Effect of Laser Irradiation on the Optical Properties of SnO_2 films Deposited by Post Oxidation of metal Films

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Abstract:

Tin oxide films (SnO_2) 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-Burstien effect and it lies at (4 eV). The optical band gap increased with increasing of energy.

Key words: Laser irradiation effect, SnO_2 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 SnO_2, SnO_2:F, SnO_2:Sb, SnO_2:In and $CdSnO_4$ [1]. Tin oxide thin films are as a window layer in solar cells [2], and as an electrode to collect the charge in CdS/Cu_2S [3], CdS/CdTe [4],and other application of SnO_2 are used for gas sensors like CO, H_2S, H, NO and CH_4 [5-9].

SnO_2 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 SnO_2 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, SnO_2 films were grown by post-oxidation of evaporated thin films of tin. These films were then subjected to laser irradiation. Optical properties of SnO_2 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:

SnO_2 thin films were grown on glass substrates using the post-

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oxidation of metal films technique. Sn metal was plased 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 λ=200 nm and λ=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 SnO_2 samples prepared by post-oxidation of Sn films were studied by measuring the transmission (T) between λ=200 nm and λ=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].

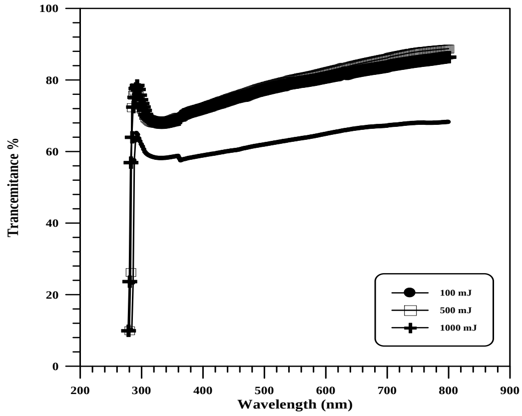

Fig. (1): The transmittance spectra of SnO_2 thin films.

The absorption spectra of SnO_2 shown in figure (2). It was found that the absorption edge shifts towards higher energies (shorter wavelength). This shift is called Moss-Burstien effect [20] or (Burstien, 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}).

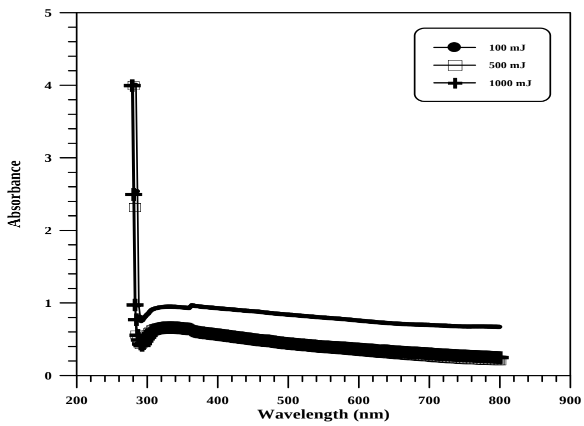

Fig. (2): The Absorbance spectra of SnO_2 thin films.

The variation of $(\alpha h\upsilon)^2$ was draw as a function of photon energy (hυ) 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:
hυ: the photon energy (eV).
B: is a constant.
E_g: the energy gap (eV)

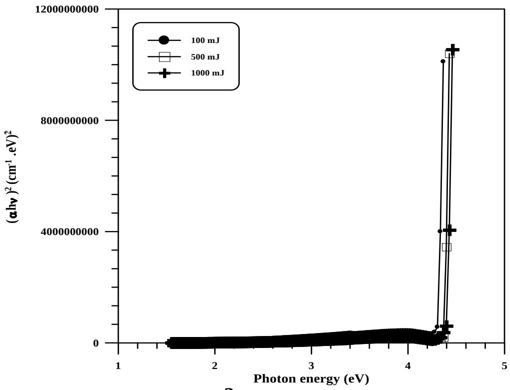

Fig. (3): $(\alpha h\upsilon)^2$ as a function of photon energy for SnO_2 thin films

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].

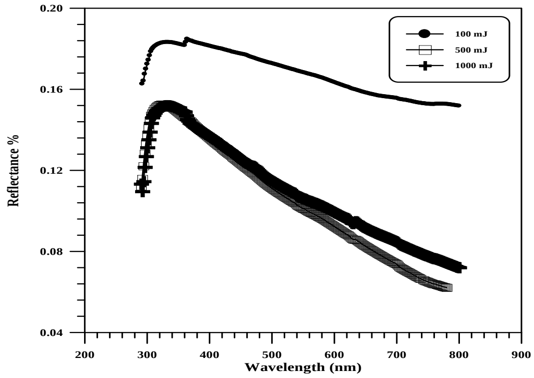

Fig. (4): The Reflectance spectra of SnO_2 thin films.

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.

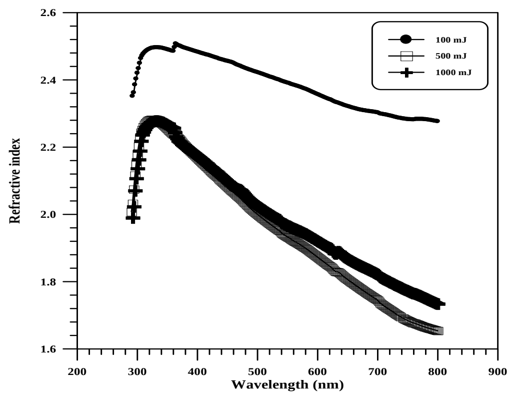

Fig. (5): The variation of refractive index as a function of wavelength for SnO_2 thin films

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.

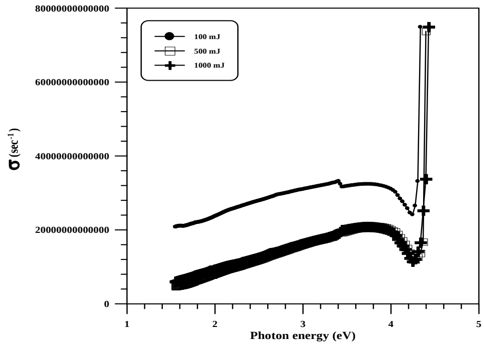

Fig. (6): The variation of optical conductivity as a function of photon energy for SnO2 thin films

Conclusion:

Tin oxide films have been deposited by post-oxidation of metal technique. The optical properties of SnO_2 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 SnO_2 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.

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

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الخلاصة:

حضرت أغشية أوكسيد الخارصين (SnO_2) بسمك (1 µm) على قواعد من الزجاج بطريقة الأكسدة اللاحقة لأغشية المعدن Sn. تم تشعيع الأغشية بنبضات ليزر Nd:YAG ذو التردد المزدوج عند الطول الموجي (532 nm) وبثلاث 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.