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Study Optoelectronic Properties for Polymer Composite Thick Film

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Abstract. Coupling the epoxy with cadmium oxide particles are important for optical properties that may be affected by various mixing proportions. The aim of this experimental study was to evaluate the effect of different mixing proportions on these properties of reinforced epoxy with cadmium oxide particles. The ultrasonic techniques were used to mix and prepared samples of composites. The surfaces topographic of the 50 μm thick reinforced epoxy films were studied using atomic force microscopy (AFM) and microscopy technique (FTIR) Spectroscopy. AFM imaging and quantitative characterization of the films showed that for all samples the root mean square of the surface roughness increases monotonically with increasing the CdO concentrations (from 0% to 15%).The observed effects of CdO concentrations on surface roughness can be explained by two things: the first reason is that the atoms of additives are combined with the original material to form a new compound that is smoother, more homogeneity and smaller in particle size. The second reason is due to high mixing due to ultrasonic mixing. It is clear also, AFM examination of the prepared samples of reinforced epoxy resin shown that topographical contrast and the identification of small structural details critically depend on hardness of epoxy resin, which in turn depended on the ratio of material (CdO) added. We show that the AFM imaging of the films showed that the mean diameter (104.8nm) of films for all of the samples decreased from 135.50 nm to 83.20 nm with the increase of CdO concentrations.

Keywords: Composites, CdO particles, Reinforced epoxy, Ultrasonic Technique, Optical properties

INTRODUCTION

Composites attracted great interest among scientists and researchers due to having many advantages compared to those individual components used alone, such as lightweight, high-strength, high-stiffness and improved performance, which can be used effectively in many scientific applications that require such properties [1-4]. These materials may exhibit unique properties differently for their constituents (combination materials) traditional such as metal, ceramic and polymer materials [5-7]. The pursuit through technology is to possess the full ability to tailor the optical, mechanical, physical, and chemical properties to achieve high-efficiency material and desirable properties different from their basic components [8-10]. Also, it can provide significant insights about their characteristics at the atomic and molecular levels [3]. The composites are characterized as one of the materials that could be easily synthesized for specific purposes and display desired characteristics for innovative industrial applications [11, 12]. The latest developments in composites and in particular in the area of Epoxy have opened up many possibilities in materials science and engineering add many interesting applications together with market and safety aspects [5]. Change in composition and structure is always related to variations in the electronic structure. In particular, the control those scientists have gained in achieving the required composites [13] and also on the variation in the

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properties are notable. In this way, a composites variation in structure and crystal phase leads necessarily to the formation of optical properties potentials. This results in the possibility of formation new advanced materials and applications in the area of electronics [14, 15] optoelectronic devices [15], energy transport [16], light emission [9] or light absorption [10,17]. In the area of optoelectronic devices, for example, epoxy resin reinforced with cadmium oxide (CdO) particles, allow a better utilization of the solar spectrum and thereby result in an increase in the efficiency of the cells by absorbing a wider range of light wavelengths [16]. Furthermore, improved performance of composites materials can be also by reinforcement of two or more basic materials (traditional) at specific proportions for obtaining advanced materials [18,19]. Among the many types of epoxy some of which are transparent for light, and some of them can pass about 29% of white light, also some other epoxy can pass up to 22% UV, unlike glass. In addition, when reinforced epoxy with cadmium oxide particles, they show a more efficient coupling and more stable when compared to individual components structures, meaning that they can become better absorbers or emitters when used as solar cells or light-emitting diodes (LEDs), respectively making it a promising future material. [7, 8].

In this work, we present production and characterization of cadmium oxide-reinforced epoxy composite with different CdO concentrations and evaluate their possibility using in optical applications. Particular attention was paid to these composites, due to their applications, specifically in the area of optoelectronic devices like transparent electrodes, gas sensors, solar cells, diodes and photo transistors [15].

EXPERIMENTAL

A homogeneous mixture was prepared from the epoxy resin and specific percentages of CdO by using ultrasound technique during a mixing time of 60 sec using (UP200S Helischer, Germany). The exact of CdO, in accordance with their specific percentages with the 5%, 10%, and 15%, were weighed using an electronic balance (4-digit type (KERN)). The thin films of the resin include a CdO-free resin (i.e. 0% CdO) as well as samples with specific CdO percentages as mentioned above. This study was conducted on the four samples produced where in the next step, a hardening material was added directly to the mixture for each sample and in the conventional hand mixing method, mixing was done. A mixture (CdO and epoxy) was placed on plastic bases and leave for 24h at room temperature for hardening. Several tests were conducted on the samples under study manufactured in this work to determine their properties. The surface topographic of the 50 μm thickness of the composite that was prepared were investigated using scanning atomic force microscopy (AFM) which gives high-resolution 3D information at the atomic level. The topographic and phase images were recorded simultaneously as shown in Fig. 1 which shows typical AFM scans of 50 μm thick composite films for the four samples under study. In order to get a more comprehensive understanding, we have applied additional experimental techniques namely, Fourier-transform infrared spectroscopy (FTIR). The importance of FTIR appears by determining the main properties of epoxy resin film thick and thick composite films where the examination was carried out within a range of 400-4000 cm^{-1} for the processed thick films. In addition, other techniques such as spectrometer to determine optical properties (transmittance & absorbance) and the Hall measurement system (HMS-300) were used. The spectrophotometer was used to measure fluorine spectra and identify the Stoke displacement between the emission and absorption spectra, and the wavelength scan was 200-900nm. Finally, to identify some electrical characteristics such as carrier type, conductivity and resistivity for the processed composite thick films, was used Hall measurement system (HMS-300).

RESULTS AND DISCUSSION

The use of AFM to determine the topography of the prepared composite thick films, the possibility of changing the added ratios in the properties of these thick films and obtaining high accuracy values for the particle size, their numbers and distribution, and the surface roughness depending on the root mean square of the average roughness (RMS) As shown in Table (1) and Fig. (1). It was observed that all the surfaces of the thick films composite prepared by different addition ratios are uniform and homogeneous surfaces. The distribution of a horizontal matrix with very low tops that move upward in a spherical or spherical shape separated by distances indicates that the particle walls are very small. The particle size and all prepared thick films composite possess a large number of lined strings that are regularly connected to the surfaces of the prepared thick films composite and without any interstitial cracks or voids or holes in the thick films structures.

TABLE 1. The root mean square of the average roughness

Added ratios (%)	Average (Diameter) (nm)	roughness (Average) (nm)	(RMS) (nm)
0	135.50	0.790	0.892
5	106.49	0.762	0.889
10	94.18	0.637	0.736
15	83.20	0.422	0.497

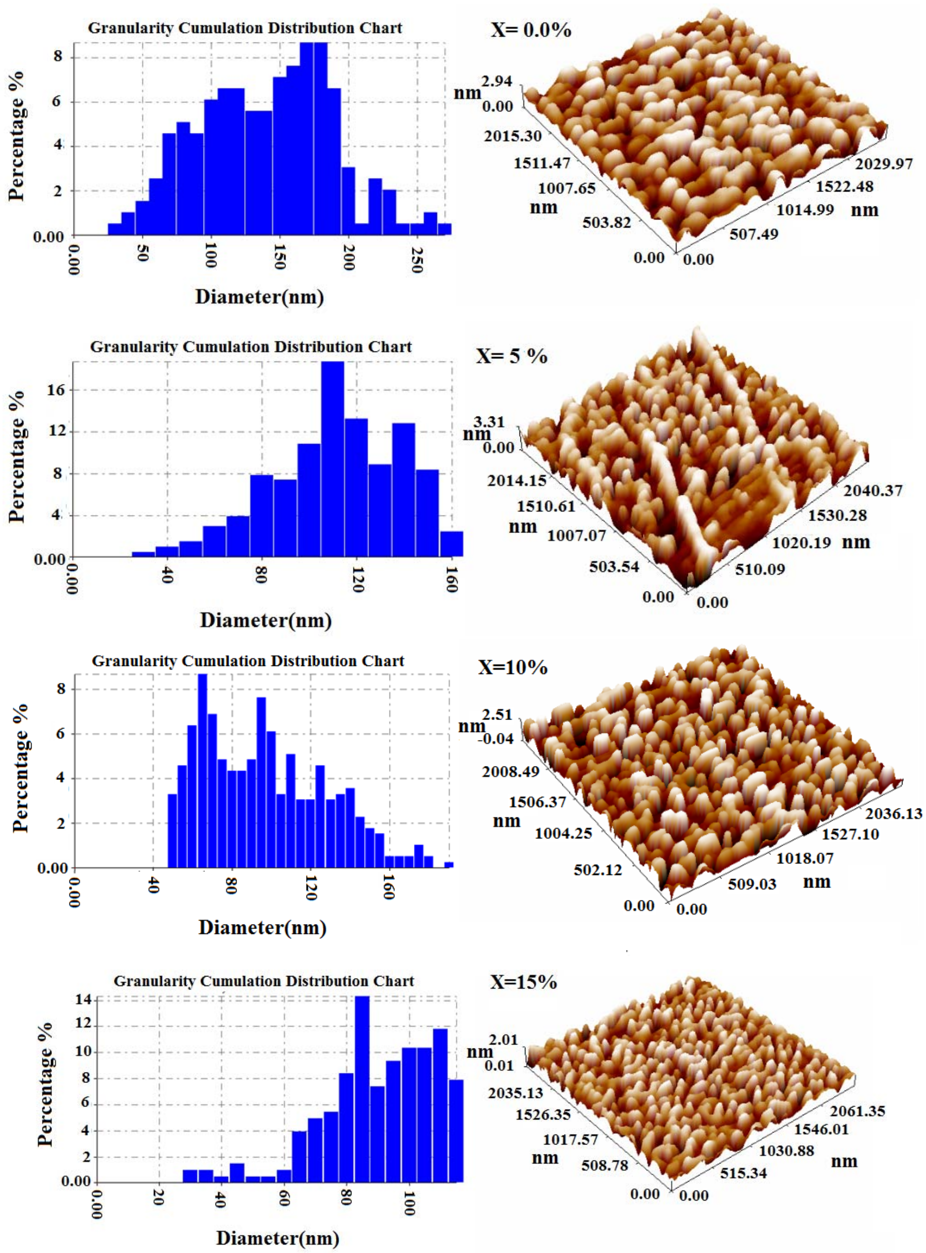

FIGURE1. AFM images of 50 μm thick composite films without CdO (a) and mixed with different percentage of CdO;5% (b) 10% (c) and 15% (d).

The Importance of (FTIR) Spectroscopy is the identification of the main properties of epoxy resin film thick and thick films composite. The ability to study the structure of films and film components is fundamental to understanding surface topology. This requires the use Fourier-transform infrared spectroscopy (FTIR) transmission which is able to provide valuable information about the atomic configuration of epoxy resin thick film. FTIR spectra are taken in transition model. Fig. 2 Shows the FTIR spectrum of epoxy resin thick film and compared with pure epoxy resin, as in Table 2. There was more than one peak obtained in the area of the O-H stretching (3522.13-3564.57 cm^{-1}). In region (3036.06-3061.06 cm^{-1}), refers to stretching of C-H of the oxirane ring, and a peaks at 2872.1-2978.19 cm^{-1} corresponds to the stretching C-H of CH_2 and CH aromatic and aliphatic. The stretching C-C of aromatic at 1500.67 cm^{-1},and a peaks at 1026.16-1076.32 cm^{-1} for stretching C-O-C of ethers, while Stretching C-O of oxirane group at 918.15 cm^{-1}, Stretching C-O-C of oxirane group(810.13-845.62) and Rocking CH2 at 727.04 cm^{-1}. The effect of addition CdO to epoxy resin on FTIR spectrum is shown in Figs. (3,4 and 5)) for different weight ratio (5,10and15%) .A significant difference was observed between epoxy resin film thick and the effect of the addition, as in Table 2.

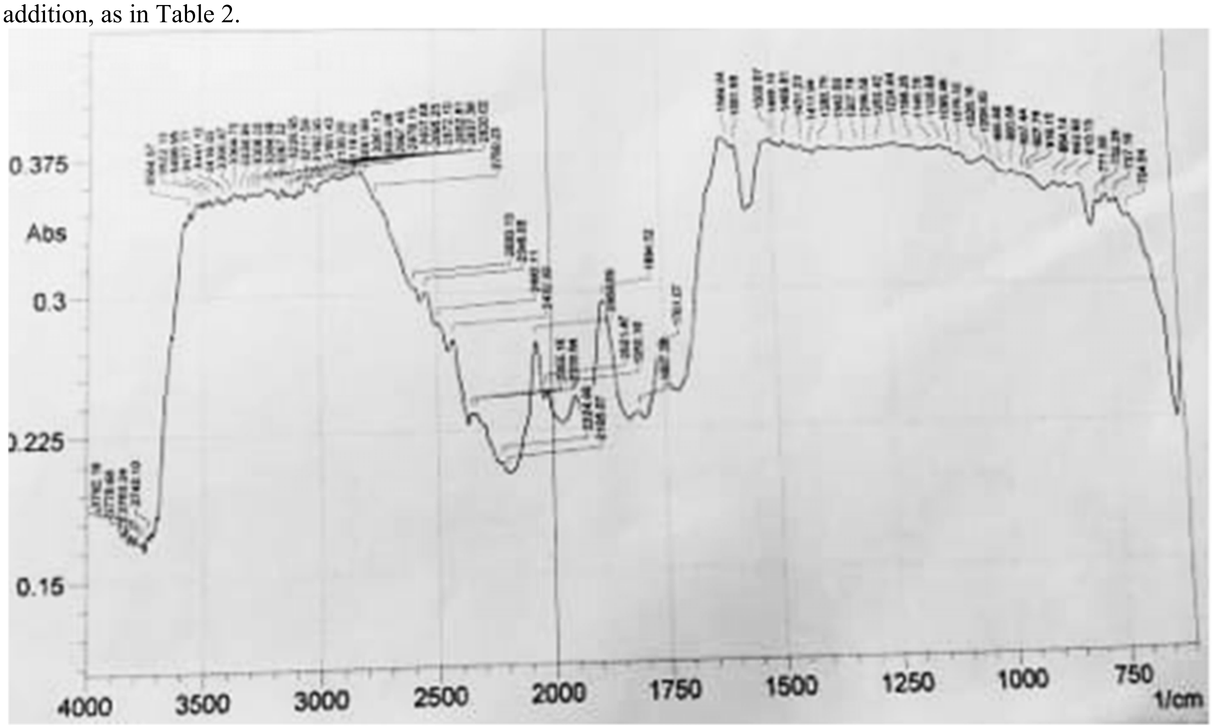

FIGURE 2. FTIR spectrum of pure epoxy resin thick film

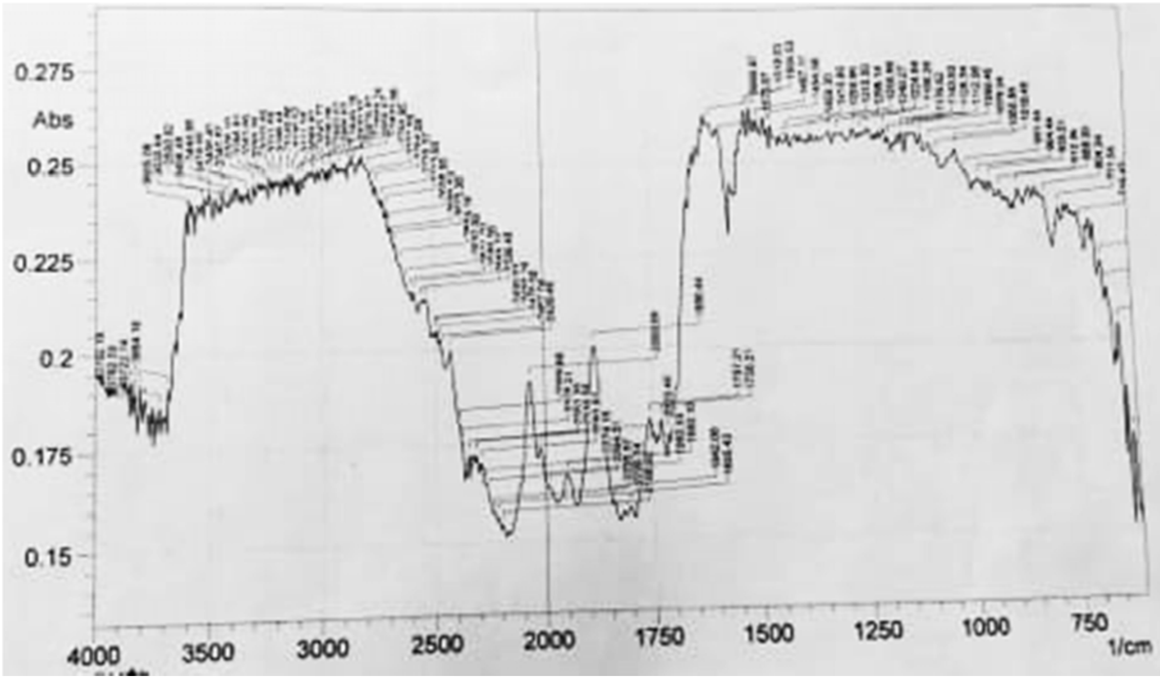

FIGURE 3. FTIR spectrum of thick film composite at X=5%

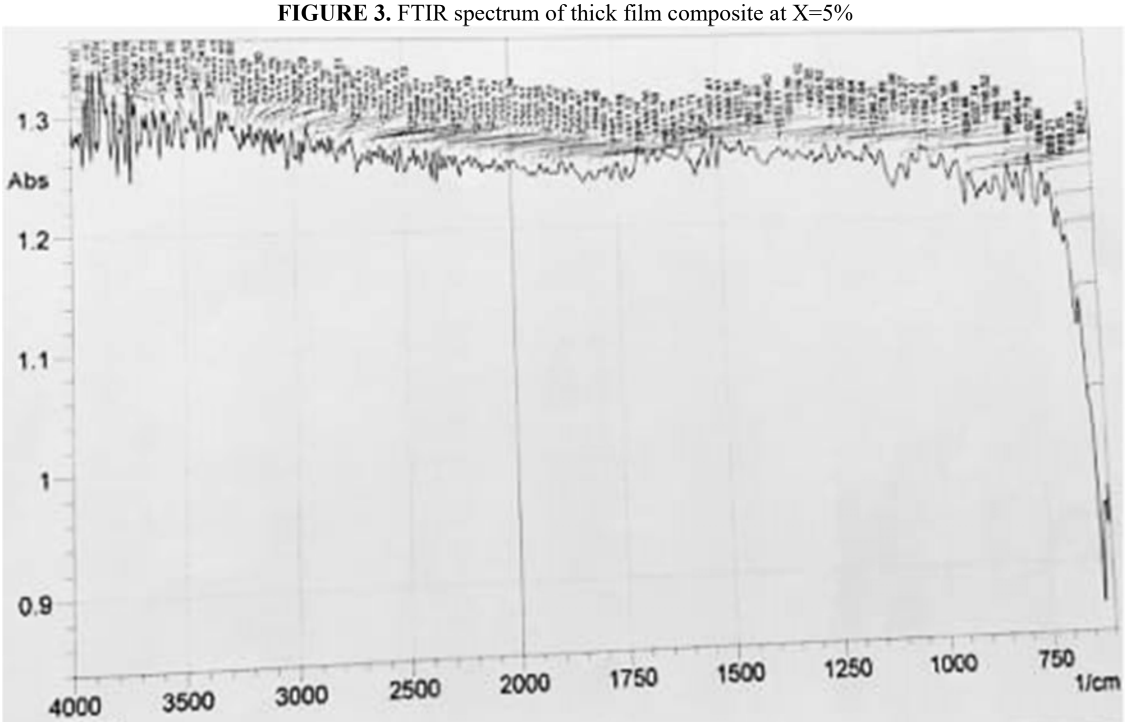

FIGURE 4. FTIR spectrum of thick film composite at X=10%

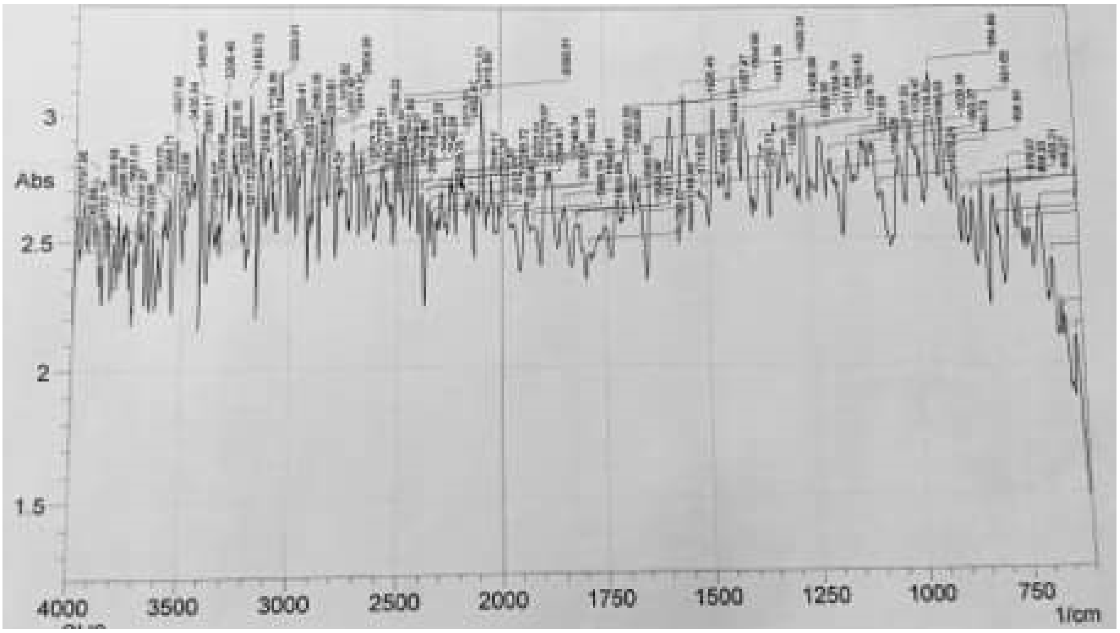

FIGURE 5. FTIR spectrum of thick film composite at X=15%.

TABLE 2. Bands of (FTIR) for Epoxy Resin thick film and thick film composite.

Band(cm^{-1}) [20]	Assignment [20]	Band (cm^{-1})of Epoxy Resins thick film, at x=0%	Band (cm^{-1}) of thick film composite, at x=5%	Band (cm^{-1}) of thick film composite at x=10%	Band (cm^{-1}) of thick film composite at x=15%
≈ 3500	O-H stretching	3522.13-3564.57	3500.92	3516.35	3510.56
3057	Stretching of C-H of the oxirane ring	3036.06-3061.06	3036.06-3093.92	3043.77-3078.49	3026-3088.14
2873-2965	Stretching C-H of CH2 and CH aromatic and aliphatic	2872.1-2978.19	2868.24-2966.62	2839.31-2976.26	2879.82-2982.05
1608	Stretching C=C of aromatic rings	-	1600.97	1616.4	1633.76
1509	Stretching C-C of aromatic	1500.67	1504.53	1516.1	1510.31
1036	Stretching C-O-C of ethers	1026.16-1076.32	1018.45-1099.46	1037.74	1031.95
915	Stretching C-O of oxirane group	918.15	912.36-991.44	927.79	931.65
831	Stretching C-O-C of oxirane group	810.13-845.62	804.34-868	833.28	835.27
772	Rocking CH2	727.04	771.55	779.27	765.77-794.7

The absorption and transmittance measurements were performed on epoxy resin flakes of within the wavelength range (300-1100) nm. Results for the transmittance as a function of the wavelength at different percentages of CdO between 0% and 15% are shown in Figs.6 and 7, respectively. The transmittance curves of epoxy resin flakes are shown in these figures the dependence of transmittance on these percentages. Where epoxy resins exhibit a decrease in transmittance with an increase in the percentage to intercalation of CdO within a compound of epoxy resins. It can be seen that for all prepared samples have similar optical behavior, also a monotonic increase in the transmittance curve starting from the 450 nm wavelength is observed. These results suggest that the transmittance decreases are governed by percentages added of the CdO, that is can be attributed to the dispersion of photons due to the dopant as foreign atoms. Obviously, the transmittance is very low at wavelengths below (300nm, 350 nm, 400 and 450 nm at x=0, 5%, 10% and 15%) for which located within the visible area of the electromagnetic spectrum, due to high absorption in this region.

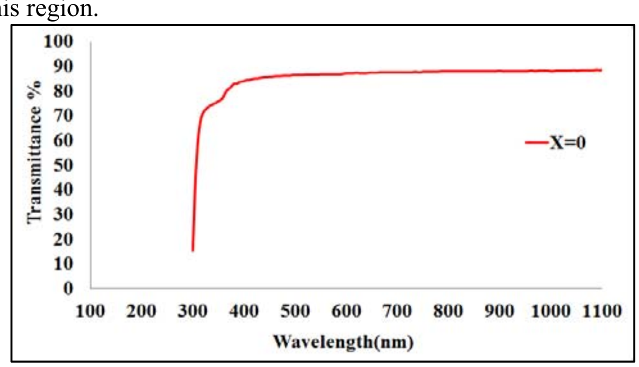

FIGURE 6. Transmittance curve for undoped (epoxy thick film).

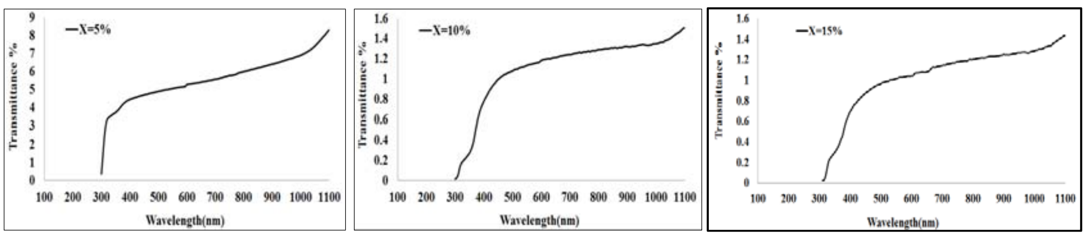

FIGURE 7. Transmittance curve for doped (thick film composite).

The ability to determine the optical band gap is fundamental because it is considered one of the most important visual constants for many semiconductor fields. The optical band gap of epoxy resin is obtained with the help of evaluated values of absorption coefficient (α) by using Tauc's relation [21,22]:

$$\alpha h\nu = A(h\nu - E_g)^r$$

Where Eg is the optical band gap energy of the investigated epoxy resins, A is constant and $h\nu$ is photon energy.The exponent r is a number depends on the type of transition and it has value 1/2 which characterizes the direct transition process and $r = 2$ for allowed indirect transition.

The values of the absorption coefficient for all samples have been observed to increase with the increase in the concentration of CdO in epoxy (the concentration increases from 5% to 15% CdO) as shown in Figs. 8 and 9.From these figures, it is clear that absorption coefficient$\alpha > 10^4\text{cm}^{-1}$ that means direct transitions while for epoxy resins without add (i.e. 0% CdO) $\alpha < 10^4\text{cm}^{-1}$and that means indirect transition [23].

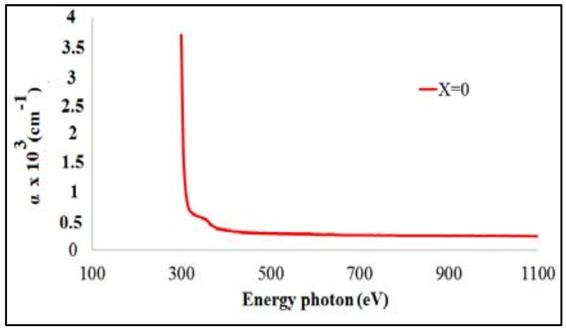

FIGURE 8. Variation of Absorption coefficient for pure epoxy resins (without CdO, 0%)

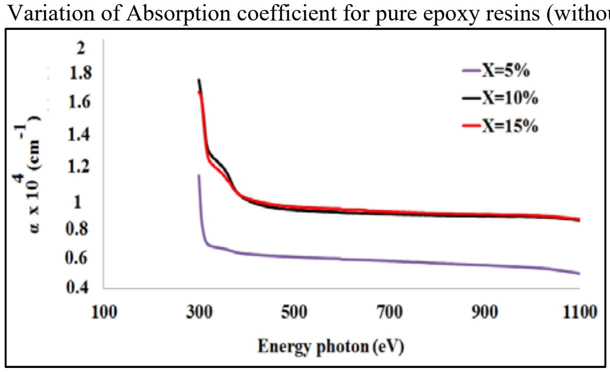

FIGURE 9. Variation of Absorption coefficient (α)with photon energy (hν) in epoxy resins(i.e. percentages CdO; 5%, 10%& 15%) thick films.

Plots of $(\alpha h\nu)^2$ versus photon energy (hν) for epoxy resins are shown in Figs. 10a, b and 11.The value of Eg is determined by extrapolating the Tauc's region (linear part of the plots) to $(\alpha h\upsilon)^{1/2} = 0$ to obtain the band gap. The addition of CdO causes a reduction in the energy band gap (Eg) of the epoxy resins that means the optical energy band gap is decreasing with increase in CdO percentages as shown in Table 3, where the values of optical energy band gap lie between (3.6 - 4eV).The reduction in the energy band gap is to be due to the generation localized states near the conduction band. That is presumed to be due to the generation of topical levels associated with the addition of CdO molecules which act as recombination of the prepared flakes.

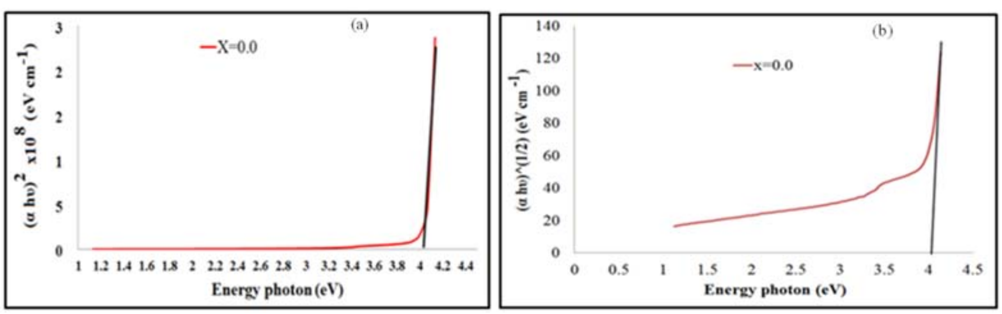

FIGURE 10. (a)$(\alpha h\upsilon)^2$ change with (eV) for undoped (epoxy thick film), (b) $(\alpha h\upsilon)^{1/2}$ change with (eV) for undoped (epoxy thick film).

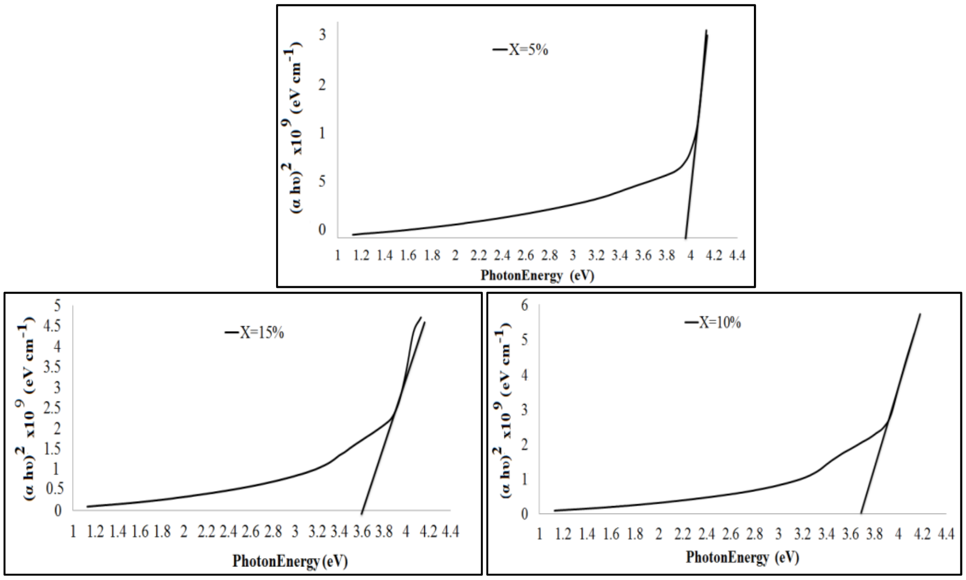

FIGURE 11. $(\alpha\ h\upsilon)^2$change with (eV) for doped (thick film composite).

TABLE 3. Optical band gap (Eg) and absorption coefficient (α) for epoxy resin thin films.

Sample No.	Composition (CdO; x%)	Optical Band Gap (Eg) in eV	Absorption coefficient (α) (Cm^{-1}) at hv=4.133eV
1	0	4.05	3721.648
2	5	3.95	11220.216
3	10	3.69	17383.044
4	15	3.6	16604.63

CONCLUSION

The reinforced epoxy composite with the different concentrations of CdO (0%, 5%, 10% & 15%) was placed onto chemically cleaned plastic bases. The surfaces images and measurements by atomic force microscope (AFM) showed all the samples of composite thin films have the uniform and homogeneous surfaces. In addition, the AFM images revealed that increasing the concentration of CdO increases the surfaces roughness. It is also observed that this increasing percentage strongly affects the final properties of the epoxy resin, where there is an increase in particle size and significant improvements in the hardness of composite, therefore, these composites have many applications potential. The studied of optical absorption spectra for epoxy resins at a wavelength range 300-1100 nm, by spectrophotometer allowed us calculated the optical parameters like absorption coefficient (α), transmittance and optical band gap (Eg).The transmittance coefficient of the composites shows significant decreases with wavelength (λ) for all the samples with the addition of CdO concentration in epoxy resin. The presence of cadmium oxide (CdO) in these composites increase their absorption coefficient (α) linearly with incident photon energy (hν) and this increase depends on the percentage of added the reinforced material, although decreased absorption coefficient with increasing CdO concentration in epoxy resin. This applies to the transport coefficient is also where it exhibits the same behavior. Absorption measurements on all epoxy resin systems exhibited presence of a direct band gap with the addition of CdO content. Where it was observed the energy band gap decreases from 4.05eV (indirect) to 3.95eV (direct) with the addition 5% of CdO content and continued to decrease with increase CdO content to arrive 3.6eV with the addition 15% of CdO. The decrease in energy band gap values with increasing CdO concentration may be due to the generation localized states near the conduction band. Overall, In the future studies, we can also study other aspects and a new composites selection using a reinforced material new to better for specific properties and the resulting experimental data can be treated similarly.

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