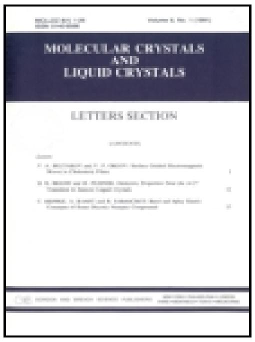

Taylor & Francis
Taylor & Francis Group

Molecular Crystals and Liquid Crystals

ISSN: 1542-1406 (Print) 1563-5287 (Online) Journal homepage: http://www.tandfonline.com/loi/gmcl20

Structural and optical properties of TiO_2:SnO_2 thin films prepared by sol gel method

Z. Essalhi, B. Hartiti, A. Lfakir, M. Siadat & P. Thevenin

To cite this article: Z. Essalhi, B. Hartiti, A. Lfakir, M. Siadat & P. Thevenin (2016) Structural and optical properties of TiO_2:SnO_2 thin films prepared by sol gel method, Molecular Crystals and Liquid Crystals, 627:1, 148-152, DOI: 10.1080/15421406.2015.1137269

To link to this article: http://dx.doi.org/10.1080/15421406.2015.1137269

MOL. CRYST. LIQ. CRYST.
2016, VOL. 627, 148–152
http://dx.doi.org/10.1080/15421406.2015.1137269

Structural and optical properties of TiO_2:SnO_2 thin films prepared by sol gel method

Z. Essalhi[a], B. Hartiti[a], A. Lfakir[a], M. Siadat[b], and P. Thevenin[c]

[a]MAC & PM Laboratory, ANEPMAER Group, Department of Physics, FSTM, University Hassan II Mohammedia Casablanca,Mohammedia, Morocco; [b]LCOMS Laboratory, University of Lorraine, Metz, France; [c]LMOPS Laboratory, University of Lorraine, Metz, France

ABSTRACT

TiO_2:SnO_2 thin films were deposited on glass substrates, by using sol gel spin coating method with different ratio (3%, 5% and 7%) at 3200 rpm, to study their effect on different properties of TiO_2: SnO_2 thin films. The structural and optical properties of films have studied for different ratio. These deposited films have been characterized by various methods such as X-Ray Diffraction (XRD), Ultra Visible spectroscopy. The (XRD) can be used to identify crystal structure of as deposited films. The Transmission spectra have shown the transparent and opaque parts in the visible and UV wavelengths.

KEYWORDS
TiO_2; thin film; sol gel; spin coating

1. Introduction

Titanium dioxide (TiO_2) is widely used in wide range of technological applications, example are dye sensitized solar cell [1,2], photo-catalysts [3,4],optical coating [5], capacitors for large scale integrated devices [6], electro-chromic systems [7].

Titanium dioxide is a cheap, non toxic and biodegradable material that is widely used in industry [8].

This material is a semiconductor that is insensitive to visible light, it absorbs in the near ultraviolet region [9]. TiO_2 crystallizes in three different phases, Rutile, Anatase and Brookite [10,11]. Among these phases Rutile is the most stable. Thermodynamically compared to the latter two phases which are in metastable state and are readily transformed to rutile when heated [12].

The Anatase phase of TiO_2 have band gap of 3,2 eV,the semiconductor SnO_2 has the tetrahedral structure with band gap equal to 3,6 eV. Both titanium oxide and tin oxide [13] are widely reported materials for many technological applications.

2. Experiment details

Precursor solutions of TiO_2, SnO_2 were prepared according to the sol gel method. Pure as well as TiO_2-SnO_2 composites (with different ratio of TiO_2:SnO_2).

Using ($Ti(OC_3H_7)_4$) Tetrapropyl-orthotitanat was dissolved in Tin dioxide SnO_2 and isopropanol. The mixture was stirred first at 60°C for 10 min, Then added Acetic acid stir by

CONTACT Z. Essalhi ✉ zineb.essalhi@gmail.com
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gmcl.

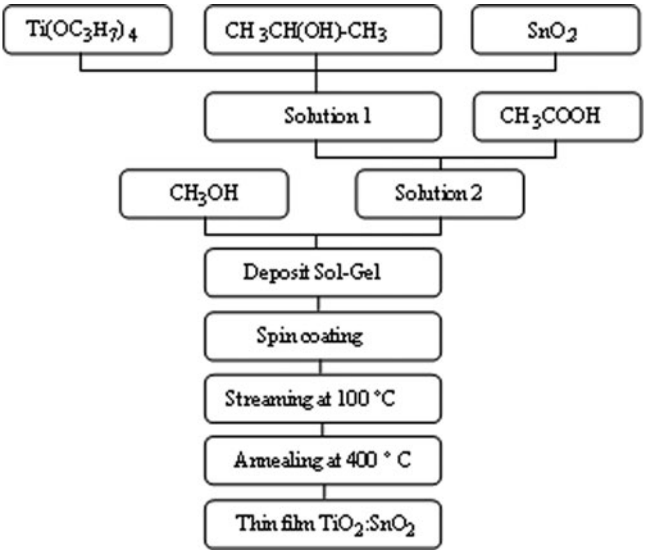

Figure 1. The flow chart showing the procedure for preparing TiO_2:SnO_2 thin films.

using a magnetic stirred it for 15 min at 60°C, finally adds Methanol and lets agitate during 2h. After prepared the solution we spin coated it at spin speed of 3200 rpm for 30s by dynamic technique, on glass substrates which were cleaned in nitric acid 3%, methanol and acetone.

Then followed by a drying process at 100°C during after each deposition up to three deposition. Subsequently, thin films were annealed in 400°C for 1h. Figure 1.

3. Results and discussion

3.1. *Structural properties*

The TiO_2:SnO_2 thin films obtained after one dipping and various ratios of doping. Figure 2 illustrates the XRD patterns of the TiO_2 based on three concentrations of Tin dioxide (3, 5 and 7% SnO_2), thin films were annealed at 400°C for 1 hour.

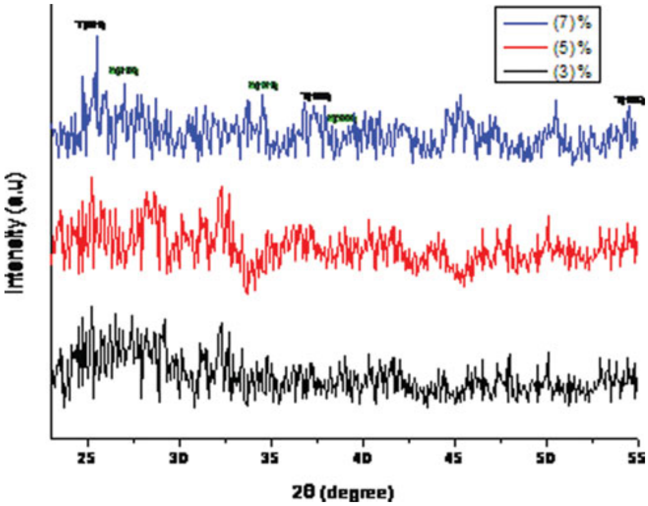

Figure 2. XRD pattern of the TiO_2:SnO_2 thin films at different ratio [3%, 5% and 7%].

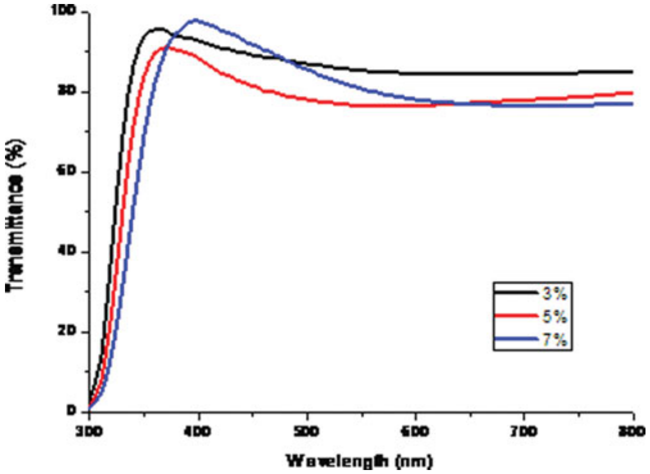

Figure 3. Transmission spectra of the layers of TiO_2:SnO_2 for various ratio [3%, 5% and 7%].

In this figure. All the XRD diffraction peaks can be indexed to the anatase phase (JCPD file No. 21–1272). At a composition of 3% Sn and beyond, peaks corresponding to Rutile SnO_2 phase (JCPD file No. 41–1445) started to appear in addition to the anatase TiO_2 phase.

The SnO_2 peaks emerge in the XRD patterns, meaning that we have successfully incorporated SnO_2 into TiO_2. From figure 2. The added SnO_2 is found to have a rutile phases with mainly (110), (101) and (200) textures, where their peak intensities become stronger with the rise of doped SnO

3.2. *Optical transmittance*

In Figure 3 we illustrate the transmittance spectra for TiO_2:SnO_2 deposited in a glass substrates at different ratio 3, 5 and 7%.

The films were transparent with an average optical transmittance exceeding 75% in the visible spectra region and present a sharp absorption edge in the UV region at wavelength ranging from 300 to 400 nm. With increasing ratio, the absorption edge and maximum transmittance peak position shift toward longer wavelengths.

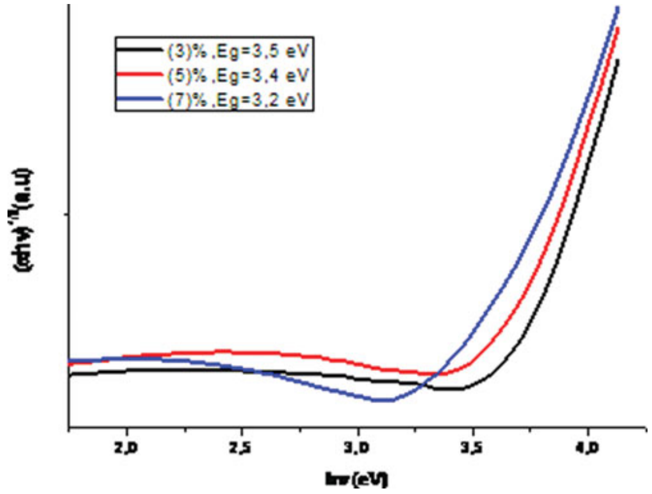

Figure 4. Determination of the energy gap for thin layer of TiO_2:SnO_2.

Table 1: Variation of energy gap with the change of ratio doped.

Samples	Eg (eV)
3%	3.5
5%	3.4
7%	3.2

3.3. *Band gap*

From the curve of transmission versus wavelength determining the absorption coefficient for each wavelength, the variation of $(\alpha h\upsilon)^{1/2}$ along with $h\upsilon$ determines the width of the band gap Eg. Accordingly, the optical energy gap (Eg) was estimated by using Tauc formulation [14].

Where **α** is the optical absorption coefficient of the material, **Eg** is optical energy band gap of the material and **A** is material constant which depends on the nature of the material, **$h\upsilon$** is the photon energy [15,16]. The optical transition processes is govern by the value of '**n**' which is a material dependent parameter. It's values are 1/2 for direct band gap material and 2 for indirect band gap material.

TiO_2 compound has an indirect gap of 3.2 eV, so $n = 2$

$$(\alpha h\upsilon) = A\left(h\upsilon - Eg\right)^n \tag{1}$$

From the plot of $(\alpha h\upsilon)^{1/2}$ as a function of $h\upsilon$, the band gap is obtained by extrapolating the linear part of the curve to the zero ($\alpha = 0$) absorption as shown in Figure 4.

Figure 4 shows Tauc plots, i.e. $((\alpha h\upsilon)^{/2}$ Vs $(h\upsilon)$. The calculated optical band gap of the prepared films varies is 3.5, 3.4 and 3,2 eV. We observe an increase of the optical band gap by increasing the doping concentration from 3% to 7%. This can explain by the grain size of the material which increases with the ratio of doping increase.

4. Conclusions

In this paper, TiO_2 thin films were prepared by sol gel spin coating process. The effects of ratio of doping on the structural and optical properties of the synthesized films were studied. The results indicate that the XRD patterns show peaks of pure Anatase TiO_2 with highest peak at (101) and a Rutile SnO_2 phases where their peak intensities become stronger with the rise of doped SnO_2.

The optical characterization of the thin films shows that the synthesized material is transparent in the visible, along with an optical transmission varying from 75% to 95%. The value of Ti:Sn band gap increase by increasing the doping concentration.

Acknowledgments

This work has been partially supported by the HORIZON Project funds (Ref: 59113PS019) of the AUF (Agence Universitaire de la Francophonie). Technical support from LMOPS & LCOMS labs (University of Lorraine) is gratefully acknowledged.

References

[1] O'Regan, B., & Gratzle, M. (1991). Nature, *353*, 737.
[2] Hagfelt, A., & Gratzel, M. (1995). *Chem. Rev.*, *95*, 49.

[3] Fujishima, A., & Honda, K. (1972). *Nature*, *238*, 371.
[4] Fujishima, A., & Honda, K. (1971). *Bull. Chem. Soc. Jpn*., *44*, 1148.
[5] Brady, G. S. (1971). *Materials Handbook*, 10th ed., McGraw-Hill, New York.
[6] Lee, Y. H. (1998). *Vacuum*, *51*, 503.
[7] Tachibana, Y., Ohsaki, H., Hayashi, A., Mitsui, A., & Hayashi, Y. (2000). *Vacuum*, *59*, 836.
[8] Larson, S. A., & Falconer, J. L. (1994). *Appl. Catal., B: Environ*., *4*, 325.
[9] Paz, Y., & Heller, A. (1997). *J. Mater. Res*., *12*, 2759.
[10] Beattie, I., & Gilson, T. (1968). *Proc. R. Soc. A*, *307*, 407.
[11] Balachandran, U., & Elror, N. (1982). *J. Solid State Chem*., *42*, 276.
[12] Hubbard, K. J., & Schlom, D. G. (1996). *J. Mater. Res*., *11*, 2757.
[13] Hideaki, Y. (1998). *Chem. Senses*, *14*, 41.
[14] Tauc, J. (1974). *Amorphous and Liquid Semiconductors Plenum*, London and New York, 159–220.
[15] Mallick, P., Rath, C., Prakash, J., Mishra, D. K., Choudhary, R. J., Phase, D. M., Tripathi, A., Avasthi, D. K., Kanjilal, D., & Mishra, N. C. (2010). *Nucl. Instrum. Meth. Phys. Res. Sect. B*., *268*, 1613.
[16] Davis, E. A., & Mott, N. F. (1970). *Philos. Mag*., *22*, 903.