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Studying the Optical Properties of Cadmium Acetate Thin Films by UV-Vis Technique

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Abstract: The optical and electrical properties of materials are very important in classifying them, and improve their uses; the Cadmium acetate is used for glazing ceramics and pottery; in electroplating baths, in dyeing and printing textiles; and as an analytic reagent for sulfur, selenium and tellurium. The use of Cadmium acetate in the bulk form is clear, but few studies only try to treat it the different scales. In this paper, thin films of the cadmium acetate compound were prepared in nanoparticles by a chemical thermal fracture method. Three samples of 5.6, 14.1 and 20.6 nm were prepared respectively. The ultraviolet device was used to study the optical properties of the prepared samples. All optical properties were determined as a function in the wavelength and the cadmium cells were found to have excellent optical properties, especially with respect to the static energy gap with membrane thickness change, as well as the good electrical and optical conductivity of the samples the use of cadmium acetate in many electronic applications.

Keywords: Acetate Materials, Bulk, Absorption, Absorption Coefficient, Transmittance, Reflectivity

1. Introduction

The optical and electrical properties of nanoparticles of compounds of some materials are of paramount importance in the development and use of these properties in different fields. There have been several studies to identify these properties, and in each experiment show the properties of new compounds and then emerged the need to study the optical and electrical properties of some acetate materials (cadmium acetate) to find out the importance of using these materials in the nanoparticles in different applications.

The studies of the properties of the material in the form of thin films have attracted the attention of physicists since the second half of the seventeenth century, where many studies have been done in this area [1]. At the beginning of the nineteenth century, the study of the scientific side of thin films developed and developed. Many semiconductors were used in the preparation of thin films such as selenium and silicon [2]. Thin films describe one or several layers of matter not more than one micrometer or several nanometers [3], because they are thin (easy to break), they should be deposited on a solid material such as glass, silicon or polymers. Thin films have physical characteristics that differ from the properties of the materials they form. They are in their bulk state. The possibility of preparing solids in the form of thin films is one of the important techniques for obtaining new properties for materials that are hard to see and feel when they are in their natural mass form. The semiconductor industry has entered all areas of daily life and continues to make significant progress in the scientific and technological development. Thin films are one of the most important technologies that have contributed to the development of semiconductor studies since ancient times [5]. Cadmium acetate membranes are semiconductor materials, and one of the most important applications used in dyeing is the textile, glass, ceramic, pottery and medical industries. [6]

The method of thermal chemical spraying is one of the most important and reliable methods in the preparation of thin films. This method is characterized by other methods as economical for the low cost and simplicity of the devices used. Thin films can be prepared in larger areas than other methods. The membranes prepared have a high stability in their physical properties Time, and thus prepare thin films for compounds with high melting points that may be difficult to prepare by other methods. Also, membranes of one or more meditating mixtures with different melting grades can be prepared [7, 8].

The study of the material in its bulk form (the natural form in which it is found in nature or derived from its compounds) differs from its study in the form of thin films, so that the properties can be derived and deduced more precisely, clearly and easily when the material is in a nanoparticles. The importance of this study stems from the multiple uses of the cadmium acetate compound and the need to know its nanoparticles properties for the importance of the use of cadmium acetate in many fields, including medical, industrial and other, necessitating knowledge of the optical and electrical properties in the nanoparticles and their impact on such industries and applications.

2. Optical Properties

2.1. Absorption

Absorption (A) is defined as the ratio between the absorbed radiation intensity absorbed by the membrane (IA) and the original intensity of the Io radiation. Absorption is a free quantity of units and is given the following relationship [9].

$$A = \frac{I_A}{I_0}$$

2.2. Transmittance

Transmittance (T) is defined as the ratio between the intensity of radiation transmitted from the membrane in a given direction to the original intensity of the radiation falling on it and the following relationship is given [10].

$$T = \frac{I_t}{I_0}$$

I_t: intensity of radiation transmitted, I_0: original intensity of the incident radiation.

2.3. Reflectance

Reflectance (R) is defined as the ratio between the intensity of radiation reflected from the membrane in a specific direction to the original intensity of the falling beam and is given the following formula

$$R = \frac{I_r}{I_0}$$

Absorption (A) with reflectivity (R) and transmittance (T) is related to the relationship [11].

$$A + R + T = 1$$

2.4. Optical Constants

The study of the optical constants of the materials is of industrial and laboratory benefit for a number of reasons, first, the use of these materials in fiber optics which requires accurate knowledge of their optical reflectivity in the long-term (Reflecting Coating) of the wavelengths. The second reason is the correlation of properties all materials with their atomic composition, and installation of electronic packages [12].

2.5. Absorption Coefficient

The absorption coefficient (α) is defined as the percentage of the decrease in the energy of the radiation relative to the unit of distance towards the propagation of the vector within the center. The absorption coefficient depends on the photon energy and on the properties of the semiconductor. When an optical beam falls on a thin membrane, the falling beam, The amount of energy reflected, window and absorbed depends on the nature of the thin membrane material and the length and wavelength of the falling beam. The determination of the value of the absorption coefficient helps to know the nature of the electronic transitions. If they are high, the highest probability of transmission is the possibility of electronic transitions. Also, the value of the low absorption coefficient, ie direct, indicates the susceptibility of the membrane material to absorb the radiation energy falling and can be found from the following equation [13].

$$I = I_0 \, e^{-\alpha t}$$

Where:

(Io), (I): the intensity of the radiation from the membrane and the outlet, respectively, α: refractive index, t: thickness of the layers. Rewriting the equation above we get

$$\alpha = \frac{2.303\, A}{t}$$

2.6. Extinction Coefficient (K)

The luminescence coefficient is defined as the amount of matter absorbed by the electrons of matter from the energy of the photons of radiation falling on it. The coefficient of inertia is related to the absorption coefficient in the following equation

$$K = \frac{\alpha\, \lambda}{4}$$

Where λ: the wavelength of the incident rays (cm)

α: absorption coefficient (cm^{-1})

Extinction coefficient represents the imaginary part of the complex refractive index on the following relation

$$N = n + ik$$

N: Complex refractive index

n: the real part of the complex refractive index

Refractive index

Refractive index (no) is defined as the ratio between the speed of light in the vacuum and its velocity in a medium. The coefficient of (no) and the true fraction of the refractive index can be expressed as follows:

$$n = [(\frac{1+R}{1-R})^2 - (1+k^2)]^{\frac{1}{2}} + \frac{1+R}{1-R}$$

And is associated with the reflection of the membrane on the following equation [14]

$$R = \left[\frac{(n_0 - 1)^2 + k^2}{(n_0 + 1)^2 + k} \right]$$

Where

K_0: represents the excitation coefficient.

The refractive index of the membrane material prepared by spectroscopy and absorption can be found by finding the reflectivity of the spectrum from the previous equation.

2.7. Dielectric Constant Insulation

The solubility constant represents the material's polarization potential. It represents the material's response to different frequencies and complex behavior. At the optical frequencies represented by the optical waves, polarization is the predominant only on other types of polarization. The polarization of the material depends not only on the electric field, Molecular properties of the material that make it an insulating material. The interaction between light and medium charges, and the resulting polarization of the medium charge, is usually described by the complex isolation constant of the mean (Ɛ) expressed by the following formula [15]

$$\varepsilon = \varepsilon_r - i\varepsilon_i$$

Where

Ɛ: Insulation constant

Ɛr: The true part of the insulation constant

Ɛi: The imaginary part of a fixed insulation

From the relationship between the insulation constant and the refractive index [16]

$$\varepsilon = N^2$$

We can find the values of real and imaginary isolation after compensation for the value of (N) to obtain the following equation:

$$(n_0 - k_0)^2 = \varepsilon_r - i\varepsilon_i$$

$$\varepsilon_r = n^2{}_0 - k^2{}_0$$

$$\varepsilon_i = 2n_0 k_0$$

2.8. Optical Energy Gap

The optical power gap is of great importance in determining the possibility of using thin films in the manufacture of solar cells, photovoltaic cells, displays and other applications. It gives a clear idea of optical absorption. The membrane is transparent to the radiation, which is less energy than the energy gap (Eg > hv) and a radiation absorber with a capacity greater than (Eg <hv). There are many factors that affect the energy gap, such as the type of membrane material and the method of deposition of membranes and also greatly affected by the processes of infusion and elongation. Furthermore, the energy gap is affected by the preparation conditions and the structural nature of the membranes prepared and the crystalline uniformity of the membrane. The energy gap can be calculated by the following equations [17]

$$h\upsilon = A\left(h\upsilon' - E_q\right)^r$$

Where

Eg: Optical power gap (eV)

hv: Photon Absorption Energy (eV)

A and r: constants

2.9. Photoconductivity of Semiconductors

Optical conductivity is defined as the increase in the number of electron charge carriers or gaps due to the fall of an optical beam on the semiconductor. The optical conductivity was calculated in this study using the following relation [18]

$$\delta_{0pt} = \frac{\alpha nc}{4\pi}$$

C: represents the speed of light in vacuum

Electrical conductivity can be calculated in terms of optical conductivity according to the following equation

$$\delta_{ele} = \frac{2\lambda\delta_{opt}}{\alpha}$$

3. Experimental

This part of the research will include a detailed description of the chemical thermal cracking method for the preparation of cadmium acetate in the laboratory, indicating the stages of the preparation process until the pure cadmium acetate compound was obtained with the mentioned materials, tools and equipment used.

4. Materials

0.04 mg of cadmium nitrate $Ca(NO_3)_2$

Cadmium oxide CaO

($C_6H_{12}N_4$) Accelerated reaction (Hexamethylene tetra amine)

6 ml ionized water

Devices

Magnetic stirrer

Oven temperature 500°C

Glass holder

Ultraviolet and optical spectroscopy

Baker 500 mL and Sensitive balance.

4.1. Cadmium Oxide Preparation (CaO)

The chemical thermal cracker $Ca(NO)_3$ took 0.49mg of $Ca(NO)_3$ nitrate and was dissolved in 6ml ionized water with Tetra Hexamethylene Amine ($C_6H_{12}N_4$) accelerator at 7C for an hour in the magnetic mixer.

4.2. Preparation of Cadmium Acetate

Add the acetic acid (CH_3COOH) to the CaO cadmium at 5C for one hour, and then put the mixture in a 30°C oven for 24 hours to remove the unwanted components or N & C reduction process.

5. Preparation of Thin Films

5.1. Glass Substrates Cleaning Method

The rules used are made of glass with a thickness of 0.1 cm (2.55 x 2.55 cm^2). The process of cleaning the glass bases is done in several stages to ensure the accuracy of the cleaning and therefore the importance of the installation of the membrane material, because the presence of impurities on the surface of the base negatively affects the quality The membrane is deposited, then placed in a water bath of soap and disposed of plankton washed with distilled water and placed in ultrasonic bath for 5 minutes and then dried in air and then placed in a flask containing pure acetone to remove any traces of greasy residues on the surface and then put in 200 ml of hydrochloric acid diluted with 100 ml of water and washed with distilled water and dried and then placed Slices in nitric acid (HNO_2 500 ml) are left for 30 minutes and dried. Clean bases are kept in appropriate containers after calculating the weight of each base and recording it on its own.

5.2. Thin Films Deposition

The glass bases shall be placed on the electric heater until it reaches a temperature of 370°C followed by a stop period of (half an hour) to return the glass bases to a temperature of 370°C and then spray the solution for a period and then resume spraying for another period until reaching the required thickness The glass is rotated during the spraying process to obtain the best homogeneity of the membrane. After the spraying process, the electric heater is closed and the glass bases are left on top of it until it reaches the room temperature to allow the prepared membranes to complete the process of oxidation and crystalline development and not to break the glass bases due to different temperatures.

5.3. Measuring the Thickness of the Layer

There are many ways to measure the thickness of thin films. In our current study, the weight method was used. The clean glass base is weighed with a sensitive electrical balance. The weight of the layer before spraying is symbolized by w1 and after spraying (w2). The weight difference (▲ w) the layer is deposited on the base.

5.4. Optical Measurements

Absorbance and transmittance spectra were measured using UV and Visible Spectroscopy (UV-Visible124 Spectrophotometer), to conduct optical measurements of cadmium acetate layers with different samples due to the thickness of samples.

Table 1. *Samples Thickness.*

No	Slide weight before deposition/(g)	Slide weight after deposition /(g)	Weight difference/(g)	Sample thickness/(nm)
1	4.714	4,981	0,267	14,1
2	4.714	5,106	0,392	20,6
3	4.714	4,821	0,107	5,6

6. Discussion

Absorption

Figure 1 shows the absorption curve against the wavelength of the three cadmium nanoparticles in the thickness of 20.6, 14.1, and 5.6 nm. The highest absorption of the material was found to be approximately 75% within the wavelength of 376nm, which increases the thickness of the material. Absorption also affects quantitative efficiency and therefore can be used (cadmium acetate) in the manufacture of diodes in general and light emitting diodes (radiated) in particular.

Absorption Coefficient

Figure 2 shows a graph of the absorption coefficient against the wavelength which shows that the absorption coefficient of this material increases as the thickness of the material decreases and the highest value of the absorption coefficient is 2.6 x 10^6 at wavelength (396nm).

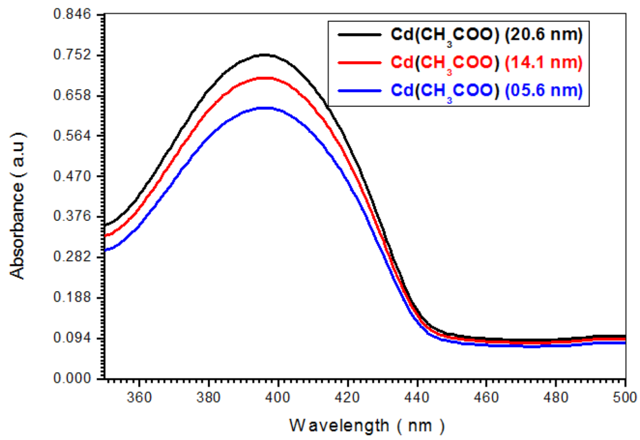

Figure 1. *Absorption spectrum vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

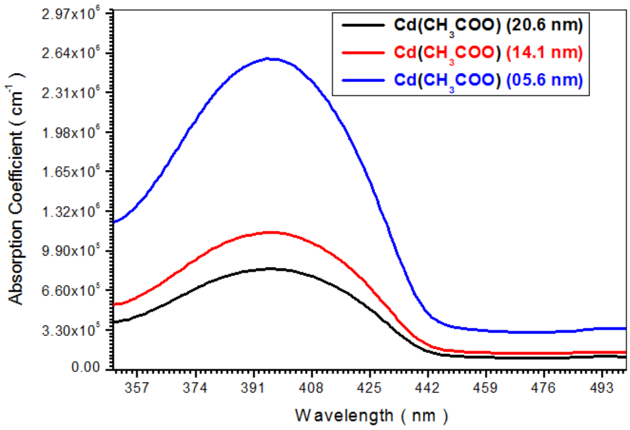

Figure 2. *Absorption coefficient vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

Energy gap

Figure 3 shows that the value of the energy gap is equal to 2.8 eV and is almost constant for all thickness values of layers 20.6, 14.1 and 5.6 nm under study because the energy gap changes with the volume of the particles and does not change with the change of thickness.

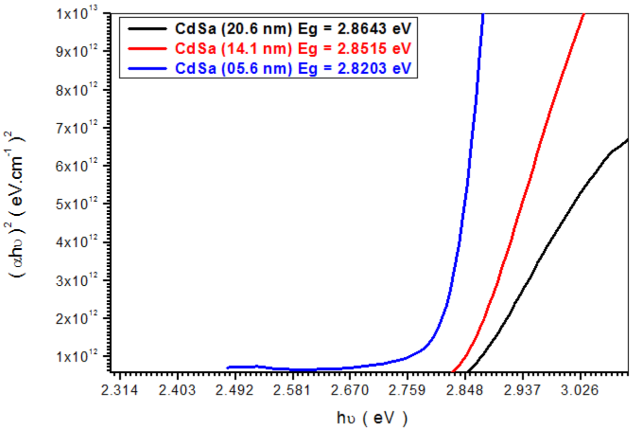

Figure 3. *Energy gap vrs square density of the longitudinal energy gap of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

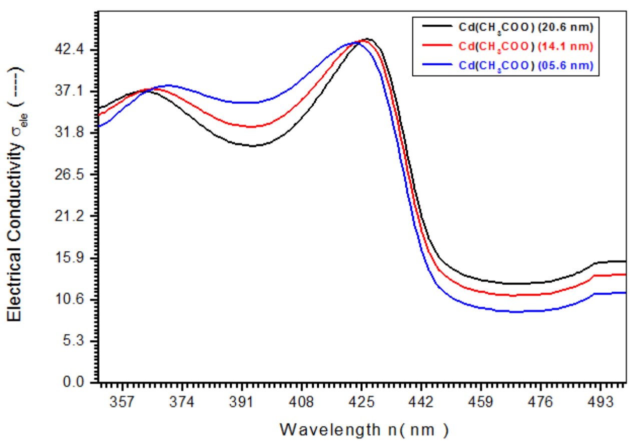

Figure 4. *Electric conductivity vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

Electrical conductivity

Figure 4 shows electrical conductivity against wavelength and is found to increase with a decrease in thickness of the layers in reverse proportion at 350nm wavelength limits because when positive and negative charges are increased, the light conduction (dipolar) decreases.

Excitation Coefficient

Figure 6 gives the coefficient of dampness against the wavelength and found that the highest value of the coefficient of laxity shall be at the lowest value of the thickness of cadmium acetate membrane at a wavelength of 400 nm and the coefficient of laxity at about 81%. The lowest value of the coefficient of oxidation shall be at the highest value of the thickness of the cadmium acetate membrane at a wavelength of 397 nm and the coefficient of laxity is about 26%.

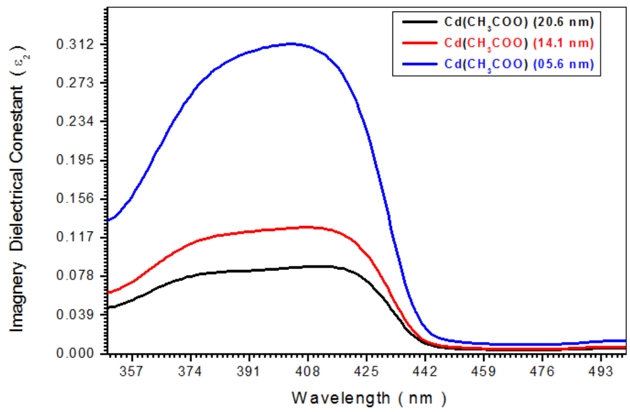

Figure 5. *Imaginary Dielectric constant vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

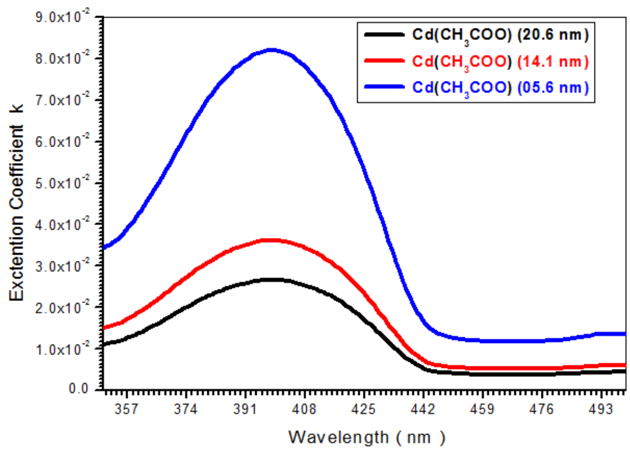

Figure 6. *Excitation coefficient vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

Refractive index

Figure 7 shows the refractive index curve against the wavelength and shows that the refractive index decreases as the thickness of the material increases and the maximum value of the refractive index is at 2.08 wavelength at 350 nm.

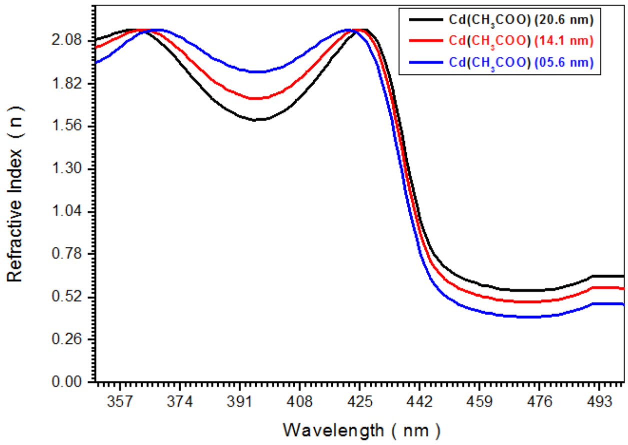

Figure 7. *Refractive index vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

Optical conductivity

Figure 8 shows the optical conductivity curve against the wavelength. The optical conductivity at the wavelength of 396 nm is inversely proportional to the thickness of the membrane and its maximum value is at the least thickness of the membrane. This corresponds to the property theoretically.

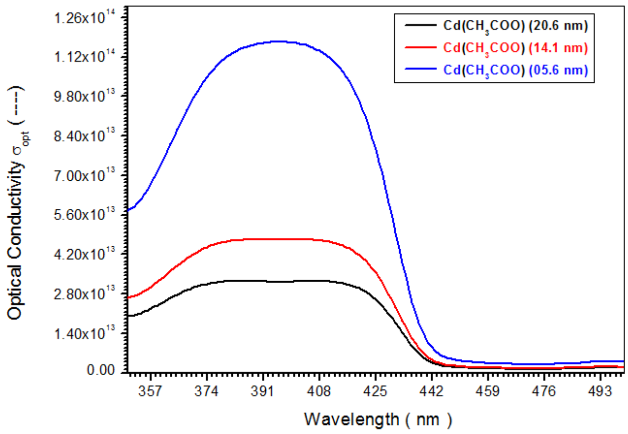

Figure 8. *Optical conductivity vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

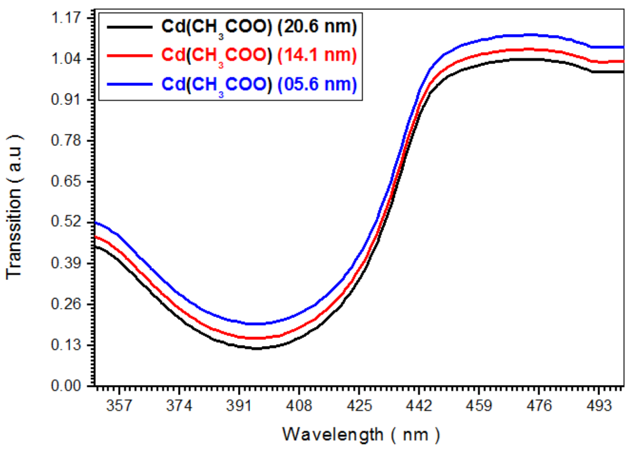

Figure 9. *Optical Transmittance vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

Transmittance

Figure 9 illustrates the optical transmittance curve against wavelength. It was found that the permeability increases as the wavelength decreases. The highest permeability within the 350nm wavelength was about 1.17 au, which is higher than the maximum allowable value and may be the result of lack of the instrument used in the measurements.

Real Dialectic Constant

Figure 10 gives a constant relationship of real insulation with wavelength and is found to be inversely proportional to the thickness of the membrane at wavelength 395 nm where the electrical insulation constant value is about 3.57 at 5.6 nm and 2.56 at 20.6 nm.

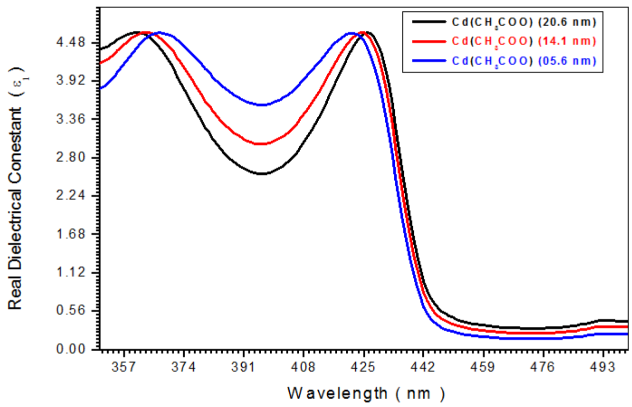

Figure 10. *Real Dielectric constant vrs the wavelength of the three cadmium acetate samples (20.6, 14.1, and 5.6 nm).*

7. Conclusion

This study showed that the Nanolayers of the cadmium nanoparticles have excellent optical properties that enable us to use them in many applications, especially semiconductor applications such as the manufacture of diodes, transistors and other electronic devices with high efficiency, they are high absorption of light and good electrical conductivity especially when the thickness of the membrane is very small as well as its conductivity Which increases as the thickness of the layers is small.

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