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The Thickness Effect Of Cuo Thin Films On Structural, Morphological And Optical Properties

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***Abstract*—In this studies the Copper Oxide (CuO) thin films which have been prepared by thermal oxidation with different thicknesses (100,150,200) nm on glass and Si substrates, we made (p-CuO/n-Si) heterojunction was deposited by high vacuum thermal evaporation, These films was tested by X-Ray diffraction and the results confirm of CuO thin films have polycrystalline structure and demonstrate with a preferred orientation (111) $(11\bar{1})$ plane, We can study Morphology properties From AFM analysis demonstrate that average. Diameter (grain size) increase with increasing thickness,**

The (uv-vis) spectrophotometer discover the direct allowed band gap ,and the energy band gap of CuO thin films were found to be in the range of (2.1eV to 2.4eV) when the thickness of films varying from(100nm to 200nm), and the optical constants calculated such as (absorption coefficient ,refractive index, and extinction coefficient)for wavelength in range (300-1100)nm.

Keywords—CuO, XRD, AFM, UV_VIS, Thermal Oxidation, Morphology properties.

1-Introduction:

The features of Copper Oxide (CuO) thin film is considered to be a p-type semiconductors which have low band gap (1.3-2.1) ev with monoclinic crystal structure [1], the conduction in p-type semiconductors increase by doping or annealing [9], low cost production processing [1,3,5], non-toxic nature [1,3,5],.good electrical and .high optical absorption[5], In additional Copper Oxides effective to Synthesizing PN junction diodes[6], therefore this films of (CuO) suitable in many application such as photovoltaic devices [7] (solar cell, photodetector, humidity and gas sensor [3,6]) and photo-thermal [1], catalytic applications [3], There are several methods of deposition techniques used to prepare copper oxide films such as thermal evaporation [1,3], electrochemical deposition [3], chemical vapor deposition [1,4], sol-gel [1,4], pulsed laser deposition [1,3,4], spray pyrolysis [1,4], plasma evaporation[1], molecular beam epitaxy [1,3], anodic oxidation [7], and reactive RF magnetron sputtering[4]. In this studies we used the thermal evaporation technique to prepare Cu thin film and then we oxidation these films to obtain (CuO) films.

The aim of this study was Focused on the preparing this films to be using in fabricating the heterodiode[10].

2-Experimental:

Firstly We recorded the films thickness by using weighing method [7],Secondly cut slides of glass and Silicon (n-type) with area $(2 \times 2)cm^2$, $(2 \times 1)cm^2$ were used as a substrate, Thirdly We cleaned this substrates with distilled water and alcohol in an ultrasonic cleaner for 15 min in order to remove impurities, residuals, and any contaminations from the surface of this substrates, eventually this substrates were wiped with special cleaner soft paper, Fourthly this substrates become ready to deposit copper pure metal on glass and silicon substrate with thickness (100,150,200)nm at RT by using thermal evaporation technique in a high vacuum system nearly of $(5.23*10^{-5})$ mbar using

Edward coating unit model(E306) with molybdenum boat, distance between the substrate and boat was about(9cm), Fifthly, placed these films of Cu in oven type (Kilns Furnaces) to exposing thermal Oxidation processes at (523K) for one hour with exist air at rate flow(1.5) liter/sec, and then the structure properties of these films was examined by X-Ray diffraction method using Shimadzu X-Ray diffractometer system 6000, this system records the intensity as function of Bragg angle with operation condition(Source: Cu Kα radiation, wavelength λ:1.5406A°, current = 20 mA, voltage = 4Kv, scanning speed = 5 cm/min).

From Bragg's law we can get information about the crystal structure such as phase crystalline, Crystal size (D), lattice parameter (a), and the inter planer distance d(hkl)for different planes[1].

$$2dsin\theta = n\lambda \quad (1)$$

n = the reflection order.

$$a = d(h^2 + k^2 + l^2)^{1/2} \quad (2)$$

The films Crystalline size (D) could be calculated from diffraction line broadening using the Scherrer equation[1].

$$D = \frac{0.9\lambda}{\beta cos\theta} \quad (3)$$

β = the full width at half maxima, θ = the angle diffraction, λ = the wavelength of X-Ray.

We can evaluate the strain (η) and the dislocation density (δ) by using the relations [2].

$$\eta = \frac{\beta \cos\theta}{4} \quad (4)$$

$$\delta = \frac{1}{D^2} \quad (5)$$

From (UV-Visible 1800 spectrophotometer) we can measurement optical transmission (T) and absorbance(A) spectrum in the range (300-1100) nm, then we get the band gap (Eg), reflectance (R) and optical constants {absorption coefficient (α), refractive index (n), extinction coefficient (K) } of the deposition films[1].

$$\alpha = 2.303\frac{A}{t} \quad (6)$$

$$K = \frac{\alpha\lambda}{4\pi} \quad (7)$$

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \quad (8)$$

$$R = 1 - T - A \quad (9)$$

The incident photon energy(hv) was calculated as a function of wavelength(nm) from this equation:

$$Eg = hv = \frac{hc}{\lambda_{nm}} \quad (10)$$

Where h : is Plank's constant (6.62*10^{-34}J. sec), c : is speed of light (3*10^{8})m/sec and λ : is the Wavelength[8].

$$E_g^{opt} = \frac{1240}{\lambda_{nm}} \quad (11)$$

From Tauc formulas which describe the energy depend of absorption coefficient(α) near the band edge for band to band and excitation transition.

$$(\alpha hv) = B(hv - E_g^{opt})^r \quad (12)$$

Where B is a constant inversely proportional to amorphousity,

r is constant indicates to the type of optical transition and take value ($\frac{1}{2}$,$\frac{2}{3}$) for direct transition,(2,3) for indirect transition.

3-Results And Discussion:

(3-1)XRD Analysis:

The major tool that which used to knowledge the phases of prepared CuO films is XRD. the pattern in figure (1) for thin film at thickness (100)nm show two peaks at (2θ=35.7°,38.7°)with d(hkl) (2.51A°,2.32A°) correspond to orientation $(11\bar{1})$(111)planes respectively this phase indicates to (CuO), for the films at (150)nm noted two peaks at (2θ=35.5°,38.7°) with d(hkl) (2.52A°,2.32A°) correspond to orientation $(11\bar{1})$,(111) planes respectively, for the film at thick ness (200)nm show two peaks (2θ=35.4,38.7) with d(hkl) (2.52A°,2.31A°) correspond to orientation $(11\bar{1})$(111) planes respectively with compared the standards (ASTM-card file)No:048-1548 the result of XRD pattern showed that prepared films as different thickness have polycrystalline in nature and monoclinic structure .

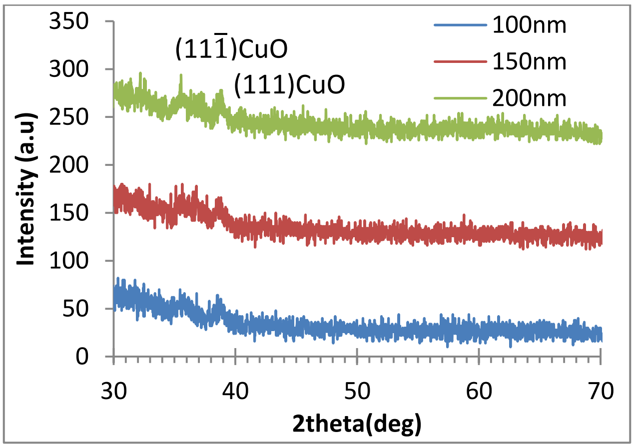


Figure (1)XRD pattern of CuO thin films at thickness (100-150-200)nm.

Table 1: XRD analysis results of structural (CuO)thin film with thickness (100)nm.

2θ (deg)	FWHM (deg)	d(A)	(hkl)	I(a.u)
38.7248	0.7	2.32339	(111)	99
35.7073	0.5	2.5125	$(11\bar{1})$	100

Table 2: XRD analysis results of structural (CuO) thin film with thickness (150)nm.

2 θ (deg)	FWHM (deg)	d(A)	(hkl)	I(a.u)
38.7398	0.57	2.32252	(111)	99
35.514	0.5133	2.52573	$(11\bar{1})$	100

Table 3: XRD analysis results of structural (CuO) thin film with thickness (200)nm.

2θ (deg)	FWHM (deg)	d(A)	(hkl)	I(a.u)
38.7947	0.68	2.31936	(111)	99
35.4974	0.72	2.52688	$(11\bar{1})$	100

Table 4: X-Ray Characterization for CuO thin films with thickness(100-150-200)nm.

Thickness (nm)	Avg. Crystalline Size(D)nm	Avg. $\delta \times 10^{14}$ lines.m^{-2}	Avg. η $\times 10^{-4}$ Lines^{-2}. m^{-4}
100	14.28923	53.02288	24.90511
150	15.43498	42.26082	22.99987
200	11.92577	70.54817	29.08729

(3-2)AFM Analysis:

From Atomic force Microscopy (AFM) we can Knowledge the morphology properties for surface ,roughness and grain size[8], the estimated values of root mean square (Sq) ,surface roughness average(Sa) and Average grain size are listed in table (4) We notes with increasing thickness increase Average diameter(Grain size).

Table5: AFM analysis results of structural of (CuO) thin films with thickness(100-150-200)nm.

thickness(nm)	Avg. G.S(nm)	Sa(nm)	Sq(nm)
100	78.32	0.848	1.01
150	98.76	0.393	0.464
200	119.87	1.08	1.26

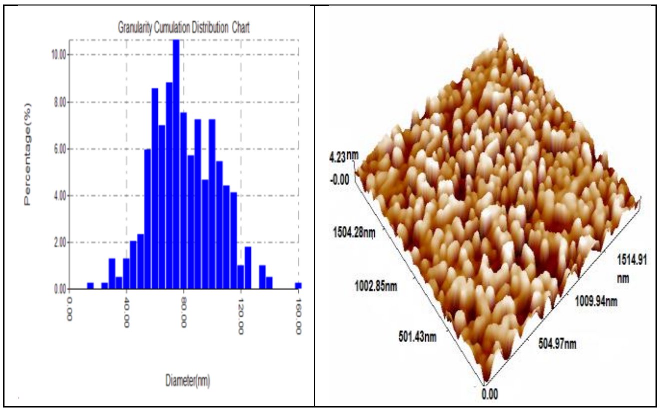


Figure.2 -a AFM Image of CuO films at thickness 100nm.

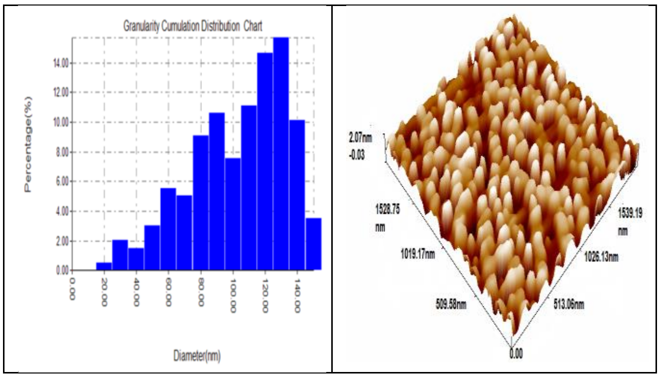


Figure.2 -b AFM Image of CuO films at thickness 150nm

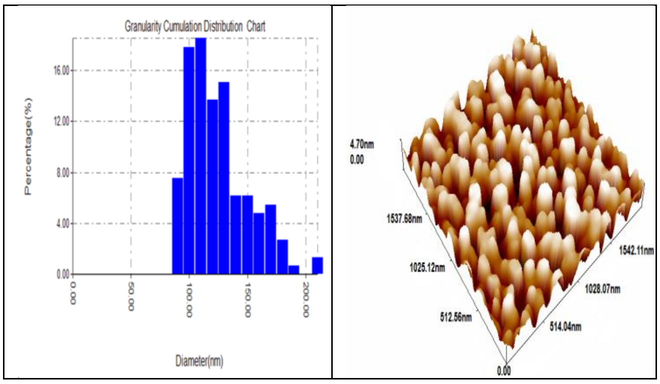


Figure.2 –c AFM Image of CuO films at thickness 200nm.

(3-3)UV-VIS Analysis:

From (UV-VIS) spectrophotometer for these film we can conclusion that the optical energy gap found to be in range (2.1eV to 2.4 eV).

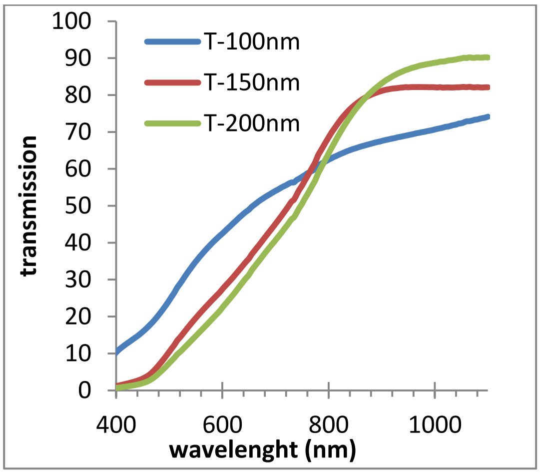
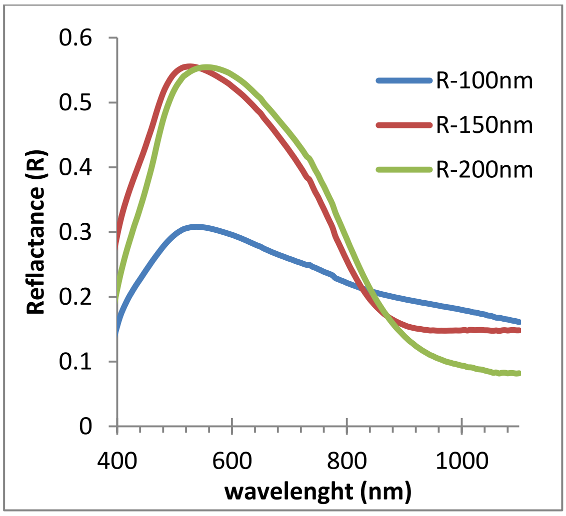


Figure.(3)Transmission spectra for CuO thin films with thickness(100-150-200)nm respectively.



Figure(4)Reflectance spectra for CuO thin films with thickness (100-150-200)nm respectively.

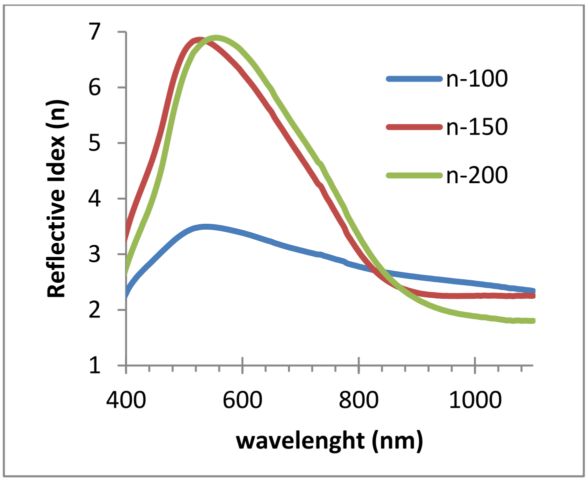
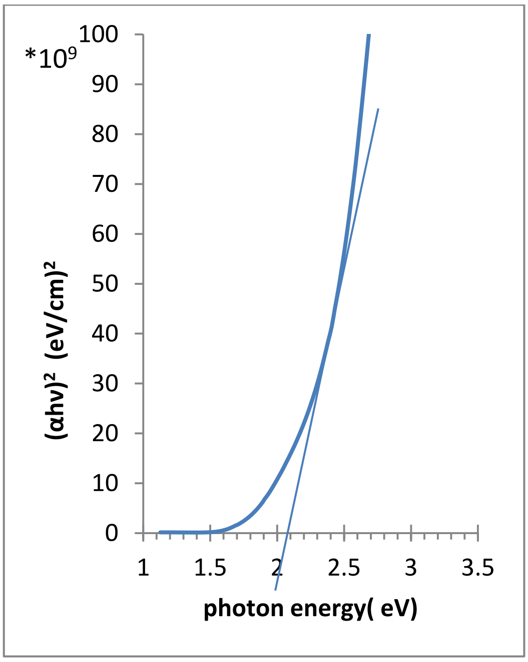
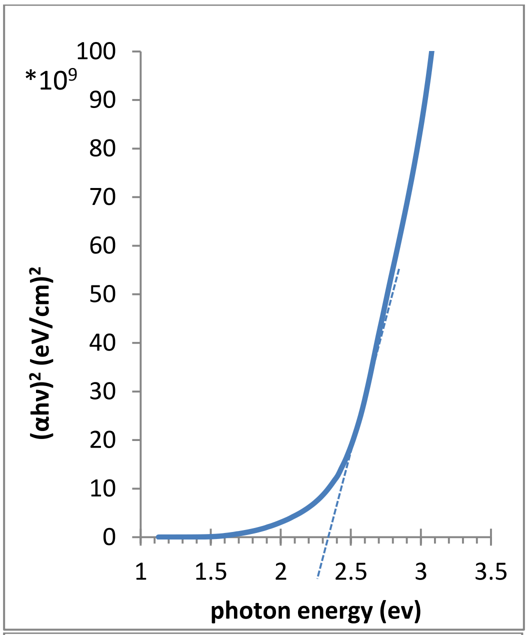


Figure (5) Refractive Index for CuO thin films with thickness (100-150-200)nm respectively.





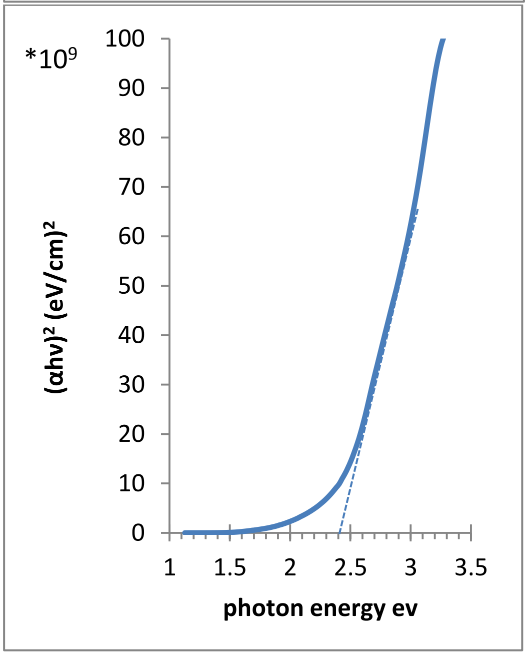


Figure .(6) $(\alpha h\nu)^2$ versus photon energy gap of CuO thin films with thickness(100-150-200)nm respectively.

Conclusion:

In our research we studied the structure, Morphology and optical properties of CuO thin films as prepared thermal Oxidation by using thermal evaporation in high vacuum , the XRD measurements showed that the CuO thin films have polycrystalline in nature with monoclinic crystal structure, we can calculated the average crystalline size from XRD data is found to be(14.2892, 15.4348, 11.257)nm of thickness(100-150-200)nm respectively, we concluded that the Grain Size increase with increasing thickness from (AFM)data , the optical energy gap was Investigated from (UV_VIS)spectroscopy of these films were found to be in the range of (2.1eV to 2.4 eV) when the film thickness varying from(100nm to 200nm).

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