

Effect of Laser Irradiation on the Optical Properties of SnO₂ films Deposited by Post Oxidation of metal Films

*Souad G. Khalil***Majida A.Ameen***Najwa J. Jubier***

Received 26, October, 2010

Accepted 14, January, 2011

Abstract:

Tin oxide films (SnO₂) of thickness (1 μm) are prepared on glass substrate by post oxidation of metal films technique. Films were irradiated with Nd:YAG double frequency laser of wavelength (532 nm) pulses of three energies (100, 500, 1000) mJ. The optical absorption, transmission, reflectance, refractive index and optical conductivity of these films are investigated in the UV-Vis region (200-900) nm. It was found that the average transmittance of the films is around (80%) at wavelength (550 nm) and showed high transmission (~ 90 %) in the visible and near infrared region. The absorption edge shifts towards higher energies, which is due to the Moss-Burstein effect and it lies at (4 eV). The optical band gap increased with increasing of energy.

Key words: Laser irradiation effect, SnO₂ films, Optical properties.

Introduction:

Transparent conducting oxides (TCOs) are used in a variety of applications including flat panel display, heat mirrors and solar energy conversion devices. Thin films of transparent oxide semiconductors like SnO₂, SnO₂:F, SnO₂:Sb, SnO₂:In and CdSnO₄ [1]. Tin oxide thin films are as a window layer in solar cells [2], and as an electrode to collect the charge in CdS/Cu₂S [3], CdS/CdTe [4], and other application of SnO₂ are used for gas sensors like CO, H₂S, H, NO and CH₄ [5-9].

SnO₂ is a crystalline solid with a tetragonal crystal lattice. It is a wide gap, non stoichiometric, and as a degenerate n-type semiconductor. Tin oxide (TO) thin films have been prepared by several methods; evaporation [10, 11], reactive sputtering (RS) [12], pulsed laser deposition (PLD) [13], spray pyrolysis (SP) [14, 15], sol-gel [16, 17] and post oxidation of evaporated thin films of

metal [18]. As SnO₂ film ($E_g \approx 3.5$ eV) is transparent it can be applied to protecting film over materials with a narrow band gap as well as an electrode for photoelectrochemical conversion.

The high transparency of oxide films in the visible region, together with their high reflectivity in the infrared, make them very attractive for use as transparent heat-reflecting material [19].

In this work, SnO₂ films were grown by post-oxidation of evaporated thin films of tin. These films were then subjected to laser irradiation. Optical properties of SnO₂ films were studied after laser irradiated, this process can be used to improve the properties of materials.

Materials and Methods:

Post Oxidation of metal films:

SnO₂ thin films were grown on glass substrates using the post-

* Department of physics, College of science for women, University of Baghdad.

** Department of physics, College of science, University of Wassit

oxidation of metal films technique. Sn metal was placed in the vacuum pumping unit. The apparatus used was flash evaporated type Balzers, the pressure during evaporation was always less than 10^{-4} Torr. The optical properties were studied by measuring the transmission (T) between $\lambda=200$ nm and $\lambda=900$ nm using a double-beam spectrophotometer (UV-Vis).

Irradiated with Laser:

The films were irradiated with laser pulses of various energy are (100, 500, 1000) mJ. Laser pulses were of (7 ns) width. The laser source used in the present work was a Nd:YAG double frequency laser of wavelength (532 nm). The diameter of the laser beam was about (6 mm).

Results and Discussion:

The optical properties of SnO₂ samples prepared by post-oxidation of Sn films were studied by measuring the transmission (T) between $\lambda=200$ nm and $\lambda=900$ nm. The optical transmittance spectra of the deposited films were recorded.

Figure (1) shows the transmission spectra of tin oxide (TO) deposited on glass substrate for different energies of laser (100, 500, 1000)mJ. It was found that the average transmittance of the films is around (80%) at wavelength (550 nm) and showed high transmission (~ 90 %) in the visible and near infrared region. High optical transparency of the obtained films demonstrates the applicability of these layers for photovoltaic applications, this result agreements with Elangovav et.al. [14].

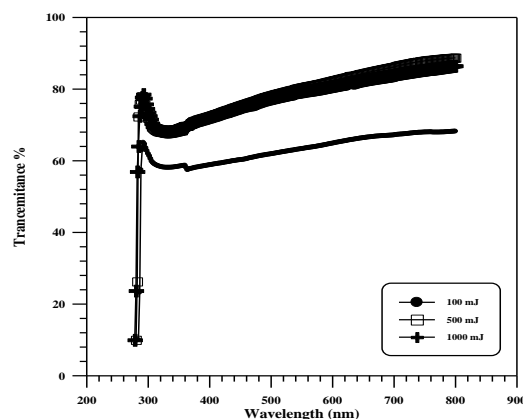


Fig. (1): The transmittance spectra of SnO₂ thin films.

The absorption spectra of SnO₂ shown in figure (2). It was found that the absorption edge shifts towards higher energies (shorter wavelength). This shift is called Moss-Burstein effect [20] or (Burstein, 1954 , Moss, 1961), and is called band filling.

The absorption coefficient can be calculated from the Lambert's formula [21]:

$$\alpha = \frac{2.303 A}{t}$$

Where:

A: the absorbance.

t: the thickness of the films.

α : the absorption coefficient of the films (cm^{-1}).

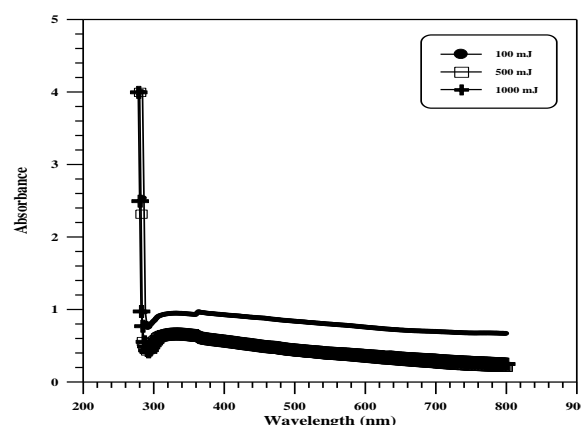


Fig. (2): The Absorbance spectra of SnO₂ thin films.

The variation of $(\alpha h\nu)^2$ was draw as a function of photon energy

($h\nu$) to determine the band gap E_g of SnO_2 film. The absorption edge values are found by extrapolating the linear portion of the curve to zero absorption as show in figure (3). The variation of absorption coefficient with photon energy for direct band-to-band transition is of the form:

$$(\alpha h\nu) = B(h\nu - E_g)^{1/2}$$

Where:

$h\nu$: the photon energy (eV).

B: is a constant.

E_g : the energy gap (eV)

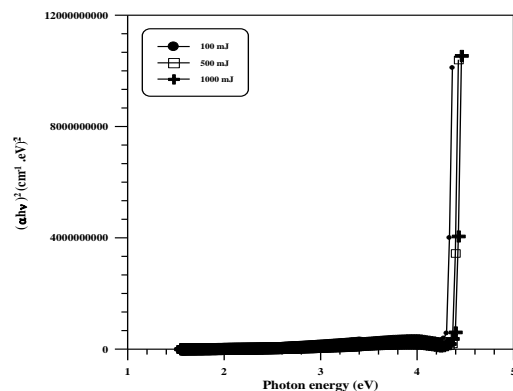


Fig. (3): $(\alpha h\nu)^2$ as a function of photon energy for SnO_2 thin films

The direct allowed transition of SnO_2 films occurs in the range (4.3-4.4) eV of SnO_2 films. The value of E_g increases with increasing laser energy, this is due to the increase of Fermi level (E_F), and it is called the Moss-Burstien effect. This shift to the shorter wavelength region is an advantage for solar cell applications.

Figure (4) shows the reflectance (R) as a function of wavelength (200-900) nm, which calculated by the formula:

$$R + T + A = 1$$

From this figure, the increase of laser energy decreases the reflectivity of SnO_2 films. It is obviously from figure (4) that SnO_2 thin films can be used as antireflection and electrode layer as well in the photovoltaic device

structure. This result agreements with Shanthi et.al. [1] and Menea et.al. [17].

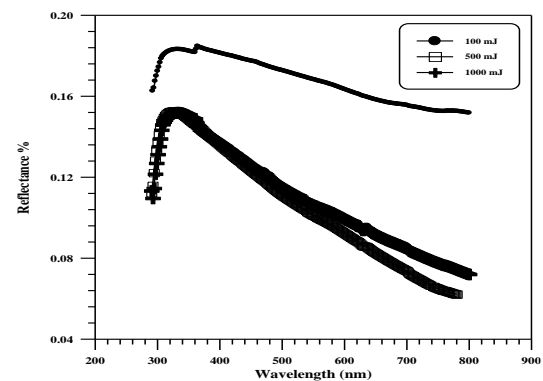


Fig. (4): The Reflectance spectra of SnO_2 thin films.

The refractive index (n) as shown in figure (5) has been found by using relation ship [22]:

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2}$$

Where:

k: the extinction coefficient in the fundamental absorption region.

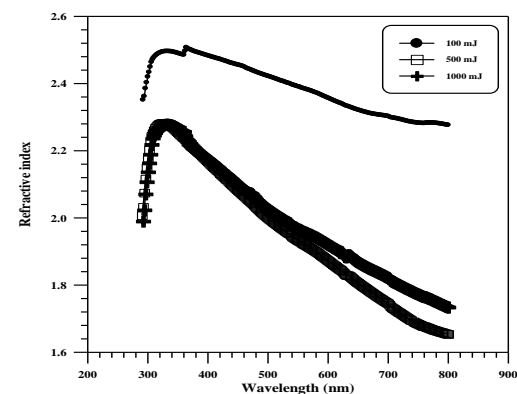


Fig. (5): The variation of refractive index as a function of wavelength for SnO_2 thin films

Optical transmission studies showed that the refractive index decreased with increasing laser energy as a result of irradiation energy, and it is seen that the value of refractive index lies in the range (2.52-2.3).

Figure (6) shows the optical conductivity (σ) and can be calculated from the formula [5]:

$$\sigma = \frac{\alpha n C}{4\pi}$$

Where:

n: the refractive index.

C: the velocity of light.

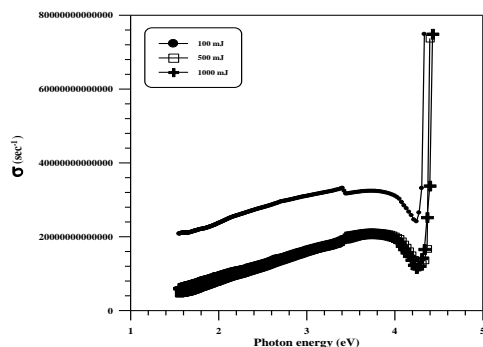


Fig. (6): The variation of optical conductivity as a function of photon energy for SnO₂ thin films

Conclusion:

Tin oxide films have been deposited by post-oxidation of metal technique. The optical properties of SnO₂ films were studied in the (VU-Vis.) region. From transmission spectra, it is observed that the refractive index decreasing with laser energy increasing.

The absorption edge of SnO₂ film shift towards higher energies and an increase in optical band gap (E_g) with increasing of irradiation energy were observed in the films as a result of laser irradiation.

References:

- 1- Shanthi, S., Subramanian, C. and Ramasamy, P. 1999. Investigation on the optical properties of undoped, fluorine doped and antimony doped Tin Oxide films, *Cryst. Res. Technol.* 34: 1037-1046.
- 2- Park, J.C., Hwang, S., Kim, M.J., Kim, J.K., Lee, W.Y., Park, J.S., Kim, E.H., Jung, Y., Shim, K. and Cho, H. 2009. Anisotropic pattern transfer in SnO₂ thin films for the fabrication of nanostructure-based gas sensors, *J. Ceram. Process. Res.* 10(6): 827-831.
- 3- Agashe, C., Marathe, R.B., Takwale, G.M. and Bhide, G.V. 1988. Structural Properties of SnO₂:F films deposited by Spray Pyrolysis Technique, *Thin Solid Films.* 164: 261-264.
- 4- Ikhmayies, J. S. 2002. Production and Characterization of CdS/CdTe thin film photovoltaic Solar Cells of Potential industrial use. Ph.D. thesis, University of Jordan, Amman, Jordan.
- 5- Mishra, R.L., Mishra, S.K. and Prakash, S.G. 2009. Optical and Gas Sensing Characteristics of Tin Oxide nano-crystalline Thin Film, *J. Ovonic Res.* 5(4): 77-85.
- 6- Kim, T. and Yoon, K. 1991. Photoeffects in SnO₂ film electrodes deposited by Spray Pyrolysis, *J. Appl. Phys.* 70(5): 2739-2744.
- 7- Leite, E.R., Weber, I.T., Longo, E. and Varela, J.A. 2000. A new method to Control Particle size and Particle size distribution of SnO₂ nanoparticles for gas sensors applications, *Adv. Mater.* 12: 965-968.
- 8- Tai, W.P. and Oh, J.H. 2002. Preparation and humidity sensing behaviors of nanocrystalline SnO₂/TiO₂ bilayered films, *Thin Solid Films.* 422: 220-224.
- 9- Nayral, C., Viala, E., Colliere, V., Fau, P., Senocor, F., Maisonnal, A. and Chaudert, B. 2000. Synthesis and use of anoral SnO₂ nanomaterial for gas sensing, *Appl. Surf. Sci.* 164: 219-226.
- 10- Kim, H.W. Shim S.H. and Lee C. 2006. SnO₂ Microparticles by Thermal evaporation and their

- Properties, Ceram. International. 32: 943-946.
- 11- Lee, M.K., Lee, D.J. and Ahn, H. 2004. XRD and TEM on Tin Oxide (II) nanoparticles prepared by inert gas condensation, Mater. Lett. 58: 3122-3125.
- 12- Pan, S.S., Ye, C., Teng, M.X., Fan, T.H. and Li, H.G. 2006. Preparation and Characterization of Nitrogen incorporated SnO₂ Films, Appl. Phys. A. 85: 12-24.
- 13- Craciun, V., Craciun, D., Yang, X., Anderson, T.J. and Singh, R.K. 2003. Transparent and Conducting Indium Tin Oxide Thin Films grown by Pulsed Laser Deposition at Low Temperatures, J. Optoelect. Adv. Mater.. 5(2): 401-408.
- 14- Elangovav, E., Singh, M.P., Dharmaprakash, M.S. and Ramamurthi, K. 2004. Some Physical Properties of Spray Deposited SnO₂ Thin Films, J. Optoelect. Adv. Mater.. 6(1): 197-203.
- 15- Ghosh, A. and Basu, S. 1991. Spray/CVD Deposition and Characterization of Surface Modified Size Oxide Thin Films for Gas Sensors, Mater. Chem. Phys. 27: 45-54.
- 16- Geraldo, V., Vicentc, L., Augusto, E., Valentim, C. and Helena, S. 2003. Sb Doping Effect and Oxygen Adsorption in SnO₂ Thin Films Deposited Via Sol-Gel, Mater. Res.. 6(4): 451-456.
- 17- Menea E., Budiaanu E., Parica M., Podaru C., Popescu A., Cernica I., Babarada F. and Parvulescu C.C. 2007. SnO₂ Thin Films Prepared by Sol-Gel Method for Honeycomb Textured Silicon Solar Cells, Romanian J. Info. Sci. Technol.. 10(1): 25-33.
- 18- Mitra, P. and Mondal, S. 2008. Hydrogen and LPG Sensing Properties of SnO₂ Films Obtained by Direct Oxidation of SILAR Deposited SnS, Bull. Pol. Ac. Technol.. 56(3): 295-300.
- 19- Dawar, A. L., Kumra, A., Sharma, S., Tripathi, K.N. and Mathur, P.C. 1993. Effect of Laser Irradiation on Structural, Electrical and Optical Properties of SnO₂ Films, J. Mater. Sci.. 28: 639-644.
- 20- Burstien E.. 1954. Anomalous Optical Absorption Limit in InSb, Phys. Rev. 93: 632-633.
- 21- Sumangala, D., Amma, D., Vaidyan, V.K. and Manoj, P.K. 2005. Structural, Electrical and Optical Studies on Chemically Deposited Tin Oxide Films from Inorganic Precursors, Mater. Chem. and Phys. 93: 194-201.
- 22- Hass, G., Healey, J.B. and Hunter, W.R. 1982. In Physics of Thin Films, Ed. G.Hass, M.H. Francombe and J.L. Vassen, Academic Press, New York, 12, P.1.

تأثير أشعة الليزر على الخصائص البصرية لأغشية SnO_2 المرسبة بطريقة الأكسدة اللاحقة لأغشية المعدن

نجوى جاسم جبر**

ماجدة علي أمين*

سعاد غفوري خليل*

* قسم الفيزياء/كلية العلوم للبنات/جامعة بغداد.

** قسم الفيزياء/كلية العلوم/جامعة واسط.

الخلاصة:

حضرت أغشية أكسيد الخارصين (SnO_2) بسبك ($1 \mu\text{m}$) على قواعد من الزجاج بطريقة الأكسدة اللاحقة لأغشية المعدن Sn. تم تشييع الأغشية بنبضات ليزر Nd:YAG ذو التردد المزدوج عند الطول الموجي (532 nm) وبتلاث طاقات (100, 500, 1000)mJ. درست الامتصاصية البصرية، النفاذية، الانعكاسية، معامل الانكسار و التوصيلية البصرية لهذه الأغشية في منطقة UV-VIS ذو المدى (200-900) nm. وجد ان معدل النفاذية لهذه الأغشية تقترب من (80 %) عند الطول الموجي (550 nm) وان اعلى نفاذية تقترب من (90 %) في المدى المرئي وتحت الحمراء القريبة. حافة الامتصاص تزحف نحو الطاقات العالية التي تعزى الى تأثير بيرشتاين-موس وتقع في المدى (4 eV). ان فجوة الطاقة البصرية تزداد عند زيادة طاقة اشعاع الليزر.