Influence of Substrate Temperature On Optical Properties of CdO Thin Films

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Abstract

CdO thin films have been prepared utilizing chemical spray pyrolysis technique. Absorbance and transmittance spectra have been recorded in order to study the reflectance, kind of transition ,extinction coefficient refractive index and dielectric Constant in real and imagery parts, all as a function of substrate temperature. It was found that all the investigated parameters affect by Substrate temperature. **Key words:** *CdO thin film, optical properties, spray pyrolysis.*

Introduction

During the last few years thin films of cadmium oxide (CdO) has revealed itself as a very promising material for use in the photovoltaic industry because of its high optical transparency high electrical conductivity in the spectrum region of sun radiation [1] . Transparent conducting oxide thin films have been widely used in solar cell applications. In spite of being a transparent conductor metal oxide, CdO has not usually been employed as a transparent electrode in solar cell technology due to it's relatively small band gap when it is compared to other materials[2].

Cadmium oxide is an oxygen deficient n- type conducting due to oxygen vacancies[3] and has Nacl structure[4].

It's nearly metallic conductivity and is caused by a large native defect concentration[5].and have a high transparency in the visible region of the electromagnetic spectrum[6], there have been a number of studies on the semiconductor aspects of pure CdO, but the formation and effect of impurities has received little attention . we try to study the effect of the differ in substrates temperature of CdO thin film on the optical properties of these films.

Experimental work

The method of chemical spray pyrolysis utilized in this paper to prepare thin films of cadmium oxide. The subsequent reaction on the heated substrates produces the CdO thin films products. By using the cadmium nitrate hydrate

$(Cd(NO_3)_2.4H_2O)$ material to produce thin films of cadmium oxide ,prepare the solution of cadmium nitrate hydrate with Concentration (0.2M) by solution (3.087gm) from the material in (100ml) of water in order to arrive the perfect solution use magnetic stirrer. The following relation used to get the weight of solution within the above molarty:

$M=(W_t /M_{wt}) .(1000/V)$ ……………..(1)

M: concentration molarty .

W_t: weight of solution.

V: volume of water .

M_{wt} :molecular weight of $(Cd(NO_3)_2.4H_2O)$ material.

After the solution is cooling locate in the spray system to spray on the glass substrate we can get the CdO thin films according to the chemical equation :

$$2Cd(NO_3)_2 \xrightarrow{Heat} 2\,CdO + 4NO_2 \uparrow + O_2 \uparrow$$

It has been found that the following deposition parameters give good films with good transparency and uniform surface :

(1) Substrate Temperatures are once 400˚ C,450˚ C,500˚ C, and last once 550˚ C.

(2) Spray rate 10 cm^3/min.

(3) Distance between sprayer nozzle and substrate is 30 ±1 cm .

The glass substrates are placed on the hot plate fan about (30) min before spraying process, so the glass substrates are nearly at the same temperature as the hot plate. Each spraying period lasts for about (15) sec followed by about (5)min waiting period to avoid excessive cooling of the hot substrates due to the spraying. The thickness of the sprayed samples were in the range of (2000±20A˚).

The films were clear, transparent, brown colored having very good adhesive properties and are of smooth surface free from pinholes.

The absorbance and transmittance spectrum were recorded for wavelengths interval in the region (360-900)nm by using PU-8800UV/VIS PYE Unicom spectrophotometer. The optical measurements were made on a large number of obtained with negligible errors.

Results and discussions

1-Reflectance(R)

Reflectance is the ratio of intensity of reflection radiation to the incident radiation and it calculated from the spectrum of absorption (A) and transmission (T) according to the law of energy conversation [7].

$R+T+A=1$……………….(2)

Fig. (1) Shows the Reflectance against photon energy for different substrate temperature of the samples. Reflectance of the films which were prepared at (400˚C, 450˚C, 500˚C) have the same behavior or nearly, but the film prepared at substrate temperature (550˚C) reflectance is slightly increase, this mean that the absorbance and transmittance are decrease.

As a direct band gap semiconductors, CdO thin films has an absorption coefficient (α) obeying the following relation [8].

$$(h\nu\alpha)^2 = A(h\alpha - E_g)................(3)$$

Where E_g is the optical band gap of thin film, A is a constant and h*v* is the incident photon energy.

The variation of $(\alpha h\nu)^2$ versus photon energy for CdO deposited at different substrate temperature (400˚C, 450˚C, 500˚C, and 550˚C) are plotted in Fig. (2) the optical band gap E_g can be evaluated by extrapolation of the liner part to (2.45eV, 2.48eV, 2.5eV and 2.7eV) respectively. The increase in substrate temperature especially at (550˚C) leads to a decrease in absorption because the films become less crystalline than other films . This result was in good agreement with the reported value by others [9,10].

2-Extinction Coefficient(k_o)

Extinction Coefficient is the absorption energy in the thin film and it also represent the imaginary part of refractive index according to the relation[2,7]

$$N = \frac{c}{V} = n_0 - iK_0....................................(4)$$

Where :

(v) is the velocity of light in the thin film,(c)is the velocity of light in the vacuum and (n_o) is the real part of refractive index.

Also the Extinction Coefficient is related to the absorption Coefficient (α) by the relation[2]

$$K_0 = \frac{\alpha\lambda}{4\pi}..(5)$$

Where the wavelength (λ) in cm if absorption Coefficient(α) in(1/cm)

From above relation the Extinction Coefficient is calculated .

The variation in the optical constant Extinction Coefficient (k_o) were shown in Fig. (3) it is seen that Extinction Coefficient (k_o) increase more with substrate temperature (550°C) than other substrate temperatures, it is clearly seen that at photon energy (2.8ev),this behavior may be due to the change in the crystallite size of these films and to the increase in Absorption Coefficient (α) at high substrate temperature of these films[7] .

3-Refractive Index(n_o)

Refractive index associated with the reflectance of thin film by the relation[11]:

$$n_0 = \left[\left(\frac{1+R}{1-R}\right)^2 - (K^2{}_0 + 1)\right]^{\frac{1}{2}} + \frac{1+R}{1-R}...............(6)$$

From above relation the Refractive index is calculated. Fig (4) shown the Refractive index against photon energy for different substrates temperature, it can be seen that the Refractive index have the same behavior or nearly of the films which were prepared at (400˚C, 450˚C, 500˚C) , but the Refractive index of the film which prepared at substrate temperature (550˚C) is slightly increase ,it is clear at photon energy (2.48ev) due to the increasing in Reflectance (R) of this samples.

4-The Dielectric Constant (ε)

The relation between the light and the charges of medium occur by process of the absorption of energy in material and that lead to polarized of the medium's charges ,this polarization described by the complex Dielectric Constant for the medium by the relation[12].

$$\varepsilon = \varepsilon_1 - i\varepsilon_2 \text{................................} (7)$$

Where :

ε_1 is the real Part of the Dielectric Constant.

ε_2 is the Imaginary Part of the Dielectric Constant.

$$\varepsilon_1 - i\varepsilon_2 = (n_0 - ik_0)^2 \text{................................} (8)$$

From the last relation the real and imaginary part of the Dielectric Constant are calculated as following:

$$\varepsilon_1 = n_0^{\,2} - k_0^{\,2} \text{.........................} (9)$$

$$\varepsilon_2 = 2n_0k_0 \text{....................................} (10)$$

Fig (5) show the Real part of Dielectric Constant against photon energy for different substrate temperature of the samples. As shown in this figure the behavior of curves are similar to the behavior of Refractive index(n_o) according to equation (9) while the effect of Extinction Coefficient(k_o) is verys lightly or may be neglected, the maximum value of Real part of Dielectric Constant is (7.70) with photon energy (2.38ev) at (550˚C) substrate temperature. while the other value of Real part of Dielectric Constant equal to (6.88) with photon energy (2.43ev) and it nearly equal for substrate temperatures (400˚ C, 450˚ C and 500˚C).

Fig (5) shows the Imaginary part of Dielectric Constant against photon energy for different substrate temperature of the samples. Here the behavior of curves are similar to the behavior of Extinction Coefficient(k_o) this association due to equation (10), the maximum value of Imaginary part of Dielectric Constant is (1.3) with photon energy (2.79ev) at (550˚C) substrate temperature, while the other value of the Imaginary part of Dielectric Constant equal to (1.1) with photon energy (2.6 ev) and it nearly equal for substrate temperatures (400˚C, 450˚C and 500˚C).

Conclusions

CdO thin films which have been prepared at a substrate temperature of (550˚C) show high transparency, this indicates That CdO thin film could transmit more light and therefore these films would be better transparent electrode for display applications.

In general the films grown at (550˚C) substrate temperature have a good optical quality properties predict a large grain size and are well-suited for solar cell application as a window material.

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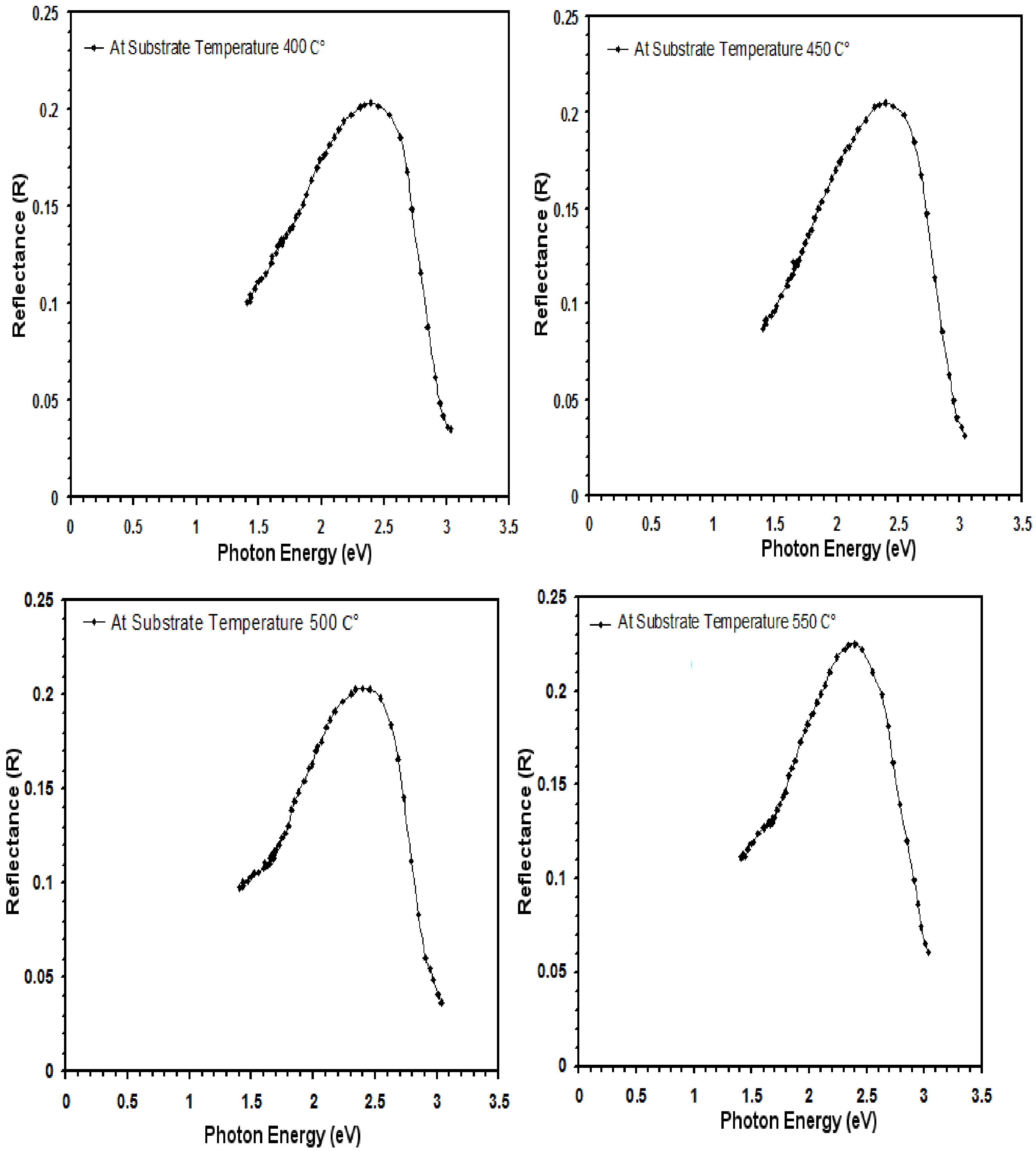

Fig (1): Reflectance against photon energy for different substrate temperature of the samples.

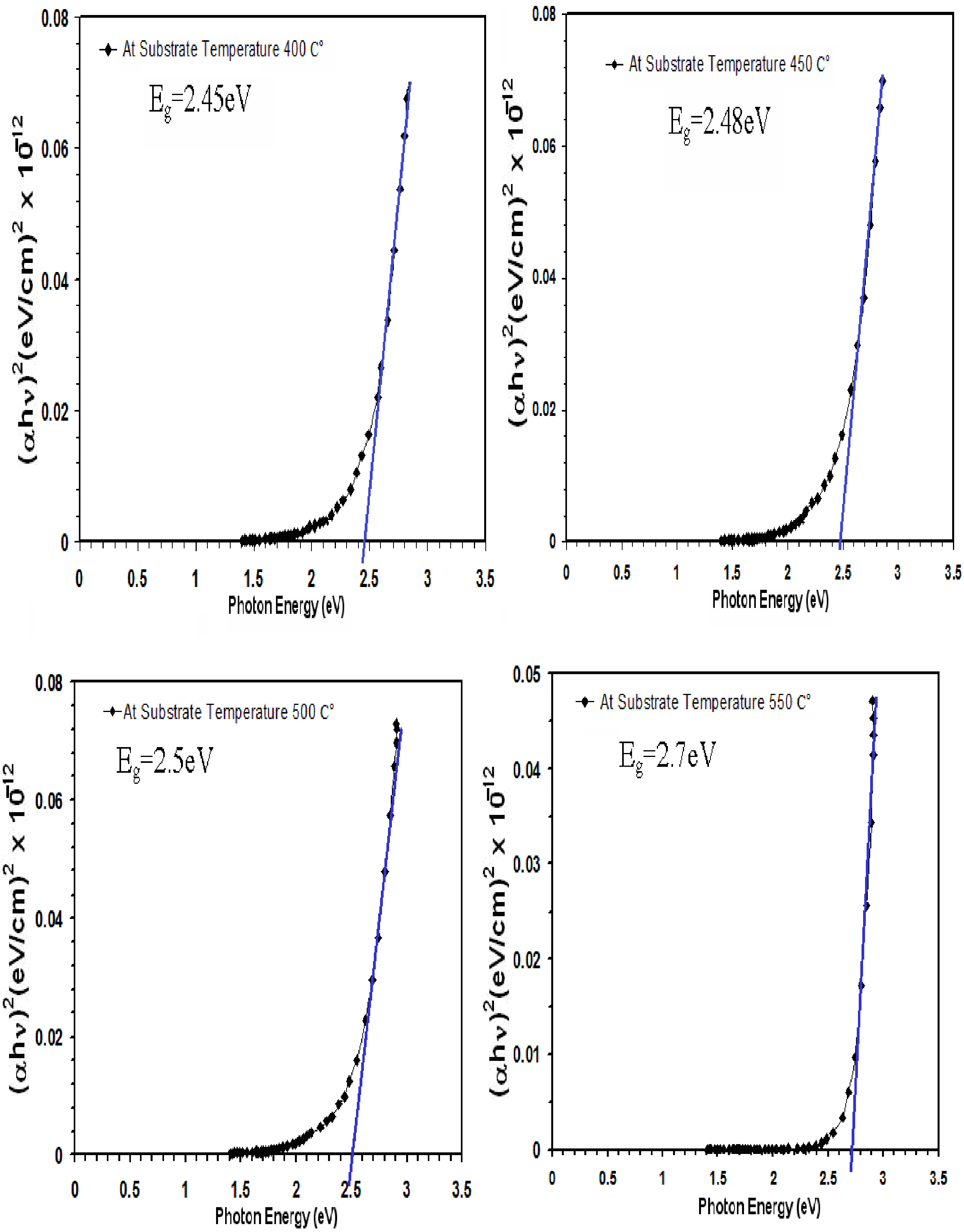

Fig (2): $(\alpha h\nu)^2$ for CdO thin film versus photon energy.

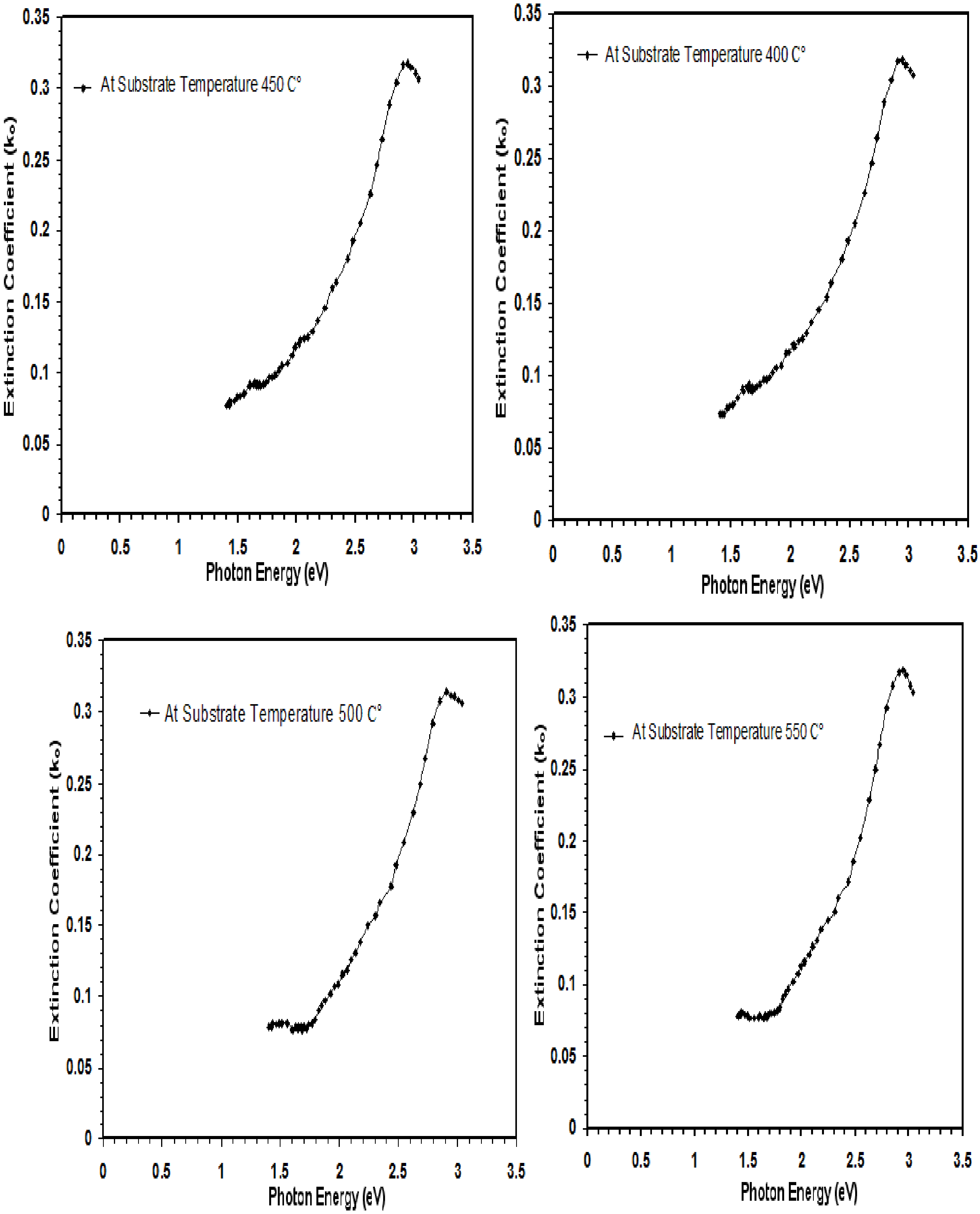

Fig (3): Extinction coefficient against photon energy for different substrate temperature of the samples.

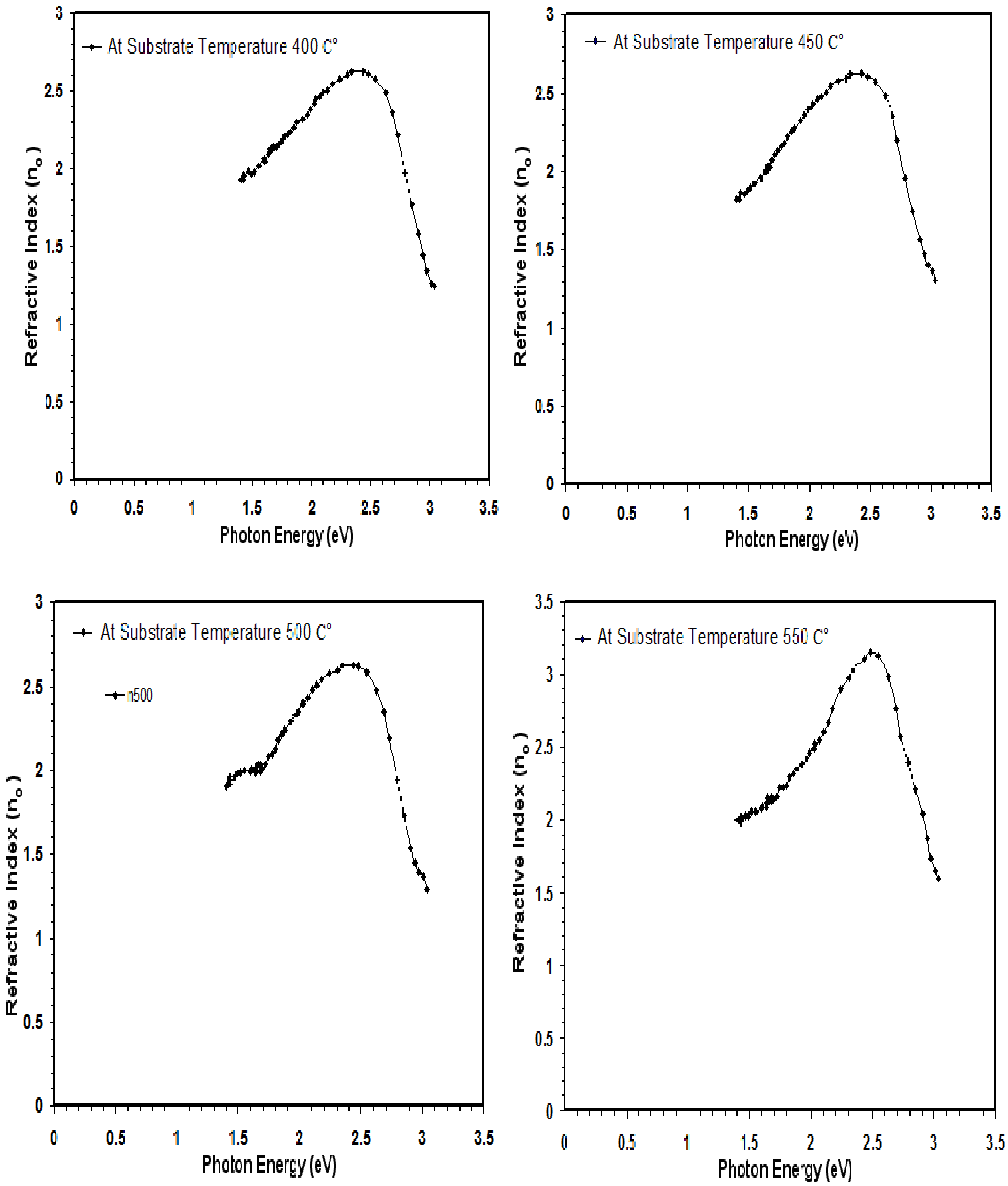

Fig (4): Refractive index against photon energy for different substrate temperature of the samples.

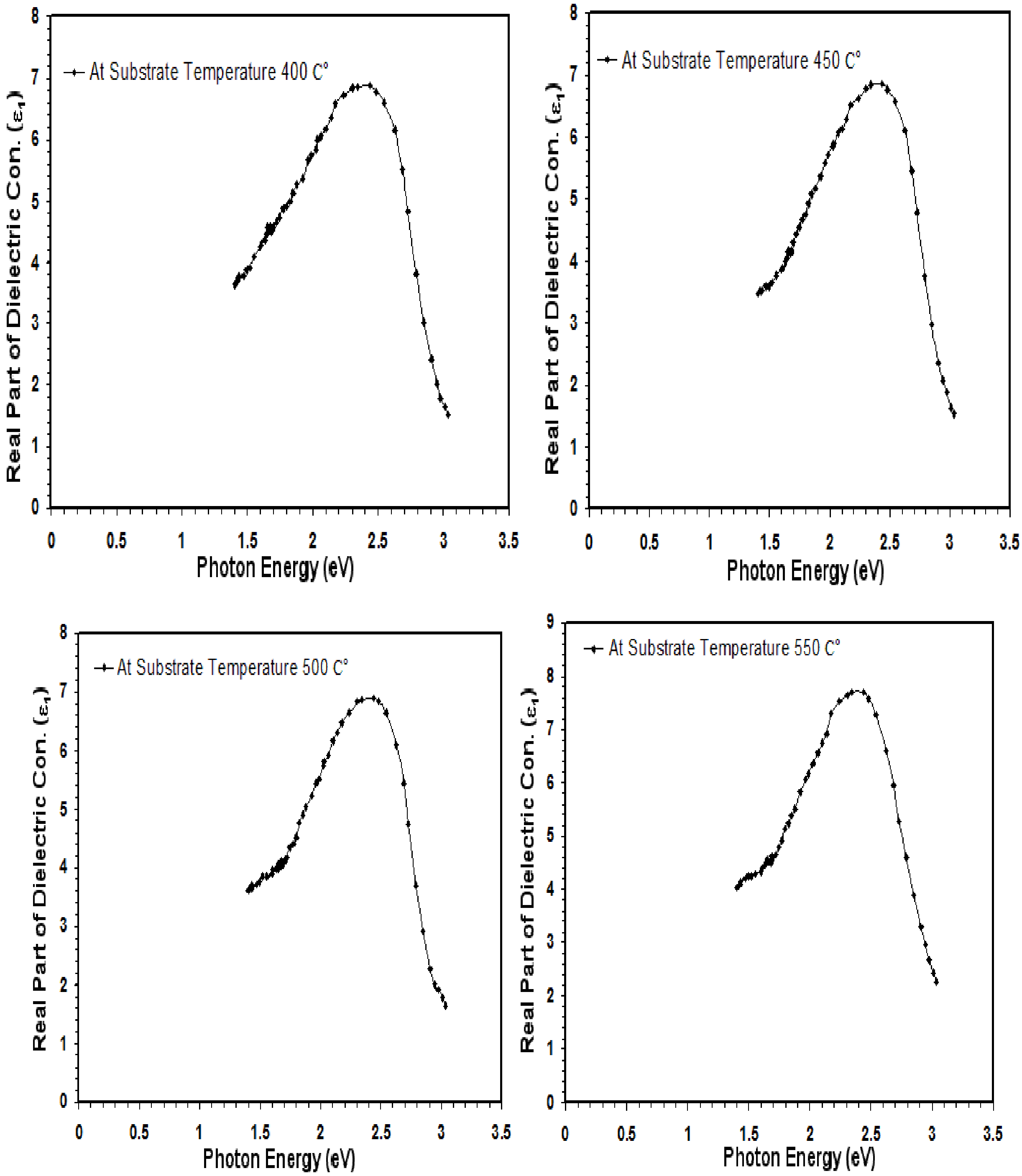

Fig (5): Real part of Dielectric Constant against photon energy for different substrate temperature of the samples.

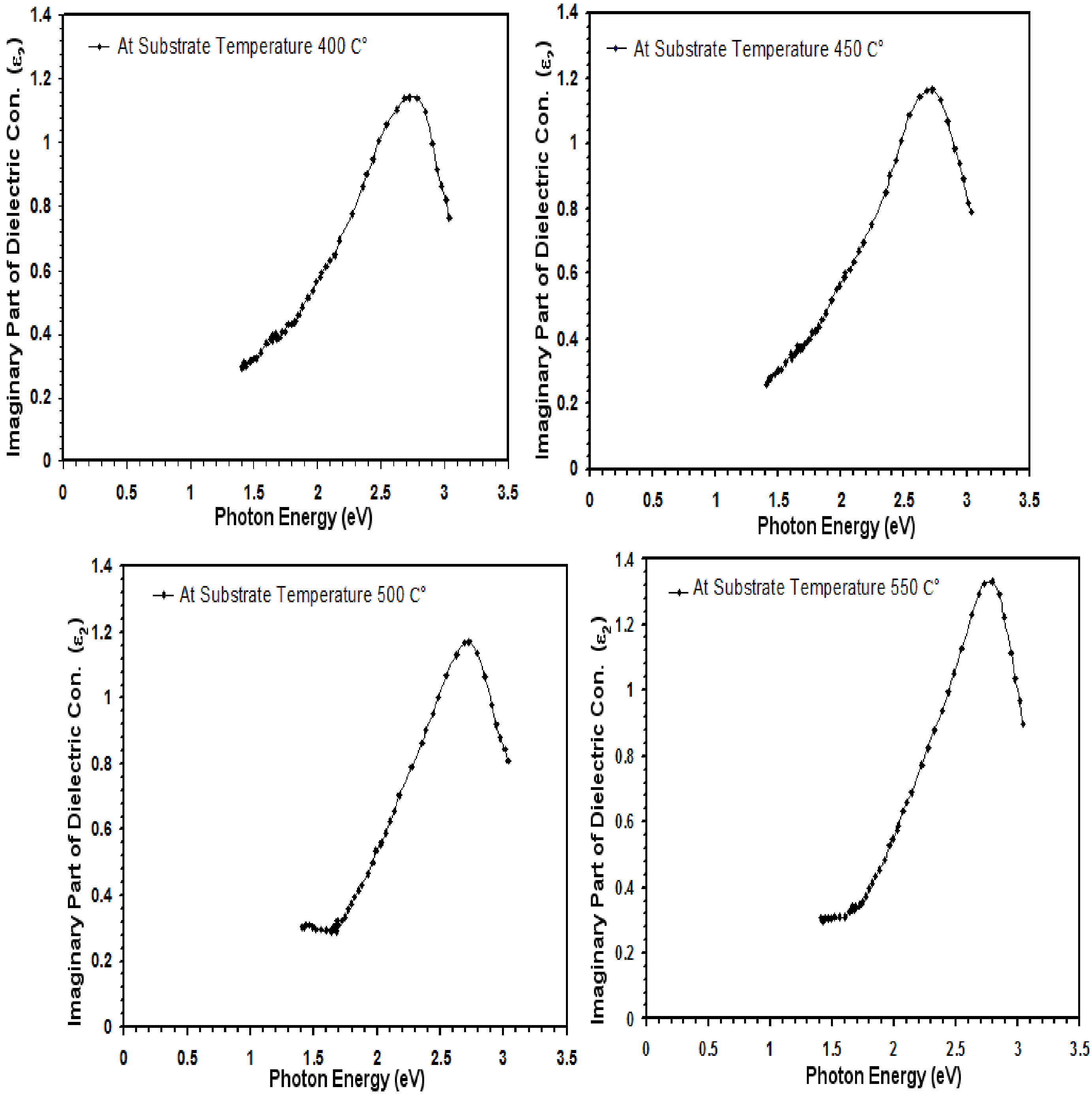

Fig (6): Imaginary part of Dielectric Constant against photon energy for different substrate temperature of the samples.

الخلاصة

حضرت أغشية رقيقة من اوكسيد الكادميوم باستخدام تقنية التحلل الكيميائي الحراري. سجل طيف الامتصاصية والنفاذية وذلك لغرض دراسة الانعكاسية، نوع الانتقال، معامل الخمود، معامل الانكسار وثابت العزل بجزئه الحقيقي والخيالي . كل هذه المعلمات كدالة لدرجة حرارة الأساس. لقد وجد بأن جميع المعلمات قيد الدراسة قد تأثرت بدرجة حرارة الأساس.