Optical Properties of Obliquely Evaporated Manganese Films

Salam A.R. Ibrahim
Ra'ad Saied Al-Rawie
Ibrahim R. Agool
Dept. of Physics / Collage of Science / University of Al-Mustansiriyah

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Abstract

The Manganese (Mn) thin films of obliquely and normal deposited were prepared by using thermal evaporation method at pressure 10^{-5} torr on glass substrate at room temperature. The optical properties of normal and obliquely deposited films are studied and also the effect of deposition angle on these properties. The deposition angle has great influence on the increase of the absorbance, absorption coefficient, extinction coefficient and imaginary dielectric constant and the decrease of the transmittance, reflectance, refractive index and real dielectric constant.

Keywords: thin films, oblique deposition, self shadowing effect

Introduction

The oblique deposition angle is an advanced physical vapor deposition technique which is used to fabricate high functional thin films with engineerable columnar morphology [1].The morphologies resulting from this method of vapor deposition have been noted and studied for their unique anisotropic mechanical, optical and electrical properties [2]. Films produced by this method of deposition exhibit a columnar microstructure consists of network of low density material that surrounds an array of parallel rode-shaped or columnar regions of high density [3].In common oblique deposition angle system, a uniform deposition flux is obtained by evaporation techniques such as thermal evaporation, sputtering, electron –beam evaporation and laser beam ablation. The deposition flux approaches a stationary substrate at angle θ (with respect to the substrate normal) [4].This method is a sophisticated technique to fabricate engineered nanostructure thin films for next generation nanodevices [5].The oblique deposited films have various applications such as optical radiation plates, circular polarization filters, wide band antireflection coatings, broadband high reflectors, three dimensional photonic crystals, photonic and biomedical devices and micro sensors [6].

Experimental Work

Pure Manganese powder (99.99%) is used .The Mn thin films were prepared by thermal evaporation method using high vacuum system (Edward Speedvac Unit E306), were placed into molybdenum boat and evaporated by resistive heating on glass substrate which has dimensions (1.25x1) cm^2 with varying angles of deposition. The transmittance and absorbance spectra of Mn films is taken at room temperature for wavelength range (300-900)nm by using the UV-Visible recording spectrometer (UV-1650PC) made by Philips, The thickness of the films is (90 nm) which is measured by weight method by using the following equation[7] (where the thickness is kept constant with varying deposition angle):

$$t=(m/2\pi\rho r^2)\cos\theta \qquad \text{----------------------------(1)}$$

Where:
t : thickness of the film .
ρ : density of the material that will be evaporate.
r : distance between boat and substrate.
θ : deposition angle.

The absorption coefficient is calculated by using the equation [8]:

$$\alpha= (2.303\ A) / t \qquad \text{---------------------(2)}$$

Where:
α: is the absorption coefficient.
A: is the absorbance of the film.
t: is the thickness of the film.

The extinction coefficient is calculated by using the equation [9]:

$$K_o = \alpha\lambda / 4\pi \qquad \text{--------------------(3)}$$

The real and imaginary dielectric constant are calculated by using the following relations [10]:

$$\varepsilon_1= (n^2-K_o^{\,2}) \qquad \text{--------------------(4)}$$
$$\varepsilon_2 = (2\ n\ K_o) \qquad \text{--------------------(5)}$$

Results and Discussion

Figure (1) shows the XRD of Mn thin film deposited at θ=0˚, the deposition rate was 15 A˚/sec (the substrates are perpendicular to the direction of vapor beam) and thickness 90 nm, The film exhibits a polycrystalline nature having (330), (332) and (510) planes with respect to $2\theta_\beta$ = (43.04˚), (47.71˚) and (52.07˚) and this agrees with (ASTM)(file number 33-0887) as shown in table (1).

Figure (2) shows the relation between transmittance and wavelength for different deposition angles. The transmittance is low for wavelength range (300-590) nm and it increases slowly for wavelength range (590-900) nm. It is noticed that the transmittance of the films is decreased with the increase of deposition angle. The formation of columns and voids in obliquely deposited films increases the ability to trap the incident rays and this will increase the absorbance and decrease the transmittance [11].

Figure (3) shows the relation between the absorbance and wavelength for different deposition angles. The absorbance is high for wavelength range (300-590) nm and it decreases slowly for wavelength range (590-900) nm, it is noticed that the absorbance is increased with the increase of deposition angle and also there is a shift in absorbance toward long wavelengths with the increase of deposition angle. The increase in absorbance in these films can be explained on the basis of "self-shadowing effect", it is postulated that in the initial stages of film formation a random distribution of small crystallite acts as a nucleus for further growth, thus the region behind the crystallite is prevented from receiving material vapor because this region is in the shadow of the crystallite. Therefore the crystallite grows into a column, the area behind it is left vacant as far as its shadow extends[3].

Figure (4) shows the relation between absorption coefficient and photon energy with different deposition angles.

We notice that the absorption coefficient increases with the increase of deposition angle. This increasing in absorption coefficient is because its value is proportional to the value of absorbance.

The physical significance of (K_O) is best expressed by the fact that the intensity falls to ($1/e^{4\pi ko}$) of its initial value in going the distance through the medium. The extinction coefficient (K_o) is directly related to the absorption of light, figure (5) shows the relation between extinction coefficient and wavelength with different deposition angles.

We notice that the extinction coefficient value increases with the increase of deposition angle for all wave lengths and this agrees with Shishoda[12]. The extinction coefficient is related with absorption coefficient value which can be seen in equation (3).

The complex dielectric constant (ε) consists of real dielectric constant (ε_1) and imaginary dielectric constant (ε_2) where real part (ε_1) is the normal dielectric constant and imaginary part (ε_2) represents the absorption associated with free carriers[13].

Figure (6) shows the relation between (ε_1) and wavelength with different deposition angles, we notice that the real dielectric constant decreases with the increase of deposition angle for all wavelengths and this can be cleared from equation (4) where is the value of real dielectric constant is inversely proportional to the value of extinction coefficient. Figure (7) shows the relation between imaginary dielectric constant and wavelength with different deposition angles, the imaginary dielectric constant increases with the increase of deposition angle for all wavelengths, the increase of imaginary dielectric constant is related to the increase of extinction coefficient which increases with the increase of deposition angle.

Conclusion

From this work, we notice the great effect of deposition angle on the optical properties of Mn films, where the absorbance, absorption coefficient, extinction coefficient and imaginary dielectric constant are increased by the increase of the deposition angle, while the transmittance and real dielectric constant are decreased. The increase of absorbance will help us to fabricate efficient detectors with wide spectral range of detection in the studied spectrum. By changing deposition angle, we can control the properties of the material without using other methods to control these properties such as doping or thickness changing which are economical costs us more than our method.

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Table No. (1): Comparison between $2\theta_\beta$ of XRD and $2\theta_\beta$ of (ASTM)

(h k l)	$2\theta_\beta$ (XRD)	$2\theta_\beta$ (ASTM)
(330)	43.04°	43.01°
(332)	47.71°	47.68°
(510)	52.07°	52.10°

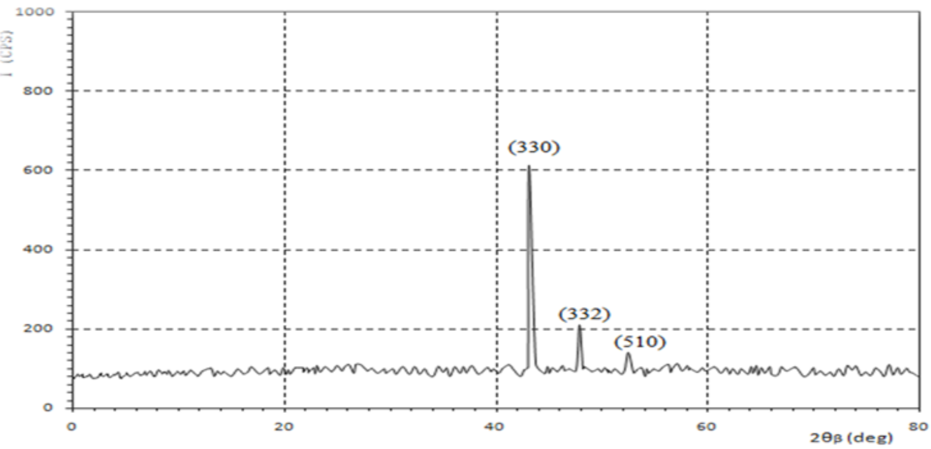

Figure No.(1) : XRD of Mn film deposited at θ=0˚

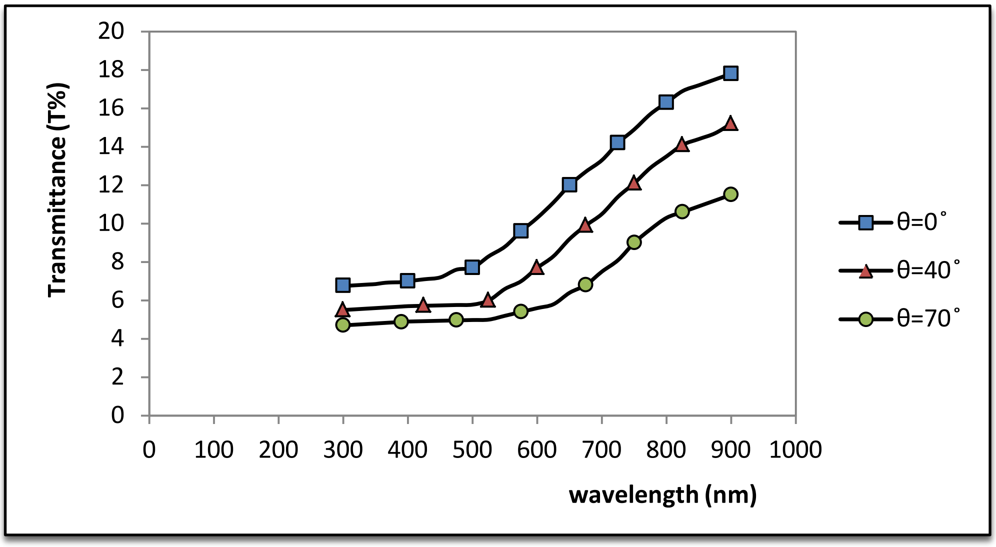

Figure No.(2) Relation between transmittance and wavelength with different deposition angles

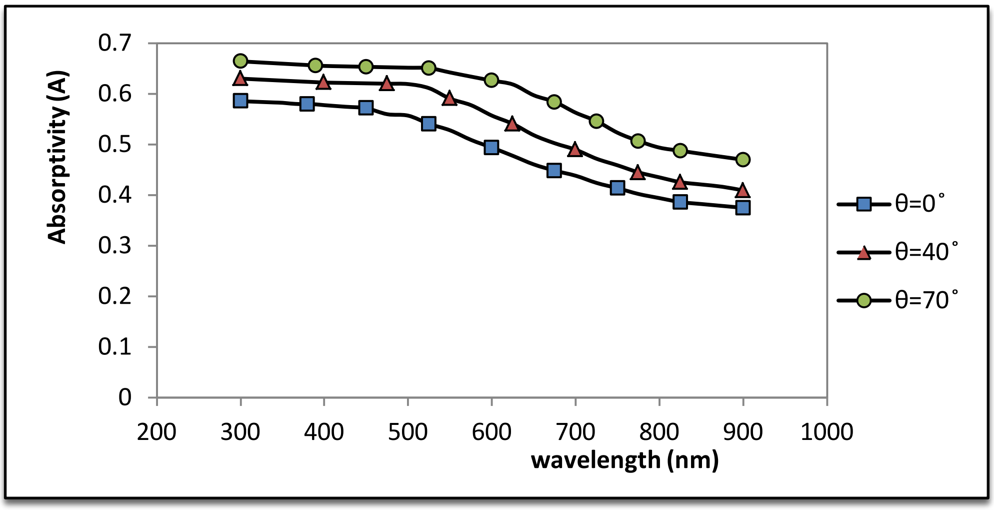

Figure No.(3): Relation between Absorbance and wavelength with different deposition angles

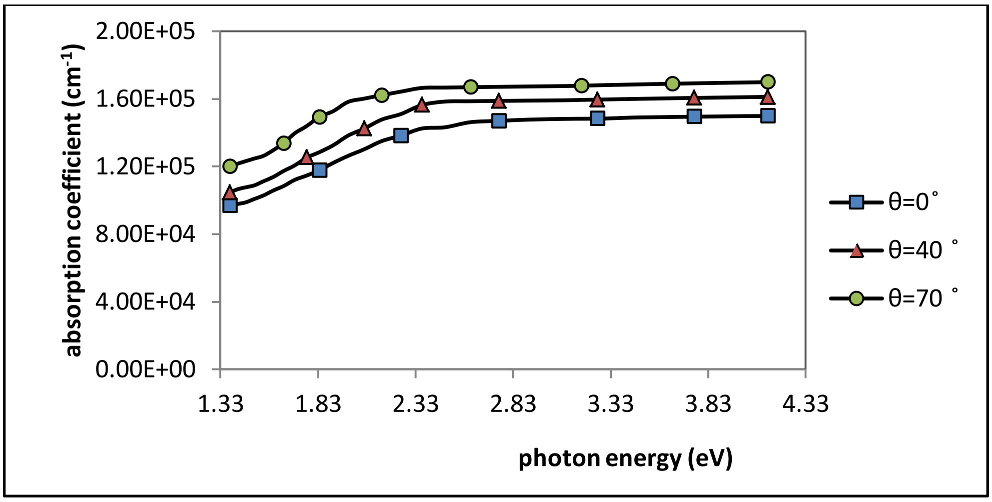

Figure No.(4): Relation between absorption coefficient and photon energy with different deposition angles

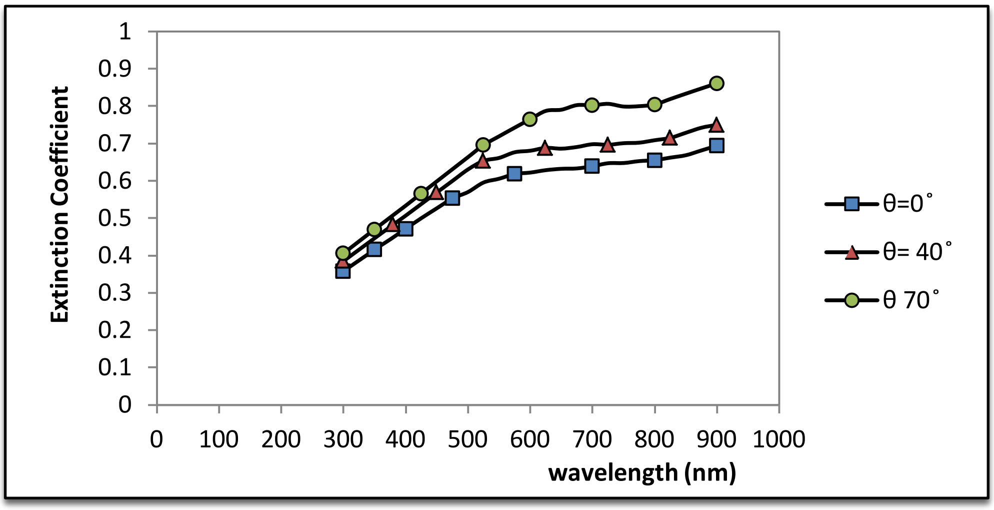

Figure No.(5) Relation between Extinction Coefficient and wavelength with Different deposition angles

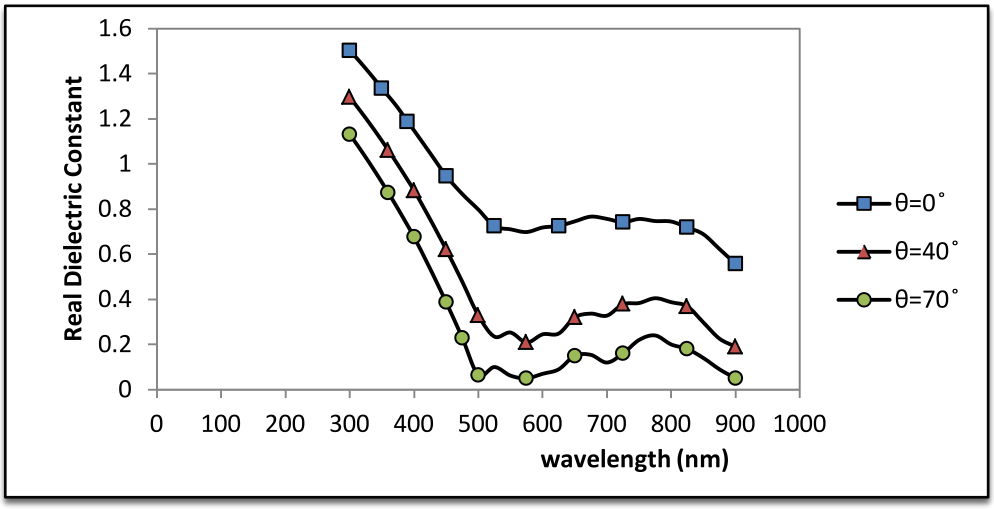

Figure No.(6): Relation between Real Dielectric constant and wavelength with different deposition angles

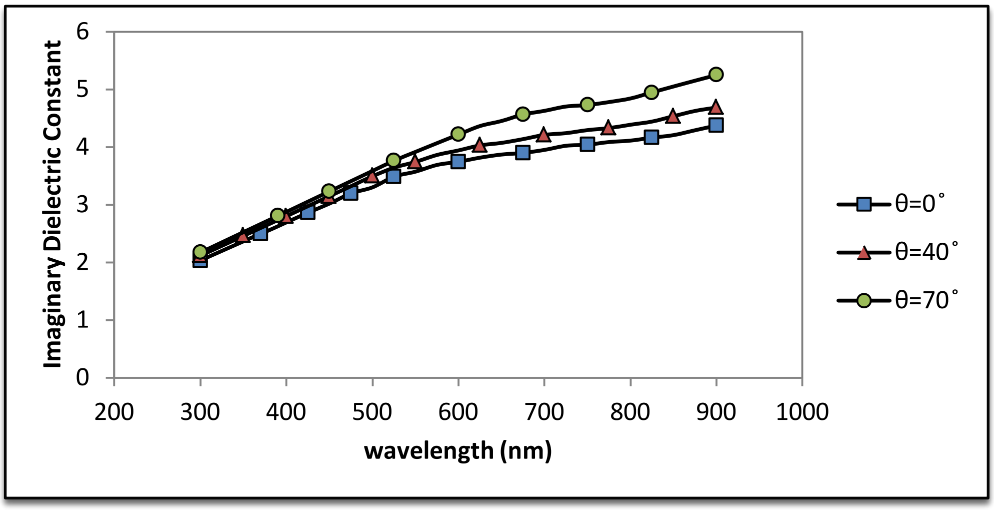

Figure No.(7): Relation between Imaginary Dielectric constant and wavelength with different deposition angles

الخصائص البصرية لأغشية المنغنيز(Mn) المرسبة بشكل مائل

سلام عبد الرزاق ابراهيم
رعد سعيد الراوي
ابراهيم رمضان عاكول
قسم الفيزياء/ كلية العلوم / الجامعة المستنصرية

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الخلاصة

في هذا البحث حضرت أغشية المنغنيز بشكل عمودي ومائل بطريقة التبخير الحراري على قواعد زجاجية وفي درجة حرارة الغرفة. وتمت دراسة الخصائص البصرية لهذه الأغشية وتأثير زاوية الترسيب في هذه الخصائص. ان زاوية الترسيب لها تأثير كبير في الخصائص البصرية للأغشية، اذ أزدادت كل من الأمتصاصية ومعامل الأمتصاص ومعامل الخمود والجزء الخيالي من ثابت العزل الكهربائي مع زيادة زاوية الترسيب، في حين تقل كل من النفاذية والأنعكاسية ومعامل الأنكسار والجزء الحقيقي من ثابت العزل الكهربائي مع زيادة زاوية الترسيب.

الكلمات المفتاحية: أغشية رقيقة ، الترسيب المائل ، تأثير التظليل الذاتي