The Thickness Effects Characterization Properties Of Copper Oxide Thin Films Prepared By Thermal Evaporation Technique

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***Abstract*—In This paper, CuO thin films having different thickness (250, 300 , 350 and 400) nm were deposited on glass substrates by thermal vacuum evaporator. The thermal oxidation of this evaporated film was done in heated glass at temperature (300)C° in air at one hour. The study of X-ray diffraction investigated all the exhibit polycrystalline nature with monoclinic crystal structure include uniformly grains. Thin film's internal structure topographical and optical properties. Furthermore, the crystallization directions of CuO (35.54°, 38.70°) can be clearly observed through an X-ray diffraction analysis XRD, Atomic Force Microscope AFM (topographic image) showed that the surface Characteristics , thin films crystals grew with increases in either the different thickness, also , the grain size increased in rang (14.65-19.39) nm. The optical properties concerning the absorption and transmission spectra were studies for prepared thin films. UV-Vis measurement spectra showed that ultraviolet (UV) transmittance intensity decreased with increases thickness, the energy band gap decreased from (1.62 to1.48) eV when the thickness varying from 250 to 400 nm.**

Keywords—CuO, Thin Films, structure properties, AFM, optical properties

1. Introduction

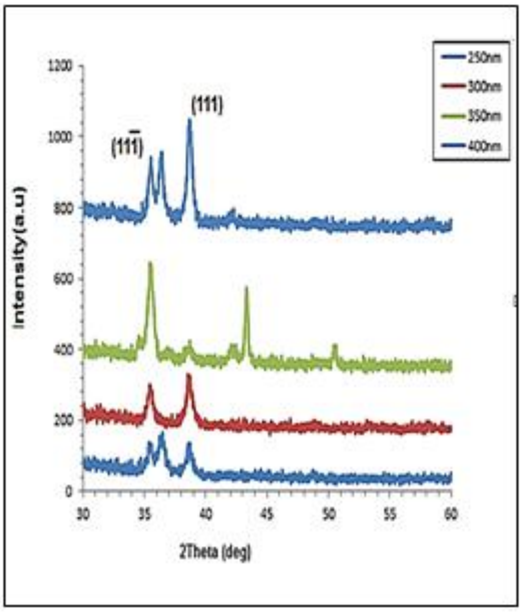
Copper(II) oxide (CuO) or known as cupric oxide has a preferred monoclinic tenorite structure. Generally , CuO material is a p-type semiconductor in general which advantageous for constructing junction such as pn junction diodes [1] ,having a relatively low band gap (1.21-1.51) eV [1,2].Copper oxides have found numerous applications in diverse fields such as solar cells and photovoltaic materials [3], electrochromic coatings [4], catalytic applications [5], and gas sensors [6]. Doped copper oxide thin films have found applications such as in the fabrication of p-type transparent conductors. Several methods such as: thermal oxidation [7]; electro deposition [8]; chemical conversion [9]; chemical brightening [10]; spraying [11]; chemical vapor deposition [12]; plasma evaporation [13]; reactive sputtering [14]; and molecular beam epitaxy [15], and sol-gel techniques [16] etc .this work, we investigated the effect of thickness on the properties of copper oxide thin film prepared by oxidation of thermal vacuum evaporated Cu thin films. The films were characterized using Atomic Force Microscope (AFM), X-ray diffraction (XRD), UV-Vis spectrophotometer .

2. Experimental

Copper pure metal thin films have been deposited on glass substrate by thermal evaporation technique in a high vacuum system of by thermal evaporation using Edward coating unit model (E 306) from molybdenum boat, the distance between the boat and substrate was about 18 cm. Films thickness was about (250,300,350,400) nm at R.T (300 K) technique using coating unit in vacuum about (2.3×10^{-5}) mbarafter cleaned the glass and the this film was measured by interference method . The thermal oxidation processes were carried out on these films at temperature of (300) C° for one hour byusing (Kilns Furnaces) with exist air flow once,The crystal structure of these films was checked by X-ray diffraction technique, (XRD) patterns were obtained with automatic Diffract meter using the CuKα radiations (λ=1.54059 Å) in the range of 2θ between 35° and 38° .Atomic force microscopy (AFM) measurements were carried out using (SPM model AA 3000 Angstrom Advanced Lns., USA) to determine the nanocrystalline topography and grain size of the films Cary 100 Conc plus UV-Vis spectrophotometer

3. Results and discussion

The XRD different pattern are presented for CuO thin films by thermal evaporation technique and deposited on glass different thickness shown in figure (3) Pattern indicated that there are two sharp reflection peaks $(11\bar{1})$and (111) at 35.54° and 38.70° respectively and the film was polycrystalline in nature. The monoclinic structure was matched with the standards peaks (ASTM - Card file No. 00-005-0661).



films at different Fig .(1): XRD spectra of CuO of thin thickness (250,300,350and400)nm

The average crystalline size of CuO thin films was calculated by using Debye-Scherrer's formula [16]

$$D = \frac{0.9\,\lambda}{\beta\cos\theta}. \qquad (1)$$

Where D is the mean crystallite size,β is the full width at half maximum (FWHM) of the diffraction line ,θ is the diffraction angle, and λ is the wavelength of the XRD radiation. which are preperd a different thickness. (250,300,350and400) nm respectively which is agreement with the determined AFM in visitation

AFM depicts the surface morphology of the copper oxide thin films analyzed by (AFM). The surface of the (CuO) thin films as observed from the (AFM) micrograph confirms that the grains are uniformly distributed within the scanning area (2000nm x 2000 nm) .Which combine to make denser films significantly with the increased thickness. From the images ,it was observed that the surfaces of the films exhibited ascertain degree of roughness and the film came rougher when the thickness increases as shown in table (1).This result indicates that the growth of larger grains with increasing thickness leads to an increase in the surface roughness It is observed that the average grain size increases with increasing of thickness and the values of the average

grain size variable from (67 -83) nm depending on film thickness as shown in Table (1) the root mean square RMS values of surface roughness and average grain size were estimated and presented in Table (1) .The CuO thin film prepared at difference thickness and formed larger particles . The average grain size results (listed in Table) disagree with those estimated from XRD due to the fact that the AFM measurement directly visualizes the grains

The results obtained from the (AFM) of the nanostructure for different thickness as of (CuO) thin film show that the histogram of the percentage of (CuO) as a function of the grain size are shown in figure (2). From this figure, the percentage of minimum grain size were (14-19)% for film thickness of (250,300,350and400) nm respectively. Also, it is clear from the figure, that the average grain size were (67, 74,79 and83) nm with for the previous thickness .This structural films are very important for many novel applications such as optoelectronic devices, gas sensors and biological science . In Table (1), it is clearly seen that the root mean square of surface roughness increases with different thickness means delivering of more energy implies a high polycrystalline.[17]

Table 1: characterization on CuO thin films

CuO Thin Film Thickenss (nm)	D (nm)	Average (Diameter) (nm)	Roughness (Average) (nm)	(RMS (nm)
250	14.65	67.38	0.645	0.525
300	14.70	74.34	0.878	0.742
350	16.24	79.44	1.09	0.928
400	19.39	83.20	1.01	0.807

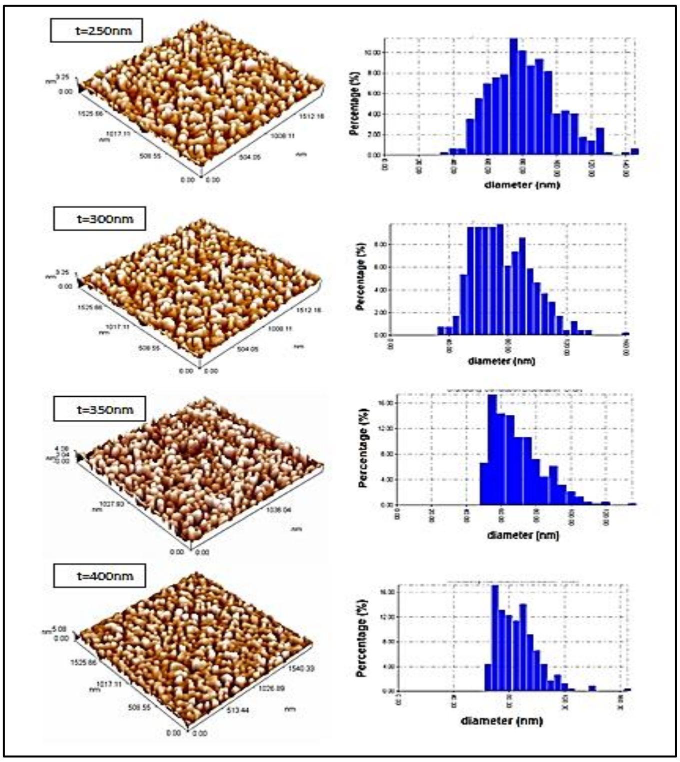


Fig . (2) :AFM images of CuO thin film

different thickness: (250,300,350and400)nm

thickness for wavelength 850 nm Figure (3) show transmission spectra of CuO thin films is which prepared by thermal evaporation techniques and deposited on glass substrate ,The date is corrected for glass in UV-regain ,the transmission is sharply decreases because of the wide of absorbed particle size .Also the Figure(3) that transmission decrease at the different thickness (250,300,350and400) nm can be used a window in detector and solar cell application in the rang to IR in other word this material can be describe is in active material 550 nm. The optical energy gap of CuO was calculated by the tauc relation [17].

$$\alpha h\nu = A(h\nu - Eg)^n . (2)$$

Where :(α) Absorption coefficient, (h) Planck's constant, (v) the frequency of the photon, (hv) photon energy, (B) Constant depends on the probability of the transfer of electronic. The relation is drawn between (α hv)^2 and photonenergy (hv),as shown in figure (4.) which illustrate the allowed direct transition electronic .The optical energy band gap were found to be in the range of (1.6 to 1.3) eV When the film thickness varying from 250 to 400 nm. where the (Eg) decreases with increases the thickness this values are in agreement with the values obtained .

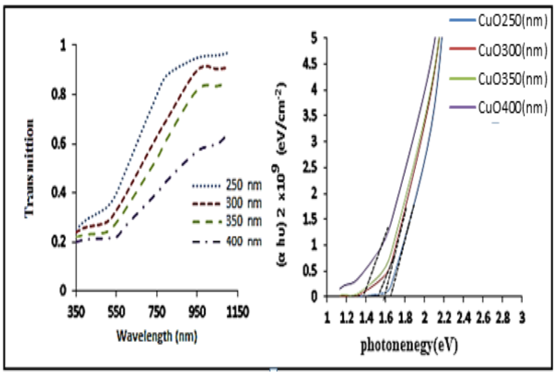


Fig.3: (left) Transmission spectra of CuO thin films different thickness (250,300,350 and 400) nm and (right) (αhv)^2 versus optical energy gap of CuO thin films

The Reflectance spectra of CuO of thin films are shows in Figure (5) .It observed that the maximum value of reflectance of CuO thin films is increases to 0.2 where the wavelength at 580 nm and ingresses with the increases the different thickness (250,300,350 and 400) nm are agreement with AFM measurement .

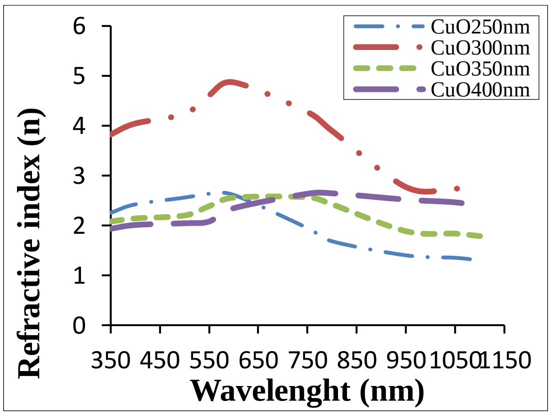


Fig (4):Reflectance of CuO thin films with different thickness (250to 400 step 50 nm) .

The variation of the refractive index values (n) versus wavelengths in the range (350-1105) nm of (CuO) films is shown in Figure.(6) . We can notice from this figure that the refractive index values decrease when shows in Fig(6) The refractive index can be fund from relation [18] ,the behavior of refractive index and can be notice that the refractive index decreases with increases in wavelength (550-750) nm. Also it is decreases with increases thickness (250,300,350 and 400) nm.

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} . (3)$$

Where R is the reflectance which calculated by using equation (R = 1-T-A).

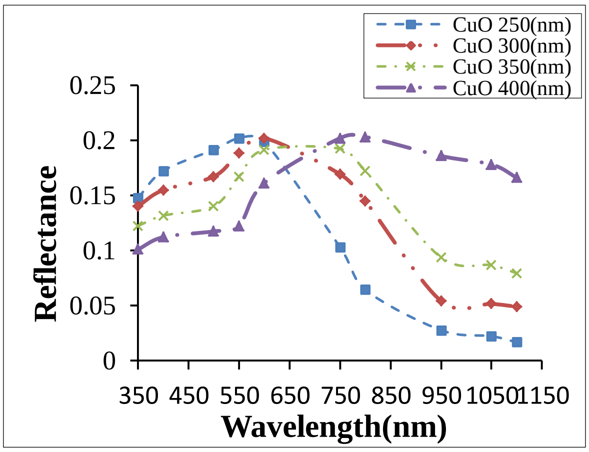


Fig. (5): Refractive index of CuO thin film with different thickness 250 ,300,350 and 400)nm

Conclusions

CuO thin films were deposited onto glass substrates at different thickness (250 , 300,350 and 400)nm .XRD results indicated that the thin films had a preferred $(11\bar{1})$ and (111) at 35.54° and 38.70° respectively. The crystallites size increased with increasing thickness. However the grain size and the roughness of the thin films depended on the thickness. The higher thickness 400 nm has bigger grain size. The thickness effects of the thin films were observed and characterized. We found that the XRD patterns and the surface morphologies of the thin films was greatly change when the thin film has greater thickness due improved in optical properties. the absorption and transmission spectra were studies for prepared thin films. UV-Vis measurement spectra showed that ultraviolet (UV) transmittance intensity decreased with increases different thickness and energy gap decreased from (1.62 to1.48) eV when the different thickness varying from 250 to 400 nm. the behavior of refractive index and Reflectance can be notice that the refractive index decreases with increases in wavelength (550-750)nm .then Reflectance is increases with the wavelength VIS-UV ordain (0.2) wavelength Andthe ingresses with the increases the different thickness (250, 300,350 and 400nm) are agreement with AFM measurement .

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