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The Urbach Energy and Dispersion Parameters dependence of Substrate Temperature of CdO Thin Films Prepared by Chemical Spray Pyrolysis

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Abstract : The CdO thin films are prepared by the chemical spray pyrolysis technique from 0.1 M of $CdCl_2$ dissolved in double distilled water. The transmittance, reflectance, and real and imaginary dielectric constants are decreased with increasing substrate temperature of CdO thin films. Energy gap decreased from 2.425 eV for CdO thin film prepared with substrate temperature 300 °C to 2.357 eV for CdO thin film prepared with substrate temperature 450 °C, while Urbach energy increased from 751 to 826 meV. Dispersion parameters such as: E_d, E_o, $å_\infty$, n(0), S_o, M_{-1}, and M_{-3} are decreased with increasing substrate temperature in the CdO thin films.
Keywords : CdO, chemical spray pyrolysis, Urbach energy, dispersion parameters.

Introduction

The semiconductor metal oxides such as CdO, ZnO, BaO, Fe_2O_3, and Cu_2O thin films have been studied extensively because of wide range of technical applications, it can additive this oxides to improve some of materials properties[1-3]. Many techniques used to prepare metal oxides as a thin films[4-10].

Cadmium oxide (CdO) is conducting, transparent in the visible region with a direct band gap of 2.5 eV and indirect band gap of 1.98 eV [11,12]. CdO has several attractive properties, such as its high optical transmittance in the visible region of the solar spectrum[13], low resistivity, high density (8150 Kg/m^3), high melting point (1500 °C), and has a cubic crystal structure (NaCl, face center cubic (fcc) type, and lattice constant a = 0.4695 nm) [14-17].

The CdO semiconducting gas sensors is spreading more to detect the pollutants, toxic gases, alcohol and food freshness and used in moisture detectors, electronic sensors[18- 21]. CdO thin films have been prepared by various techniques such as sol–gel, DC magnetron sputtering, radio-frequency sputtering, spray pyrolysis, pulsed laser deposition, chemical vapor deposition, and chemical bath deposition[22-26].

The Urbach energy and dispersion parameters of CdO thin films prepared by chemical spray pyrolysis method and effect of substrate temperature on these films are studied.

Experimental Procedures

The CdO thin films were prepared onto glass substrate by a spray pyrolysis technique. The spraying solution was prepared from 0.1 M of $CdCl_2$ (supplied from BDH Chemicals Laboratory, England) dissolved in double distilled water. CdO thin films prepared with various substrate temperature (300, 350, 400 ^oC). The deposition parameters kept at optimized values such as: the carrier gas was compressed air, spray time was 8 sec. the stopping period 2 minutes, pressure of 10^5 Pascal, deposition rate was 3 ml/min, and distance between nozzle and substrate 28 cm. Thickness was calculated from the gravimetric method to be 450 nm. UV-Visible spectrophotometer used to record absorption spectra in the range 300-900 nm and calculating some optical properties.

Results and Discussion:

The optical transmittance spectra of CdO thin films in the wavelength range between 300 to 900 nm shown in Fig.1. It is observed that the transmittance increased with increasing wavelength for all deposited thin films, while the transmittance decreased with increasing substrate temperature of the CdO thin films.

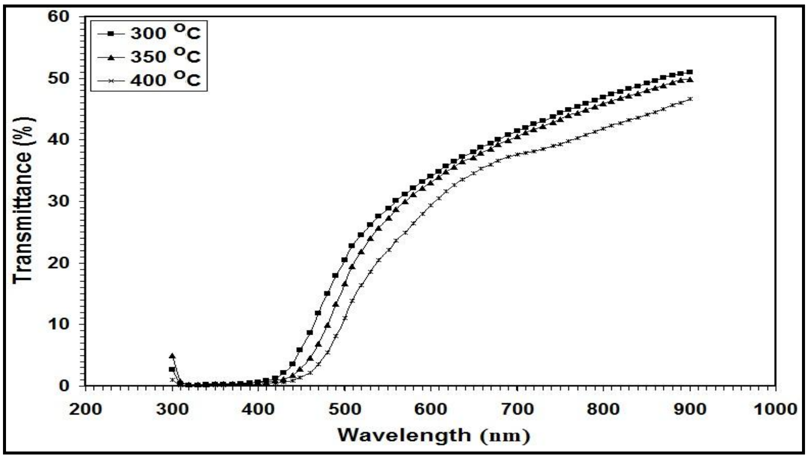

Fig. 1: Transmittance spectra as a function of wavelength for CdO thin films with different substrate temperature.

The reflectance of CdO thin films with defferent substrate temperature are shown in Fig. 2. From this figure, the reflectance decreased with increasing substrate temperature up to 500 nm of wavelength and then the reflectance uncganged with increasing wavelength and substrate temperature, this behavior may refere to the foughness of prepared films.

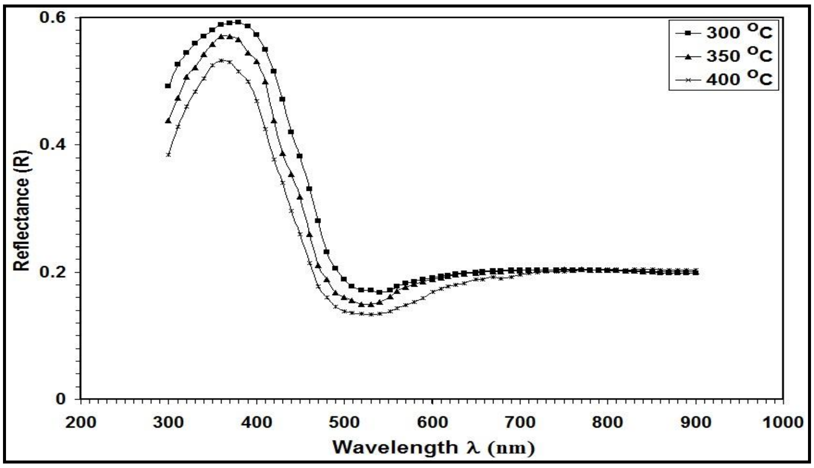

Fig. 2: reflectance spectra as a function of wavelength for CdO thin films with different substrate temperature.

The real (ε_1) and imaginary (ε_2) parts of dielectric constant are expressed as[27]:

$\varepsilon_1 = n^2 - k^2$ (1)

and

$\varepsilon_2 = 2nk$ (2)

where n is the refractive index and k is the extinction coefficient. The real part of the dielectric constant relates to the dispersion, while the imaginary part provides a measure of the dissipative rate of the wave in the medium. Real and imaginary dielectric constants are shown in Figs.3-4. From these figures, ε_1 and ε_2 are increased with increasing of wavelength.

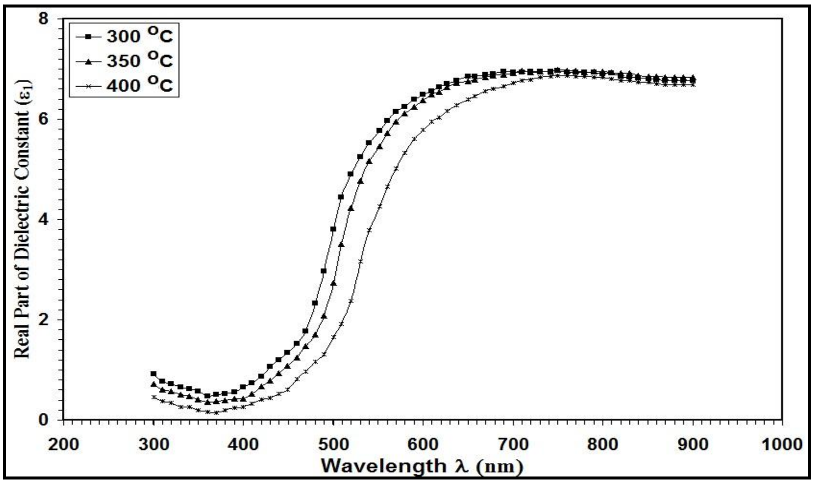

Fig. 3: Real part of dielectric constant as a function of wavelength for CdO thin films with different substrate temperature.

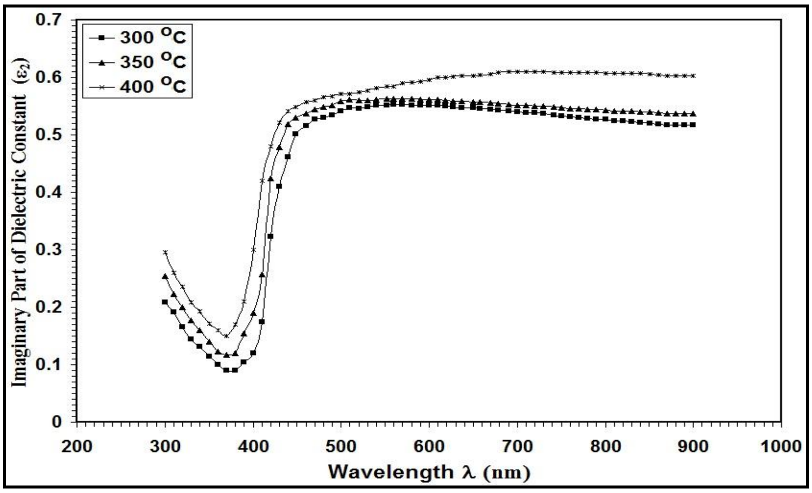

Fig. 4: Imaginary part of dielectric constant as a function of wavelength for CdO thin films with different substrate temperature.

Urbach spectral tail, where the absorption coefficient a falls off exponentially for decreasing photon energy E, and it is expressed as:

$\alpha = \alpha_o \exp(E/E_u)$ (3)

where E_U is the Urbach energy, which corresponds to width of the band tail. α_o is a constant. A plot of ln(α) versus hν should be linear whose slope gives Urbach energy as shown in Fig. 5. From this figure, we find the values of Urbach energy are listed in Table 1. Urbach energy increased with increasing substrate temperature in CdO thin films. This behavior attributed to the broadening in the sublevels in the structure of CdO thin films.

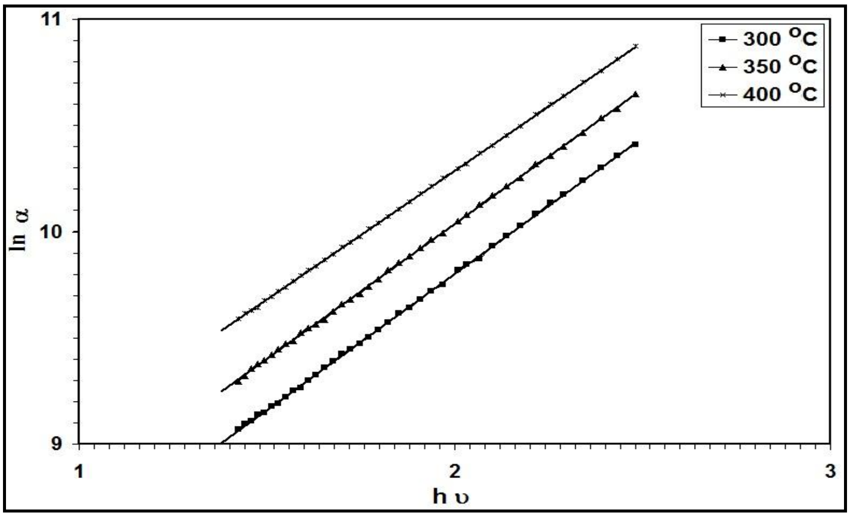

Fig. 5: Plot of lnα versus hυ for CdO thin films with different substrate temperature.

By using an excellent long-wavelength approximation, Wemple and Didomenico[28] developed a single-term Sellmeier relation:

$$n^2 - 1 = \frac{S_o \lambda_o^2}{1 - \lambda_o^2/\lambda^2} = \frac{E_d E_o}{E_o^2 - E^2}, \quad (4)$$

where n is the refractive index, S_o is the average oscillator strength, λ_o is the average oscillator position, E_o is the single oscillator energy, E_d is the dispersion energy, λ is the wavelength and E is the energy of the incident light (hυ).

From plotting $(n^2-1)^{-1}$ versus E^2 and λ^{-2} as in Figs.6-7, it can find E_o and E_d values were determined from the slope, $(E_oE_d)^{-1}$ and intercept (E_o/E_d), on the vertical axis and also the values of the refractive index at infinite wavelength. These values are listed in Table 1.

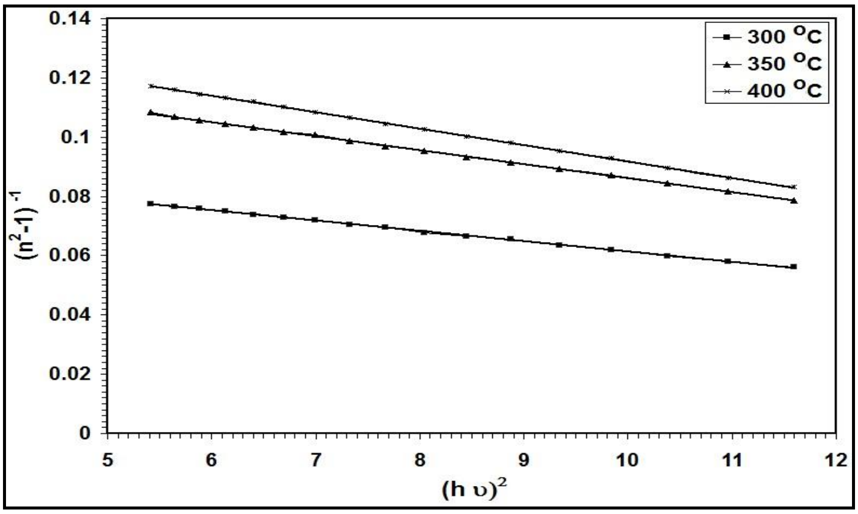

Fig. 6: Plot of $(n^2-1)^{-1}$ versus $(h\upsilon)^2$ for CdO thin films with different substrate temperature.

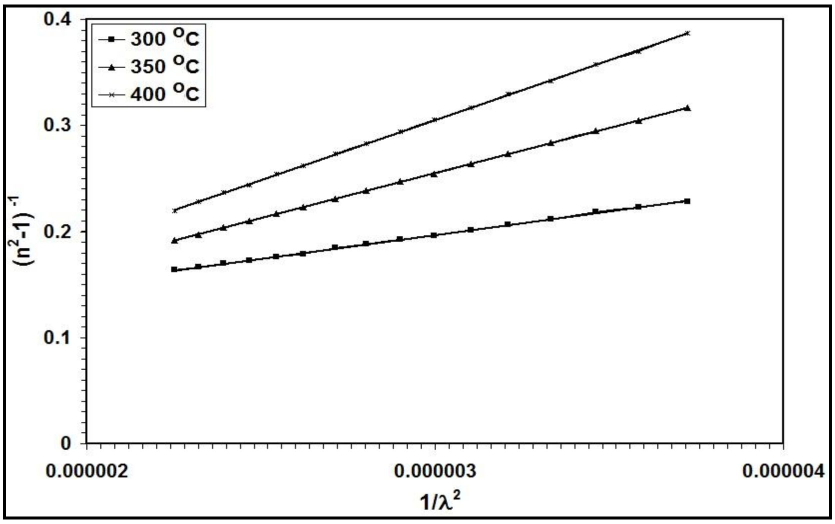

Fig. 7: Plot of $(n^2-1)^{-1}$ versus $1/\lambda^2$ for CdO thin films with different substrate temperature.

The moments of the imaginary part of the optical spectrum M_{-1} and M_{-3} moments of CdO thin films can be derived from the following relations[29]:

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

$$E_d^2 = M_{-1}^3/M_{-3} \quad (6)$$

The values of optical spectrum M_{-1} and M_{-3} moments are decreased with increasing substrate temperature in the CdO thin films as shown in Table 1.

Table (1) the optical parameters for CdO thin films with different substrate temperature.

Substrate Temperature	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	n(o)	M_{-1}	M_{-3} eV^{-2}	S_o x10^{13} m^{-2}	λ_o nm	U_E meV
300 °C	60.60	4.85	2.425	13.50	3.67	12.50	0.531	2.24	545	751
350 °C	43.51	4.78	2.390	10.09	3.17	9.09	0.396	1.17	707	793
400 °C	39.28	4.71	2.357	9.33	3.05	8.33	0.375	0.589	750	826

Conclusions

The CdO thin films have successfully been grown by the chemical spray pyrolysis technique from 0.1 M of $CdCl_2$ dissolved in double distilled water. The transmittance, reflectance, and real and imaginary dielectric constants are decreased with increasing substrate temperature in the CdO thin films. Energy gap decreased from 2.425 eV to 2.357 eV for CdO thin films prepared with substrate temperature from 300 to 450 °C respectively, make this films suitable in solar cell application. Dispersion parameters such as: E_d, E_o, $å_\infty$, n(0), S_o, M_{-1}, and M_{-3} are decreased with increasing substrate temperature in the CdO thin films.

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