Studying the Structural and Optical Properties of $AgO_{70\%}$:$In_{30\%}$ Thin Films Prepared by Thermal Vacuum Evaporation Technique

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Abstract

Thin films of ($AgO_{70\%}$:$In_{30\%}$) have been prepared on glass substrates under a vacuum ~10^{-4} Torr by the Thermal Vacuum Evaporation technique. Thickness of the films varied between (50-100) nm. The surface morphology and crystal structure were investigated by X-ray diffraction (XRD). The optical properties also investigated by UV- spectrometer, Atomic Force Microscopy (AFM) and Optical Microscopy respectively. The X-ray diffraction (XRD) analysis reveals the peaks at (012) ($\bar{1}12$) and (222) plans Which confirm that the prepared films are $AgO_{70\%}$:$In_{30\%}$. Transmittance and absorption data in range of wavelength (320 – 1100) nm have been used to calculate the optical constants for the prepared films, and this optical results showed that $AgO_{70\%}$:$In_{30\%}$ films has a band gap of 3. 5 eV. The AFM technique showed that the grain size of particle for $AgO_{70\%}$:$In_{30\%}$ thin films was 46.2 nm.

Keywords : Silver oxide , AFM , thin film , Structural and Optical properties

دراسة الخصائص التركيبية والبصرية لأغشية ($AgO_{70\%}$:$In_{30\%}$) المحضرة بطريقة التبخير الحراري في الفراغ

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المستخلص

تم تحضير أغشية ($AgO_{70\%}$:$In_{30\%}$) على قواعد منْ الزجاج باستخدام طريقة التبخير الحراري في الفراغ وتحت ضغط (10^{-4}) تور تقريباً ، حيث كان سمك الاغشية المحضرة بحدود nm (–50

100). تمت دراسة طبيعة السطح والتركيب البلوري للأغشية المُحضرة بأستخدام حيود الاشعة السينية. فحص الاشعة السينية أوضح ان القمم كانت عند المستويات(012) $(\bar{1}12)$ (222) والتي تؤكد ان الاغشية المُحضرة هي أغشية $AgO_{70\%}:In_{30\%}$. بيانات الامتصاصية والنفاذية ولمدى الأطوال الموجية nm(320−1100) استُخدمت لحساب الثوابت البصرية للأغشية المُحضرة وان هذه النتائج بينت ان $AgO_{70\%}:In_{30\%}$ يمتلك فجوة طاقة مقدارها (3.5 eV). بينت تقنية AFM ان الحجم الحبيبي لأغشية ($AgO_{70\%}:In_{30\%}$) الرقيقة كان 46.2 nm.

Introduction

Silver (Ag) existence multivalent forms varied phases such as(Ag:O, $Ag_{2:}O$, $Ag_{3:}O_4$, $Ag_{4:}O_3$, $Ag_{2:}O_3$) through interplay with oxygen(O_2)[1].This oxide has contrastive crystal structure lead to a diversity of properties. The most stabilized and observe phases are(Ag:O, $Ag_{2:}O$) [2].The novel interest in silver oxide because of its potential in optical applications. (Ag:O) semiconductor films are famous to show p-type semiconductor properties for bandgap reach to (1.20-3.40) eV. This wide range of band gap is as a result of different stoichiometric , crystal phase and properties arising from different deposition techniques[3]. (Ag:O) crystallize out by a myriad patterns of crystal structures, lead to disparate of gratifying physiochemical properties like as catalytic, electrochemical, electronic and optical properties [4]. It is famed that the silver oxide phase was comparatively uniform with highness oxygen pressures and at low temperatures. The silver oxide dwell in disparate crystal shapes like as cubic, monoclinic and tetragonal [5,6]. It is witted that the (Ag), because of its d shell electrons, subsist in dissimilar oxidation states and shapes. The method of formation of these oxides relies at the growth conditions/reaction kinetics, accessibility of (O_2) in the growth chamber with the energy refrain to the oxidation. The surface morphology and the nucleation kinetics of the (Ag:O) pend the kinetic energy of the particles (Ag and O_2 atoms) arrival to the substrate [7]. Amongst the varied metal, (Ag) denoted affective thermally conductive , highly electrically conductive and can be combined into silver based composites with diverse compositions. Silver(Ag) remains further interactive than gold(Au) or platinum(Pt) so, Silver(Ag) is the furthermost suitable nominee for several applications [8, 9].

The solid state oxides are transparent conducting oxides (TCOs) with low electrical resistivity and high optical transparency in visible region on electromagnetic spectrum. They have wide range of applications in electrical and optical device, such as solar cell, light emitting diode (LED), photo transistor, gas sensor and flat panel display etc. The important properties of TCOs is that, they reflect I.R light up to high extent which makes them appropriate in smart windows[10].

It was observed that by mixing (Ag:O) with different kinds of metallic ions, the physical properties of (Ag:O) could be controlled for optoelectronic applications. So that mixing with ions like(In), (Sc), (Sn) and (Al) improves it n-type conductivity and increase optical band gap. Surface roughness, intrinsic defects and inhomogeneity, etc. are the cause of the optical losses. from the practical point of view, these properties can severely modify or degrade the performances of a component. Overall, the optical and structural properties of the thin film depends on the method of the preparation[11].

Thin film of (AgO:In) can be manufactured by several deposition methods such as electron beams evaporations, laser pulse deposition, the thermal vacuum evaporation which it will used in this work [12,13].

Experemental:

In the present work, AgO:In prepared of compound from alloy of ratio (70:30) % (AgO ,In) (lineage key -live equivalent to an atomic ratio of each compound). Then the mixture put in furnace at a temperature reach up to (1200^{o}C) and left the sampler inside furnace until it is cool gradually and then flushed sample and extract the broken substance. Grinded substance by Mill specials . $AgO_{70\%:}In_{30\%}$ thin film was prepared by the thermal vacuum evaporation technique on glass substrate. glass slide substrates were first cleaned with detergent water, degreased with acetone and rinsed with deionized water in an ultrasonic cleaner for 20min, then immediately dried by blowing air and wiped with soft paper. $AgO_{70\%:}In_{30\%}$ powder with high purity (99.99%) was used in the films preparation. Thin films were prepared under a vacuum ~10^{-4} Torr using (EDWARED coating unit -model 306A). A molybdenum boat with a cover was used as the evaporation source and the substrate was (plate) held at 200^{o}C of temperature, which were placed directly above the source at distance of 22cm. Films thickness was measured by using the weight method which is the most approximate method and the magnitude of material is required to achieve that the thickness of films is given by[14]:

$$m= 2\pi d^2 \rho\, t \quad \text{……………..(1)}$$

(m): is the mass of matter in gm , (d): is the space in cm between the target and the piece holder, (ρ): is density of matter and (t): is the thickness of the film. The structural properties were studied by using X-ray diffractometter type(XRD-6000, SHIMEDZU) with Cu:kα radiation of wavelength (λ=1.54056 A°) . The optical transmittance of sample is measured using spectrophotometer type(CARY100CONCplusUV-Vis-NIRSplit- beam Optics, Dual detectors) with range of wavelength (320-1100nm). The size and shape of AgO:In thin films were examined by using AFM type (AA3000ScanningProbeMicroscope).

Results and discussion

Figure. 1 shows the X-ray diffraction patterns of the $AgO_{70\%:}In_{30\%}$ nanostructures diffraction peak absorb at (2θ) value .The distinct peaks are used to compute the crystal size(G) by Scherrer`s equation [14]:

$$G = \frac{0.9\,\lambda}{\beta\, COS\,\theta} \quad .... \quad ....\ldots\ldots\ldots.(2)$$

(β): is the full width at half maximum(FWHM) and (θ): angle of diffraction .

The XRD study confirms that the thin films have face center cubic (FCC) crystal. The polycrystalline $AgO_{70\%:}In_{30\%}$ thin film can be observed and the peaks namely the (012) ($\bar{1}12$) and (222) plans with diffraction angles 37.2◦ ,43.16◦,79.28◦ for $AgO_{70\%:}In_{30\%}$ thin film. The (012) AgO peak intensity was larger than that of the other peaks because the (012) direction in $AgO_{70\%:}In_{30\%}$ film has the lowest surface energy[14,15,16]. The microstrain(ɲ) and the dislocation density (σ) calculate by using the following equations:-

$$ɲ = (\beta \cos\,\theta)/4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\delta = G^{-2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where G : is the crystallize size.

Table (1) shows the XRD parameters which was calculated for $AgO_{70\%:}In_{30\%}$ thin film .

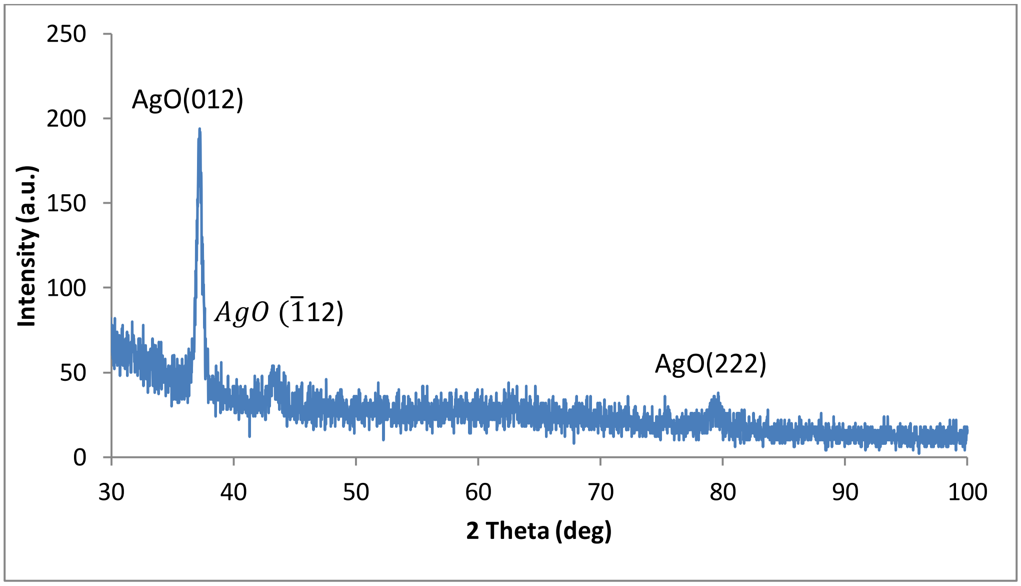

Fig. 1: XRD pattern of $AgO_{70\%}:In_{30\%}$ film.

Table (1) shows the XRD parameters which was calculated for $AgO_{70\%}:In_{30\%}$ thin film .

2Theta (degree)	F W H M (degree)	G(nm)	strain x 10^{-4} lines $^{-2}$.m^{-4}	$\delta \times 10^{14}$ lines.m^{-2}
37.2069	0.52	15.9267	21.7983	39.422887
43.1618	0.38	22.41819	15.48631	19.897517
79.2887	0.42	24.54873	14.14228	16.593656

Table 1: XRD Parameters.

Figure 2 explains 3D AFM pictures and Granularity accumulated distribution of ($AgO_{70\%}:In_{30\%}$ **)**
thin films prepared by Thermal Vacuum Evaporation Technique. Substrate is fully wrapped with $AgO_{70\%}:In_{30\%}$ nanoparticle dispensed homogeneously on the surface. It`s clear from this figure that the nanoparticles have small ordered particles with semispherical shape. the average diameter of the grains that estimated with the aid of software Imager is 46.2 nm.

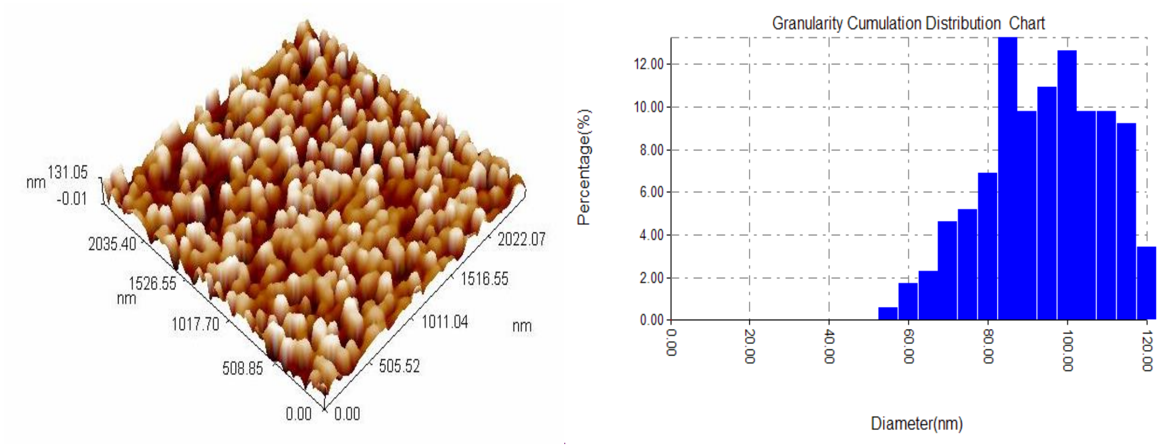

Fig. 2: AFM picture of $AgO_{70\%}$:$In_{30\%}$ thin film surface.

The microstructure of $AgO_{70\%}$:$In_{30\%}$ thin films was studied by using optical microscope. These images reveal that the $AgO_{70\%}$:$In_{30\%}$ morphology can be simply recognized from films color and homogeneities. The surfaces are rough and have various colors, as shown in figure 3.

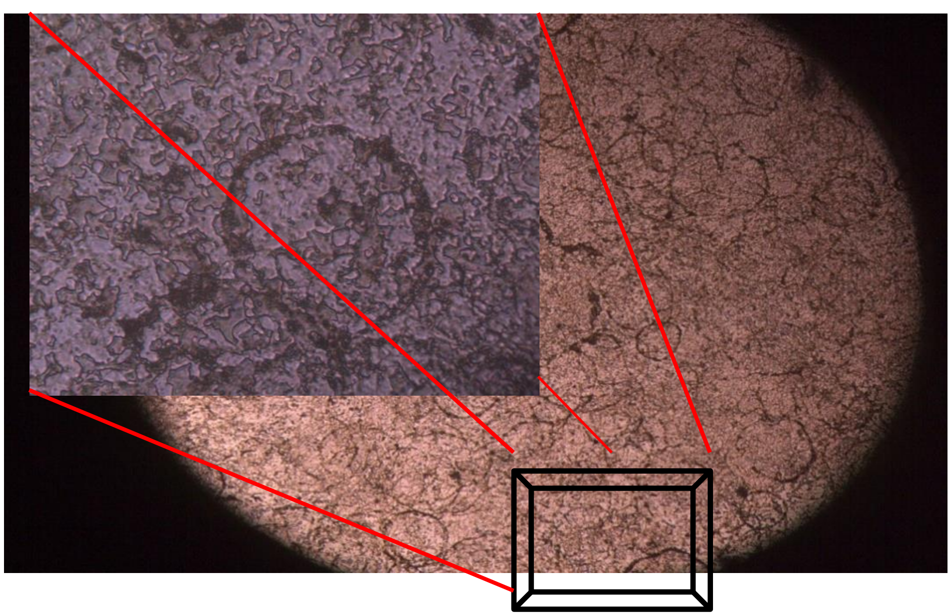

Fig.3: micrograph of $AgO_{70\%}$:$In_{30\%}$ thin film.

Figure 4 and 5 show the UV-VIS transmission and absorption spectrum of sputter deposited $AgO_{70\%}$:$In_{30\%}$ thin film were studied in wavelength range (320 – 1100) nm, these figures show that the optical transmission accomplish to(65%)at (1100nm) wavelength and this characteristic to transmission of nanoparticles at these wavelength, then the transmittance increases with wavelength increases.

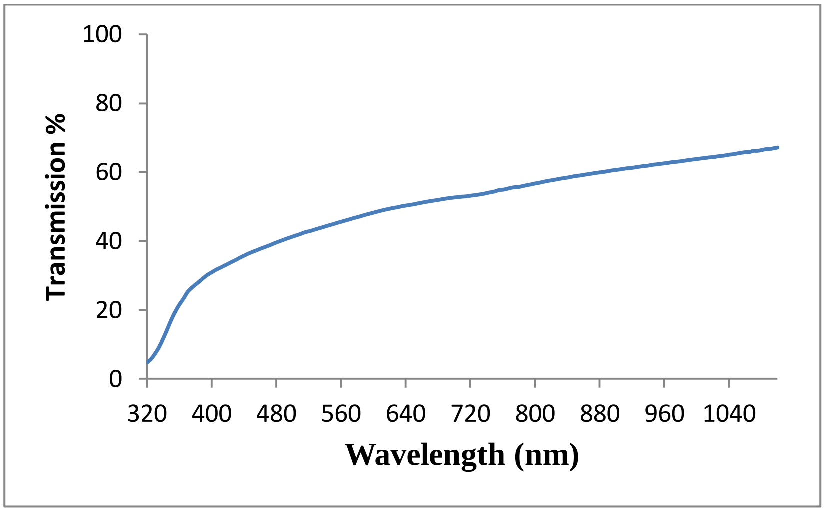

Fig. 4: Optical transmittance of $AgO_{70\%}$:$In_{30\%}$ thin film.

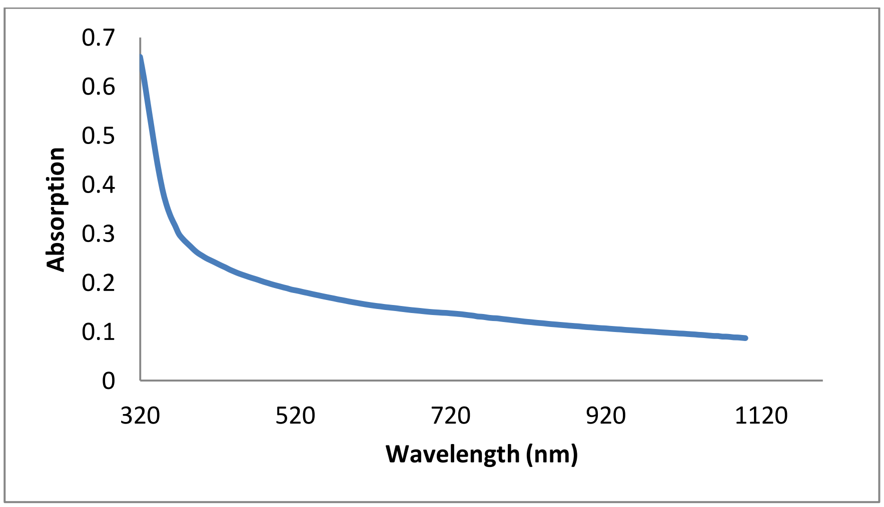

Fig. 5: Optical Absorption of $AgO_{70\%}$:$In_{30\%}$ thin film.

From the absorbance values, near at the principal absorption edge, the absorption coefficient(α)was calculate in the area of powerful absorption using the relation below:

$$\alpha = \frac{2.303\,A}{t} \quad \ldots\ldots\ldots\ldots (5)$$

The fundamental absorption ,which corresponds to electron excitation from valence band to conduction band ,can be used to determine the kind and amount of the optical band gap (Eg) .The value of band gap (Eg) has been computed by using Tauc's equation[17]:

$$\alpha h\upsilon = A(h\upsilon - Eg)^{1/2} \ldots\ldots\ldots\ldots\ldots (6)$$

where α : absorption coefficient , (hυ) : energy of incident photon , A : constant.

The optical band gap of $AgO_{70\%}$:$In_{30\%}$ film can be computed by plotting (hυ) as x-axis versus $(\alpha h\upsilon)^2$ as y-axis and extrapolating the straight line portion of this plot to the energy axis as shown in Fig. (6). The linear dependence of $(\alpha h\upsilon)^2$ to $h\nu$ (at α=0) indicates that $AgO_{70\%}$:$In_{30\%}$ film are direct transition type semiconductors . which explains a plot of $(\alpha h\nu)^2$ versus $h\nu$ for $AgO_{70\%}$:$In_{30\%}$ nanoparticles the intercept of the straight line with $h\nu$ (at α=0) axis give the band gap (E_g)which is equal to 3.5eV.

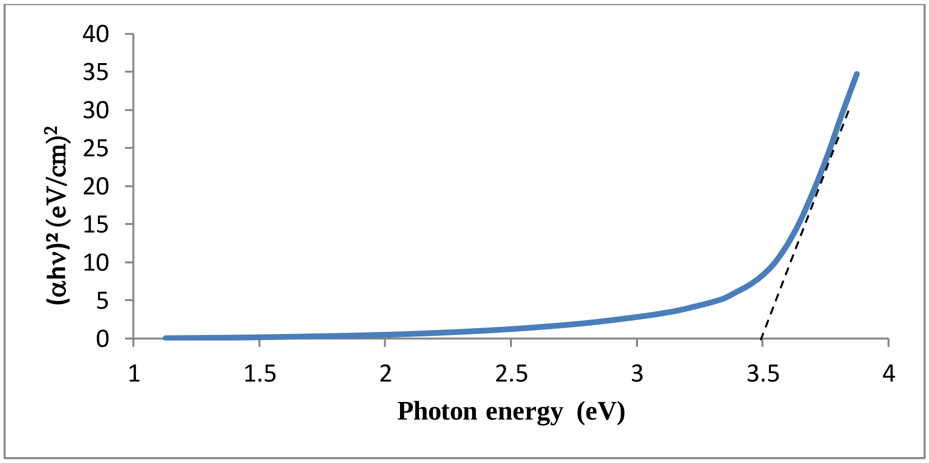

Fig. 6: Band gap for $AgO_{70\%}$:$In_{30\%}$ film.

Conclusion

This study obviously presents how $AgO_{70\%}:In_{30\%}$ samples growth by Thermal Vacuum Evaporation Technique (easy, low cost, and quick technique to the combinations $AgO_{70\%}:In_{30\%}$ nanostructures). The expulsion of the sample as illustrated in the figures obvious that the sample is a visible transmitting thin films (in which the transmittance increases with wavelength increases) with a good crystallize and confirms that the thin films have face center cubic (FCC) crystal and it may be said that nanoparticle of AgO: In material can be grown using the Thermal Vacuum Evaporation Technique.

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