absorbance spectrum in the range of wavelength (300-900) nm. Transmittance, reflectance, and optical conductivity are studied for various annealing temperature of Co:CdO thin films. These results are related inversely with the value of the energy gap. Dispersion parameters such as E_d, E_o, M_{-1}, M_{-3}, S_o, and λ_o are evaluated according to the single-effective-oscillator model.

KEYWORDS

Co doped CdO;
Conductivity;
Dispersion parameters.

INTRODUCTION

During the last several years, cadmium oxide (CdO) has been considered as a promising material in the manufacture of solar cells, due to its high electrical conductivity (even without doping) and its high transparency in the visible range of electromagnetic spectrum. CdO thin films were used as transparent contacts and windows instead of tin oxide (SnO_2) and cadmium sulfide (CdS) in the SnO2 /n-CdS/p-cadmium telluride (CdTe) heterostructure solar cells[1–2]. CdO has attracted much attention as a transparent conducting oxide (TCO) because of i ts unique properties mention above with a moderate refractive index[3]. It has n-type semiconducting characteristics of a band gap between 2.2 and 2.7 eV[4-5] and a high electrical conductivity (10^{-2}–10^{-4}Ùcm)[6-7].

Highly conducting and optically transparent materials such as doped zinc oxides, indium oxides, tin oxides and cadmium oxides are widely used with the same applications of CdO[8–11]. Undoped and doped CdO thin films have been obtained by different techniques such as reactive sputtering (RS)[12], sol–gel (SG)[13] and direct current reactive magnetron sputtering (DCRMS)[14], spray pyrolysis[15] and pulsed laser deposition (PLD)[16].

The aim of this study is to determine the optical and dispersion parameter of CdO thin film that doped by Co, prepared by the chemical pyrolysis method for different annealing temperatures.

EXPERIMENTAL DETAILS

Co doped CdO thin films were prepared by chemical pyrolysis method. Cadmium chloride supplied by (BDH Chemicals Laboratory, England) 0.1

M was used as a matrix dissolved in redistilled water, and doped by 1% of Cobalt chloride with same molarity as the matrix under the conditions of: spray time was 8 s and the stopping period two minutes were kept constant, the carrier gas (filtered compressed air) was maintained at a pressure of 10^5 Pascal, distance between nozzle and the substrate was about 29cm, and the solution flow rate was 5ml/min. These prepared films are deposited on class substrate temperature at a temperature of 400 °C. Gravimetric method was used to determine the film thickness,which was found to be 350±30 nm. Double beam UV-VIS spectrophotometer supplied by (Shimadzu UV-VIS, Japan) was used for recording the optical transmittance with a wavelength range of (300-900) nm. The temperatures 450 °C and 500 °C were used in this research to anneal the samples of Co:CdO thin films.

RESULTS AND DISCUSSIONS

Figure 1 represent the relationship between the transmittance and wavelength. From this figure, it can be notice that the transmittance decreased when the annealing temperature increases. On the other words, there is a shift of the edge into lower wavelengths (blue shift) as the annealing temperature increases.

The reflectance (R) can be calculated from the following equation[17]:

$$R + A + T = 1 \quad (1)$$

Where A and T represent the absorbance and transmittance respectively. Figure 2 represent the relationship between the reflectance against wavelength. From this figure, it can notice that the reflectance increasing up to a wavelength of 550 nm, and then the reflectance decreases with wavelength. In addition, it can be noticed that the reflectance increases with increasing of annealing temperature.

The optical conductivity ($\sigma_{optical}$) depends directly on the wavelength and absorption coefficient as the following relation[18]:

$$\sigma_{optical} = \frac{\alpha n c}{4\pi} \quad (2)$$

Where α is the absorption coefficient, n is the refractive index, and c is the speed of light. The optical conductivity decreases with the increasing annealing temperature (as shown in Figure3). In general the optical conductivity decreased sharply before the wavelength of 550 nm for all deposited thin films, and then decreased gradually in the wavelength more than 550 nm.

The single-oscillator parameters were calculated and discussed in terms of the Wemple–DiDomenico model. The dispersion parameters of various materials were investigated by using the model from the literature[19-21]. This model describes the dielectric response for transitions below the optical gap. The absorption edge, refractive index dispersion can be

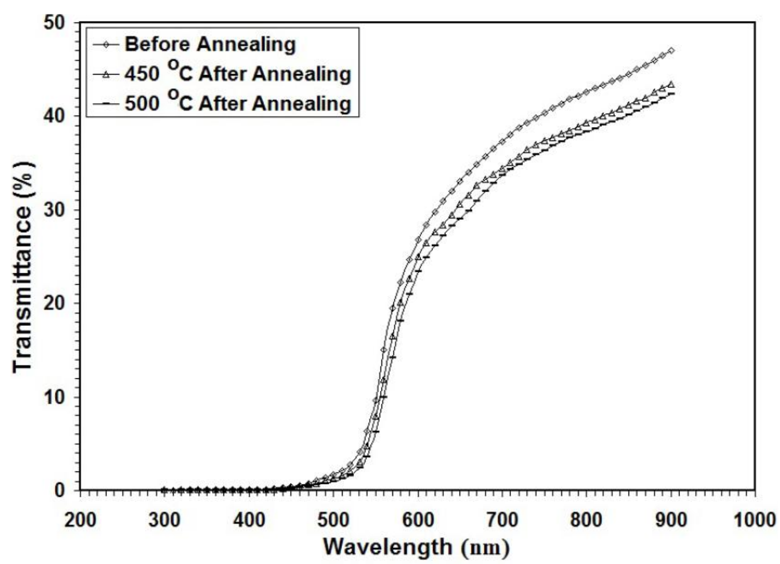

Figure 1 : The transmittance spectra of the films

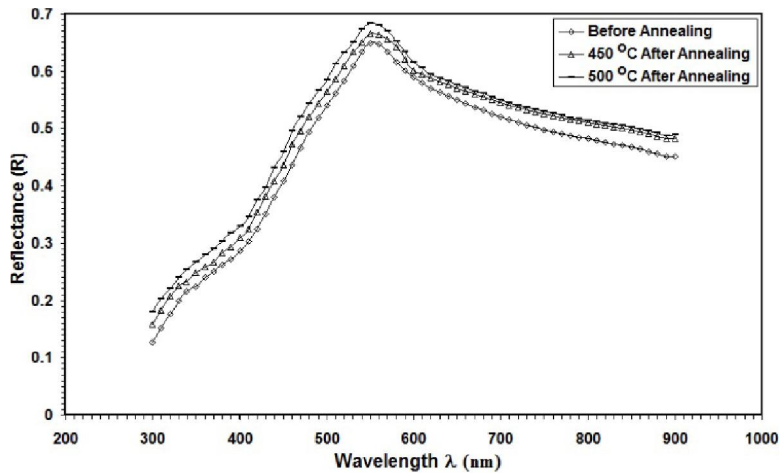

Figure 2 : The reflectance of the films

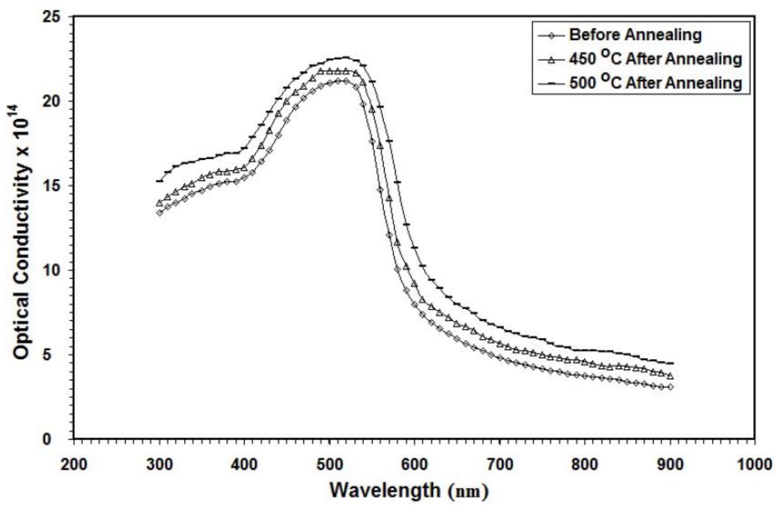

Figure 3 : The optical conductivity of the films

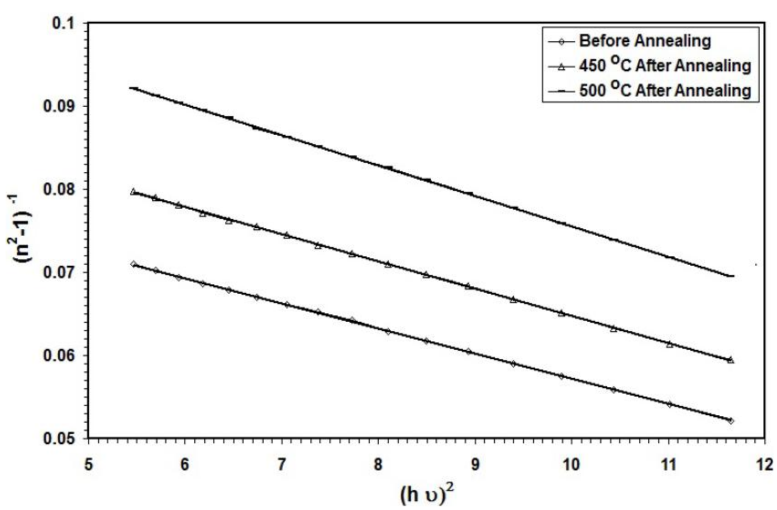

Figure 4 : $(n^2-1)^{-1}$ as a function of $(h\upsilon)^2$

analyzed by the single oscillator model[22]:

$$n^2 = 1 + \frac{E_d E_o}{E_o^2 - (h\nu)^2} \quad (3)$$

Where E_o is the average excitation energy for electronic transitions and E_d is the dispersion energy, which is a measure of the strength of interband opti-

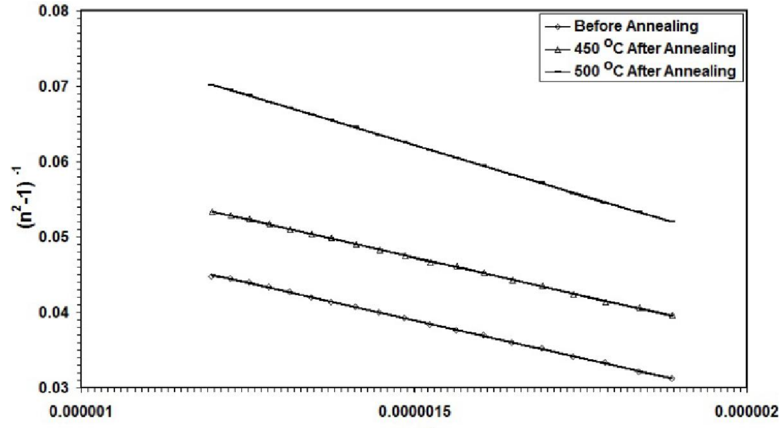

Figure 5 : $(n^2-1)^{-1}$as a function of $(1/\lambda^2)$

TABLE 1 : The optical parameters of Co doped CdO thin films

Sample	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	N (o)	M_{-1}	M_{-3} eV^{-2}	S_o x10^{13} m^{-2}	$\lambda_o$nm
ıefore Annealing	66.67	5.00	2.50	14.33	3.78	13.33	0.533	8.33	547
00 °C After Annealing	60.70	4.98	2.49	13.19	3.63	12.19	0.49	8.20	493
50 °C After Annealing	54.79	4.93	2.46	12.11	3.48	11.11	0.456	6.41	455

cal transitions. These parameters can be easily obtained by plotting of $1/(n^2-1)$ vs.$(h\upsilon)^2$ as shown in Figure5. The E_d and E_o values were calculated from the slope $(E_dE_o)^{-1}$ and intercept (E_o/E_d) on the vertical axis, that listed in TABLE 1.

Also, the long wavelength refractive index (n_∞) for these samples was determined from the interception of the vertical axis in Figure 4. The values of E_o and E_d for the Co doped CdO thin films are shown in TABLE 1. These values decrease with increasing of the film annealing temperature.

The moments of the imaginary part of the optical spectrum M_{-1} and M_{-3} moments, can be derived from the following relations[22]:

$$E_o^2 = M_{-1} / M_{-3} \quad (4)$$

$$E_d^2 = M^3_{-1} / M_{-3} \quad (5)$$

The values of M_{-1} and M_{-3} that obtained from above equations are listed in TABLE 1, and clearly from these results, M_{-1} and M_{-3} decrease with increasing annealing temperature.

For the definition of the dependence of the refractive index (n) on the light wavelength (λ), the single-term Sellmeier relation can be used[23]:

$$n^2(\lambda) - 1 = S_o.\lambda_o^2 / 1 - (\lambda_o/\lambda)^2 \quad (6)$$

Where λ_o is the average oscillator position and S_o is the average oscillator strength. The parameters S_o and λ_o in Eq. (7) can be obtained experimentally by plotting $(n^2-1)^{-1}$ against λ^{-2} as shown in Figure 5, the slope of the resulting straight line gives $1/S_o$, and the infinite wavelength intercept gives $1/S_o\lambda_o^2$.S_o and λ_o are decreased with increasing annealing temperature.

CONCLUSION

The CdO thin films that doped by Co, prepared by spray pyrolysis method and annealed by various temperatures. The results show that the transmittance, refractive index, and optical conductivity are increased with increasing annealing temperature for all prepared thin films. Dispersion parameters such as E_d, E_o, M_{-1}, M_{-3}, S_o and λ_o increases with the increasing of annealing temperature that determined by single-effective-oscillator model.

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