Effects of Substrate Type on Some Optical and Dispersion Properties of Sprayed CdO Thin Films

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Abstract

Cadmium oxide films were grown on three different substrate types (glass, quartz, ITO) by spray pyrolysis technique SPT. Transmittance spectra were recorded to obtain some optical parameters. The transmittance decreased when the glass substrate replaced with quartz or ITO glass, while the reflectance increase by increasing wavelength and also by changing kind of substrate. Real and imaginary parts of dielectric constant indicate that both constants have a higher value when the film deposited on ITO glass substrate Urbach energy increased by changing the substrate from slide glass to ITO glass. Single effective oscillator model used to determine dispersion parameters is decreased when the glass substrate replaced with quartz or ITO glass substrate.

Key Words: CdO, SPT, Optical Properties, Dispersion Parameters, Urbach Energy.

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Introduction

Cadmium oxide is n type semiconductor, and energy gap between 2.2-2.7eV [1-4]. The wide band gap CdO, make this material suitable in solar cells and transparent electrodes TCO [5-6], photodiodes [7], phototransistors [8], liquid crystal displays, gas sensor [9], CdOdeposited by many procedureslike spray pyrolysis [10,11], ion beam sputtering [12], sol-gel [13]. Altıokka and Yıldırım [14] use ITO substrate to prepare CdO by electro deposition technique. Anitha et al. [13] prepare CdO on glass, quartz, FTO and Silicon substrates, they found that FTO substrate has a bandgap value of 2.34 eV which might be convenient for optoelectronic applications. Rajput et al. [15] deposited CdO onto glass substrates using different molar concentrations of cadmium acetate utilizing so-gel method. The chemical spray pyrolysis can use for deposited high melting point materials [16-17].

This work is subject to prepare CdOfilms on different types of substrate utilizing SPT to discuss effects of substrate type on optical properties and dispersion parameters.

Experimental Procedures

CdO thin films are grown on different types of substrate at a constant temperature of 400 ºC by SPT. 0.1 M of $Cd(COOCH_3)_2$(supplied from Sigma-Aldrich Chemicals) with re-distilled waterwas used as an aqueous solution. Space between sprayer and substrate was 28cm.

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Compressed air was employed as a carrier gas and deposition average was 2 ml/min. Weighing method was utilized to measure thickness, its value was about 300 nm.

The structural properties were evaluated by XRD with CuKα radiation (λCu=0.154056nm). Film morphology was determined by AFM (AA3000 SPM), The spectrophotometer (Shimadzu UV probe 1640 Japan) was applied to determine absorbance and transmittance.

Results and Discussion

The XRD patterns depict that deposited films for all types of substrates were cubic polycrystalline structure with a dominant orientation along (111). Minor peaks are observed with orientation (200), (220) and (311) planes.

These peaks were fit with ICDD card no. 05-0640. It can be noticed that peak intensity of ITO substrate was the higher one as shown in Fig. 1. These results agree well with Mohammed et al. [18] and Mishra et al. [19].

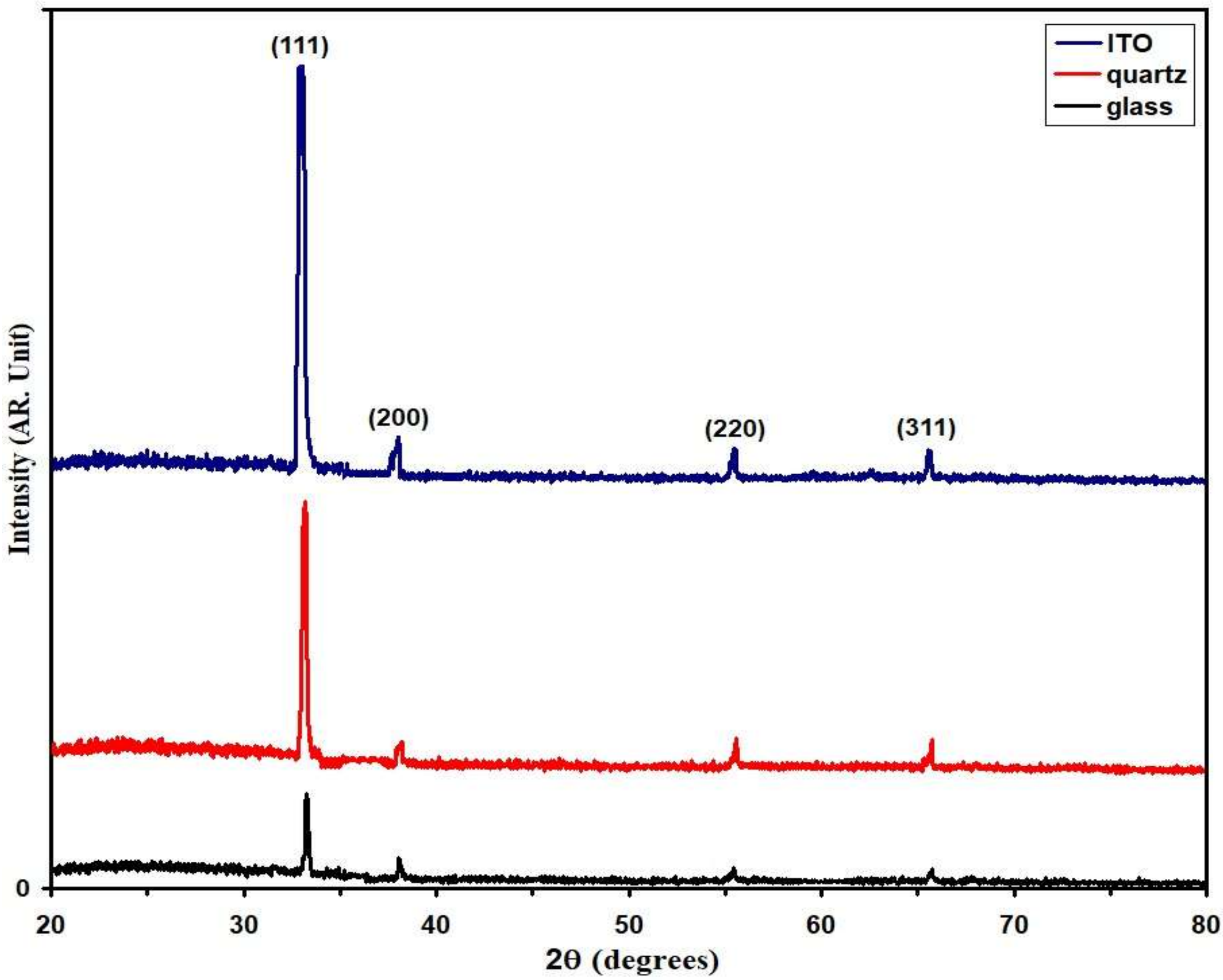

Fig. 1. XRD patterns of deposited films on varioussubstrate types

Surface topography of the as grown films was noticed via AFM images as shown in Figure (2, 3 and 4). These images indicate an increase in columnar size, roughness and surface area related to the deposition films on various types of substrates.

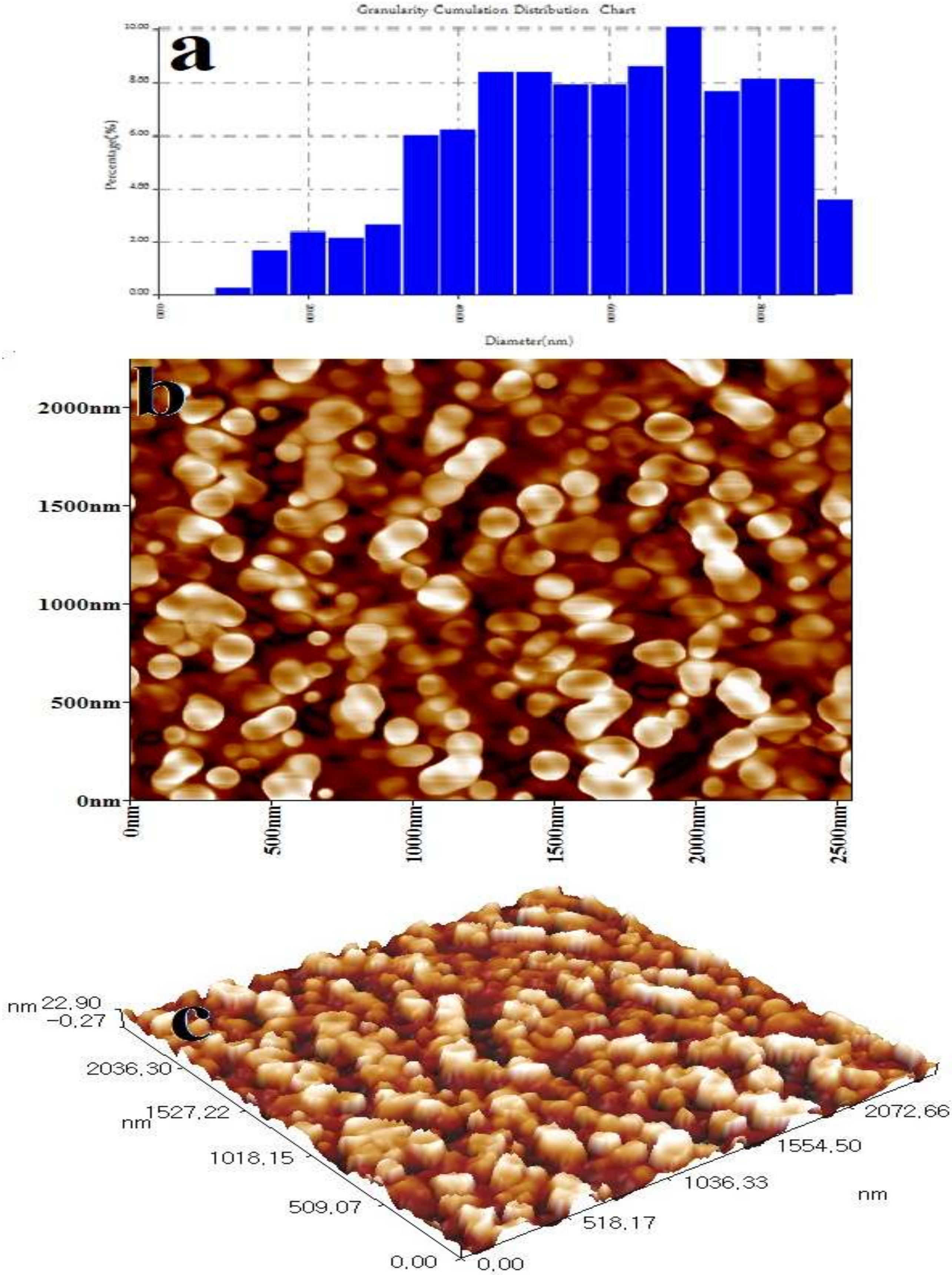

Fig. 2. AFM images and Granularity distributed curve (glass)

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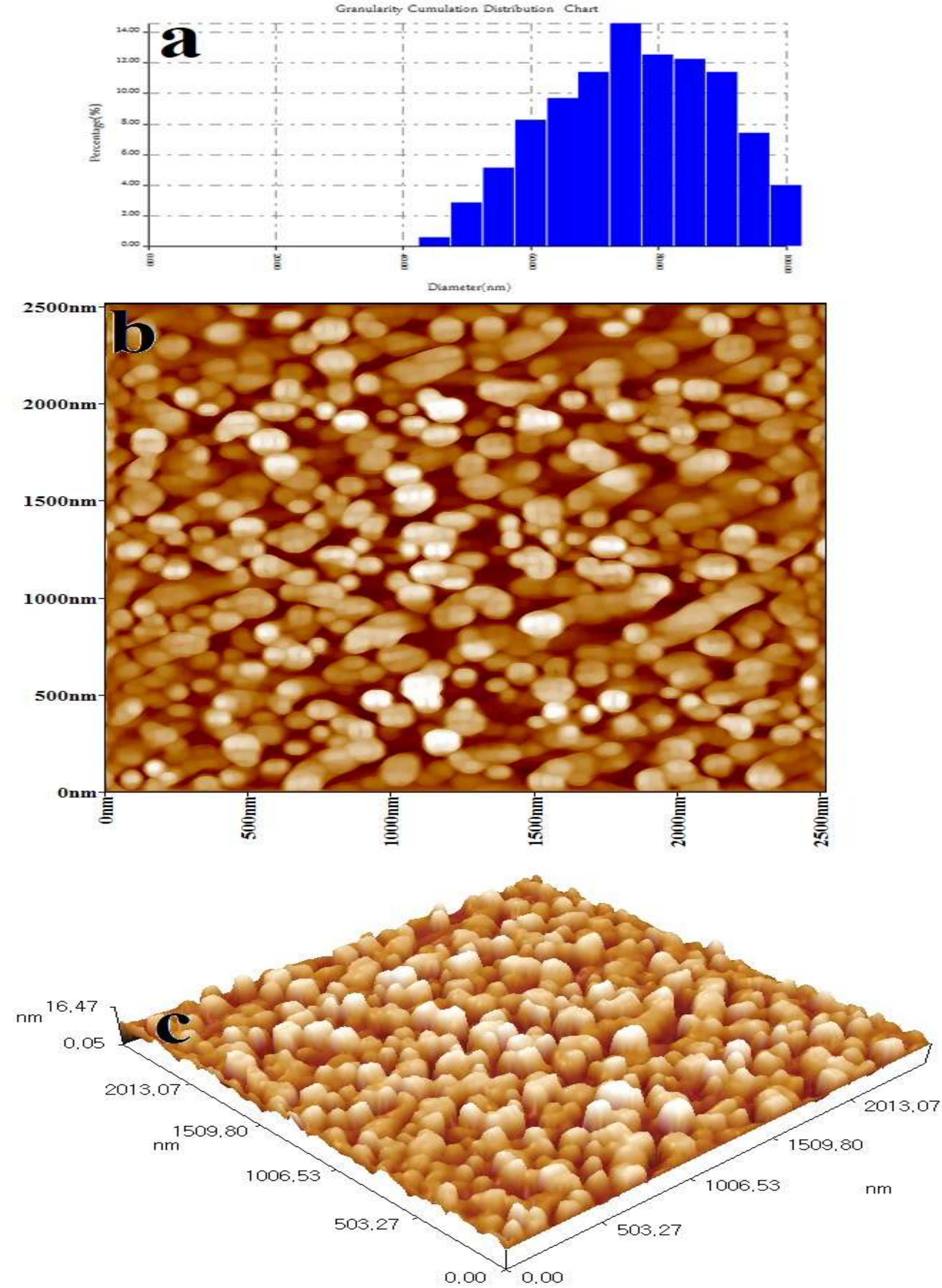

Fig. 3. AFM images and Granularity distributed curve (Quartz)

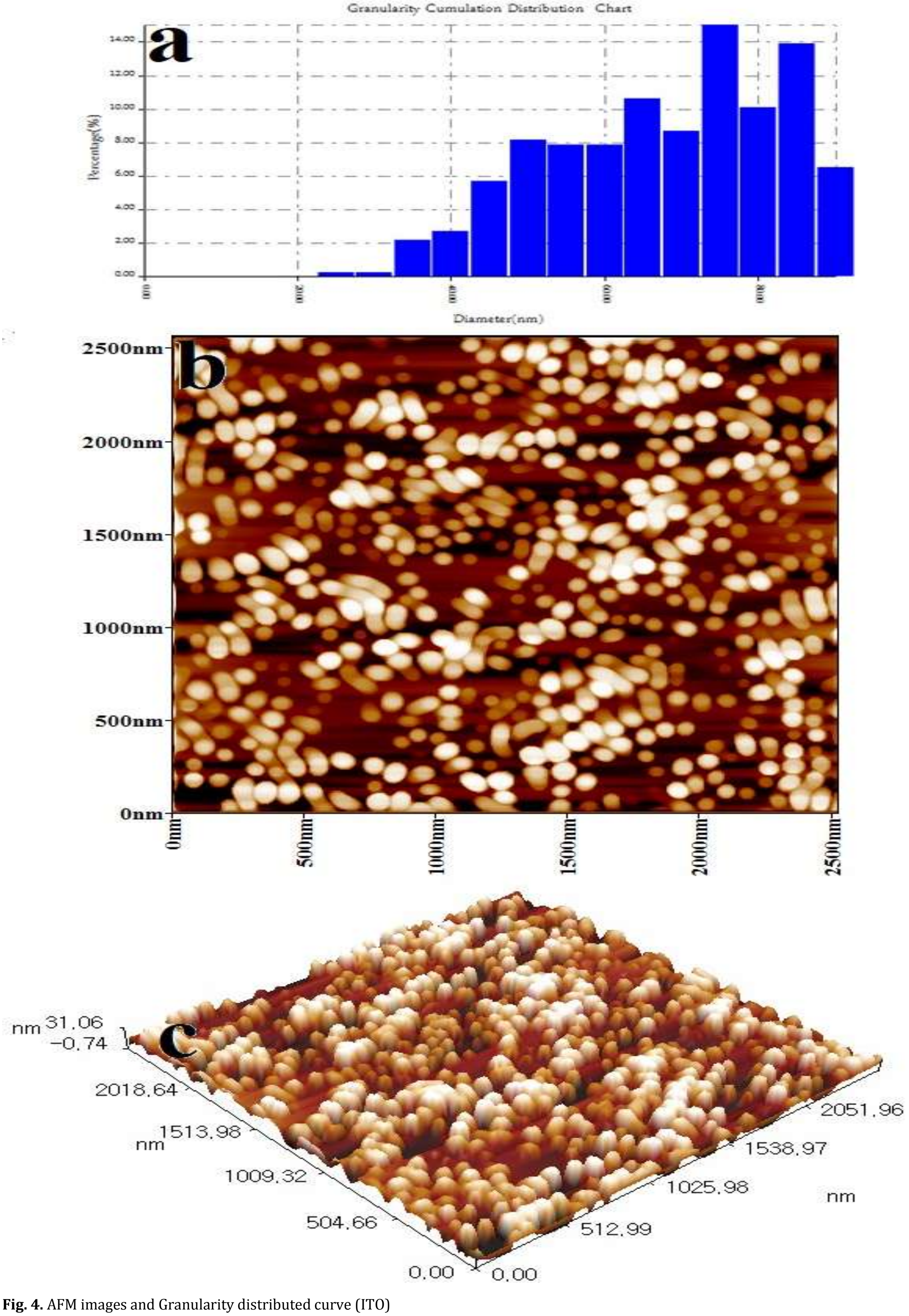

Fig. 4. AFM images and Granularity distributed curve (ITO)

Transmission spectra of CdO samples at various substrate types in wavelength range (300-900) nm are displayed in Fig. 5. Transmittance increases via increasing wavelength for the deposited films, and decreased when glass substrate replaced with quartz or ITO glass, this attributed to the arrangement of crystals.

Fig. 6. represents reflectance versus wavelength. It can be noticed that reflectance increased via increasing wavelength and replacing glass substrate to quartz or ITO glass until to 500 nm, while reflectance is unchanged when the glass substrate replaced with quartz or ITO glass for the deposited films at wavelengths higher than 500 nm.

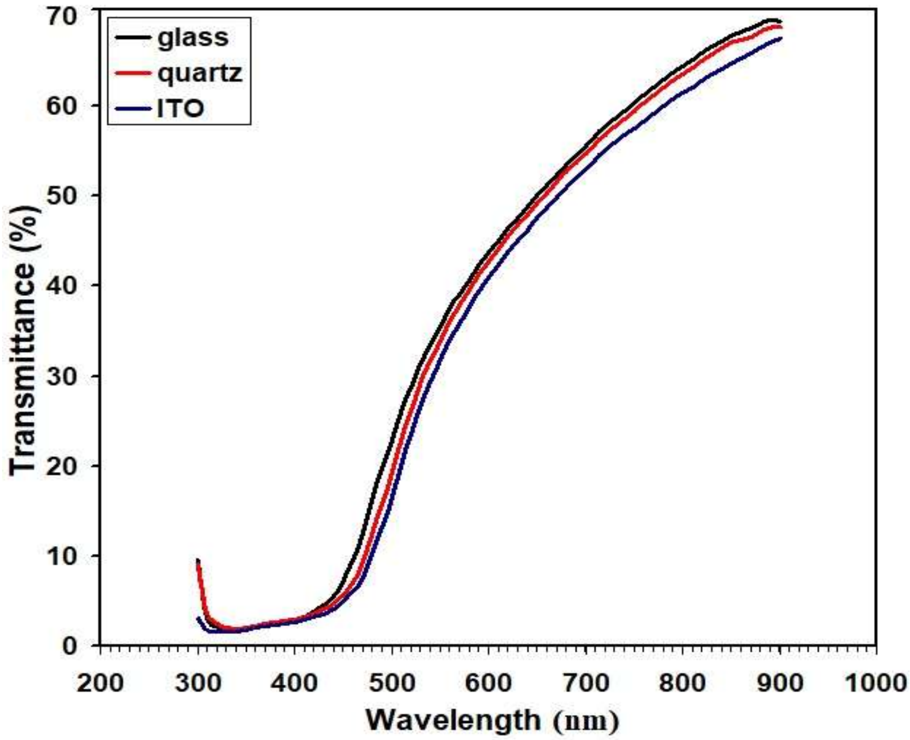

Fig. 5. Transmittance spectra of CdO films grown on various substrate types

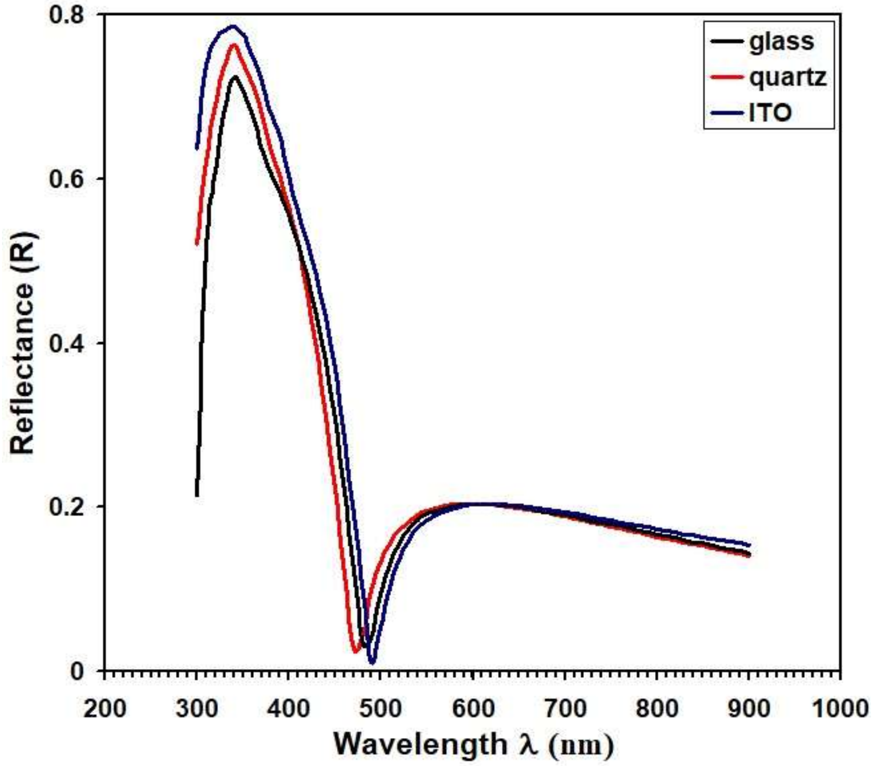

Fig. 6. Reflectance spectra of CdO films grown on various substrate types.

The dielectric constant, which represented material respond of incident electromagnetic field, is calculated from following formulas [20-21]:

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

$$\varepsilon_2 = 2nk \qquad (2)$$

Where ε_1, ε_2, n, k represented real, imaginary dielectric constants, refractive index and extinction coefficient respectively.

Figs. (7,8) represent relationship betweenε_1 and ε_2 via wavelength respectively.

Urbach energy E_U was obtained via Eq. 3[22-23]:

$$\alpha = \alpha_o \exp\left(\frac{h\nu}{E_U}\right) \quad (3)$$

Where α_o is a constant [24]. By plotting lnα versus photon energy to evaluate the value of E_U of various substrate types as in Fig. 9. Results of E_U are display in Table 1.

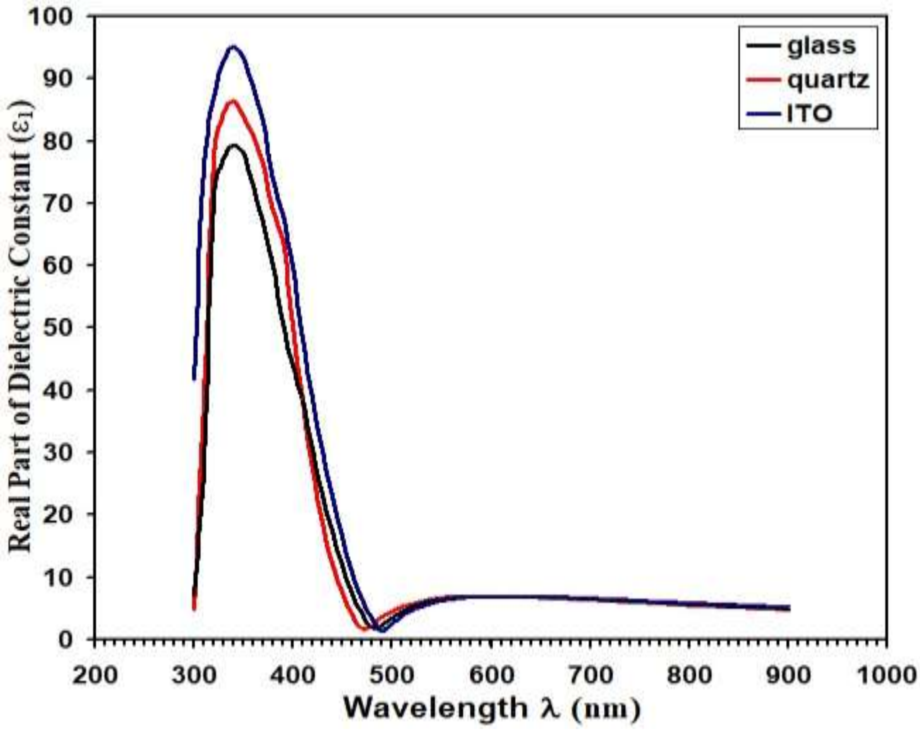

Fig. 7. ε_1 against wavelength of deposited films.

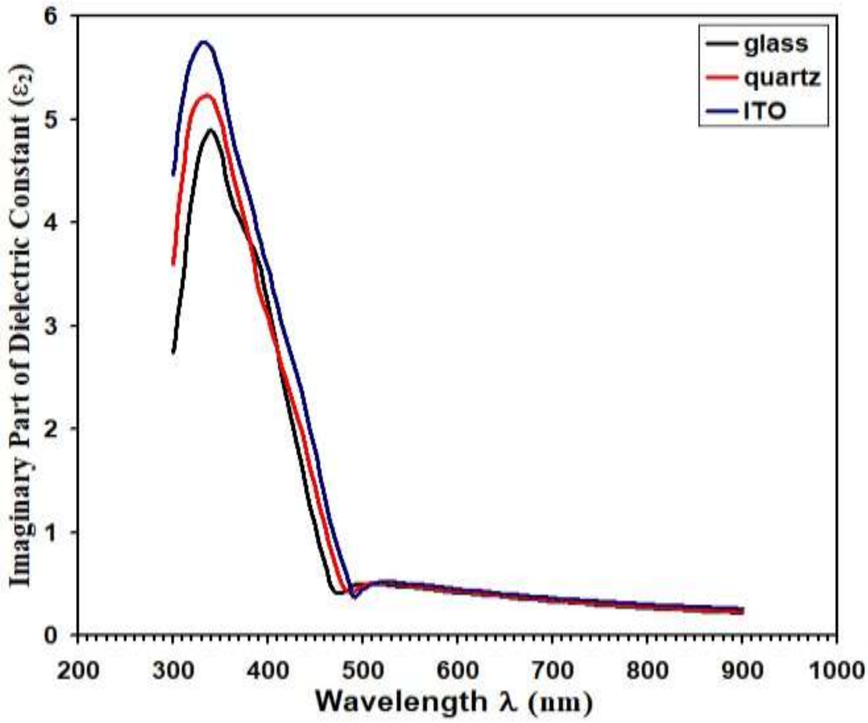

Fig. 8. ε_2 against wavelength of deposited films.

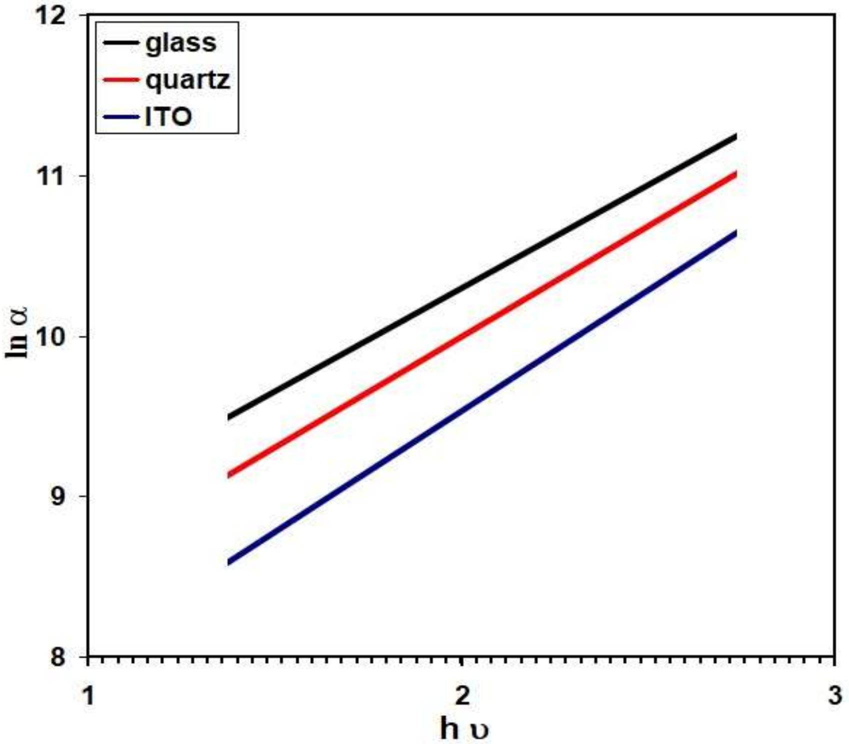

Fig. 9. Lnα versus hυ of deposited films.

Refractive index n was evaluated via single oscillator proposed by Wemple and Di Domenico [25,26]:

$$n^2 (h\nu) = \frac{E_o E_d}{E_o^2 - (h\upsilon)^2} + 1 \quad (4)$$

Where E_o is average electronic energy gap for transition, and $E_d$is dispersion energy. These coefficients were evaluated from plotting $(n^2-1)^{-1}$ versus $(h\upsilon)^2$ as in Fig. 10, E_d, E_o and E_g values are listed in Table 1.The values of optical bandgap agrees with Chopra and Das [27].

The single-term Sellmeier was obtained from the relation [28, 29]:

$$n^2 (\lambda) - 1 = \frac{S_o \lambda_0^2}{1 - (\lambda_o / \lambda)^2} \quad (5)$$

Where λ_o, S_o are average oscillator position and strength respectively, and they were evaluated from Fig. (11).

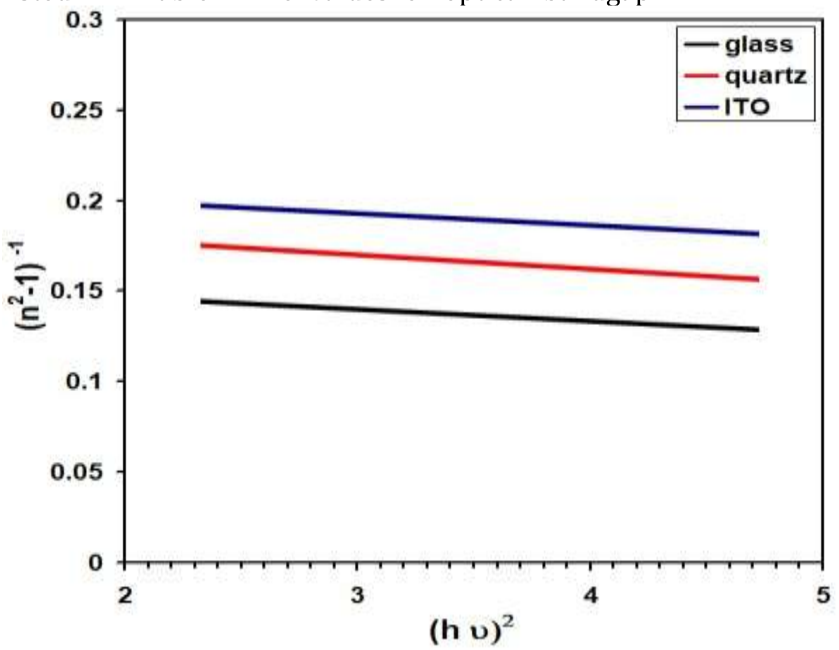

Fig. 10. $(n^2-1)^{-1}$against $(h\upsilon)^2$ of CdO films deposited on various substrate types.

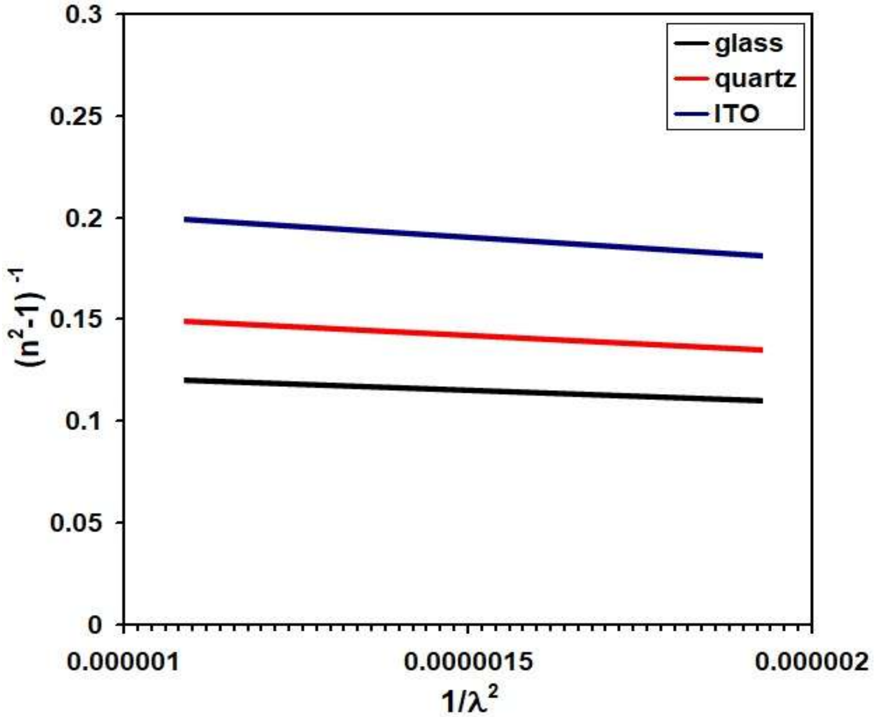

Fig. 11. $(n^2-1)^{-1}$against $1/\lambda^2$ of deposited films.

M_{-1} and M_{-3}, moments of the optical spectra for as depositsare calculated from next relations [30-31]:

$$E_d^2 = \frac{M_{-1}^3}{M_{-3}} \text{ and } E_o^2 = \frac{M_{-1}}{M_{-3}} \quad (6)$$

These results are display in Table (1).

Table 1. Dispersion parameters of CdO thin films with various Substrate types

Sample	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	n(o)	M_{-1}	M_{-3} eV^{-2}	S_o ×10^{13} m^{-2}	λ_o nm	E_U meV
Glass	32.03	4.80	2.400	6.67	2.77	6.67	0.289	4.86	321	699
Quartz	26.35	4.74	2.372	7.67	2.56	5.56	0.247	6.22	327	719
ITO Glass	23.57	4.41	2.357	6.00	2.45	5.00	0.225	7.13	341	793

Conclusion

Transmittance decreased when glass substrate replaced with quartz or ITO glass. Urbach energy increased while bandgap decreased byreplacing substrate from 2.4 eV of CdO thin film grown on glass substrate to 2.357 eV of film grown on ITO glass substrate. Single effective oscillator model used to determine.All dispersion parameters were affected by substrate type. According to our results ITO substrate seem to be the best substrate for deposited CdO thin film. (less, E_d, E_o, energy gap, and ε_∞, refractive index and transmittance)

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