JOURNAL OF KUFA−PHYSICS
www.uokufa.edu.iq/journals/index.php/jkp | ISSN: 2077−5830

Study the Structural and Optical Properties of CuO Thin films Prepared by d.c Magnetron Sputtering

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KEYWORDS:
- Thin films
- Magnetron sputtering
- Optical properties
- magnetic field

ABSTRACT

In this research (CuO) films were prepared onto glass substrate of glass using plasma magnetron sputtering technique. The results of XRD showed that the thin films had a polycrystalline structure with monoclinic lattice unit cell. The roughness of the prepared films were identified by atomic force microscope (AFM), where the results showed that the roughness increased from (0.386-4.22)nm with increasing the thickness from(95-316)nm. Optical properties of the prepared films of (335-1135) nm showed that the absorption of the films decreased with increasing of wavelength for all thicknesses, optical energy gap for the prepared films decreased from (3.15-2.8)eV with increasing thickness from (95-316)nm.

http://dx.doi.org/10.31257/2018/JKP/100209

دراسة الخصائص التركيبية والبصرية لأغشية اوكسيد النحاس المحضرة بطريقة الترذيذ المغناطيسي

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الـــخُـــلاصـــة:

في هذا البحث تم تحضير أغشية (CuO) على أرضيات من الزجاج ,باستخدام طريقة الترذيذ الماكنتروني البلازمي. نتائج حيود الاشعة السينية (XRD) أظهرت أن الاغشية المحضرة ذات تركيب متعددة التبلور مع تركيب لشبائك خلية الوحدة ذات تركيب(monoclinic). خشونة السطح تم تشخيصها باستخدام جهاز مجهر القوى الذرية(AFM)،حيث ان النتائج اظهرت ان الخشونة ازدادت من nm (0.386-4.22) مع زيادة السمك منnm (95-316). الخصائص البصرية للأغشية المحضرة ضمن المدى من (335-1135)nmأظهرت بأن امتصاصيةالأغشيةتقل بزيادة الطول الموجي ولكل الاسماك المحضرة. أن فجوة الطاقة البصرية للأغشية المحضرة تناقصت من eV (3.65-3.95) عند زيادة السمك من nm (95-316).

الكلمات المفتاحية:
- الأغشية الرقيقة
- الترذيذ الماكنتروني البلازمي
- الخصائص البصرية
- المجال المغناطيسي

1. Introduction

Copper oxide has two common forms : cupric(tenorite) oxide (CuO) , and cuprous (Cuprite) oxide (Cu_2O)[1],There are intrinsic p-type semiconductors which can be synthesized from the oxidation of Cu metal[2]. The band gap of the CuO is in the range of 1.2-2.0 eV [3] and 2.10 - 2.60 eV for Cu_2O[4]. The (CuO) is an important functional material used for magnetic storage media, gas sensors, electronics ,semiconductors, solar energy transformation, varistors, and catalysis. **[5]** The physiochemical properties of CuO such as the photoconductivity and the photochemistry can be tailored for fabricating optical switches and solar cells [6]. The two basic requirements for materials to be used as solar cell windows are a high optical transmittance in the visible wavelength range and low electrical resistivity[7]. Several methods such as magnetron sputtering have been developed for the fabrication of copper oxide thin films[8] Since DC magnetron sputtering technique has the advantage of better productivity than other deposition methods, it is widely used as mass production processes[9]. Coatings through DC magnetron sputtering appreach offers the benefit of uniform and homogenous coatings over a large area [10].This method has a number of advantages like :high deposition rate, high purity and homogeneity of obtained films, high adhesion and high precision of the control of thickness or grain size of obtained films [8].

2. Experimental Details

Start the process of deposition, after the system reaches the pressure of the required space ($1.5*10^{-1}$ mbar) , we begin to break the pressure by introducing the gas, which is the argon gas from bottle to the vacuum chamber that consists of pyrex glass with height (10 cm) ,radius(8 cm) ,and (2 mm)thickness , install the operational pressure of the system at work pressure(**P=1mbar**)which is measured using a pressure gauge, aftercertain voltage(205V) ,and When the magnetic field was (B=80,160 G) , then shed even dump generation bipolar investigations and generate a plasma because the magnetic field is generated in small Pack plasma .It can be maintained by the electrons resulting from the negative electrode by the effect of positive ions and thus produces gas ionization near the target, and here lies the benefit of the magnetic field generated from the coil that hunts(traps) electrons near the target . With the magnetic field, the electrons move in a helical path close to the target. This means more ionization of the gas and this leads to an increase in the output of the feeder(yield sputter) and this also leads to the fact that less argon pressure is needed to maintain the plasma, compared with the system without magnetron [11]. A vacuum known as vacuum discharges an unusual(abnormal) glow. Because of ionization, the charged particles (the positive ions) strike the surface and cause atoms to dissipate by exchanging the momentum between the positive ions and target atoms, thus aggregating the surface of the glass base(substrate) of the desired film [9].(at room temperature) . The topography of the surfaces of the prepared films and the extent of the effect of increasing the thickness of the CuO films were studied using the atomic force microscope, whose type is**(** SPM AA3000), and the ability to photograph and analyze these surfaces and to give the exactstatistical values of the Roughness values based on the root mean square of roughness (RMS). (AFM) effect of increasing thickness on a surface roughness (RMS). In this research ,thin films ofCuOwere prepared using magnetron sputtering technique and the structural and optical properties were studied.Samples were tested with X-ray diffraction type (SHIMADZU Japan XRD 6000) to identify the crystal structure of the prepared films , the crystallite size (D) was calculated using the following equation[12] :

$$D = k\lambda / B\cos\theta \quad \dots \quad 1$$

Where k=0.94 λ: wavelength , B: Full Width at Half Maximum.

Optical spectrums of the thin films were recorded by (UV-Visible 1800 spectra photometer). The optical absorption and transmittance spectra were analyzed to determine the optical constants such as absorption coefficient(α) according to the following equation [13]

$$\alpha = 2.303\ A/t \qquad \dots\ 2$$

Where A is the absorption , t is film thickness , the optical band gap Eg was calculated by the following relation [12] .

$$\alpha h\upsilon = B\,(h\upsilon - E_g)^r \qquad \dots\ 3$$

Where $h\upsilon$ is Photon energy , B Constant depends on the nature of the material and r is value depends on the nature of the transition .

Measurements of thickness of the films prepared by optical interference was measured using the He-Ne laser (0.632 μm)Wavelength. Using the equation below[11] .

$$\left(t = \frac{\lambda}{2}\frac{\Delta x}{x}\right) \qquad \dots\ 4$$

λ is wavelength, Δx is width of fringe and x is distance between fringes.

3. Results and discussion

The results of thickness can be seen in tab.1.

Table (1): Shows the thickness of the films prepared for CuO.

Materiel	Time(min)	Thickness(nm)		
		Without coil B=0	With coil B=80 G	With coil B=160 G
CuO	10	73	87	95
	20	91	105	120
	30	134	168	183
	40	199	235	258
	50	235	270	294
	60	271	295	316

It can be noted from the figure (1), that the thickness increases with increases time deposition ,this result agreed with[5] has little to no magnetic field and is increased by all the prepared films and both substances. This is because the magnetic field has worked to traps the electrons near the cathode(target) and increased the product of the sputter yield.

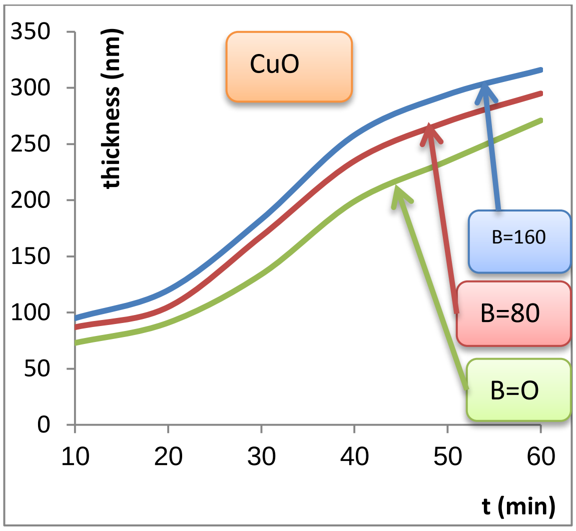


Figure (1): Effect of time and magnetic field on the thickness of CuO films.

The samples of CuO (316) nm, were examined to identify the crystalline structure of the film In figure 2, it was found that the structure of the films have a polycrystalline structure and comparing the results with the standard card number(00-048-1548) that the films with phase monoclinic,This finding comes in a good agreement with[14] , where peaks sites noted at(2θ=36.75,38.55,35.56) for planes (002), (111) and(11-1) respectively, and the preferred trend of growth was at the plane(11-1) These results are in agreement with [15,16], and the wide peak was amorphous in (2θ=23)for glass.The average crystallite sizeof the prepared film (CuO) with the thickness of (316nm) and at the peak of (2θ=35.5674)show preferential orientation of **(11$\bar{}$1)** plane was 11.77 nm

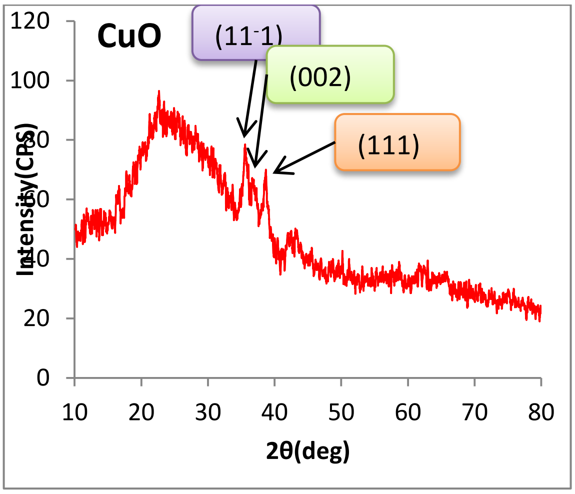
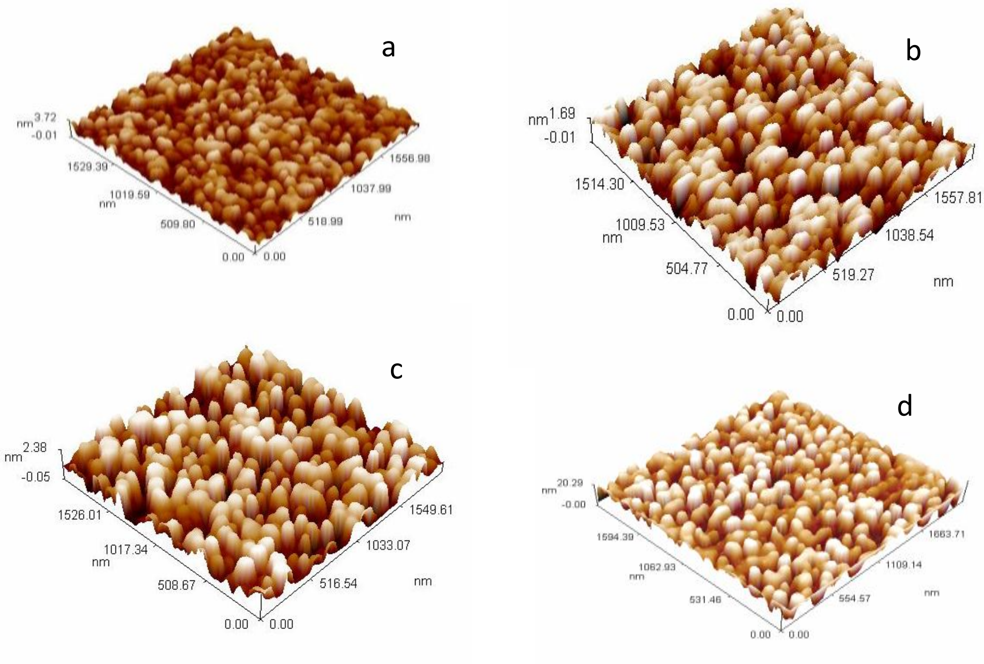


Figure (2) X-ray diffraction of CuO film of (316 nm)thickness

AFM) effect of increasing thickness on a surface Prepared films, where the square root of the mean roughness (RMS) From Fig3. .The roughness was(0.386,0.58,0.611,4.22)nm and corresponding to films (95,120,294,316)nm , respectively, due to the increase in films, this result agreement with[17,18] ,As shown in the following table (2)



Figure(3): Atomic Force Microscopy (AFM) image of CuO films.
a) t = 95 nm b) t =120 nm c) t =294 nm and d) for t =316 nm.

Table (2): Shows the results of the AFM test of the CuO films.

Sample	Material	Thickness (nm)	Root mean Square (nm)	Average Roughness (nm)
1	CuO	95	0.451	0.386
2		120	0.684	0.58
3		294	0.697	0.611
4		316	5.04	4.22

The absorption and transmittance spectrometry measurements were performed within the wavelength range (335-1135nm) of the prepared films.

Figure (4) shows that the absorbance spectrum is increased with increasing thickness ,and this is consistent with the published research [19]

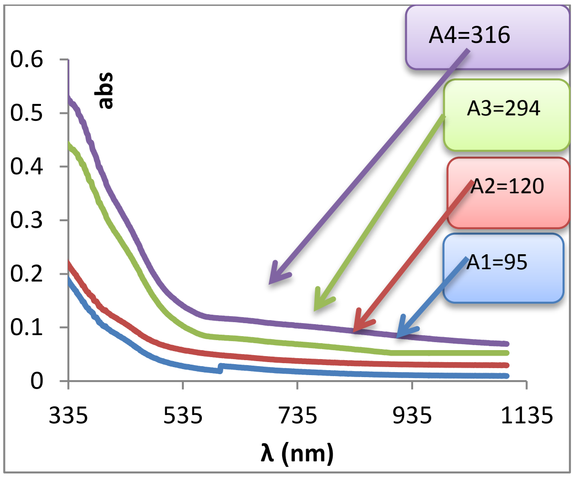


Figure (4):The absorption spectra of CuO films with at different thickness.

Figure (5) shows the transmittance spectrum of CuO films with multiple thickness . note that films transmittance increases with increasing wavelength , which is consistent with published research [20]

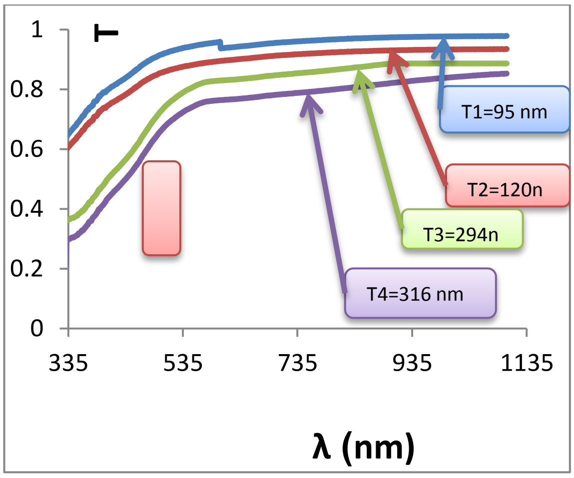


Figure (5): The transmittance spectrum of CuO films with at different thicknesses.

Fig6. Shows the optical energy gap for the allowed direct transmission through the cut point.The optical energy gap of the prepared films with thickness (95, 120, 294, ,316) nm was (3.15,3.05,2.85,2.87eV) , respectively, this result agreed with[15]. The highest values of the energy gap compared to its large size(Bulk)(1,35eV)[21], The high values of direct band gap obtained for magnetron sputtering CuO thin films are making them highly suitable for use as window layer in solar cells[16] , Several researchers have reported that the band gap of CuO can be changed to a wide range depending on the preparation conditions of CuO [16],or the observed shift in the optical absorption spectra with particle size reduction is a clear sign of the energy gap enlargement due to the quantum-confinement effects. In this case, the optical band gap changes in CuO samples upon increasing in synthesis time due to the change of crystallinity [20]

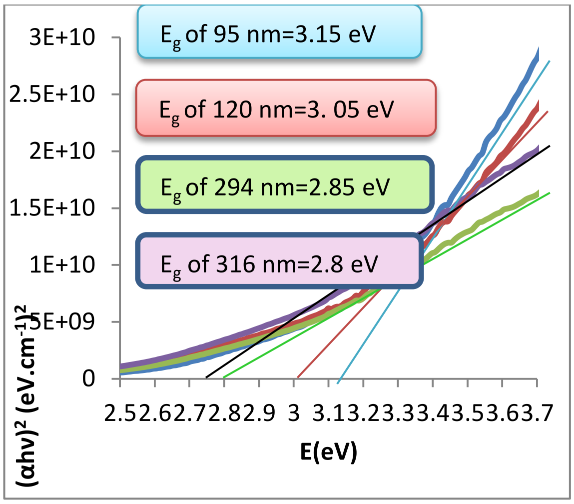


Figure (6): Optical energy gap of CuO thin films.

4. Conclusions

The locally manufactured system is suitable for the deposition of thin nanoparticles. It is possible to product CuO films that semiconductor from conductor metal .

CuO films were found to be polycrystalline, monoclinic, and the preferred tendency forgrowth (11¯1). The films prepared by the Atomic Force Microscope (AFM) were diagnosed and the surface roughness and the root mean square were found to increase with increasing thickness.

By recording the transmittance spectra (T) and absorption (A) of the wavelength range, it was found thatAbsorption increases with increasing thickness, while transmittance decreases with increasing thickness.

the energy gap of CuO films were decreased with increase thickness.

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