MINAR International Journal of Applied Sciences and Technology
ISSN: 2717-8234
Article type: Research Article

Received: 17/01/2025 **Accepted:** 10/02/2025 **Published:** 01/03/2025

EFFECT OF CdO CONTENT ON THE OPTICAL PROPERTIES OF TiO2 THIN FILMS

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Abstract

Thin films of pure and doped TiO_2 were examined for their optical properties with varying concentrations of CdO (10 and 20 %wt). Using the Spin-Coating technique, Thin films were efficiently prepared on glass substrates with varying concentrations of CdO. Use UV-VIS transmittance spectroscopy to look at the optical characteristics. Transmittance of the TiO_2 film in the visible field reaches 79%, according to the optical parameters associated with the absorption and transmission spectra of the produced thin films. The computed optical band gaps for (TiO_2, CdO, 10% CdO, 20% CdO) were (3.82, 3.7, 3.87, and 3.86) eV, respectively. At 350 nm, all of the following values were found: optical energy gap, real and imaginary dielectric constants, extinction coefficient, refractive index, absorption coefficient, reflection, and weight percent accordingly.

Keywords: *TiO2 Thin Films; CdO, Spin-Coating, Optical Properties.*

http://dx.doi.org/10.47832/2717-8234.22.48

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1-Introduction

Photocatalysis, photochromic devices, optical waveguides, dye-sensitized solar cells, antireflection coatings, sensors, optical amplifiers, biocompatible materials, and other optoelectronic devices have prompted extensive research into titania in recent years. An oxide sheet of titanium dioxide (TiO_2) has a wide energy band gap and shows promise as an optoelectronic material [1].

A substance containing titanium dioxide One of the three crystalline forms of titanium dioxide is rutile, the other is anatase with a bandgap of approximately 3.2 eV, and the third is brookite with a bandgap of approximately 3.3 eV. The anatase phase's crystal structure and greater band gap of 3.2 make it ideal for those uses. With its high refractive index and excellent chemical stability, TiO_2 has found usage in sensing applications as an n-type semiconducting material [2,3].

Because of its abundance of oxygen vacancies, cadmium oxide exhibits exceptional transparency in the visible light spectrum. having a band gap that ranges from 2.2 to 3.2 eV. It is well-known that excellent conductivity and a high transmission coefficient in the visible range are not easy to achieve at the same time [4].

These features make CdO an attractive candidate for use in gas sensors, photodiodes, and solar cells, among other electrical and optoelectronic devices [5]. Titanium Dioxide (TiO_2) coatings are likewise quite popular due to their many desirable characteristics, such as high temperatures, excellent transmission in the visual and near infrared areas, and excellent cohesiveness [6].

Many different kinds of TiO_2/CdO systems have been created and researched, including core-shell structures, thin films, nanocrystals with exposed extremely energetic facets, and nanopowders. Films made of TiO_2/CdO composite materials can have their physical properties fine-tuned by changing the ratios of the two components. Surface roughness, charge storage capacity, hardness, dielectric constant, lattice constant, and refractive index are just a few of the thin film parameters that have been controlled using this method. In the solar radiation spectrum, cadmium oxide exhibits excellent electrical conductivity and optical clarity. When it comes to photovoltaic applications, cadmium oxide (CdO) has shown to be an extremely promising material [7].

2-Experimental Part

2-1 prepared samples using spin-coating method

The materials of CdO and TiO_2 are among the chemical components utilized in this investigation. Materials: distilled water, ethanol (Eth) (99% purity, Brazil), and glass as the base. The process of preparing samples Prior to anything else, you must clean the substrate. In order to create nanoparticles with noticeable crystallinity from TiO_2-doped CdO that have excellent adhesion and are uniform in size, this study will employ spin-coating procedures.

Films were prepared from these mixes using the spin-coating procedure, (model VTC-100) [8]. Each created TiO_2-doped CdO solution was applied to the cleansed soda lime glass for a duration of 15 min. TiO_2 solutions with pure concentrations of 50 g/L mixtures with pure and different concentrations of CdO. Each prepared nanoparticle solution was carefully deposited onto the cleaned soda lime glass (20 mm × 20 mm × 2 mm) for the ideal coating time (30 seconds at 3000 rpm).

2-2 Characterization

Many different techniques were used to prepared film samples. One of this method involved using spin-coating procedure, (model VTC-100) .The film is prepared by depositing the material on the glass plate after washing, and the deposition process is carried out using spin-coating procedure. Spin-coating is an effective and versatile film preparation technique. … The properties and quality of films depend largely on specific parameters.. It also relies on future by a fast, balanced, and stable system, the scan mode runs continuously at 60,000 rpm. A spectrophotometer (SHIMADZU UV-1650 PC) was utilized in the method, which involved ultraviolet-visible spectroscopy. The transmission and energy gap, two examples of optical qualities, can be uncovered using this method.

3-Results and Discussion

3-1 Optical measurements

The optical properties of thin films depend on added ratios of concentrations, homogeneity, structure, membrane material and preparation conditions : In a spectrometer—called a UV-Visible Recording Spectrophotometer—many optical parameters can be measured, including energy gap, reflectance, extinction coefficient, absorption coefficient, real and imaginary dielectric constants, and transmittance spectra. to demonstrate the characteristics of semiconductor membranes.

3-1-1 Absorbance Spectrum

Figure (1) illustrates the absorbance spectra as a function of wavelength in the range of (300-1000) nm for TiO_2 thin film doped with different CdO contents,. The graph clearly shows that absorption drops off as the wavelength goes up. Also it is noted that the absorbance of CdO is higher than absorbance of TiO_2, but after adding a concentration with a percentage of 10% CdO leads to decrease and then after increasing the concentrations, it returned increases . Because there are more atoms in the structure at higher concentrations, more photons will collide with them, raising the absorbance. This phenomenon is responsible for the observed trend. Consistent with the researcher's expectations, higher concentrations lead to a rise in charge carriers, which in turn leads to higher absorption rates as a result of more light being absorbed [9,10].

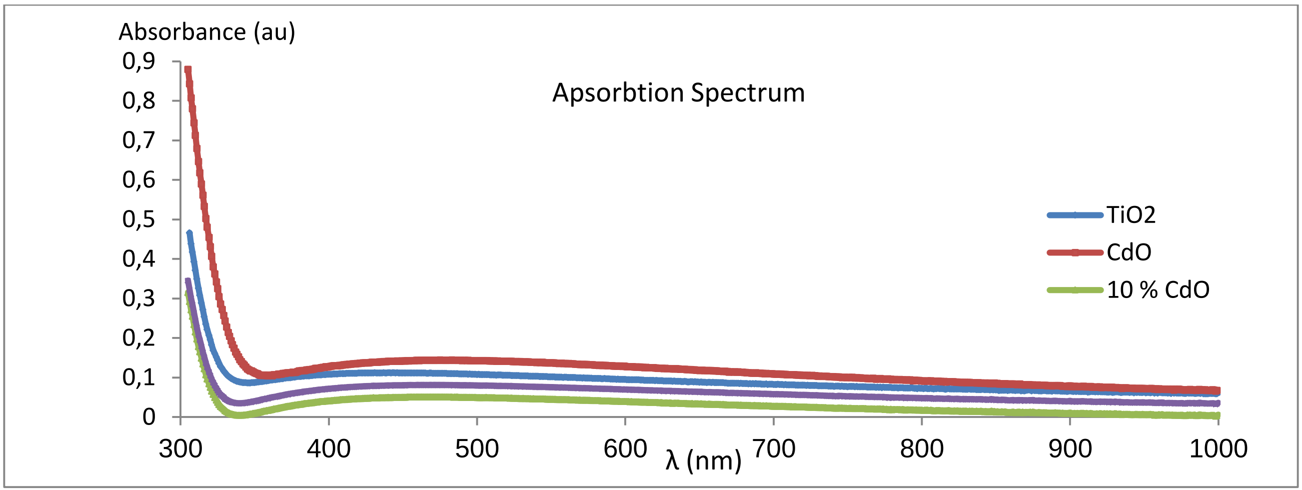

Figure (1).The variation of absorption spectrum of $TiO_2$with wavelength for different concentrations of CdO.

3-1-2 Transmittance Spectrum

The transmittance spectra of TiO_2 thin films at various CdO concentrations in the 300–1000 nm range are displayed in figure (2). All deposited thin films show an increase in transmittance value as (λ) increases, as is generally observed. Figure and table(1) also show the transmission values at 350 nm for pure TiO_2 and doped TiO_2 thin films with t x= (10 and 20)% wt. of CdO. The values of transmittance, which increase for pure film, drop as the concentration of CdO thin films increases. Since variations in transmittance are known to be dependent on the material qualities of films, this reduction in transparency is associated with the film's structural features [11]. The reason why the T value drops as the CdO content rises is because increasing the density of TiO_2 by adding CdO makes the samples more opaque to the light that hits them. displays excellent transmission [12]. Solar cell applications are so possible. If we take the following exponential connection for both absorption and transmittance, we see that the transmittance spectrum acts in the exact opposite way as the absorbance spectrum.

$A = \log(1 / T)$ …………………… (1)

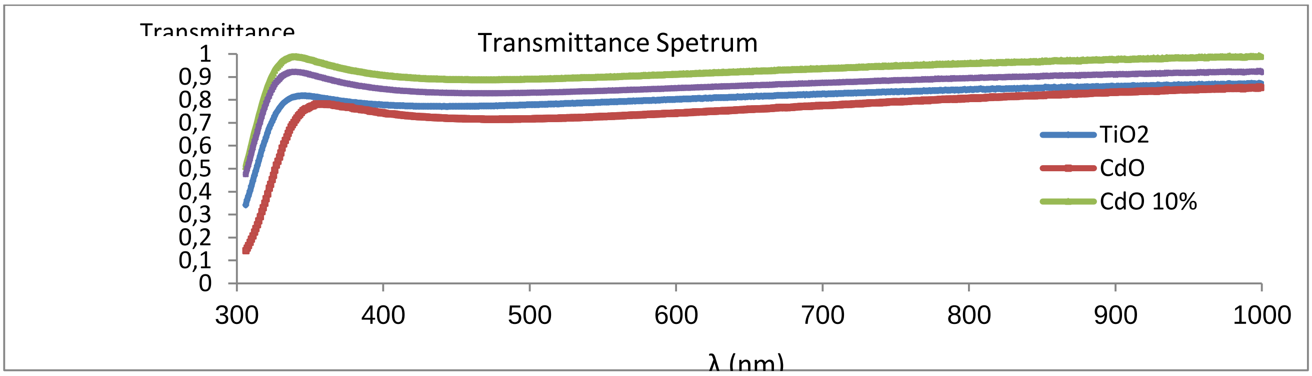

Figure (2). variation of transmittance spectrum of TiO_2 with wavelength for different concentrations of CdO.

3-1-3 The Optical Energy Gap

Tauc relation equation (2) was used to calculate the band gap energy of the synthesized films.

$\alpha h\upsilon = B\,(h\upsilon - E_g^{opt.})^r$............(2).

Where α is the absorption coefficient hv, is the incident photon energy, B is an constant depending on the transition probability, Eg, band gap energy, and r is give the nature of transition, it takes values such as and 2 for indirect allowed and 1/2 direct allowed transitions.

Direct optical band gap values were estimated by drawing $(\alpha h\nu)^2$ with energy (hv) extrapolating to the x-axis $(\alpha h\nu)^2 = 0$ as shown in Figure 3 from straight line obtained at high photon energy the direct allowed energygap could be determined which was equal (3.82,3. 7, 387and 3.86 eV) for the (TiO_2, CdO, 10 %CdO, 20% CdO) thin film respectively. The decrease may be attributed to the due to the increase in density of localized states of the band gap, which causes a shift to lower values [10,11].

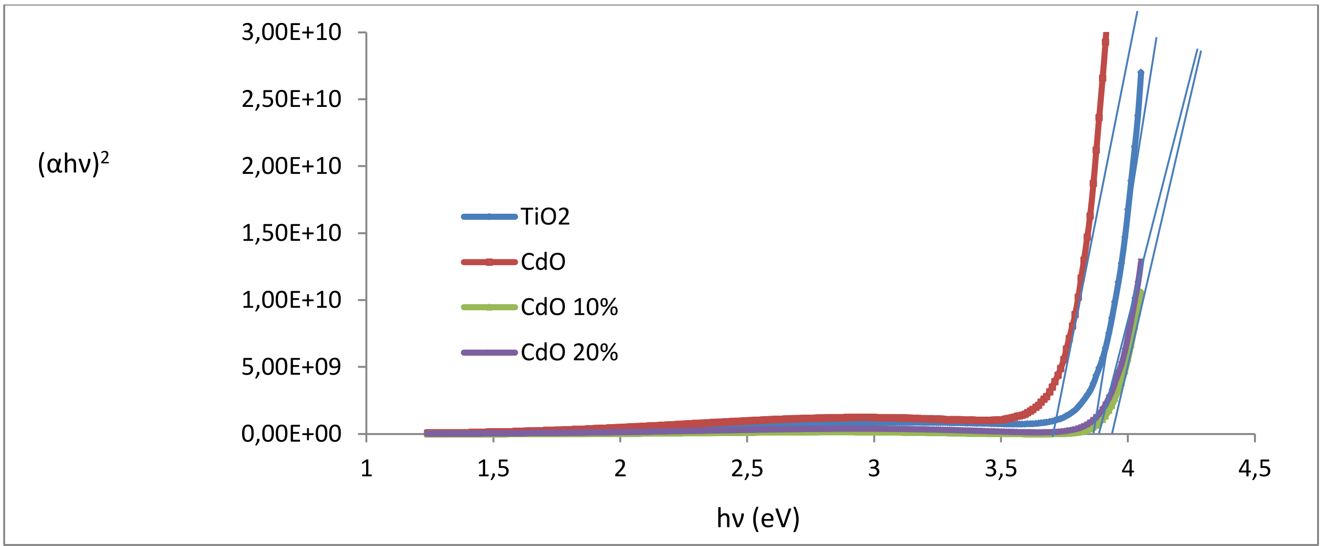

Figure (3). Variation of $(\alpha h\nu)^2$ vs. photon energy(hv) of TiO_2 for different concentrations of CdO.

3-1-4 Reflectance Spectrum

The relationship between reflectivity and wavelength is shown in figure 4. It is interesting to note that CdO has a higher reflectivity than TiO_2, but when 10% CdO is added, the reflectivity starts to decrease. However, as the concentrations increase, the reflectivity starts to increase again. This could be because the refractive index is the basis of reflectance.

$$R = (n-1)^2 + k^2/(n+1)^2 + k^2 \text{........(3)}$$

Where n is refractive index, k is extinction coefficient, therefore the reflectance behave is similar to the refractive index.

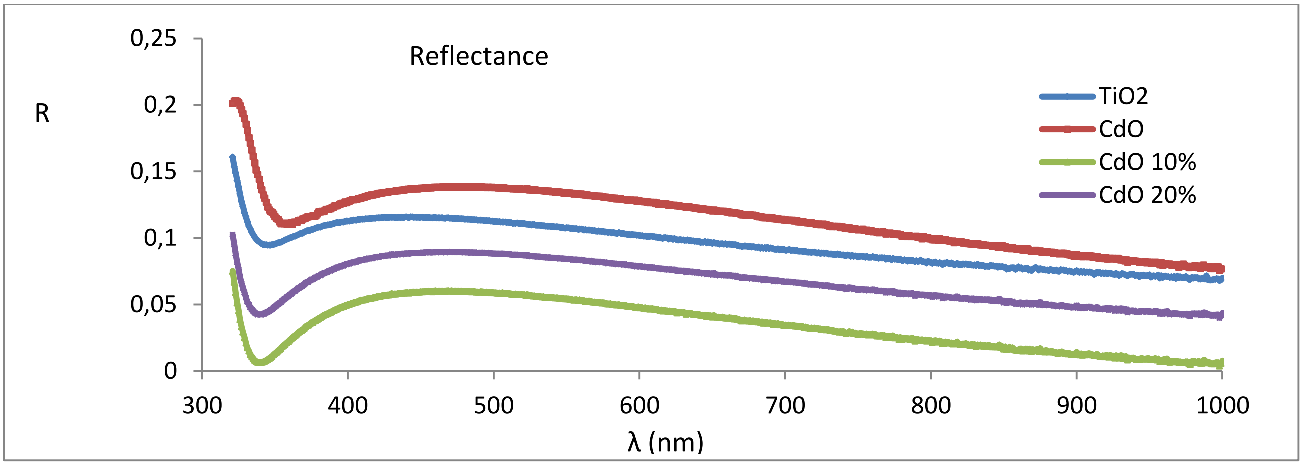

Figure (4). Variation of reflectance vs. with wavelength of TiO_2 for different concentrations of CdO.

3-1-5 Absorption Coefficient

The absorption coefficient (∝) can be calculated using equation :

$K = (\propto\lambda)/4\pi$ ………………… (4)

Where k extinction coefficient, λ wavelength . For both undoped and doped TiO_2 with varying concentrations of CdO, figure (5) displays the change in the absorption coefficient (α) with respect to wavelength in the range of (300 -1000)nm. A direct electronic transition is expected to occur in these films since the results show that the absorption coefficient values are higher ($\alpha > 10^4$) cm^{-1}. It is generally understood that as the wavelength increases, α decreases. Researchers have also discovered that adding CdO to a material causes its absorption coefficient to drop. The reason behind these outcomes is because the transmission becomes more efficient and moves to shorter wavelength with increasing CdO content which means a decrease in absorbance that occur due to the increase of energy gap. .

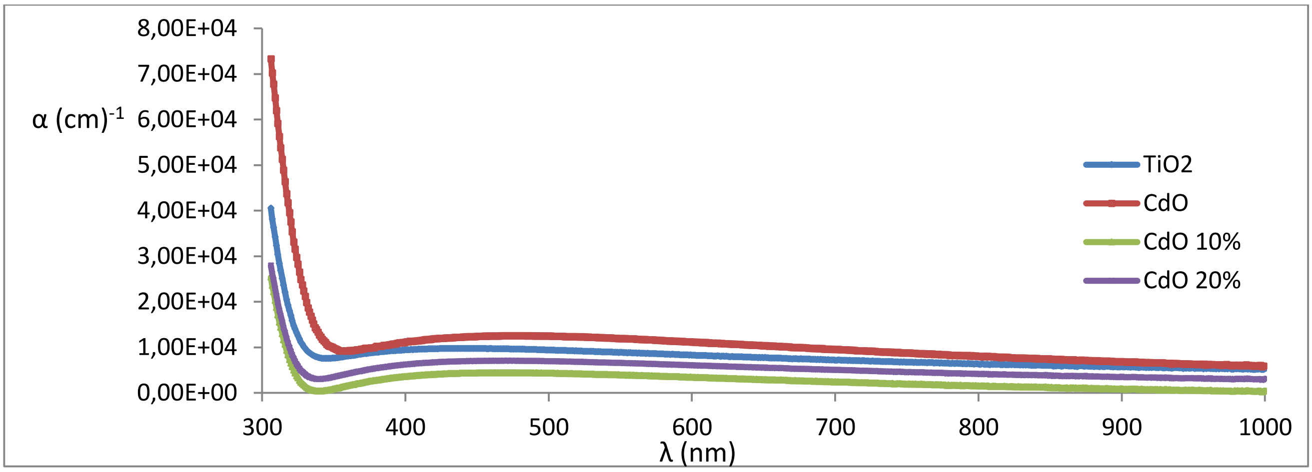

figure (5). Shows the variation of absorption coefficient as a function of wavelength of TiO_2 thin films with different concentrations for CdO.

3-1-6 Refractive Index

It can be attributed to the basis of refractive index that depends on the reflectance as the relationship[12].

n=[((1+R)/(1-R))^2-(k_o^2+1)]^(1/2)+(1+R)/(1-R)…………………(5).

Where R is reflectance, k_o is extinction coefficient . For every CdO film concentration, the physical parameters n, R, α, and k of TiO_2 were calculated and are presented in table 1. The compound concentrations of TiO_2 films doped with varied concentrations of CdO are shown as a function of wavelength in figures (6,7), together with the refractive index (n) and extinction coefficient (k). Both the refractive index and the extinction coefficient values drop as the wavelength increases, as demonstrated in the figures. Hence, they exhibit typical distribution. The extinction coefficients and refractive index values are both affected by the CdO film concentrations, and as the film concentrations grow, so do these two variables. Increasing the concentration of CdO causes the packing density to rise, which in turn causes the refractive index to rise slightly. Since the film porosity drops as the CdO concentration rises, this makes sense.

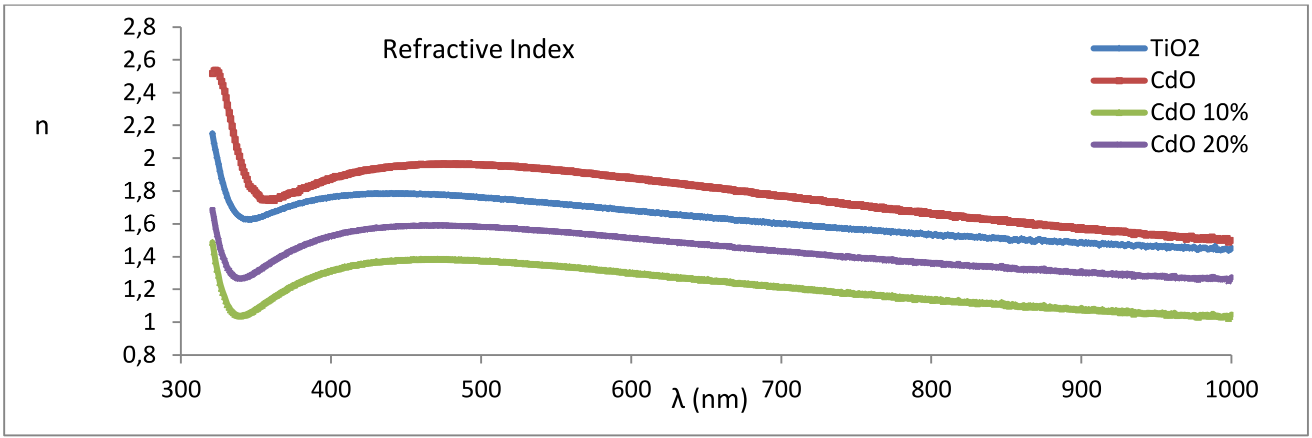

figure (6). Shows the variation of refractive index, of TiO_2 thin films as a function with wavelength for different concentrations of CdO.

3-1-7 Extinction Coefficient

Figure (7) .shows the variance of extinction coefficient of TiO_2 thin films as a function of wavelength for different concentrations of CdO .the behavior is the simaller to that of absorption coefficient according to equation:

$K=\alpha\boldsymbol{\lambda}/4\boldsymbol{\pi}$ --------------------------(6)

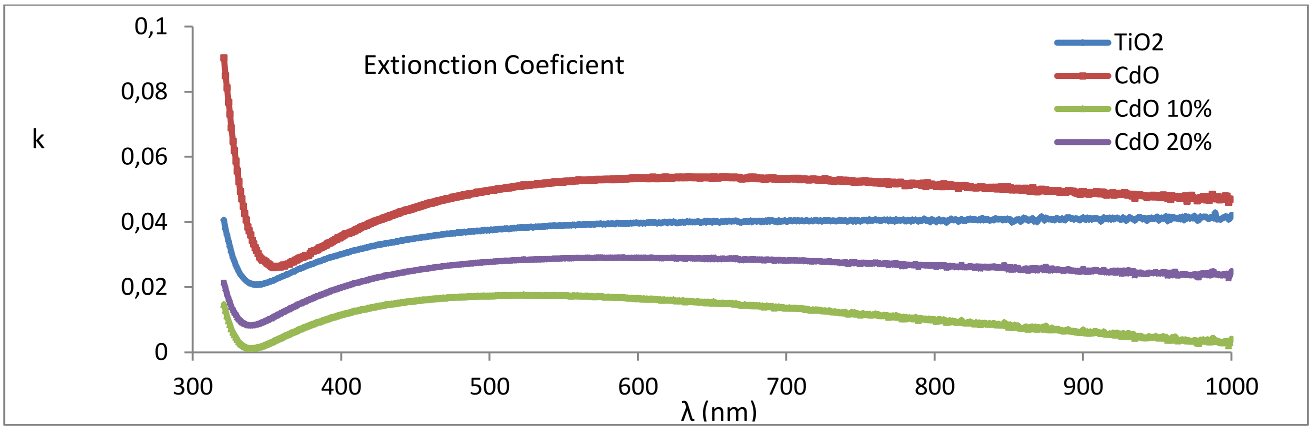

figure (7) .shows the variation of extinction coefficient as a function with wavelength of different concentrations for CdO.

3-1-8 Real and imaginary dielectric constant

The real (Ɛr) and imaginary (Ɛi) parts of dielectric constants for TiO_2 thin films system are determined by using following equations (7), (8) respectively.

$\varepsilon r = n^2-k^2$ .... (7)

$\varepsilon i = 2nk$ .... (8)

The changes in the imaginary (Ɛi) and real (Ɛr) components of the dielectric constant with respect to wavelength for TiO_2 doped with varying amounts of CdO are shown in figures (8) and (9) correspondingly. The results show that when the concentrations of CdO grew, Ɛr and

Ɛi also increased. Equations (7,8) states that εi is mainly dependent on the k values, but the behavior of εr is similar to the refractive index due to the lesser value of k^2 compared with n^2. The findings of [12,13,14] are consistent with this conduct.

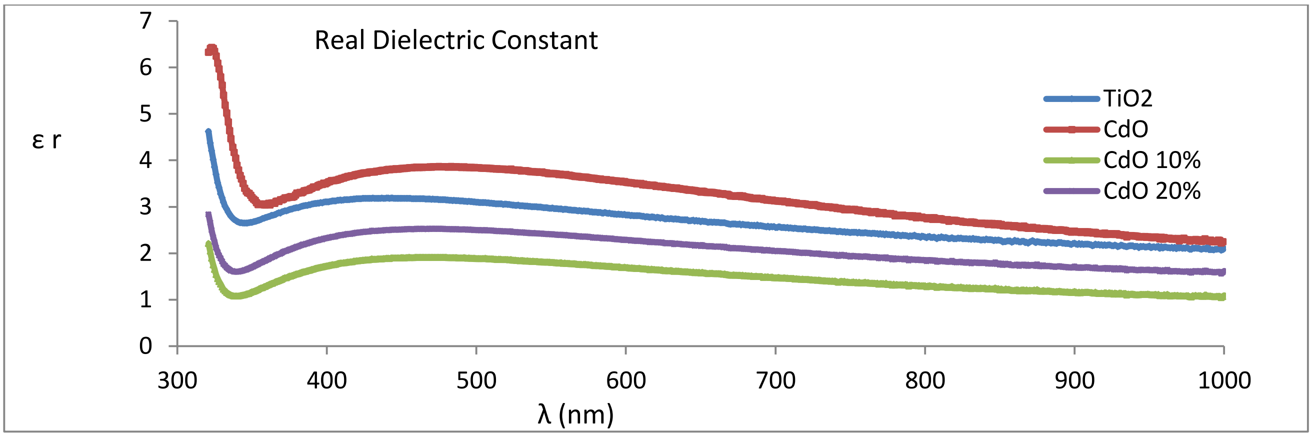

figure (8). Shows the variation of the real dielectric constant of TiO_2as a function with wavelength for different concentrations of CdO.

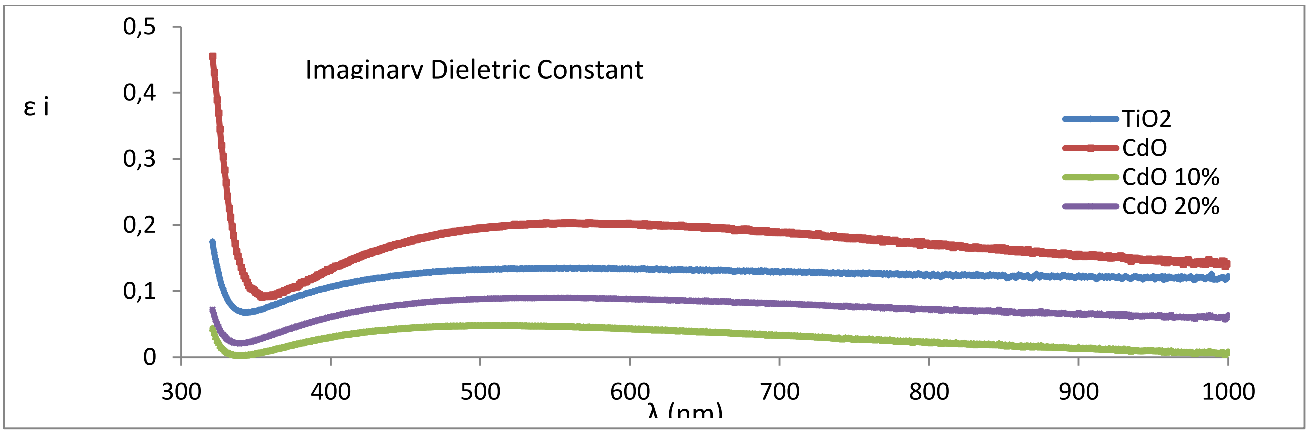

figure (9). Shows the variation of the imaginary dielectric constant of TiO_2as a function of with wavelength for different concentrations of CdO.

For TiO_2-doped CdO at a wavelength of 350 nm and varying CdO concentrations, Table(1) displays all optical parameters, including transmittance spectra (T), absorption, reflectance, absorption coefficient, refractive index, extinction coefficient, real and imaginary parts of dielectric constants, and optical energy gap.

concentration	A%	T%	Eg(eV)	R	α (cm^{-1}) ×10^4	n	k	εr	εi
Pure TiO2	0.1	0.79	3.82	0.11	0.935	1.71	0.023	2.75	0.08
Pure CdO	0.11	0.77	3.7	0.10	0.98	1.79	0.028	3.11	0.095
10 % CdO	000 8	0.94	3.87	0.01 7	0.17	1.17	0.0035	1.27	0.0085
20 % CdO	0.04	0.87	3.86	0.05 6	0.41	1.32	0.011	1.83	0.03

Table(1): transmittance spectra (T) for all films, absorption, a reflectance, absorption coefficient, refractive index, extinction coefficient, real and imaginary dielectric constant, transmittance and optical energy gap in the wavelength of 350 nm with different concentration of CdO.

4- Conclusions

The addition CdO to TiO_2 has improved the optical properties of thin film. Also absorption, a reflectance, absorption coefficient, refractive index, extinction coefficient, real and imaginary dielectric constant, as a function of wavelength increases with different concentration adding of CdO. Transmittance, optical energy gap, as a function of wavelength decreases for various with different concentration adding of CdO. and at 350 nm absorption, a reflectance, absorption coefficient, refractive index, extinction coefficient, real and imaginary dielectric constant, transmittance and optical energy gap were determined.

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