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Structural behavior of RF magnetron sputtered cuprous oxide (Cu_2O) films

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ABSTRACT

In this paper a Cu_2O thin films, were deposited using RF sputtering technique. Sputtering process can be defined as ejection atoms of material surface due to positive ions bombardment of (mostly) inert gas, sometimes called cathode sputtering. Then the thin films were characterized by XRD. The results obtained showed that, the thin films had a polycrystalline structure with cubic lattice unit cell. strongest peak was seen at 61.3967 degree, and FWHM was at 0.215 degree, while lattice constant was 4.26 Aº. The average grain size was 44.87 nm. While AFM analysis showed that the increasing of four samples temperature (523, 573, 623 and 673) Kelvin, led to increase of roughness average from (3.39 to 9.2) nm, and ten points height from (13.7 to 36.3). On the other hand granularity cumulation distribution charts showed that the average diameter was varied from (43.31 to 51.28) nm with grain numbers (739, to 414) respectively.

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السلوك التركيبي لغشاء اوكسيد النحاس Cu_2O المحضر بطريقة الترذيذ المغناطيسي بالموجات الراديوية

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الكلمات المفتاحية:

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الـــخُـــلاصـــة

في هذه الدراسة تم تحضير غشاء رقيق من اكاسيد النحاس Cu_2O ثم تم اجراء فحص حيود الاشعة السينية للغشاء واظهرت النتائج المستحصلة من الفحص بان الاغشية المحضرة ذات تركيب متعدد التبلور مع تركيب لشبائك خلية الوحدة ذو تركيب مكعب ، وان اعلى القمم كانت بزاوية ٦١.٣٩٦٧ درجة وكانت قيمة عرض منحنى الطيفFWHM ٠.٢١٥درجة بينما كانت قيمة ثابت الشبيكة ٤.٢٦ انكستروم ، اما معدل حجم الحبيبة فقد كان ٤٤.٨٧نانومتر. وقد تم ترسيب مجموعة اخرى من الاغشية وعددها اربعة ولكن في درجات حرارة مختلفة (٥٢٣، ٥٧٣، ٦٢٣، ٦٧٣) كلفن ، اذ تم رفع درجة حرارة حامل الغشاء الى

درجات حرارة عالية لدراسة تاثير ذلك على خشونة سطح الغشاء فاظهرت نتائج فحص مجهر القوة الذرية ارتفاع معدل الخشونة من ٣.٣٩ الى ٩.٢ نانو متر وقيمة ارتفاع النقاط العشرة من ١٣.٧ الى ٣٦.٣ نانومتر ، ومن جهة اخرى اظهرت النتائج ان التوزيع التراكمي للحبيبات المرسبة قد اظهرت معدلات متباينة لمعدل قطر الحبيبة وتراوحت بين ٤٣.٣١ الى ٥١.٢٨ نانومتر بينما تراوح عدد الحبيبات بين ٧٣٩ الى ٤١٤ حبيبة على التوالي.

1. INTRODUCTION

Cuprous (Cuprite) Oxide (Cu_2O) is one of the three main forms of Cooper Oxides[1]. The band gap of Cu_2O is ranged between 2.1-2.6 eV[2]. Cu_2O has seen to have a variety of applications such as solar cells [3], cathode in lithium ion batteries[4] and CO_2 gas sensors, semiconductors, etc [1]. Many techniques have been developed to fabricate Cu_2O thin films , For example; this includes thermal oxidation[5] , thermal evaporation[6], electrodeposition[7] spray pyrolysis [8] chemical vapour deposition [9] , sol-gel [10] molecular beam epitaxy[11] plasma deposition[12] pulsed laser deposition [13] DC and RF magnetron sputtering[14]. In this research, Cu_2O thin film was deposited by using RF magnetron sputtering which allow researcher to control sputtering power , pressure and substrate temperature, then to sputter extra thin films under different substrate temperature to study surface morphology.

2. MATERIALS AND METHODS

Cu_2O thin films were deposited as follows: Pure 99.95% copper target (5cm dia.) was cleaned with soft sanding and ethanol. The substrate was cleaned with deionized water and ethanol using ultrasonic and placed on sample stage (18.5cm dia.) at the center of chamber (30*30) cm. The cover of the chamber was closed and engaged the doorknob clock wise until tightened firmly, then the rotary vacuum was started, then turned on the pressure gauge. After reaching pressure value of 1.5*10-3 mbar, the sputtering system (13.56Hz) was turned on, the heat has been up to 423 K degree. Then Argon gas (purity 99.99%) was pumped in the chamber, until the working pressure was reached 4.5*10-2 mbar. The water chiller was turned on, RF (200W.Max) supply was turned on, loading the power up to 150 W., reducing the reflected power until reached zero to generate most effective plasma. At this stage the deposition process was started, time of deposition lasted for 40 minutes. The experiment run was ended, the system was shut down and cooled to the room temperature, substrate was taken outside of chamber. The deposited thin film was characterized with XRD to study structural behavior. The same process was repeated with different temperatures at (523, 573, 623 and 673) Kelvin, then deposited thin films were analyzed with AFM to study morphology of thin films surfaces.

3. RESULTS AND DISCUSSION

Structural Properties: thin film was characterized by XRD (SHIMADZU Japan XRD 6000), result obtained can be seen in Table (1) below.

Table (1) XRD structural parameters of Cu_2O

Compound	2 θ (deg)	FWHM (deg)	Lattice const. (nm)	G.S (nm)
Cu_2O	61.3967	0.215	0.426	44.87

Also the XRD test results (Card 01-075-4299) revealed that the Cu_2O revealed a polycrystalline (Cubic), the strongest peaks were at (2θ= 36.4352, 42.3220, 61.3967), that is equal to [hkl= (111), (200), (220)] respectively. as shown in Fig. (1)

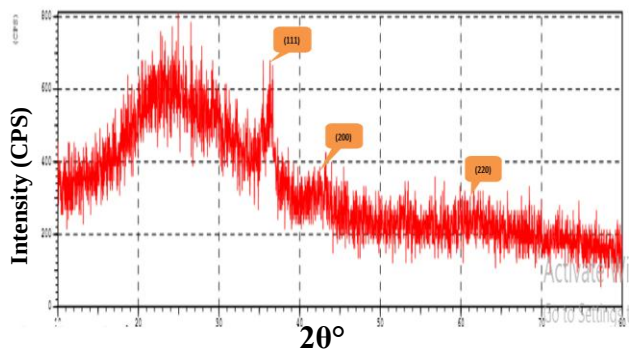


Fig. (1): XRD Patterns of Cu_2O thin film.

Average of Grain Size was calculated by Scherer's Crystallite Size Formula[15].

$$G.S = \frac{k\lambda}{\beta cos\theta} \qquad (1)$$

where k is refers to shape factor equals to 0.94. λ is the wavelength, ß is FWHM (full-width at half- maximum value) and θ is Bragg's diffraction angle.

Morphology: In order to study the effect of temperature change on structural behavior, four Cu_2O thin films were deposited on glass substrates with following parameters (working Pressure: $4.5*10^{-2}$ mbar, deposition Time: 40 min. , and applied Power: 150 Watt.), the four films were deposited in different temperatures, (523, 573, 623 and 673) K, then the samples were analyzed with AFM (SPM AA3000) to analyze surface morphology of the films. The results are shown in Table (2)

Table (2): AFM results of Cu_2O thin films prepared under different temperatures:

Sample No.	Temp. K	**Roughness average (nm)**	**Root mean square (nm)**	**Ten points height (nm)**
1	523	3.39	3.92	13.7
2	573	3.78	4.59	22.5
3	623	4.82	5.88	26.0
4	673	9.2	10.7	51.28

Also AFM images show Cu_2O films with different temperatures Fig.(2):

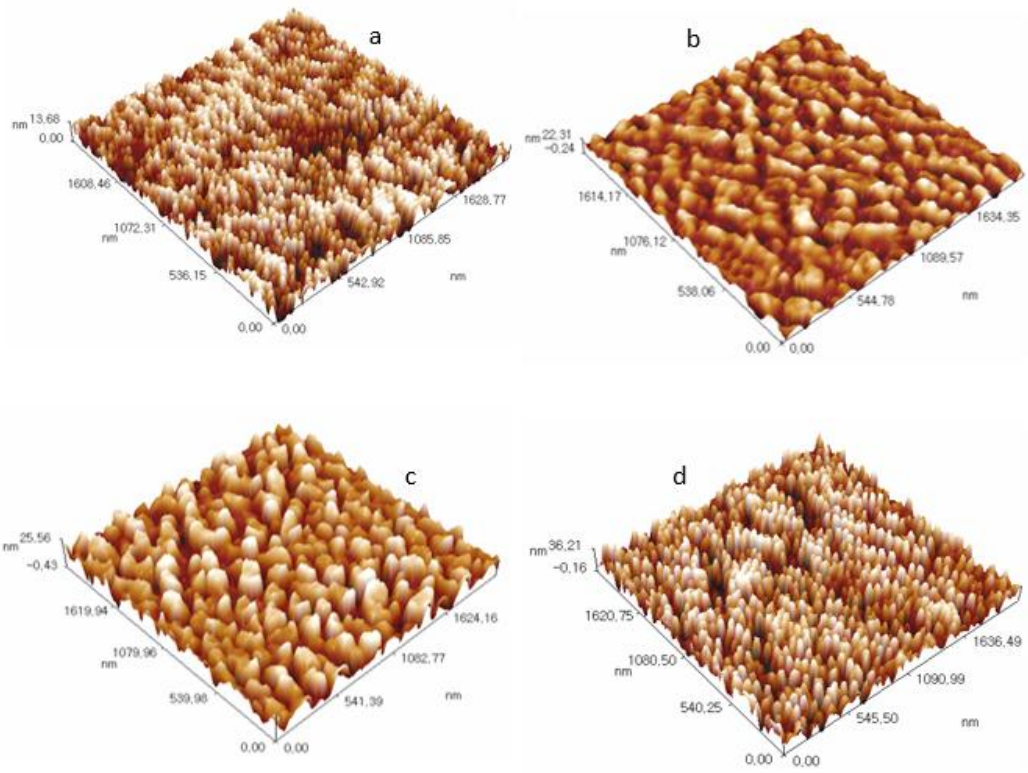


Fig. (2): AFM images of Cu_2O prepared films at a.523 k, b.573k, c. 623k, d.673k.

Also the granularity cumulation distribution data showed the average grain diameter and number of grains for each sample , as shown in Table(3)and Fig(3).

Table (3): Average diameter and number of grains per line.

Sample No.	Temp. k	Average diameter of grain nm	**No. of grains per line**
1	523	43.31	739
2	573	66.55	171
3	623	64.83	181
4	673	51.28	414

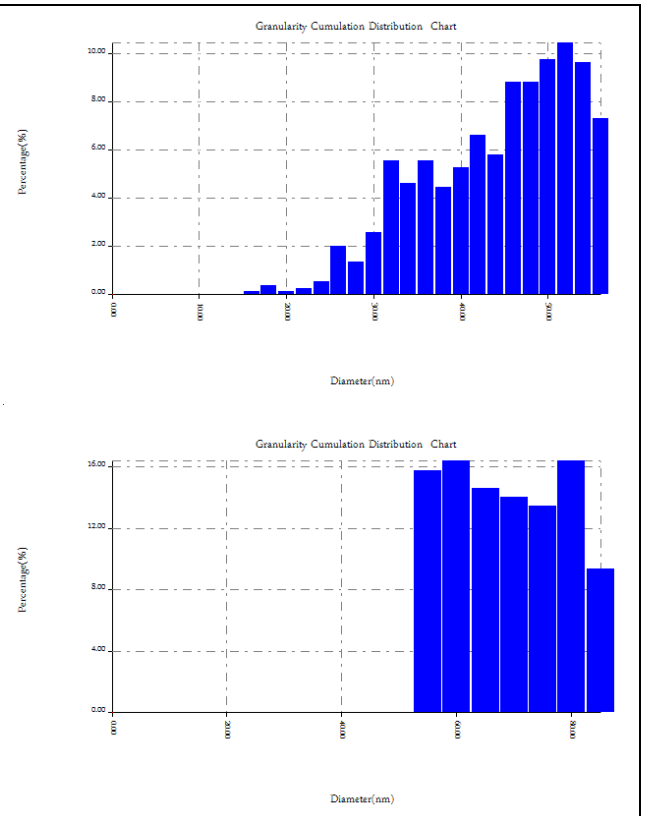
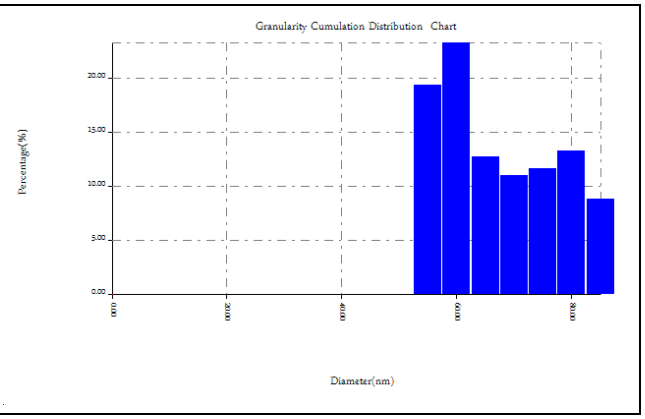


Fig. (3): Granularity cumulation distribution of Cu_2O prepared thin films above at 523k and below at 573 k.



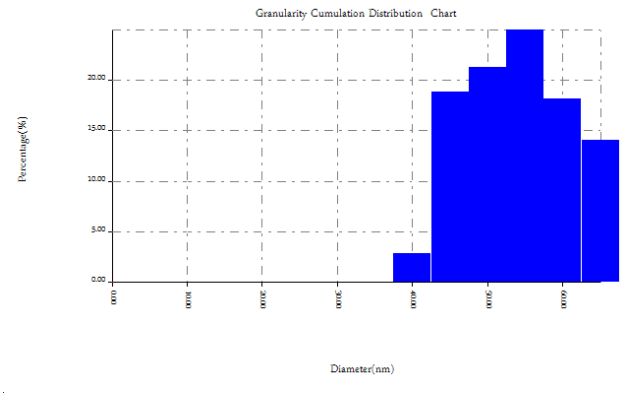


Fig. (4): Granularity cumulation distribution of Cu_2O prepared thin films above at 623k and below at 673 k.

In general it is clear from tables and images above that the roughness average and ten points height were increased when the temperature of the sample is increased.

4. CONCLUSION

Firstly Cu_2O thin film, was deposited on glass substrates using RF sputtering technique at applied power 150W., working pressure $4.5*10^{-2}$mbar , substrate temperature 423k for 40 minutes, then the thin film was characterized by XRD, the result obtained showed that strongest peak was 61.3967 degree, and FWHM was 0.215 degree, while lattice constant was 4.26 Aº, and the average grain size was 44.87 nm then four more samples were deposited with the same previous parameters, but in different temperatures, then the four samples were analyzed with AFM to study the effect of increasing temperature on morphology of surface, results showed that the increasing of temperature led to increase of roughness average. Which means at higher temperature roughness of thin film surface will increase due to increasing of grains size.

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