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Preparation and Characterization of Titanium Dioxide (TiO_2) Thin Films Prepared By Spin Coating Method

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Abstract:

Transparent semiconducting thin films of titanium dioxide (TiO_2) were deposited on glass substrates by spin-coating technique and with thickness was in order of 150 ± 5 nm . The XRD analysis reveals that the films are polycrystalline with an anatase crystal structure and a preferred grain orientation in the (101) direction. The optical properties of the films were characterized by UV–visible spectrophotometry, which shows that the films are highly transparent in the visible and near infrared , with an average value above (99 %), with energy gape (3.79 e.v). The dependence of the refractive index (n), extinction coefficient (k), and absorption coefficient (α) of the films on the wavelength was investigated.

keywords : titanium dioxide, Spin Coating Method.

تحضير وتشخيص اغشية ثنائي اوكسيد التيتانيوم(TiO_2) المحضرة بطريقة تدوير الطلاء (Spin Coater)

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الخلاصة :

تم في هذا البحث تحضير اغشية رقيقة لثنائي أوكسيد التيتانيوم (TiO_2) باستعمال تقنية تدوير الطلاء (Spin Coater) عند درجة حرارة الغرفة وتم ترسيب المحلول على قواعد زجاجية شفافة وبسمك (nm) ٥±١٥٠ . شخصت الاغشية الرقيقة المحضرة باستخدام حيود الاشعة السينية (X-ray Diffraction) ,وتبين انها من نوع anatase ، وكذلك تمت قياس الخواص البصرية للاغشية باستخدام جهاز(UV–visible spectrophotometry,) سجلت اعلى قيمة للنفاذية عند (99%) وفجوة الطاقة المسموحة وكانت (3.79 e.v) اما فجوة الطاقة الممنوعة كانت (3.75 e.v) وكذلك تم قياس الامتصاصية والانعكاسية ومعامل الانكسار والخمود .

1. Introduction:

Titanium doxide (TiO_2) thin films have attracted much attention due to their optical, physical, chemical, and electronic properties, including excellent transmittance of visible light, photocatalytic activity, high dielectric constant, high refractive index, and high chemical stability [T.L. Chen, *et al* (2007) - P.D. Prajna, *et al* (2008)]. A variety of TiO2 films have been developed for several applications, such as solar cells [O. Regan and Grätzel, (1991)], photocatalysis [K. Masaaki *et al* (2007) - Š. Kment, *et al* (2012)], gas sensors [Ibrahim A, *et al* (2007)], and antireflective coatings [G. San Vicente, *et al* (2002)]. It is well known that TiO2 is a n-type semiconductor with a wide indirect energy band gap [M. Gräzel, (1989) - N. Serpone, *et al* (2995)]. TiO_2 generally crystallizes in three structures, the tetrahedral anatase structure. The anatase and rutile structures belong to different space groups but both have a tetragonal crystal lattice. Rutile is the most stable form of TiO2, whereas anatase and brookite are met stable and transform to the rutile phase upon heating [C. Rath, et al (2009) – H. Zhang, et al (1999)]. The characteristics of TiO2 films depend on their crystal structure, orientation, and morphology, and phase structure of the films during growth is important. Various techniques have been used for the deposition of TiO2 films, such as sol–gel spin coating [K. Pomoni, et al (2008) - M. Morozova, et al (2011)], spray pyrolysis [C. Natarajan, et al (1998)], pulsed laser deposition [T. Masahiro, et al (2000)], e-beam evaporation [S. Lianchao and H. Ping, (2004)], chemical vapor deposition [S. Hongfu, et al (2008)], and reactive magnetron sputtering [S. Boukrouh, et al (2008)].

Fig.2: shows the device UV- Visible recording Spectrophotometer

2. Experimental

The TiO_2 sol was prepared using of titanium chloride dissolved in hydrochloric acid As a solution ready for use (with purity 99.8%). In the sol, the titanium concentration was 1 mol/L. glass substrates were successively cleaned with acetone, ethanol, and deionized water. TiO_2 thin films were deposited on the glass substrates by spin coating (as illustrated in figure (1) at room temperature with a rate of 3000 rpm for 30 s, then spin-coating step, the films were heated on a hot plate at 100 °C in air for 15 min to remove organic contaminations. The X-ray diffractometer (ShimadZu 6000) Target: Cu kα, Voltage 40 KV, Current 30 MA. Where λ is the X-ray wavelength (1.54060 Å).. The absorptance and transmittance of the prepared films were measured using UV- Visible recording Spectrophotometer(UV, VTC 100) in the wavelength range (300-1000 nm), as illustrated in figure (2).

Fig. 1: shows the device spin coating (VTC 100)

3. Results And Discussion

1. X- ray Diffraction Investigation

The X-ray diffraction of TiO_2 films deposited on glass substrate was at room temperature. Figure (3) displays XRD spectrum of TiO_2 film. It is obvious that the film is (polycrystalline and multiphase). The structure of TiO_2 in XRD investigation is anatase titanium dioxide, which agrees with (ASTM) card, and with the previous study [I. Oja, *et al* (2006)].

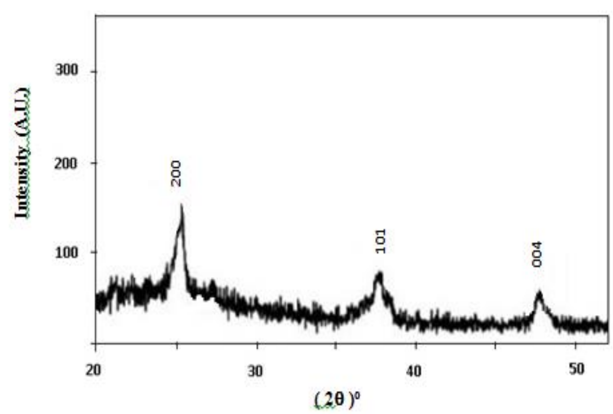

Fig. 3: The X-ray diffractograms of TiO_2 films

2. Transmittance (T)

Fig. (4) . Show the optical transmission as a function of wavelength in the range (300 – 1000 nm) for TiO_2 films. The maximum transmittance observed was almost (99%). The figure show that the transmittance of film has a high value at (λ>500nm), i.e. in visible and near infrared regions. Our result is in good agreement with [A. A. Daniyan, *et al* (2013)]

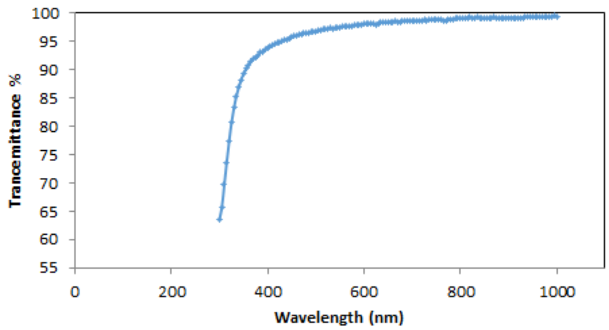

Fig. 4: the relation between transmittance and wavelength of TiO_2 thin films

3. Absorbance (A)

Fig.5. shows the variety of observance as a function of wavelength, within the range (300 – 1000nm) for TiO_2 film's investigation. In general the absorbance of films has low values in the visible and near infrared region, this behavior can be explained as follows, at high wavelength the incident photons don't have enough energy to interact with atoms, the photon will transmitted. When the wavelength decreases, the interaction between incident photon and material will occur.

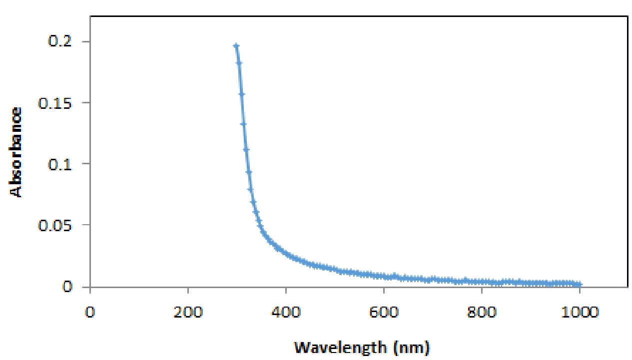

Fig.5: relation between wavelength and absorptance of TiO_2 thin films

4. Absorption Coefficient Measurements: (α)

Fig. (6) shows the relation of absorption coefficient as a function of incident photon energy for TiO_2 thin films. Also we can evidently see that TiO_2 thin films have high value of absorption coefficient ($\alpha > 10^5$ cm^{-1}) which leads to increasing the probability of occurrence direct transitions.

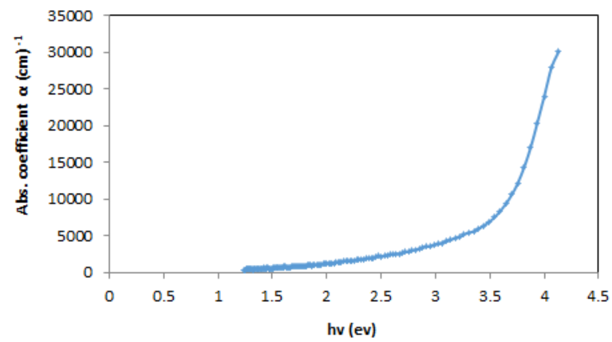

Fig. 6: absorption coefficient as function of energy photon of TiO_2 thin films

5. Optical Energy Gap (Eg)

Fig. (7) shows the relation of ($\alpha h\nu$)^2 against photon energy, from straight line obtained at high photon energy the direct allowed energy gap could be determined which was equal (3.79 eV) and Fig. (8) shows direct forbidden energy gap equal (3.75 eV). Our result is in good agreement with [I.Karabay, *et al* (2012)].

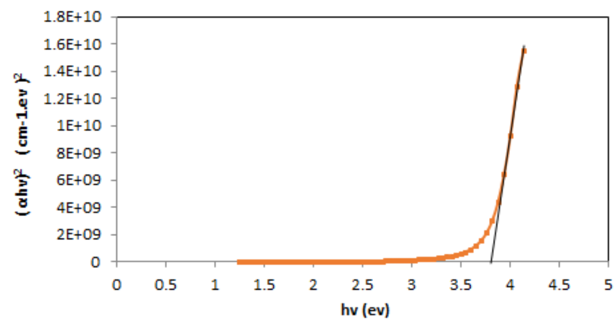

Fig. 7: relation between ($\alpha h\nu$)^2 and photon energy of TiO_2 thin films (e.g for Direct allowed transition)

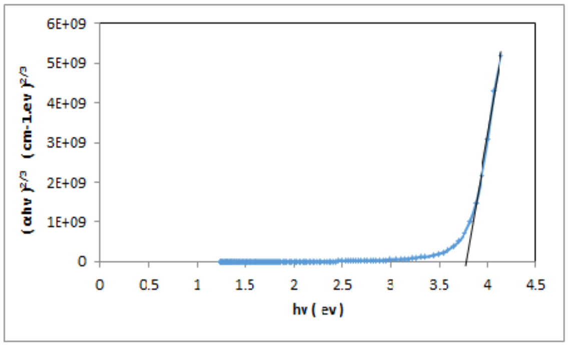

Fig. 8: relation between $(\alpha h\nu)^{2/3}$ and photon energy of TiO_2 thin films (e.g for Direct forbidden transition)

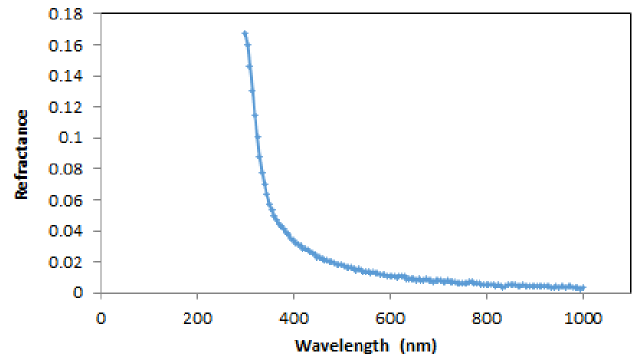

Fig. 10: relation between wavelength and reflectance of TiO_2 thin films

6. Extinction Coefficient Measurements (K_o) :

Figure (9) illustrates variation of (K_o) as a function of wavelength for (TiO_2) films. From the figure extinction coefficient decreasing with wavelength increasing, because of dependent on coefficient absorption.

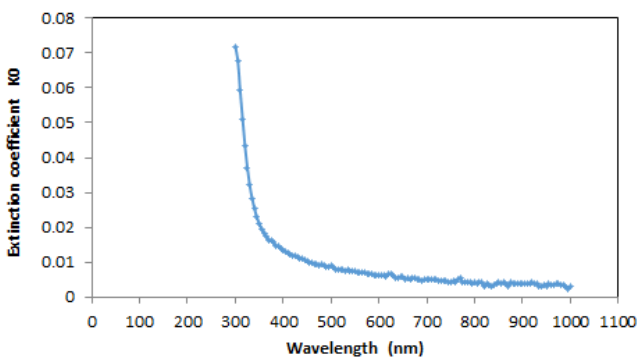

Fig. 9: extinction coefficient as function of wavelength of TiO_2 thin films

7. Reflectance (R):

We observed that reflectance have high value which decreasing with increasing of wavelength for films, as in figure(10). The behavior of reflectance is in agreement with the behavior of transmittance and absorbance according to equation :

$$A+T+R = 1$$

8. Refractive Index (n) :

Figure (11) shows relation between refractive index and wavelength, we can notice that the behavior of refractive index with wavelength is the same behavior reflection, which means that the reflective index increase with increase photon energy

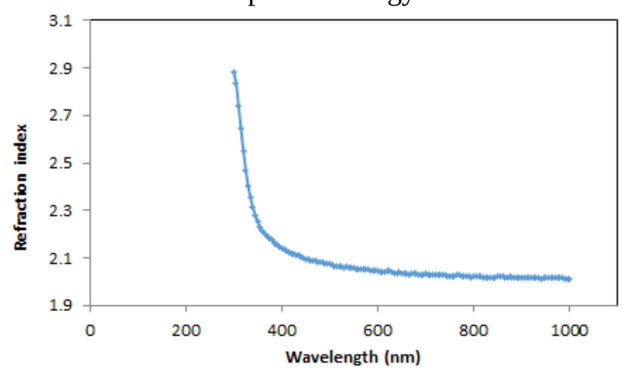

Fig. 11: refraction index as function of wavelength of TiO_2 thin films

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