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Effect of the Magnetic field and duration time on Thickness and Structure of Silver Thin films Deposition by Magnetron Sputtering

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ABSTRACT

In this paper, the effect of magnetic field on thickness of silver (Ag) thin films were deposition on glass substrates by DC magnetron sputtering method of silver target were studied, with permanent and variable magnetic field. Ag thin films with (84,89,94,269,290) nm, thickness were prepared at different deposition times (10,30,60) sec. The crystalline structure of thin films was evaluated by X-ray diffraction (XRD) and the atomic force microscopy (AFM) were employed for surface morphological studies of the films. The results show that the thickness of the films increases with increases magnetic field to 250 Gauss, and when are greater than (250Gauss) the effect of magnetic field starts to decrease and be ineffective, and also the results indicate an increase of the grain size from (144.9 -276.7) nm and films surface roughness from (0.431-22.7) nm.

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تأثير المجال المغناطيسي والمدة الزمنية على السمك وتركيب لأغشية Ag الرقيقة المرسبة بالترذيذ الماكنتروني

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الكلمات المفتاحية:

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الـــخُـــلاصـــة

في هذا البحث تم دراسة تأثير المجال المغناطيسي على سمك اغشية الفضة (Ag) الرقيقة والمرسبة على القواعد الزجاج بطريقة الترذيذ الماكنتروني بالتيار المستمر (DC) الهدف الفضة ،مع مجال مغناطيسي دائم ومتغير . تم الحصول على اغشية Ag الرقيقة مع سمك nm (84,89,94,269,290) المحضرة عند أزمان ترسيب مختلف (10,30,60)sec. التراكيب البلورية الأغشية Agالرقيقة تم تشخيصها بواسطة حيود الاشعة السينية (XRD) ومجهر القوة الذرية (AFM) لدراسة مورفولوجية سطح الاغشة . اظهرت النتائج ان سمك الأغشية يزداد مع زيادة المجال المغناطيسي الى Gauss250 وعند قيم اكبر من 250 Gauss فأن تأثير المجال المغناطيسي يبدأ بالتناقص ويكون غير مؤثر، وتضمنت النتائج ايضا زيادة الحجم الحبيبي (144.9- 276.7)nm وخشونة سطح الاغشية من nm (0.431-22.7).

1. INTRODUCTION

Silver (Ag) thin films have potential applications in fields of nanosicenc and technology [1], and widely used in transparent and heat reflective layers stacks of the solar – control, applied in glazing units for building and automobiles as well as for solar energy engineering purposes for passive heat gain [2]. Silver thin films can be used for multiple purposes such as the solar cell industry ,sensors devices[3] , decrease the microbial of food and increase shelf life food[4], and it could application on electron device[5].silver thin films had been prepared by several techniques such as DC and RF magnetron sputtering , chemical vapor deposition(CVD) , pulsed laser deposition(PLD) [6], ion-assisted deposition and electron beam evaporation[7].In the present investigation ,DC magnetron sputtering was used to prepare Ag films and study its effects on thickness films. .Magnetron sputtering is one of well –developed method for thin film fabrication ,its extensive use in industrial application depends on the ability of obtaining high quality films with high value of deposition rate [8]. Dutch physicist F.Penning was the first to suggest using magnetron sputtering for the film deposition as early as 1935 , it's important not only for industrial application but also for science and technology research [9]. In a basic sputtering process , a target material to be deposition on substrate , is bombarded by energetic ions ,usually inert gas ions used ,such as argon gas (Ar) . the strong collision of these inter gas ions on the target causes the removal of target atoms which condense on the substrate as a thin film of stoichiometry similar to that of target material [10]. Magnetron sputtering systems produce a strong magnetic field near the target area which causes the mobile electrons to spiral along magnetic flux lines near the target . this arrangement confines the plasma in near the target area without causing the damage to the thin films being formed on the substrate and maintains on thickness uniformity of deposition thin film [11]

2. EXPERIMENTAL

2-1 Material preparation

In the first step ,Ag films were deposition on substrates by using DC magnetron sputtering using SPC-12system compact plasma sputtering coater (MTR Corporation, CA 94804, USA) ,and by addition coil to product variable magnetic field and permanent magnetic field, before the deposition process the glass substrates cleaned with water and washing powder and then placed in a glass container and flooded with distilled water and placed in a bath device ultrasound for period of (15min) and ethanol with a purity 96%,extract and dried well by using special cleaning lens paper to be ready for use . The sputtering target was the metal of silver with purity of 99.9%. Before deposition process the deposition chamber has been evacuated to base pressure of 4×10^{-2} mmHg .the sputtering gas used was argon (Ar 99.9%)into the chamber ,the deposition pressure was 8×10^{-2} mmHg and the deposition time for all films was (10,30,60 s) ,the distancebetween the target to substrate was (4cm). The thickness of Ag films was 269,290nm).

In the second step , the method of sputtering without magnetic field at the same deposition conditions for deposition Ag filmswe used , where the thickness of thin films was (84,89,94 nm) in this method . The crystal structures of thin films was analysis by X-ray diffraction (XRD) using the device carries the following specifications (TYPE: XRD - 6000, SHIMADZU, JAPANESE ORIGIN, TARGET: Cu Kα, $\lambda =$ (1.5406) Å, Speed: (5) deg / min, voltage: (40) KV, current: (30) MA, range (2θ): 30-100 deg) . For surface morphological studies of the films the atoms force microscopy (AFM) used from type(SPM-AA3000, contact, mod, Angestrom, Advanced Inc., US).

2-2 Thin films thickness measurements

The thickness of Ag thin films were measured by using an optical interferometer method employing He-Ne laser (632.8)nm wavelength with incident angle 45^0 as shown schematically in figure(1). This method depends on the interference of the laser beam reflected from thin film surface and the substrate , the films thickness(t) was determined using the following formula [12]

$$t=\frac{\lambda}{2}\cdot\frac{\Delta X}{X}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where t: is the thickness of the thin film, λ: is the wavelength of laser light (632.8)nm, ΔX:is the fringe width, X:is the distance between two fringes.

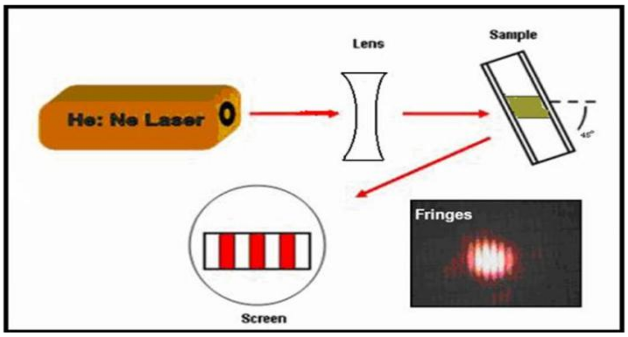


Figure 1: The schematic diagram of the film thickness measurement.

3. RESULTS AND DISCUSSION

In this paper several tests used to determine the effect of Magnetic field on thin films thickness , as well as the effect increasing the deposition time on the structural and morphological properties of Ag thin films prepared by DC magnetron sputtering and without magnetron sputtering on the glass substrate was characterized by.

3-1 X-ray diffraction (XRD) :

Figure 1 shows the X-ray diffraction pattern of Ag thin films deposition on glass substrates and different with thicknesses (t=269 nm, t=290 nm) . the polycrystalline Ag films can be observed and the peak namely the (111), (200), (220), (311) illustrates in fig.1,according to ICDD numbered card (00-004-0783), cubic type the (111) Ag peak intensity was larger than that of the other peaks because the (111) direction to Ag films has lowest surface energy , and we calculate the lattice constant of the Ag films prepared for installation cube from equation (2) [13]

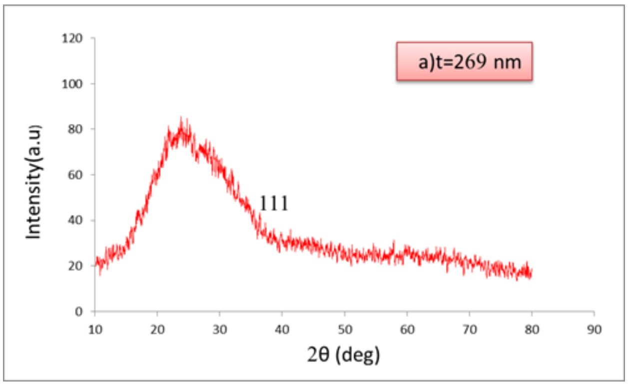
$$d_{hkl}=\frac{a}{\sqrt{h^2+k^2+l^2}}\ldots\ldots\ldots\ldots(3)$$

Where:(hkl) Miller coefficients, a:lattice constant, d_{hkl} :distancebetween the plans(hkl). The average crystallite size to the prevailing direction (111) was calculated from the equation(1). while the average grain size was calculated from the equation(3) [14].

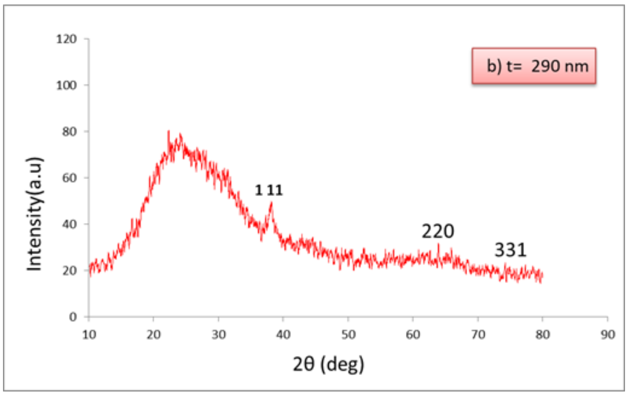
$$D_{av}=\frac{0.09\,\lambda}{B\,COS\theta}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where D_{av}:is the grain size , λ:is the wavelength of cu-kα radiation used(λ =1.5406 Å), □: is full width half maximum intensity (FWHM),θ: is the Bragg angle

we notice that average grain size cause increases thickness of films and also leads to increase the surface roughness ,and lead to increasing the homogeneity of the film as shown in Table(1).This result corresponds with research[6]



(a)



(b)

Figure 2: The XRD patter of as deposition Ag films on glass substrate, a) without magnetic field, (b) within magnetic field.

Figure 3 shows the effect of magnetic field on the thickness of silver thin films, we note that with increasing magnetic field ,the thickness of thin film will increase , because the magnetic field working on confined electrons closer to the cathode , on the other hand , lead to increase the path length of the electron around the cathode ,this type of electrons motion increase the collision probability between the electrons and the atoms , therefore, the ionization rate increase the resultant effect is that the plasma density become very high in the vicinity of the cathode due enhanced ionization rate with increased plasma density , therefore, the sputtering rate also increase leading to increase the thickness of thin film with magnetic field.

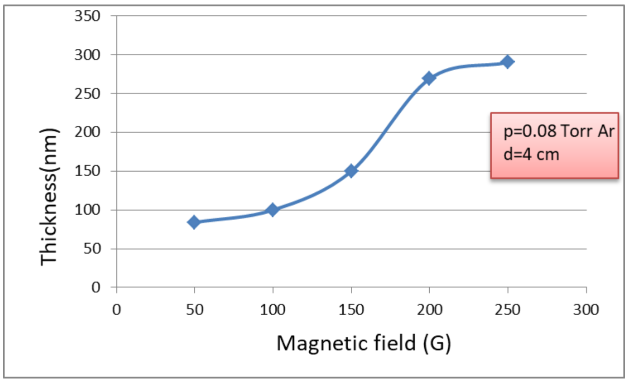


Figure 3: effect magnetic field on the thickness of thin film Ag.

Table 1: values structure from XRD for prevailing direction(111) of silver thin films.

sample Ag	2θ(deg)	2θ(deg) ICDD	d(A)	hkl	$a_0(A^0)$	The Average grain size (nm)
sample a t=269nm	38.8047	38,1164	2,359000	111	4.0875	144.97616
	44.1312	44,2773	2,044000	200		
	64.28	64,4257	1,445000	220		
	77.4492	77,4723	1,231000	311		
sample b t=290nm	38,1164	38,1164	2.359976	111		
	44,2773	44,2773	2.043882	200		
	64,4257	64,4257	1.445113	220		
	77,4723	77,4723	1.230897	311		

Surface morphology of the Ag films was analysis by AFM , deposition on glass substrate by DC magnetron sputtering , fig.4 show two and three- dimensional AFM images with different thickness ,where we note that the small particles grown on substrate surface , can be seen the pyramidal morphology, the surface roughness will increase, when thickness increase and also we note increase the mean root square (RMS) with increase thickness and this results corresponds to the researcher [15], as show in Table2.

Table 2: result AFM of silver thin films, root mean square and roughness.

sample	Roughness Average (nm)	Root mean square (nm)
t=84	0,431	0,525
t=89	5,91	6,93
t=94	7,04	8,86
t= 269	13,4	15,5
t=290	22,7	26,1

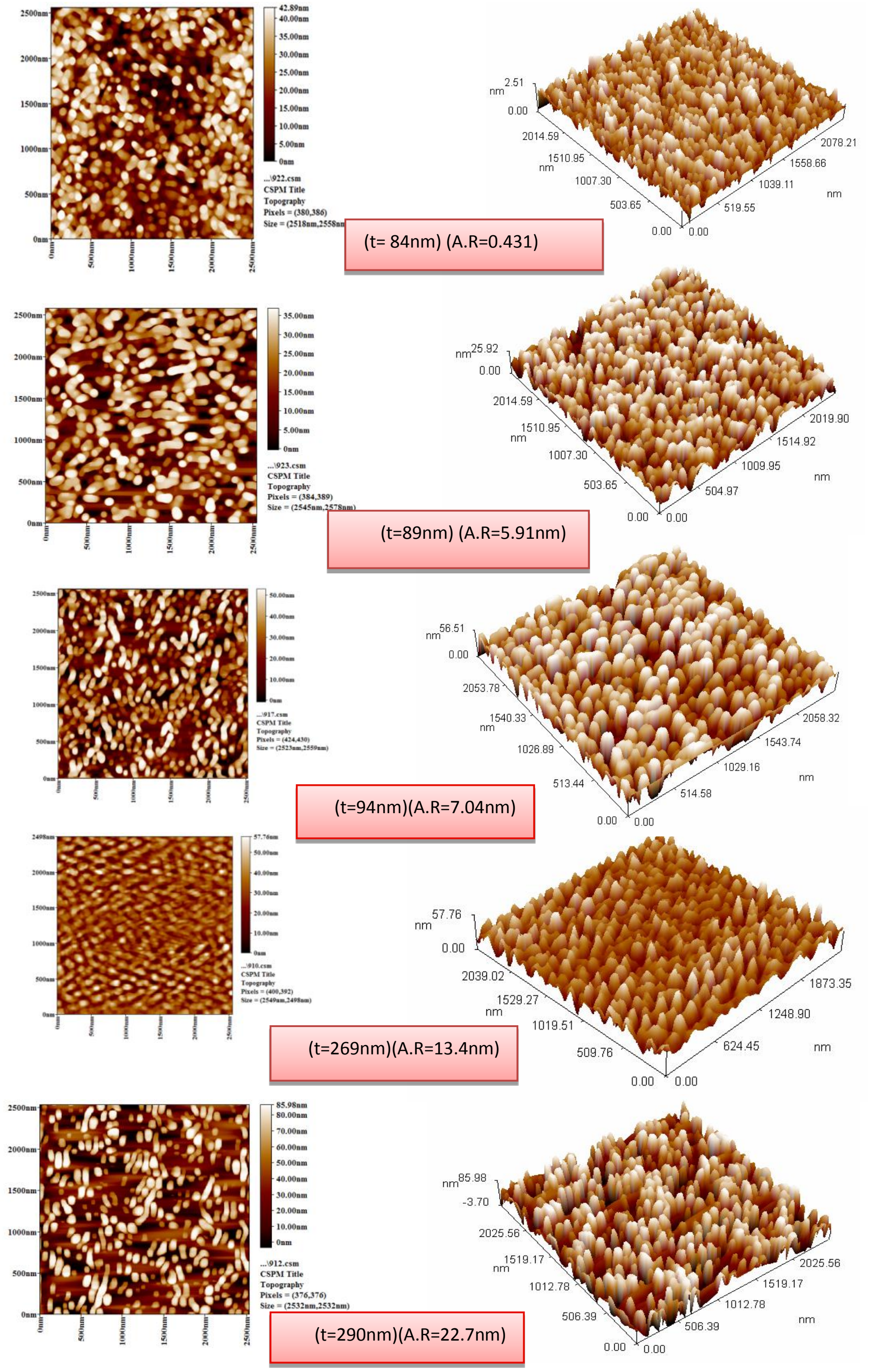


Figure 4: 2D and 3D AFM images of Ag films deposited on glass substrate.

4. CONCLUSIONS

In this study, Ag thin films were deposited on glass substrate by using DC magnetron sputtering method and argon plasma of pure silver target, the structure of silver films was analysis by XRD, AFM. The XRD results show that Ag films havepolycrystalline structurewith characteristic peaks of Ag, and only the face – centered cubic structure was found, thelattice constant decrease a with increase thickness of thin film, whilethe average grain size increases with increases thickness . AFM results show that surface roughness and mean root square will increase by increasing thickness, we observed that with increasing magnetic field, the thickness of thin film will increase. Aswell as magnetic field reach to 250 Gauss, while greater than (250Gauss) the effect of magnetic field starts to decrease and be ineffective, in addition, the homogeneity of the film increased and lead to improve qualities.

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