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Study the Effect of Thickness on Optical Properties of Titanium Dioxide (TiO_2) That Preparation of Via the Sol-Gel Process

*[1]Mohammed Sami Abdali [2]Ahmed Shaker Hussein
[3]Mohammed Hadi Shinen

[1]*Department of Environmental, College of Science ,University of Al-Qadisyah , Iraq*
[2]*Department of Basic Science , College of Dentistry ,University of Babylon, Iraq,*
[3]*Department of Science, College of Basic Education,University of Babylon, Iraq*

*Corresponding Author E-mail: mohammed.sami68@yahoo.com

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ABSTRACT

This research, study the effect of the thickness on titanium dioxide (TiO_2) , that prepared by the Sol-Gel Process method on the optical properties of (TiO_2) thin film with different thickness (54, 64 and 89 nm), the thickness effect on optical properties (energy gap , absorbance spectrum, transmittance spectrum, reflectance, refractive index, extinction coefficient, absorption coefficient, real and imaginary dielectric constant) ,this study shows that thickness have an effect on all these parameters .

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دراسة تاثير السمك على الخصائص البصرية لثنائي اوكسيد التيتانيوم والمحضر بعملية (المحلول – الجلاتيني)

محمد سامي عبد علي[١] احمد شاكر حسين[٢] محمد هادي شنين[٣]

[١] جامعة القادسية / كلية العلوم / قسم البيئة
[٢] جامعة بابل / كلية طب الاسنان / فرع العلوم الاساسية
[٣] جامعة بابل / كلية التربية الاساسية / قسم العلوم

الـــخُـــلاصـــة

تم في هذا البحث دراسة تـأثير السمك على ثنـائي أوكسيد التيتـانيوم والمحضر بطريقة عملية (المحلول – الجلاتيني) على الخصائص للغشاء الرقيق ثنائي أوكسيد التيتـانيوم باسماك مختلفة (٥٤ ، ٦٤ ، ٨٩ نـانومتر) ، تـأثير السُمك على الخصـائص البصـرية (فجـوة الطاقة ، طيـف الامتصـاص ، طيـف النفاذيـة ، الانعكـاس ، معامـل الانكسـار ، معامـل الخمـود ، معامـل الامتصـاص ، ثابـت العـزل الحقيقي والخيالي) ، أظهرت هذه الدراسة أن هذه الاسماك لها تأثير على جميع هذه المعاملات.

الكلمات المفتاحية:

الخصائص البصرية
طريقة الطلاء الدوراني
الأغشية الرقيقة.

1. INTRODUCTION

In the recent years TiO_2 films are widely studied because of their perfect photocatalytic properties. TiO_2 thin films find a broad range of applications in various fields like photocatalysis , antireflective ,gas sensing , also antibacterial, protective coatings and optical coatings, dielectric films for a new generation field effect transistors, etc.[1]. Titanium dioxide is a solid substance,white inorganic , which is non-stable, poorly soluble, non-flammable , cheap non-toxic material that has good semiconducting properties. Its not sensitivity to the visible light, because of its band gap , which have value (3.2) eV [2].Some techniques including spray pyrolysis, sol–gel coating, chemical vapor deposition , also rf magnetron sputtering have been advanced for TiO_2 thin films manufactures . TiO_2 films prepared from these mechanism exhibit a broad variety of optical properties and structures [3].From across existing techniques, sol-gel. technique , has appear as one of the most favorable technique , as this method, yields samples with a perfect homogeneity at low cost. Furthermore, the processing of sol gel is essentially efficient to producing transparent, thin ,multi-component oxide layers of various compositions on many substrates, counting glass[4].

2. Experimental details

Three type of components are employ in the production of the TiO_2 Sol-Gel films can be explained as following as : " (TIP) $Ti[OCH(CH_3)_2]_4$ " Titanium Isopropoxide, that purity is (98%), "CH3COOH Acetic acid that purity is (99.5%,) and Ethanol CH_3CH_2OH that purity is ranging from (99.7-100%). Titanium Isopropoxide (TIP) $Ti[OCH(CH_3)_2]_4$, is a metal alkoxide , which has the broad formula M(OR)n, where (M) represent the metal , alkyl group represent by (R) and the valence of the metal atom is represent by (n) . Thin films of (TiO_2) It has been prepared by sol-gel spin-coating method by using volume (50 ml) of ethanol and permitting to be mixed for a time (50 min) ; an amount of volume (5 ml) of acetic acid with a pipette into ethanol and stir by using a magnetic stirrer it for time (5 min), or at minimum time (3 min), and measurement amount volume (6.3 ml) of titanium isopropoxide has adding to a beaker containing a mixture of glacial acetic acid and ethanol , that have been mixed for time (5 min). The blend is permanent stirred by a magnetic stirrer is used addition for further time (2 min), after adding of the precursor. The influence of altering molar ratios of acid titanium isopropoxide on absorption properties and thickness of the films are studied. The manufactured of sols due to the technique described above are instantly used to make coating on the many substrates, like silicon or indium tin oxide (ITO) -glass substrates.

Figure (1) show X-ray diffraction peaks of TiO_2 thin film as a function of 2θ between 10 and 70 degrees. The 2θ peaks at 25.2°, 28° and 47.9° confirm its anatase structure . The intensity of XRD peaks of the sample reflects that the formed nanoparticles are crystalline and broad diffraction peaks indicate very small size crystallite, as shown in figure (1). this behavior is consistent with the researcher [5,6].

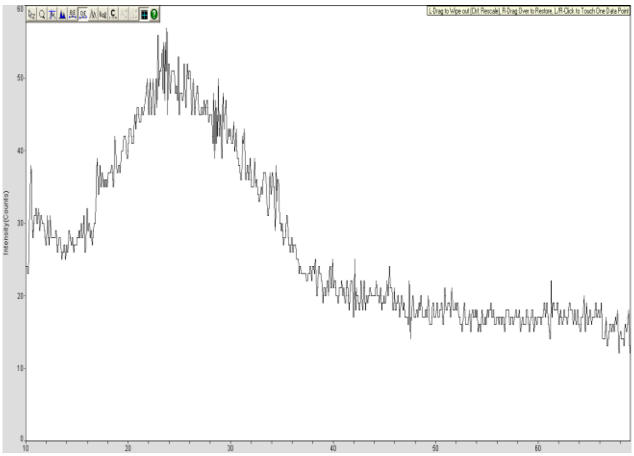

Figure (1): X-ray diffraction patterns of as prepared Ti02 thin film.

The optical properties of thin films depend on membrane thickness, homogeneity, structure, membrane material and preparation conditions.

These factors are responsible for demonstrating the properties of semiconductor membranes ,use a spectrometer(UV-Visible Recording Spectrophotometer) to procedure optical measurements , optical measurements included measurement(energy gap, absorbance spectrum, transmittance spectrum, reflectance, refractive index, extinction coefficient, absorption coefficient, real and imaginary dielectric constant).

3. Results and discussion

From the figure (2) shown that the absorbance measurements of (TiO_2) thin film, were plotted against wavelength in the range of (290-990) nm. From this figure it is noticed that absorption increases with increasing thickness after the wavelength (590 nm) ,This manner is attributed to the number of atoms increasing with thickness this behavior leads to the increasing the number of collisions between atoms and incident photon , which leads to the increasing of absorbance, also note the decrease in absorbance by increasing the wavelength this behavior is consistent with the researcher [7].

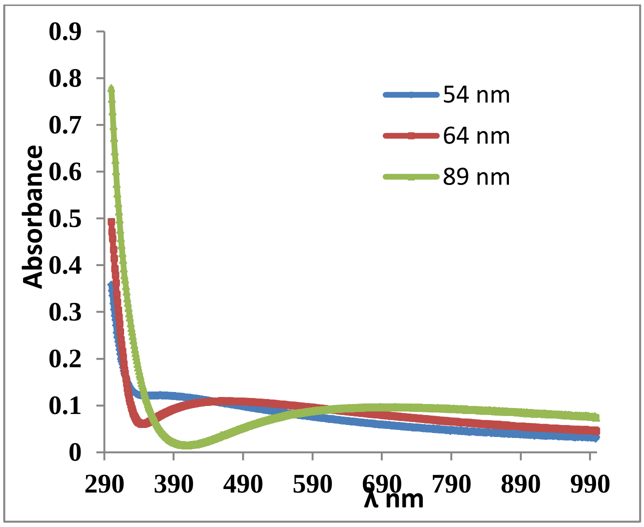

Figure (2): variation of absorption spectrum of $TiO_2$with wavelength for different thickness.

From the figure (3) shown that the transmittance spectrum of (TiO_2), were plotted against wavelength in the range of (290-990) nm. From this figure it is noticed that transmittance spectrum decreases after the wavelength (590 nm) with increasing thickness. The transmittance spectrum behaves as an opposite behavior of the absorbance spectrum according to the following exponential relationship through the for both absorption and transmittance which :

$A = \log (1 / T)$ .... (1)

This behavior is consistent with the researcher [7].

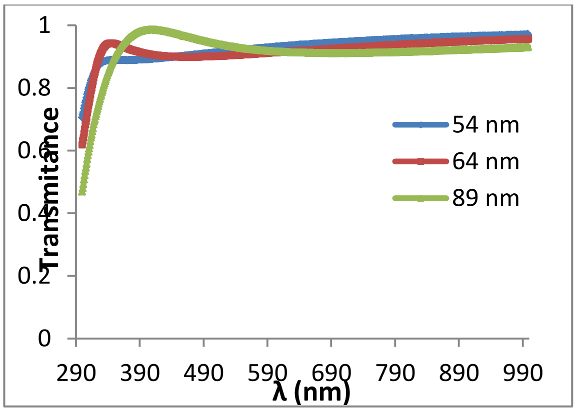

Figure (3): variation of transmittance spectrum of $TiO_2$with wavelength for different thickness.

when plot of $(\alpha h\nu)^2$ with energy ($h\nu$) . Figure (4) 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. the film thickness is very important in the optical band gap assignment, it is observed that the optical energy band gap is decrease from (3.97, 3.95 and 3.85 eV) with increasing of film thickness from (54,64 and 89nm) as shown in figure (4), the direct band gap results are in good agreement with research [8,9].

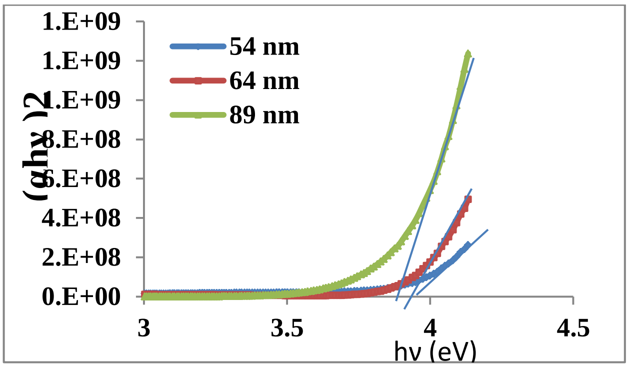

Figure (4): Variation of $(\alpha h\nu)^2$ vs. photon energy(hν) for TiO_2 for different thickness.

From figure (5) it is noticed that reflectivity increases with increasing thickness that can be attributed to the basis of reflectance that depend on the refractive index as the relationship $R = (n-1)^2 + k^2/(n+1)^2 + k^2$ ……..(3) therefore the reflectance behave is similar to the refractive index. and this is consistent with the researcher [9,10].

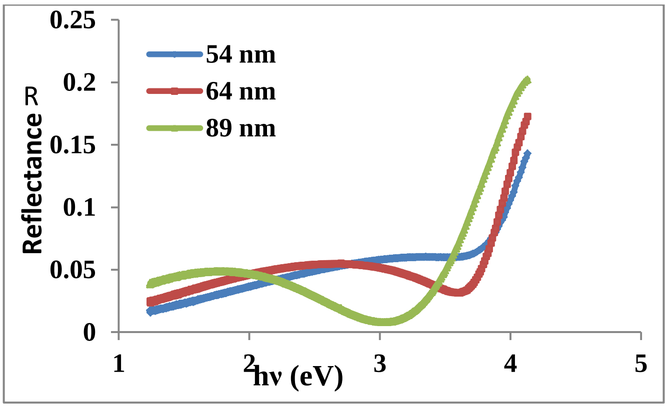

Figure (5): Variation of reflectance vs. with photon energy(hν), for TiO_2 for different thickness.

Figure (6) show that the values of refractive index varies with increasing thickness and it can be attributed to the basis of refractive index that depend on the reflectance as the relationship

$$n = \left[\left(\frac{1+R}{1-R}\right)^2 - (k_o^2+1)\right]^{\frac{1}{2}} + \frac{1+R}{1-R} \quad \text{..................} (4)$$

Note from the figure that the refractive index increases with increasing thickness , it is observed that the refractive index is increase from (1.07,1.1 and 1.17) with increasing of film thickness from (54,64 and 89nm) as shown in figure (6) , mainly due to increased density of the deposited films leading to increased refractive index , this is consistent with the researcher's findings [10 ,11].

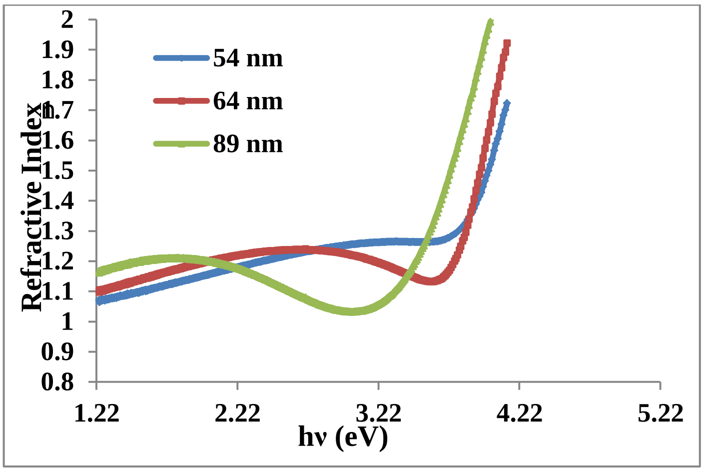

Figure (6): Shows the variation of refractive index, as a function of photon energy(hν)for TiO_2 for different thickness.

Figure (7) shows the variance of extinction coefficient of TiO_2 as a function of photon energy (hν) for different thickness [11 ,12] Note from the figure that the extinction coefficient as increases with increasing thickness , it is observed that the extinction coefficient is increase from (0.0025, 0.004and 0.0065) with increasing of film thickness from (54,64 and 89nm) as shown in figure (7) where the value of extinction coefficient is a small quantity.

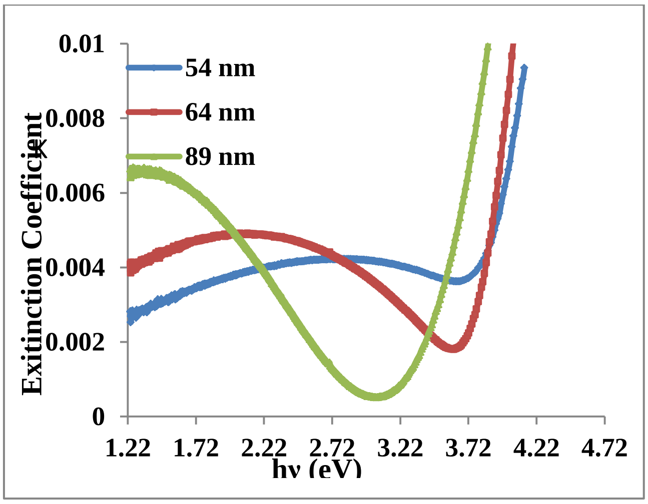

Figure (7):.shows the variation of extinction coefficientas a function of photon energy(hν)for TiO_2 for different thickness.

3.2 Optical Properties

Figure (8) illustrates the change in the values of the absorption coefficient for TiO_2 as a function of photon energy(hν) for different thickness [3]. Note that behavior of absorption coefficient is similar to behavior of extinction coefficient and so depending on the relationship:

$$k_o = \frac{\alpha\lambda}{4\pi} \ldots\ldots\ldots(5)$$

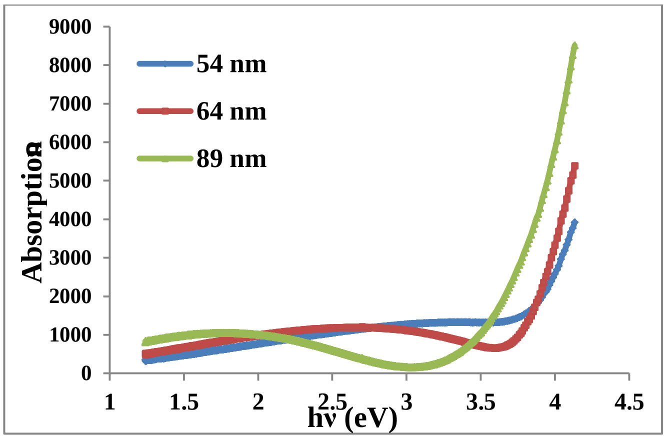

Figure (8): Shows the variation of absorption coefficient for $TiO_2$for different thickness.

The real (Ɛr) and imaginary (Ɛi) dielectric constant for TiO_2 thin films is determined by using equations (6), (7) respectively. The change of imaginary (Ɛi) and real (Ɛr) parts of dielectric constant values versus of photon energy(hν) for different thickness. From figures (9, 10), it is found that Ɛr and Ɛi increased with increasing of thickness. The manner of Ɛr is like to that of the refractive index because of the smaller value of k^2 compared with n^2, while εi is essentially depended on the k values according to equation (7). This behavior is in agreement with the results of [13,14] , it is observed that the real (Ɛr) parts of dielectric constant is increase from (1.14, 1.2and 1.35) with increasing of film thickness from (54,64 and 89nm) as shown in figure (9) while it is observed that the imaginary (Ɛi) dielectric constant is increase from (0.0052, 0.008and 0.0152) with increasing of film thickness from (54,64 and 89nm) as shown in figure (10) .From following relationship can be calculated real and imaginary dielectric constant

$$\varepsilon_r = n^2 - k^2 \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$\varepsilon_i = 2nk \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

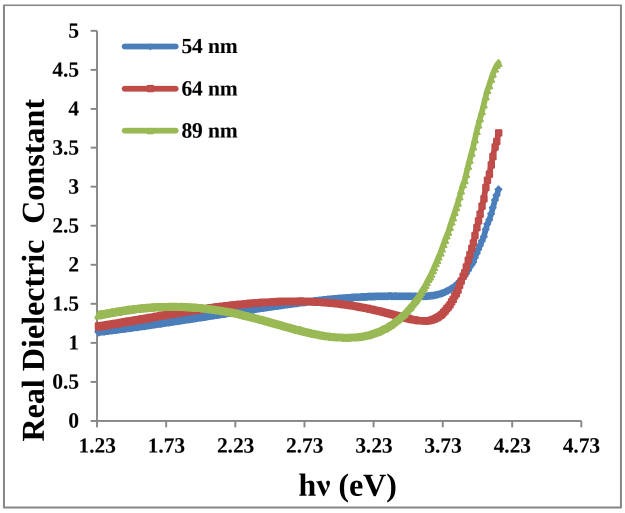

Figure (9): Shows the variation of the real dielectric constant of TiO_2as a function of photon energy(hν) for different thickness.

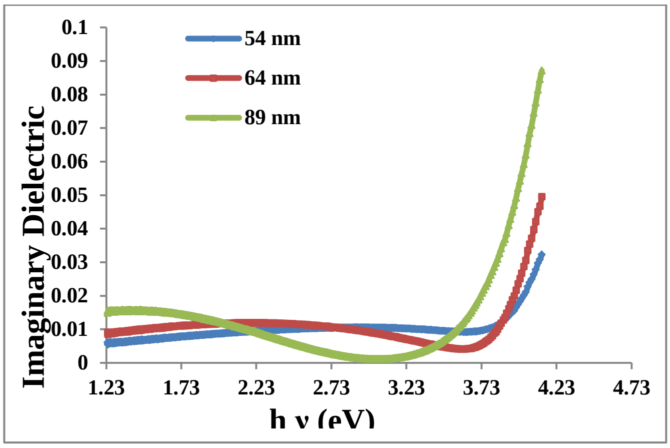

Figure (10): Shows the variation of the imaginary dielectric constantof TiO_2as a function of photon energy(hν) for different thickness.

4. Conclusions

Optical constants of TiO_2 film are dependent on the thickness of the film. Absorption as a function of wavelength increase for various thickness .while transmittance as a function of wavelength decrease for various thickness after the wavelength (590 nm). The corresponding increase in optical constant such reflectance ,refractive index ,extinction coefficient , absorption coefficient, real and imaginary dielectric constant increase for different thickness . increase with increasing film thickness. Also decreases in band gap of the films with the increase of thickness.

REFERENCES

[1] L. Bedikyan, S. Zakhariev, M. Zakharieva , "Titanium Dioxide Thin Films: Preparation And Optical Properties " , Journal of Chemical Technology and Metallurgy, P.P. (555-558) , 48, 6, (2013).

[2] Z. Essalhi, B. Hartiti, A. Lfakir, M. Siadat, P. Thevenin , " Optical properties of TiO2 Thin films prepared by Sol Gel method ",J. Mater. Environ. , P.P. (1328-1333) , Sci. 7 (4) ,(2016).

[3] Chu-Chi Ting and San-Yuan Chen , "Structural evolution and optical properties of TiO2 thin films prepared by thermal oxidation of sputtered Ti films " , Journal Of Applied Physics , Volume 88, Number 8 ,P.P.(4628 4633- , (2000).

[4] F. Hanini, A. Bouabellou, Y. Bouachiba, F. Kermiche, A. Taabouche, M. Hemissi, and D. Lakhdari , " Structural, optical and electrical properties of TiO2 thin films synthesized by sol–gel technique " ,IOSR Journal of Engineering , Vol. 3, Issue 11., ,V1, P.P. (21-28) ,(2013).

[5] Ali A. Abed, Ahmed R. AL-Mathloom " Titanium Dioxide Thin Film Prepared By Sol-Gel Technique ", Journal Of Education For Pure Science- University Of Thi-Qar , Vol.9, No.1 ,(2019).

[6] Bushra R. Mahdi, Abass F. Al.mamori, Adnan meship Mahdi, " Synthesis of Nano-TiO2 Thin Films by Sol-gel Dip-coating Method " , The 5th International scientific Conference on Nanotechnology& Advanced Materials Their Applications (ICNAMA 2015)3-4 Nov, (2015).

[7] Mohammed. H. Shinen, Khalid. I. Ajeel, Fadhil. A. Rasin, ″Preparation of Titanium Dioxide (TiO2) Via the Sol-Gel Process″, Journal of Babylon University/Pure and Applied Sciences/ No.(1)/ Vol.(20): 2012 .

[8] Ahmed K. Abbas, Mohammed K. Khalaf, LaithK.Athab,"Growth Of TiO2 Films By RF Magnetron Sputtering Studies On The Structural And Optical Properties ", Journal of Multidisciplinary Engineering Science and Technology, Vol. 3 Issue 9, ISSN: 2458-9403 , (2016).

[9] R.Mechiakh, R.Bensaha, "Analysis of optical and structural properties of soi-gel TiO2 thin films", M.J.Condensed Mat.",V.7, N.1, pp.54-57(2006).

[10] Arwaa F. Saleh, Batool D. Balawa and Areej A. Hateef , " Effect of the Thickness on the Optical Properties of (TiO2) Thin Films." , Al- Mustansiriya J. Sci, Vol. 21, No 4, (2010).

[11] L. Bedikyan, S. Zakhariev, M. Zakharieva , "Titanium dioxide thin films: Preparation and optical properties " , Journal of Chemical Technology and Metallurgy, 48, 6, P.P.(555-558) ,(2013).

[12] NajlaGhrairi and MongiBouaicha ,"Structural, morphological, and optical propertiesof TiO2 thin films synthesized by the electrophoretic deposition technique , springer , Ghrairi and BouaichaNanoscale Research Letters, 7:357 , (2012).

[13] M.Hemissi*, H. Amardjia-Adnani , "Optical and structural properties of titanium oxideThin films prepared by sol-gel merhod " ,Digest Journal of Nanomaterials and Biostructures, Vol. 2, No. 4, P.P. (299-305) , (2007).

[14] M. M. El-Nahass, M. H. Ali, A. El-Denglawey,"Structural and optical properties of nano-spin coated sol−gel porous TiO_2 films " , Elsevier,Trans. Nonferrous Met. Soc. China 22, P.P. (3003−3011), (2012).