Optical Properties of Tin Oxide Nanostructure Thin Films Prepared by Simple and Classical Method

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ABSTRACT

In the present work, preparation of transparent conductive SnO_2 thin films by classical-oxidation technique of thermal evaporated tin metal films, on glass substrates was carried out. The optical properties showed high transmission at visible and NIR regions. The energy band gap was found to be (3.82eV). The structure properties showed that the tin oxide peak appears at (2θ =30.24) and (2Θ=63.39°) . The atomic force microscopy (AFM) results showed a nano-structured for the thin film with particle size ranging (15-140)nm and its root mean square (RMS) value was found to be (5.72 nm).

Keywords: Thin film, SnO_2 Nanostructure, Optical properties.

الخصائص البصرية لاوكسيد القصدير النانوي المحضر بالطريقة التقليدية والبسيطة

الخلاصة

في هذا البحث تم تحضير غشاء اوكسيد القصدير على قواعد زجاجية بطريقة الأكسدة التقليدية لتبخير الحراري لغشاء من معدن القصدير, حيث أظهرت الخصائص البصرية نفاذيه عالية في المنطقة المرئية والمنطقة القريبة من تحت الحمراء وقد تم حساب فجوة الطاقة فكانت (3.82eV)، وضحت الخصائص التركيبية تكون أوكسيد القصدير عند زاوية حيود براك (2θ=30.24) و (2θ=63.39°)ووضحت نتائج قياس مجهر القوة الذرية (AFM) نتائج تكون تراكيب نانوية للغشاء الرقيق مع حجم جسيمات يتراوح (15-140)nmووجد ان قيمه معدل الجذر التربيعي (RMS) هي 5.72nm.

INTRODUCTION

The first semitransparent and electrically conductive films were reported as early as 1907. However substantial technological advances were only made after the 1940s when interest on these materials was generated by their potential applications in industry [1].

For many manufacturing companies of Transference Conductive Oxide (TCO) films the aim is to achieve stable film properties for large area coating processes with

low film resistance and high transmittance within the visible spectrum range [2]. Among the TCO films, the most appropriate material for the application seems to be tin oxide films, which are chemically inert, mechanically hard and heat-resistant.

Tin oxide (SnO_2) compounds have been recognized as very promising materials with large technological applicability's.

SnO_2 thin films in general are used in some applications as transparent conductors, such as: (i) electrodes in solar cells covering the front surface of these devices or electrodes in organic semiconductors based devices; (ii) flat-panel displays; (iii) electromagnetic shielding maintaining transparency; (iv) defrosting windows; (v) low emissivity windows; (vi) oven windows [3]. SnO_2 thin films are produced by different techniques such as thermal evaporation, sputtering, spray pyrolysis, sol–gel and hydrothermal [4,5].

Tin oxide (SnO_2) is a tetragonal rutile structure with lattice parameters a = b = 4.737 Å and c = 3.826 Å [6]. The unit cell contains two tin and four oxygen atoms. Each tin atom is bound to six oxygen atoms at the corners of a regular octahedron, and every oxygen atom is surrounded by three tin atoms [7]

Tin oxide Films have a good transparency in the visible and a high reflectivity in the IR spectral range, when the tin oxide coatings are used as heat mirrors a sharp decrease in transparency of these films in the UV and IR regions is obtained due to fundamental light absorption and free–carrier absorption respectively [8].

In the present work, prepared SnO_2 nanostructured thin films by simple and classical method and investigated their structural and optical properties.

THEORETICAL BACKGROUND

Much of the information about the properties of materials is obtained when they interact with electromagnetic radiation. When a beam of light (photons) is incident on a material, the intensity is expressed by the Lambert-Beer-Bouguer law [9,10]:

$$I = I_o \exp(-\propto d) \qquad (1)$$

If this condition for absorption is met, it appears that the optical intensity of the light wave, (I), is exponentially reduced while traveling through the film. If the power that is coupled into the film is denoted by I_0, gives the transmitted intensity that leaves the film of thickness d.

(α) Is called "absorption coefficient". From (1) it follows that:

$$\propto = \frac{1}{d} ln \frac{1}{T} \qquad (2)$$

Where T is transmition (I_0/I)

It is clear that α must be a strong function of the energy hν of the photons . For hν < *E*g (direct), no electron hole pairs can be created, the material is transparent and α is small. For hν ≥ *E*g (direct), absorption should be strong. All mechanisms other than the fundamental absorption may add complications (e.g. "sub band gap absorption"

through excitons), but usually are not very pronounced. The optical constants were determined from the optical transmission measurements using the method described by Swanepoel [11].

EXPERIMENTAL WORK

Test glass slides, each of 2×2 cm^2 area, were used as substrates. They were cleaned by alcohol with ultrasonic waves produced by Alkattl in order to remove the impurities and residuals from their surfaces.

A thermal evaporation system type (Edwards) was used to evaporate high purity (99.9 %) Tin on glass slides substrate at room temperature under low pressure (~ 10^{-6} torr), Figure (1) show thermal evaporation system.

Figure (1). Thermal evaporation system.

Thin film thickness (t) is measured by using laser interferometer and applying the following equation:[12]

$$t_t = \frac{\Delta x}{x} \cdot \frac{\lambda}{2} \qquad (3)$$

Where x is the fringes spacing, Δx is the displacement between two fringes and λ is the wavelength of the used laser light (632.8nm).

The evaporated films at room temperatures were oxidized using classical oxidation method by using a tube furnace operated at different temperatures (150, 200 and 250 C^o) Figure (2) shows the typical experimental set up of the classical oxidation.

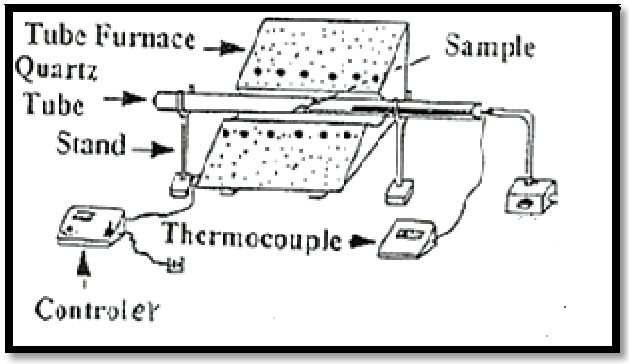

Figure.(2) Setup of Classical Oxidation.

A double-beam UIR-210A spectrophotometer from Shimadzu was used in order to record the optical transmittance and absorption spectra of the deposited films on glass substrate at different preparation conditions within the wavelength spectrum range (300 -900 nm) .

The particle size distributions and surface morphology of SnO_2 nanostructure film prepared under various conditions were analyzed by atomic force microscope (AFM) (from a very high- resolution type of scanning probe microscopy AA3000).

X-ray diffraction measurement has been done and compared with the International Center for Diffraction Data (ICDD) cards, using Philips PW1050 X-ray diffract meter of λ=1.5406 A^o from Cu-Kα.

Results and discussion

The optical transmittance spectrum for SnO_2 films deposited at room temperature and oxidized at different oxidation temperatures is shown in figure (3). The absolute transmittances (i.e. when the substrate contribution was deduced) of these films vary over the spectrum range (55-75)% in the region (400–900) nm for films oxidation at (200 and 250)C^o, while its (10-25)% for film oxidant at (150)C^o. In general, it has been found that the transmittance of the films was increased when the oxidation temperature was increased due to film transformation from metal to transparent oxide. The absorption coefficient (α) was evaluated using equation (2) where (d=150 nm) is shown in Figure (4).

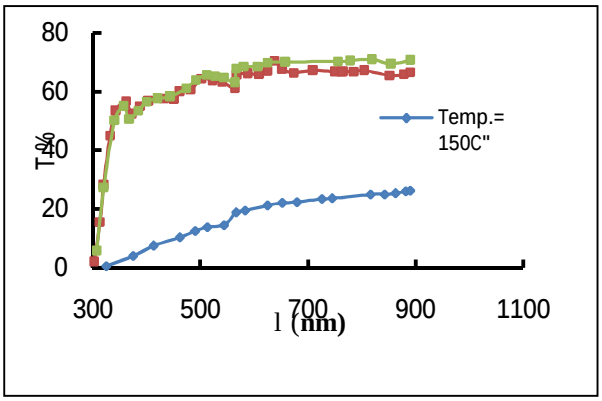

Figure.(3) Optical transmittance T(%) of SnO_2 thin film as a function of wavelength(λ).

Figure (5) shows the variation of $(\alpha h\upsilon)^2$ with the incident photon energy for (200C°) as an oxidation temperature. The nature of the plots indicates the existence of direct optical transitions (since it has direct band gap). The band gap (Eg) is determined by extrapolating the straight line portion of the plot to the energy axis. The intercept on energy axis gives the value of band gap energy Eg for the sample and the value was found to be about (3.82 eV) of this work is the result was found to be consistent to other similar work [13].

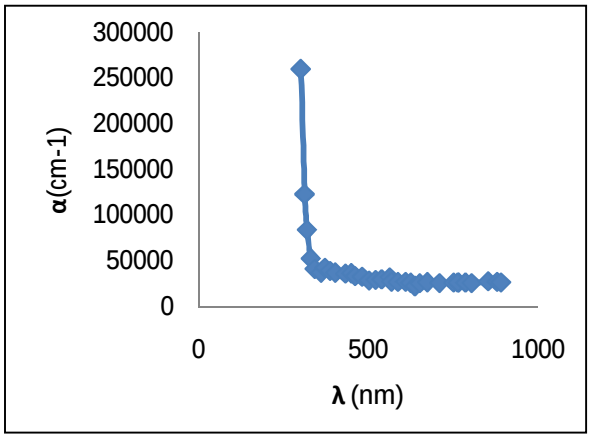

Figure (4).Absorption coefficient(α) of SnO_2 thin film as a function of wavelength(λ) for oxidation (200 C°).

Figure (6) shows the excitation coefficient (k) of SnO_2 film with the wavelength where the k values are very small for long wavelengths, i.e where the film is nearly transparent. The XRD pattern of SnO_2 thin film shown in figure (7) consists of sharp peak at $2\theta = 30.24^{\circ}$ and $2\Theta = 63.39°$ which corresponds to reflection form (111) and (311) planes respectively ,which is related to the formation of SnO_2 thin film at (200C°) oxidation temperature.

Figure (8) shows the AFM image of the surface morphology of SnO_2 thin film oxidation at(200C°) ,image size (2000nm*2000nm),it was observed that the Root Mean Square (RMS) IS (5.72nm).The histogram of size distance show the particle size ranging from (15-140)nm. Several potential applications could get benefit of this research such as transparent conductive electrode, solar cells and gas sensing [13].

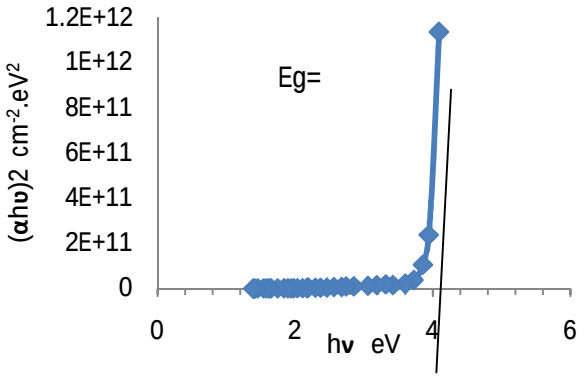

Figure (5) Variation of$(\alpha h\upsilon)^2$ with the incident photon energy for SnO_2thin film at oxidation (200 C°).

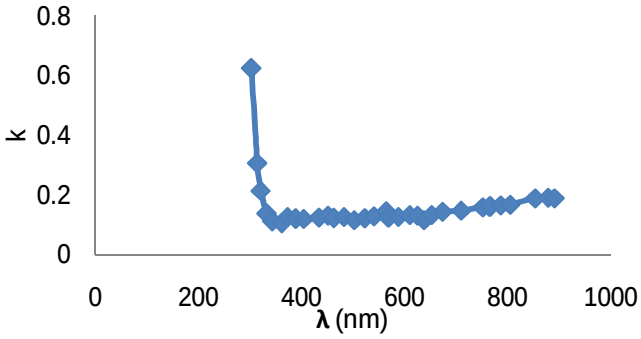

Figure (6).Varition of excitation coefficient(k with wavelength(λ) for SnO_2 thin film at oxidation(200C°).

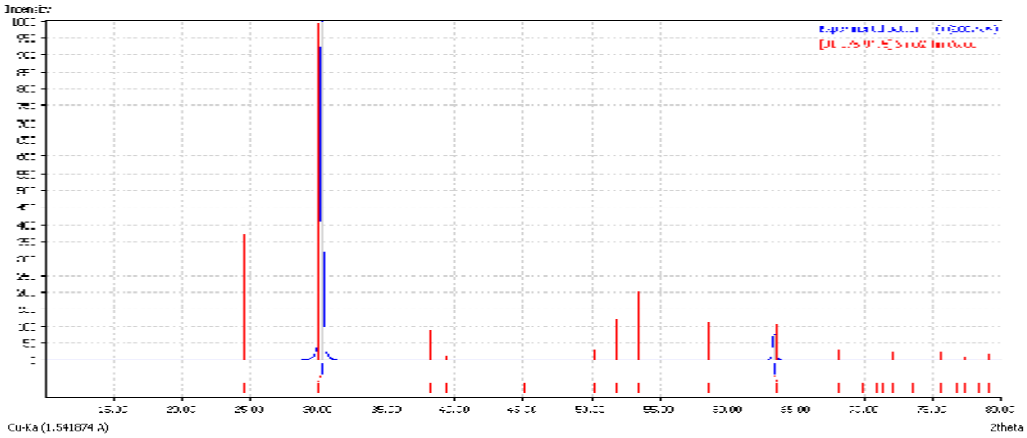

Figure (7) XRD pattern of the SnO_2thin film at oxidation temperature (200C°).

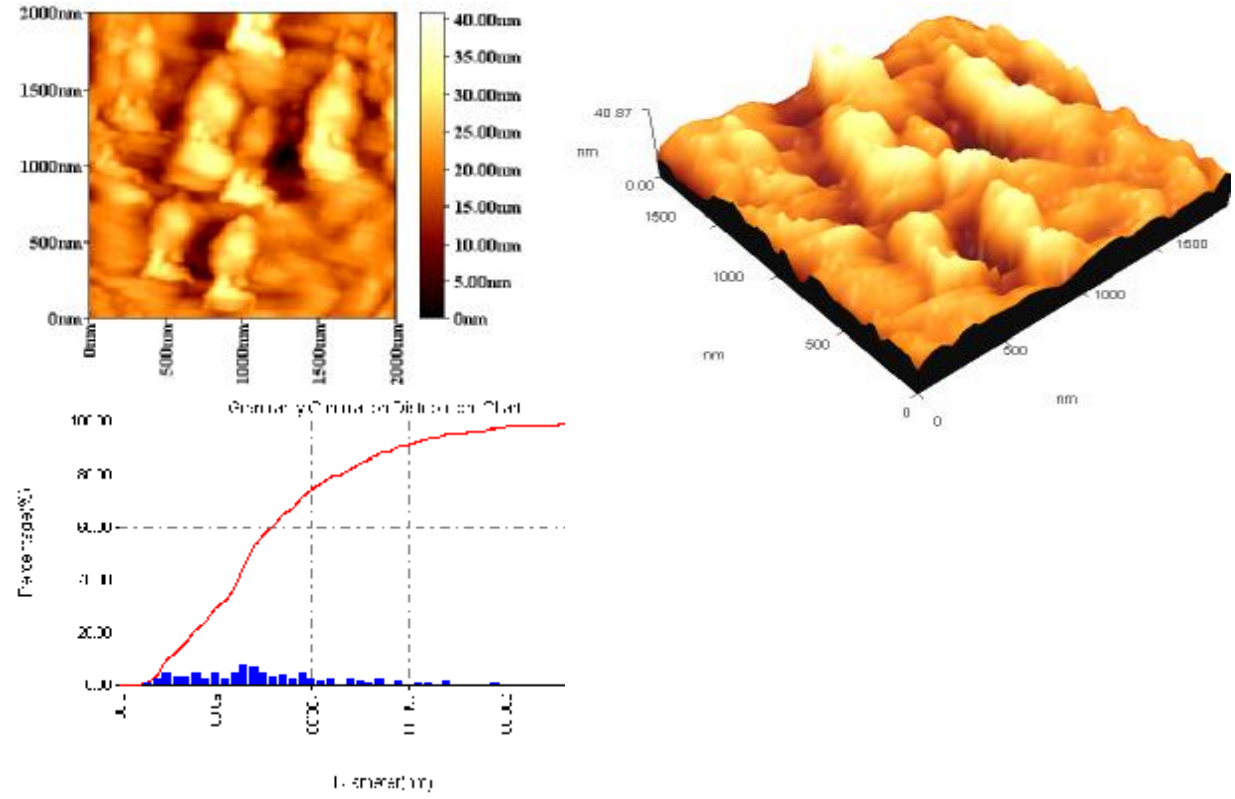

Figure (8) AFM image of SnO_2thin film at oxidation temperature (200C°).

CONCLUSIONS

Tin oxide (SnO_2) thin film was deposited successfully by thermal evaporation deposition technique using Sn metal. All films have high transmittance in the visible region, which increased with oxidation temperature, with energy band gap (3.82ev) at (200C°). The (α) and (k) were also calculates from transmission spectrum. X-ray diffraction pattern conformed that the crystalline SnO_2 thin film. From AFM show that the particle size was the ranges (15-140) nm with RMS (5.72)nm.

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