Optical properties of Indium oxide thin films deposited by thermal evaporation Kahtan N.Abdullah

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Abstruct

In this paper, Indium oxide films of thickness 400 nm were prepared using thermal evaporation under vacuum. First indium films were deposition by and followed by thermal oxidation at different temperature 150-350 °C for 60 second. The optical properties such as optical bandgap, Absorbance (A), Transmittance (T), Reflectance (R) ,Absorption coefficient (α) and refractive index (n) were determined. The results revealed that the absorbance range is 3% at visible and near IR range , the transmittance range is 95 % while the reflectance range is 2 %.The optical bandgap for indium oxide thin film is (3.7-3.8) eV., the average value for n is 1.4 while the average value for Absorption coefficient (α) is 0.334 cm⁻¹.

Introducation

Indium oxide (In₂O₃) has bixbyite Structure (C-rare earth crystal structure) as given in figure (1), the space group symmetry being Ia_3 and lattice constant 10.117 A^0 . Every Unit cell contains eight formula units In_2O_3 :Indium atoms occupy Wyckoff position 8b and 24d while oxygen atoms occupy Wyckoff position 48e [1] .Indium oxide are used in a wide variety of application in electronic industry and engineering [1,2]. Indium oxide (In₂O₃) is important transparent conducting oxide (TCO) materials that has application in optoelectronic devices and flat panel display due to high electrical conductivity and high optical transparency. This oxide also has very interesting superconductorinsulator transition behavior at low temperature . Indium oxide also is used as antireflection coating in solar cells its low reflectivity for this films, other because applications of this films to make high efficient low pressure sodium lamps, defogging aircraft and automobile windows, gas sensors, wear resistant layers on glass and cold mirrors [5,7,14]. Preparation methods can be classified: molecular beam epitaxy (MBE) and chemical vapor deposition (CVD) are technologically demanding and are used to generate high quality films. Wet chemical methods offer experimentally straight forward alternatives that do not require high temperature or vacuum conditions. Traditional methods include chemical solutions deposition. Electro chemical deposition, successive ionic layer adsorption and reaction (SILAR), laser -ablation associated CVD (LA-CVD), pulsed laser deposition (PLD), RF deposition and DC Sputtering, spray pyrolysis and sol-gel technique [3,9,10,11,12]. Thermal evaporation technique was used in this work to deposited indium oxide film this method its cheap ,simple and safety . Electronic structure of In_2O_3 have been investigated by Xiang et al [1] and Cheng et al [2]. They are grown indium oxide (In_2O_3) in nanostructure including octahedral nanocyrstal (NCs), nanobelts (NBs), nanosheets (NSs) and nanowires (NWs). These nanostructures have shown great promise as chemical and biological sensors. Due to the dangers of exposure to natural gas and fast growth in motor traffic which leads to increase pollution and poisonous gases of our environment, gas sensors play vital role in detecting and controlling the presence of hazardous gases at the low concentrations. Workers such as G.Kiriakidis et al [3] deposited indium oxide films to fabricate gas sensors. This study shows that Indium oxide film is a candidate for air monitoring applications as small and easy use ozone (O₃) sensors. K.K.Makhiga et al [4] prepared

indium oxide film sensors for ammonia gas and ethanol vapor. The sensitivity of sensor has been found to be independent of film thickness of the films for ethanol vapors, while it does depend on thickness for the ammonia gas. Available studies shown that preparation methods and conditions strongly affect the electrical ,optical properties and structure of Indium oxide [5,6]. S.M.Rozati and T.Ganj [7] prepared transparent conducting In₂O₃ using spray pyrolysis technique on glass substrate with varying thickness, they are observed that the physical properties of coated films can be improved by increasing film thickness. This result in a decrease in sheet resistance and further increase in thickness result in decrease of optical transmittance. M.Amirshahbazi et al [8] prepared indium tin oxide (ITO) by DC magnetron and show the effect change temperature of substrate on electrical properties of this films. R.X.Wang et al [9] were deposited ITO thin films on glass substrates by using e-beam evaporation ,this films have been annealed in different ambient gases (Ar, N₂, Air) which results view change transmittance of ITO films. D.R.Gibson et al [5] prepared indium tin oxide (ITO) by using magnetron sputtering technique, this study show that properties of films depend strongly on deposition parameter and heat of deposition. The attention of our work study optical properties of indium oxide film which prepared by thermal evaporation of indium films followed by thermal oxidation to produce two indium oxide film in same thickness but at two different temperature.

Experimental

To achieve desirable films properties, cleaning of the substrates surfaces must be done. For this reason glass substrates were cleaned by immersion in chemical solution and distilled water, and were then ultrasonically cleaned in detergent solution and dried it. To fabricate these films, the indium metal was first deposited under vacuum 10^{-5} torr by using Edwards evaporation system (physics lab .- college of science – A l- Mustansiriyah University), after deposition these films were followed by thermal oxidation in ambient air at different temperature 150,350 °C for 60 second to produce tow sample of In_2O_3 films. The films were grown at substrates at room temperature.

Optical properties calculated for the indium oxide films were transmittance (T), reflectance (R), absorption coefficient (α), refractive index (n) and the optical energy bandgap.

The transmittance of In_2O_3 thin films is measured in the wavelength region 300-1100 nm $\,$ by using UV-VIS spectrophotometer (Cintra 5 computerized system) .

Absorption coefficient(α) can be used to determine the optical bandgap energy of In₂O₃ thin films. The relation between absorption coefficient(α) and incident photon energy (hv) can by written as

$h\upsilon - E_g)^r$(1) $ah\upsilon = A($

Where A is aconstant, E_g is the bandgap energy of the thin films, the exponent equal 1/2 depending on the type of transmission. The values of the optical energy bandgap can be determined by extrapolating $\alpha^2h\nu$ versus hu graphs to the hu axis.

Results and discussion

From figures (2),(3)it is shown that the optical energy bandgap increase as the oxidation temperature increase, the value of optical energy bandgap increase from 3.7 eVto 3.8 eV as the oxidation temperature increase from 150°C to 350 °C due to the converting of film from metal phase to oxide phase. Oxygen atoms may have enough energy to diffuse inside films and interacts with indium atoms and oxidation the films. These values of optical energy bandgap are in god agreement with values reported by workers[3,4].

Figrures (4) ,(5) show the absorbance of indium oxide films with thickness 400nm oxidated at temperature 150,350 ^oC for 60 second.

The absorbance of films are generally very low with range 0-3%.. Figures (6) show the transmittance of thin film deposited and followed by thermal oxidation at 150 C for 60 second while figure(7) show the transmittance of thin film deposited and followed by thermal oxidation at 350 °C for 60 second. A high optical transparency of about 95% in the visible and near infrared region for two In_2O_3 films due to have indium oxide wide optical energy bandgap behaves as transparent material.

This result is in agreement with R.X.Wang et al[9]. low reflectance of these films may be due to the smooth surface of deposition carried out by thermal deposition on glass substrate. Oxidation temperature, refractive index (n) absorption coefficient (α) and other optical properties are summarized in table (1).

Conclusion:

Thermal evaporation technique has been used to prepare indium films followed by thermal oxidation in ambient air to produce tow samples in the same thickness, the energy bandgap of these thin films was calculated to be 3.7 eV, 3.8 eV for the two films which oxidation at two different temperature 150,350. Beacuse In₂O₃ high transparency in visible and infrared region, these films are suitable for technological application such as antireflection coating for solar cells and photo electronic devices. The properties of these films depend strongly on

deposition technique and parameter of oxidation.

 Table(1): summarized of Oxidation temperature Refractive index(n) Absorption coefficient (α) and other optical properties summarized

Sample	Oxidation	E _g (eV)	T%	A%	R%	n	$\alpha \text{ cm}^{-1}$
	temperature	-					
١	150 °C	3.7	90	٢	٣	1.487	0.3324
۲	350 °C	3.8	٩ ٤	٢	٤	1.413	0.319



figuare1. Unit cell of In₂O₃



Figure 7. The square Absorption coefficient (α^2) hv vs photon energy (hv) of indium oxide thin film oxidation at $T=1\circ 0$ C° for 60 sec.



Figure ". The square Absorption coefficient (α^2).hv vs photon energy (hv) of indium oxide thin film oxidation at T=350 C° for 60 sec.



Figure⁴. Spectral absorbance of indium oxide film oxidation at T=150 C⁰ for 60 sec.



Figure[•]. Spectral absorbance of indium oxide film oxidation at $T=350 \ C^0$ for 60 sec.



Figure \mathcal{T} . Spectral transmittance of indium oxide film oxidation at T=150 C⁰ for 60 sec.



Figure^V. Spectral transmittance of indium oxide film oxidation at T=350 C^0 for sec.

References:

1-Xiang Yang Kong, Zhong Lin Wang Solid State Communication Vol. 128 (2003) p1

2-G.Cheng, E. Stern, S. Guthrie, M.A. Read, R. Klie, Y. Hao, G. Meng, L.

Zhang Applied Physics A85 (2006) P233

3-G.Kiriadis, H. Ouacha, N. Katsarakis Rev. Adv. Mater Sci. Vol (2003) P32

4-K.K.Makhija, Arabinda Ray, R.M. Patel, U.B. Trived, H.N. Kapse

Bull. Mater. Sci. Vol.28 No1 (2008)p9

5-D.R.Gibson, I.T. Brinkley, G.H. Hall, E.M. Waddell, J.M. Walls. 49 Annual Technical Conference Proceeding (2006)

6-Luis C. Jimenez B., Henery A. Mendez p., Beynor A. Paez S, Maria E. Ramierz O., Hernan Rodriquoz H. Barzilian Journal Of Physics Vol 36 No.3B(2006)

7-S.M.Rozati, T. Gany Materials Science-Poland Vol 22 No.2 (2004)

8-M.Amirishahbazi, H.R. Fallah, M. Zahedi, International Journal of Nanowires and Nanotechnology Vol.1 (2005) p61

9-R.X. Wang, C.D. Beling, S. Fung , A.B. Djurisic, C.C. Ling, S. Li Journal of Applied physics Vol 97 (2005) p 33504

10-M.N.Nrabuchi The Pacific Journal Of Science and Technology Vol.6 No.2 (2005)p105.

11-Fiona C.Meldrum Johannes Flath, Wolfgang Knoll J . Mater. Chem. Vol9 (1999)p711

12-S.M.Sze Semiconductor Devices Physics & Technology (1985)

13-Raid A. Ismail, Omar A. Abdulrazaq, Khalid Z. Yahya

Surface Review Letter Vol.12 No.4 (2005) p515

14-G.Korotcenkov, A. Cerneavschi, V. Brinzari, A. Palagnuk, A. Cornet J. Morarite, A. Cabori ,J. Arbial Moldavian Journal Of The Physical Science Vol 1 No.3 (2002) p26

15-S.M. Sze VLSI Technology (1987)

الخصائص البصرية لاغشية اوكسيد الانديوم والمرسبة بطريقة التبخير الحراري

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قسم الفيزياء ، كلية التربية ، جامعة تكريت ، تكريت ، العراق (تاريخ الاستلام: ۲۱ / ۹ / ۲۰۰۸ ، تاريخ القبول: ۱ / ۳ / ۲۰۰۹)

الملخص

تم في هذا البحث ترسيب أغشية اوكسيد الانديوم بسمك ٤٠٠ نانومتر باستخدام تقنية التبخير الحراري. رسبت أغشية من معدن الانديوم ثم اتبعت بأكسدة حرارية في درجات حرارية مختلفة بين ١٥٠–٣٥٠ مئوية ولمدة ٢٠ ثانيه. الخصائص البصرية لهذه الاعشيه مثل فجوة الطاقة الممنوعة، الامتصاصية، النفاذيه،الانعكاسية، معامل الامتصاص ومعامل الانكسار تم حسابها. بينت النتائج إن هذه الاغشيه لها امتصاصية قليلة بحدود ٣% في المنطقة المرئية والقريبة من الاشعه تحت الحمراء في حين كانت النفاذيه عالية جدا بحدود ٩٥% بينما ألاتعكاسيه كانت بحدود ٢% معامل الامتصاص ومعامل الانديوم فكانت بحدود ٣,٠ ومعامل الانكسار قم حين كانت النفاذيه عالية جدا ومعدل معامل الانكسار بحدود ٢، بينما معامل الامتصاص كان معدل قيمته .¹