Preparation of Al_2O_3 thin films by magnetron sputtering system and study their optical and structural properties

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Abstract

In this research we prepared (Al_2O_3) films on substrate of glass by using plasma magnetron sputtering technique. We studied the structural and optical properties for the prepared films with different thicknesses. The results of XRD showed that the thin films had a polycrystalline structure with Rhombohedra (Trigonal)lattice unit cell. Surface morphology and the roughness of the prepared films were diagnostic by atomic force microscope (AFM). Where the results showed that the roughness increased from (11-24.4)nm with increasing thickness from(60-308)nm. optical properties of the prepared films with in(300-1100)nm showed that the absorption of the films decreased with increases of wavelength for all thicknesses, and transmittance of the films increased with increases of wavelength for all thicknesses. The results of optical measurement showed that the optical energy gap for the prepared films increased from (3.65-3.95)eV with increases thickness from (60-308)nm.

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Keywords: Thin films, Magnetron sputtering, Optical properties, magnetic field.

تحضير اغشية Al_2O_3الرقيقة باستخدام منظومة ترذيذ ما كنتروني محلية الصنع ودراسة خصائصها البصرية والتركيبية

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الخلاصة

في هذا البحث تم تحضير أغشية (Al_2O_3) على أرضيات من الزجاج ,باستخدام طريقة الترذيذ الما كنتروني البلازمي. تم دارسة الخصائص التركيبية والبصرية للأغشية المحضرة ولأسماك مختلفة ،نتائج حيود الاشعة السينية (XRD) أظهرت أن الاغشية المحضرة ذات تركيب متعددة التبلور مع تركيب لشبائك خلية الوحدة ذات تركيب (Trigonal). مورفولوجيا وخشونة السطح تم تشخيصها باستخدام جهاز مجهر القوى الذرية(AFM), حيث ان النتائج اظهرت ان الخشونة ازدادت من nm(11-24.4)مع زيادة السمك من nm(60-308). الخصائص البصرية للأغشية المحضرة

ضمن المدى من (300-1100)nm أظهرت بأن امتصاصيه الأغشية تقل بزيادة الطول الموجي ولكل الاسماك المحضرة. ونفاذية الأغشية ازدادت بزيادة الطول الموجي لكل الأسماك المحضرة . نتائج القياسات البصرية أظهرت أن فجوة الطاقة البصرية للأغشية المحضرة تزداد من (3.65-3.95)eV عند زيادة السمك من (60-308)nm.

الكلمات المفتاحية: الاغشية الرقيقة، الترذيذ الماكنتروني، الخصائص البصرية، المجال المغناطيسي.

1. Introduction

A thin films is a layer or several layers of specific atoms that do not exceed 1µm [1-3]. Their finite thickness and the large surface-to-volume ratio give them a unique physical structure [4].The thin layer has several advantages, including Rectifier, Capacitor and Transistors .They are also used in the manufacture of different components like Integrated Circuits ,Photocopying, regular, thermal mirrors, reflective and non-reflective coating, optical filters and detectors. Also it uses in the digital computer industry because of its small size and light weight[1,5,6,7] because of the expansion of applications of thin films and use of multiple ways of deposition, the methods of film deposition are generally classified into two methods: physical methods and chemical methods [3,8] .

Sputtering or Physical Vapor deposition(PVD) is one of the physical methods, to obtain a coating of a specific specification in an appropriate vacuum medium [9].When the surface of a material is subjected to bombardment with particles with sufficient energy to separate atoms from the surface of the material and make it leave the surface causing erosion of the target surface. This process is called **sputtering** [9,10]. These process can be done by Generating of a magnetic field supplied from coil as shown in the figure (1).

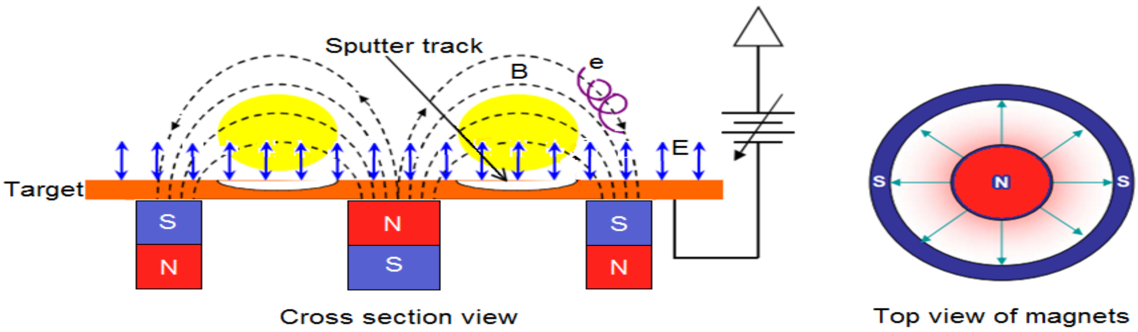


Figure (1): The composition of the magnet and the lines of the field in the typical magnetron system [11]

Magnetic field improve ionization in two ways:

1- by increasing the probability of collisions of electrons with argon atoms.

2- Increasing the length of the electron path, by limiting the electrons near the target area. [11] Without the magnetic field, many electrons lose their recombination at the walls This is the basic idea of magnetron sputtering[12]. In order to enhance the retention of electrons near the target and increase ionization efficiency, the magnet is included in the source of the sputtering. Magnets in the following form capture electrons with spiral orbits around the magnetic field lines [11].

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 made 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, after Certain voltage(205v) is 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) to the desired film [9].

In this research ,thin films of Al_2O_3 were prepared by using magnetron sputtering technique and the structural and optical properties were studied.

3. Results and discussion

The sample of Al_2O_3 (308) nm, sample were examined to identify the crystalline structure of the film using XRD diffraction technique by (XRD- 6000 Shimadzu) . In Figure 2, it was found that the structure of the films have a polycrystalline structure and comparing the results with the standard card with number(00-010-0173) that the films with phase α-rhombohedra (Trigonal),this result agreement with[13] where peaks sites note at(2θ=43.76) for plane (113), and the preferred trend of growth was at the plane (113) These results are in agreement with [14,18] relatively consistent with[16,17] in 2θ.

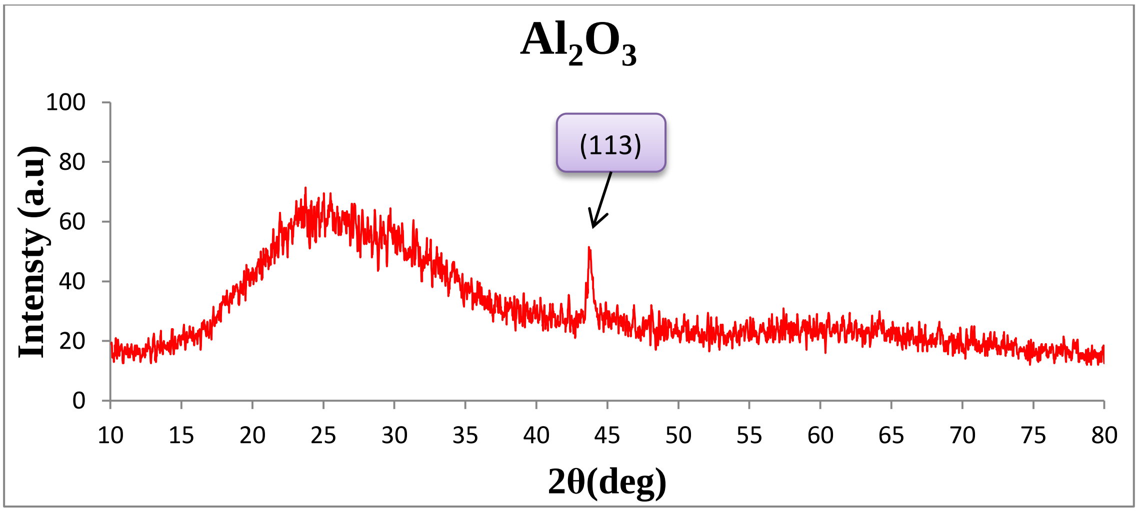


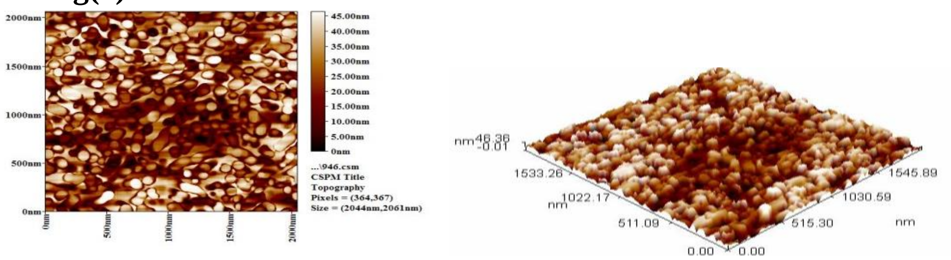
Figure (2): X-ray diffraction pattern of Al_2O_3 films with (308 nm) thickness.

The topography of the surfaces of the prepared films and the extent the effect of increasing the thickness of the Al_2O_3 films were studied using the atomic force microscope, its type (SPM AA3000), and the ability to photograph and analyze these surfaces to give the exact statistical values of Roughness based on the root mean square of roughness (RMS). (AFM) effect of increasing thickness on a surface roughness (RMS). (AFM) measurement of increasing thickness on a surface Prepared films, where the square root of the mean roughness (RMS)increased from (12.7,19.2 ,22.5 , 28.5). The roughness was nm (11,16.4,19.2,24.4) and corresponding to films (60,110,193,308), respectively, due to the increase in films, this result agreement with[13], and shown in the Table (2).

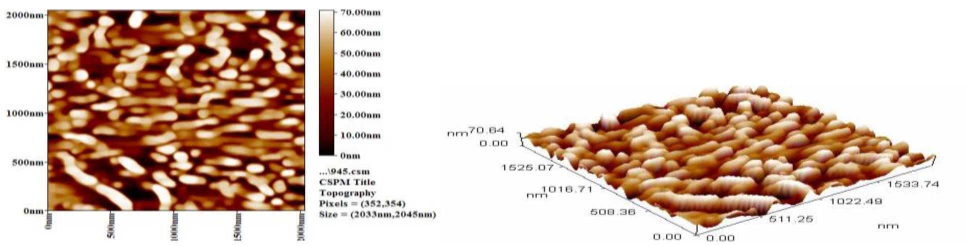
Table (2) shows the values of thickness, root mean square and roughness.

Sequence	Thickness nm	root mean square nm	Roughness nm
1	60	12.7	11
2	110	19.2	16.4
3	193	22.5	19.2
4	308	28.5	24.4

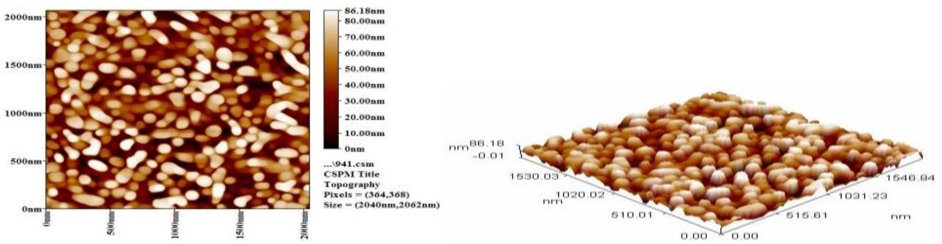
And as the fig(3)



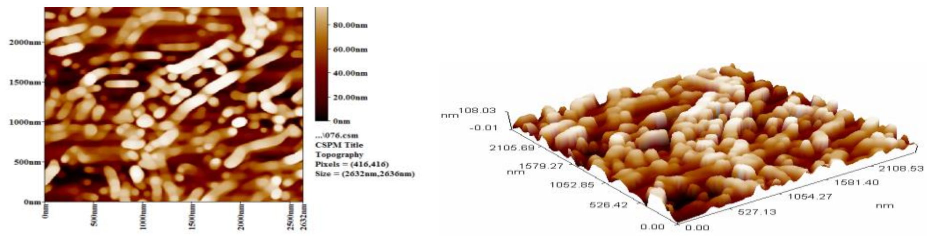
(Al_2O_3)(A.R=11nm) (t=60nm)



(Al_2O_3)(A.R=16.4nm) (t=110nm)



(Al_2O_3) (A.R=19.2 nm) (t=193)



(Al_2O_3)(A.R=24.4nm) (t=308nm)

Figure (3): Atomic Force Microscope (AFM) images of Al_2O_3 films.

The absorption and transsmation spectrometry measurements were performed within the wavelength range (300-1100nm) of the prepared films, by using(UV-Visible 1800) Through this spectrum, the optical energy gap and optical constants were calculated for all films. The absorption Coefficient (α) was calculated. The absorption factor (A) ,transsmation factor (T).

The optical energy gap was calculated for direct (or indirect) transmission of the films using the equation[19]

$$\alpha h\nu = B(h\nu - E_g^{opt})^r \quad \ldots\ldots(1)$$

where:

α: absorption coefficient, B: constant depends on the properties of both valence and conductivity, r: exponential coefficient depends on the type of transition, $h\nu$:photovoltaic energy, E_g^{opt}: Optical energy gap

If transition is directly allowed (r = 2), whereas transition is directly forbidden to (r = 3/2) $(\alpha h\nu)^2$ and photon energy and extra polated the straight line of the curve to cut the photon energy axis at point α=0. We obtain the value of the optical energy gap for the allowed direct transmission through the cut point. The optical energy gap of the prepared films with thickness (60, 110, 193,308)nm was (3.7, 3.75, 3.9, 4 eV), respectively, this result agreement with[21] from which it can be seen that the value of the energy gap has increased, because increased the crystallization of the material and increased particle size, thereby reducing local levels near the valence and conduction bands, thereby increasing the optical energy gap. The values of the optical energy gap for the direct transmission blocked for all films were found to be similar to those of published research and different preparatory techniques [21].and Relatively consistent with [22].

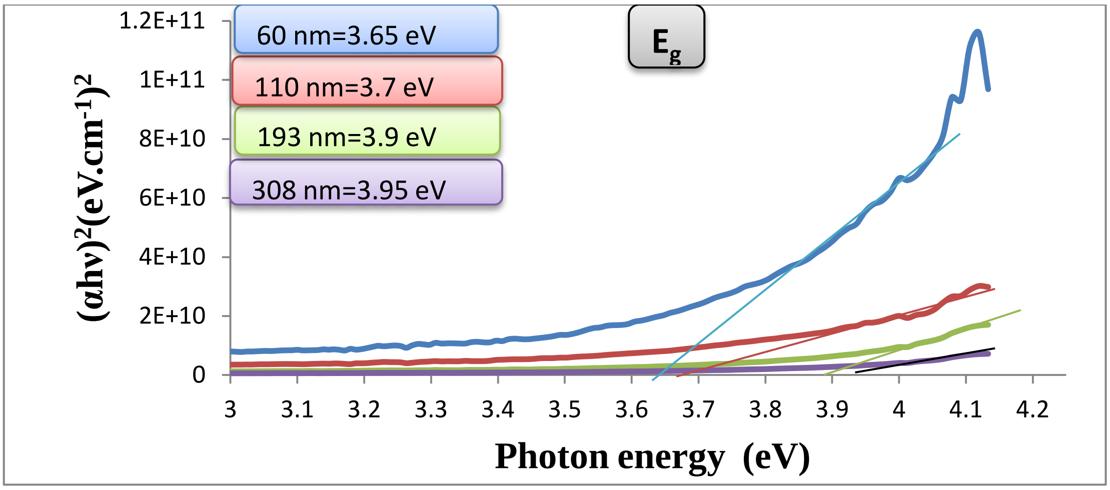


Figure (4): Optical energy gap of Al_2O_3 thin films.

The absorption coefficient was calculated from equation[27]

$\alpha = 2.303\ A\ /\ t$ .... (2)

Where : A: film's absorption

t: Thin film thickness

Figure (5)shows the change of the absorption coefficient as a function of the wavelength of the prepared films. Decreased absorption coefficient values can be attributed to increased thickness, which reduces the optical energy gap and thus reduces the absorption of the fallen radiation by increasing the crystallization of the material .

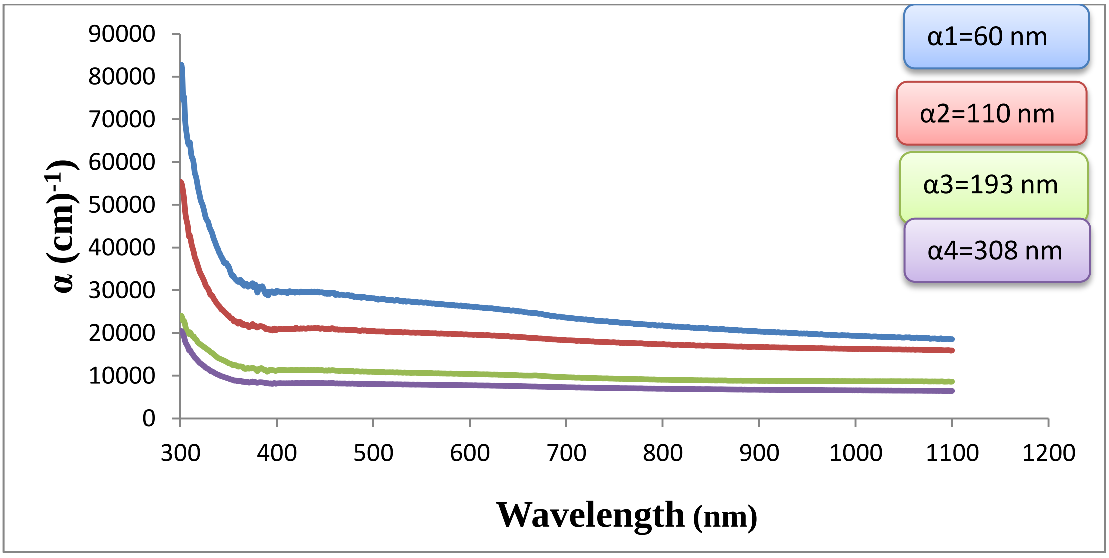


Figure (5): Absorption coefficient as a function of the wavelength of the prepared films.

Figure (8) shows the transmittance spectrum of Al_2O_3 films and multiple thickness . note that films transmittance increases with increase wavelength , which is consistent with published researches[20,24].

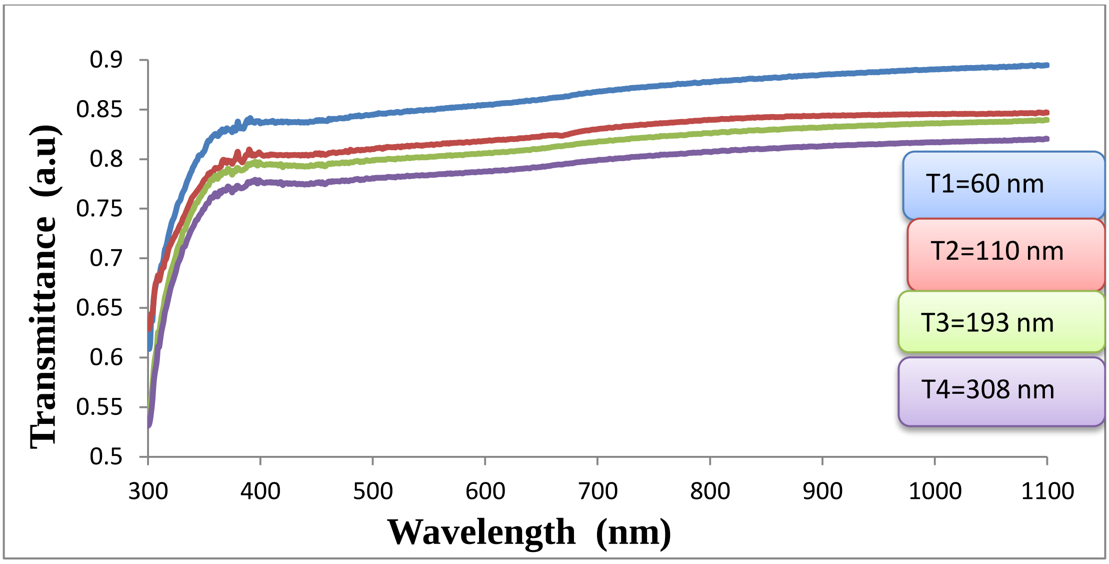


Figure (6): The transmittance spectrum of Al_2O_3 films with multiple thicknesses.

Figure (7) shows that the absorbance spectrum is increased with increasing thickness, and this is consistent with the published research [25].

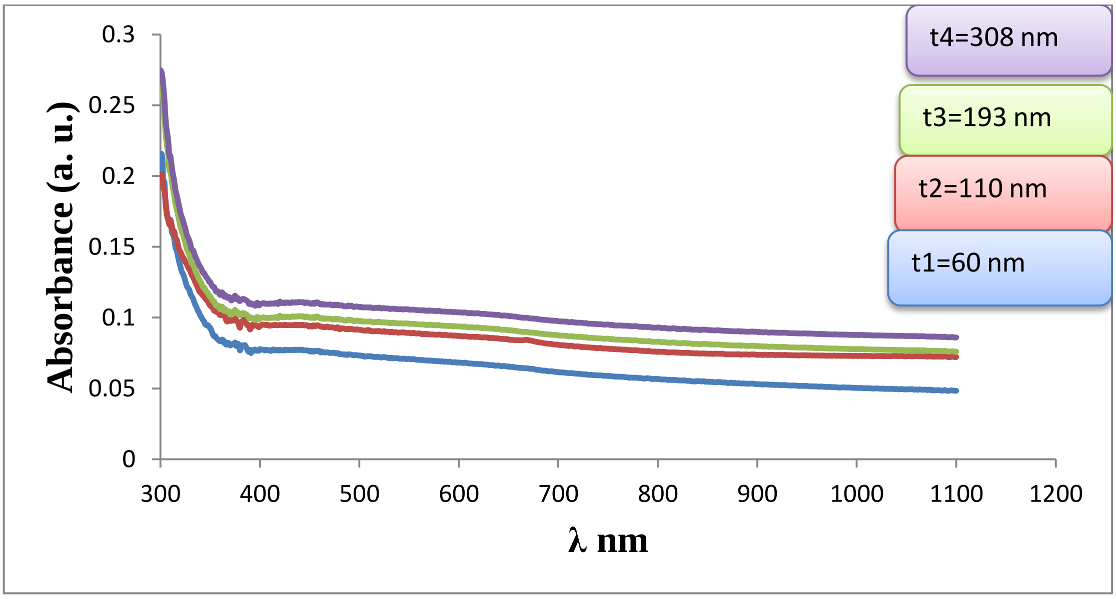


Figure (7): The absorbance spectrum of Al_2O_3 films and multiple thicknesses.

4. Conclusions

The locally manufactured system is suitable for the deposition of thin nanoparticles. we can product Al_2O_3 films that semiconductor from conductor mate.

α-Al_2O_3 films were found to be polycrystalline , Rhombohedra (Trigonal), and the preferred tendency for growth (113).

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 that:

Absorption increases with thickness, while transmittance decreases with thickness.

The energy gap of Al_2O_3 films were increased with increase thickness.

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