The Effect of Indium Doped SnO2 Thin Films on Optical Properties Prepared by Sol-Gel Spin Coating Technique

by Aris Doyan

Submission date: 06-May-2020 01:12AM (UTC+0700)
Submission ID: 1316785600
File name: C63_Prosiding_Internasional.pdf (1.82M)
Word count: 3779
Character count: 17856

Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

The Effect of Indium Doped SnO_2 Thin Films on Optical Properties Prepared by Sol-Gel Spin Coating Technique

The Effect of Indium Doped SnO_2 Thin Films on Optical Properties Prepared by Sol-Gel Spin Coating Technique

A. Doyan[1,5], Susilawati[2,5], S. Hakim[3], L. Muliyadi[4], M. Taufik[5], Nazarudin[6]
Master of Science Education Program, University of Mataram, Lombok, West Nusa Tenggara, Indonesia[1,2,3,4], Physics Education, FKIP, University of Mataram, Lombok, West Nusa Tenggara, Indonesia[1,2,5], Chemistry Education, FKIP, University of Jambi, Jambi, Indonesia[6]

E-mail: aris_doyan@unram.ac.id, susilawatihambali@unram.ac.id, syamsulhakim@unram.ac.id

Abstract. This study aims to investigate the optical properties of SnO_2 thin films doped with Indium synthesized using the sol-gel spin coating technique. The optical properties of thin films were measured using *Thermo Scientific GENESYS UV-Vis Spectrophotometer*. The results of characterization of optical properties showed that the thin films of Indium doped SnO_2 experienced an increase in transmittance from 75 - 96.6% at wavelengths 300 - 350 nm and increased maximum absorbance at a wavelength of 300 nm from 3.19 - 4.32 with an increase in doping percentage. This shows that thin films absorbance the maximum wave at a wavelength of 300 nm. Increasing the percentage of doping causes the thin films of SnO_2 to experience a decrease in energy gap both in the direct energy gap of 3.64 - 3.57 eV and indirect energy gap i.e from 3.92 - 3.87 eV. The optical activation energy of the SnO_2 thin films decreased with increasing doping percentage from 2.91 - 2.35 eV. The results of this study indicate that SnO_2: In thin films is high-quality because it has high transmittance and low energy gap.

1. Introduction

The study of semiconductor materials has a significant contribution to the development of technology. Semiconductor materials are widely used as electronic devices. One of the semiconductor materials is tin oxide. Semiconductor SnO_2 is an N-type semiconductor material. As a development, semiconductor materials can be modified to micro-size to nano-size in the form of a thin film. Energy gap SnO_2 thin films is 3.60 - 3.98 eV [1, 2], the energy gap value is large enough for thin films of semiconductor material.

Modification of semiconductor materials into thin films makes the use of semiconductor materials more diverse. Some uses of semiconductor materials in the form of thin films such as solar cells, touch screens [3], and gas sensors [4].

The function of SnO_2 thin films will be more optimal to be used as an electronic device that has high quality, so doping is needed which is expected to reduce the energy gap so that electronic devices become more sensitive. Some of the doped of SnO_2 thin films have been studied such as Fluoride Dehydrate [5], Aluminum [6], Aluminum-Zinc [7], Cesium [8], Fluorine [9], and Indium [10].

The results of the research on SnO_2 thin films which stated that doped SnO_2 thin films had increased conductivity and decreased gap energy. The selection of Indium material as doping on SnO_2 thin films because Indium has fairly high transparency [11], temperature reflexes [12], and it can be synthesized in low temperatures [13].

Thin films growth techniques are as diverse as *Pulsed Laser Deposition* [14], *RF sputtered* [15], *Enhanced Plasma RF Reactive Thermal Evaporation* [16], *Reactive Magnetron Sputtering* [17], *Dc and RF Sputtering* [18] which are less efficient in electric power [19], *Dip-Coating* [20], and the *Spin-Coating* Technique [21]. From all of these methods, the spin-coating is the most efficient, economical, and simple technique [22]. Although the method is simple, it can produce high-quality thin films with adjustable thickness according to the rotation speed and playback time [23].

2. Experimental

Synthesis thin films are carried out by a sol-gel spin coating technique that utilizes centrifugal forces in flattening films across the surface of the substrate. The sol-gel injected on the glass substrate is assembled in one place, in order that spin process made the sol-gel spread smoothly. The thickness of films can be controlled by the speed of spin. This synthesis process was by speed 3000 rpm for all of thin-film percentage doping. The basic material of the thin films is $SnO_2.2H_2O$ which is doped with $InCl_3.4H_2O$ which is dissolved using C_2H_5OH. The main ingredients of the SnO_2 thin films are doped with Indium with a mass percentage of 0, 5, 10, 15, 20, and 25% [24].

The optical properties of the thin films consist of absorbance and transmittance. Thin-film transmittance and absorbance measuring instruments using Thermo scientific *Genesys 150 UV-Spectrophotometer* with a wavelength range of 200 - 1100 nm. The energy gap is obtained from the absorbance spectrum. The amount of energy gap is the minimum amount of energy absorbed by the material so that electrons from the valence band can jump to the conduction band. The magnitude of the gap energy can be obtained from the sloop graph $(\alpha h\nu)^n$ on the energy of the photon hν. The energy gap can be either direct optical (n = 1/2) and indirect optical band gap (n = 2) [25].

Mathematically, the energy gap is obtained using equations

$$\alpha(\nu)h\nu = C(h\nu - E_g)^n \quad (1)$$

where: $h\nu$ is incident photon energy, h is Planck's constant, E_g is energy gap, and C is a constant.

3. Result and Discussion

The following figure 1 show that SnO_2:In thin film with percentage of doping 0, 5, 10, 15, 20, and 25%, respectively.

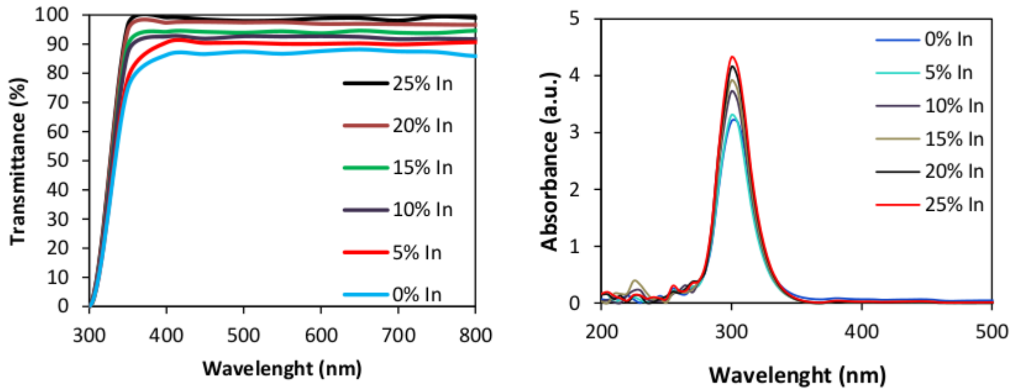
(a) (b) (c) (d) (e) (f)

Figure 1. Thin Films SnO_2:In with Percentage of Doping (a). 0:100, (b). 5:95, (c). 10:90, (d). 15:85, (e). 20:80, and (f). 25:75%.

The optical properties of the thin films obtained from UV-Vis Spectrophotometer equipment are transmittance and absorbance properties of thin films indium doped SnO_2.

3.1. Measurement of Transmittance and Absorbance

Transmittance and absorbance of thin films of SnO_2 by doping Indium measured using a *UV-Vis spectrophotometer* are shown in the graph below.



(a) (b)

Figure 2. (a) Transmittance of SnO_2:In thin films with variations in percentage of doping (wt%) 0, 5, 10, 15, 20 and 25%, (b) Absorbance of thin films SnO_2: In with doping percentage 0, 5, 10, 15, 20 and 25%.

Based on the wavelength graph of transmittance in Figure 2 (a), thin films with a percentage of doping (wt%) obtained the transmittance of SnO_2:In thin films at a constant thickness of 120 nm with 0, 5, 10, 15, 20, and 25% doping concentrations experience an increase in transmittance in sequence. This phenomenon is in accordance with the research that has been done before [26].

Increased transmittance occurs at wavelengths of 300-350 nm. The highest peak transmittance value at 350 nm wavelength sequentially from the lowest to the highest doping percentage i.e 75.0, 78.2, 87.1, 90.6, 94.7 and 96.6%. This means that the occurrence of electron movements due to the energy of photons at wavelengths of 300-350 nm. Whereas at wavelengths 350-800 nm the transmittance graph looks constant, meaning that the wavelengths of light photons 350-800 nm do not occur in the movement of electrons jump.

The wavelength graph of absorbance in figure 2 (b) shows that an increase in doping percentage makes the thin films increased in absorbance value. The highest absorptions were 25% doping percentage and respectively decreased to 0% doping percentage. Maximum absorbance value at a wavelength of 300 nm with an absorbance value of 4.32. The percentage of doping is 0, 5, 10, 15, 20, and 25% with absorbance values of 3.20, 3.31, 3.72, 3.91, and 4.32, respectively. Increasing the absorbance of photon energy with a wavelength of 200 - 300 nm.

3.2. Calculation of Energy gap

Energy gap thin films obtained from two types of analysis, namely the analysis of direct energy gap and indirect energy gap. The absorbance value of the Indium doping SnO_2 thin films can be used to find the thin films gap energy. The energy gap is obtained from the slop graph of the photon energy towards $(\alpha h\upsilon)^n$.

3.2.1. Direct energy band gap (n=1/2)

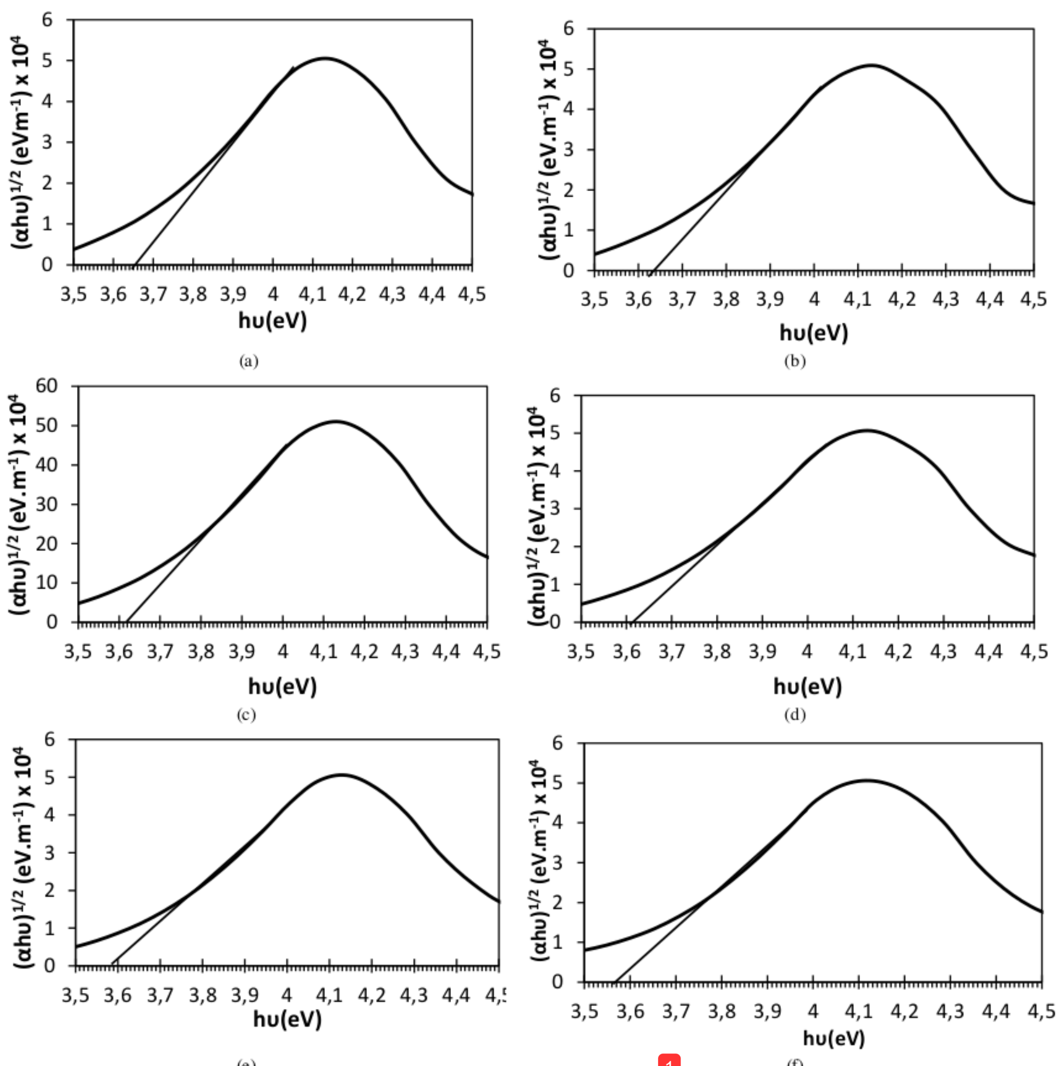


Figure 3. Direct allowed transition (αhυ) 1/2 versus *hυ* thin films SnO_2:In (a) 0% , (b) 5%, (c) 10%, (d) 15%, (e) 20%, and (f) 25%.

The addition of Indium doping to the thin films of SnO_2 made the thin films gap energy decrease from 3.64 to 3.57 eV. The higher doping percentage ie 0, 5, 10, 15, 20 and 25%, the decreasing gap energy from 3.64, 3.63, 3.62, 3.61, 3.58, and 3.57 eV, the higher the percentage of indium doping, the electron mobility in the thin films SnO_2 fast.

3.2.2. The indirect energy band-gap (n=2)

Another form of energy gap other than direct is indirect. The indirect energy gap is obtained from the slop graph hυ to $(\alpha h\upsilon)^n$ with a value of *n*=2.

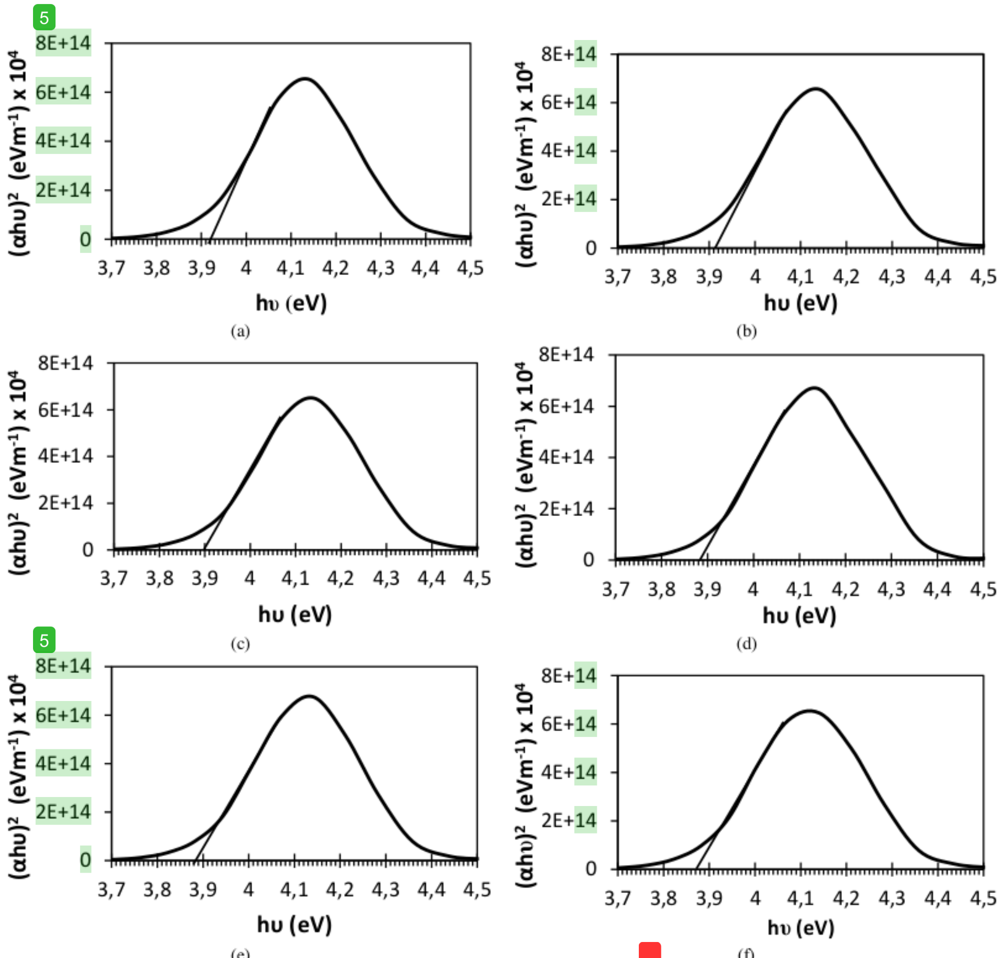


Figure 4. allowed transition $(\alpha h\upsilon)^2$ versus hυ thin films SnO_2: In for (a) 0%, (b) 5%, (c) 10%, (d) 15%, (e) 20%, and (f) 25%.

In Figure 4, it can be seen that there are differences in the slope graph of each variation of doping. Increasing the percentage of doping made thin films gap energy values decrease the energy gap ranging from 3.92, 3.91, 3.90, 3.89, 3.88, and 3.87 eV, respectively.

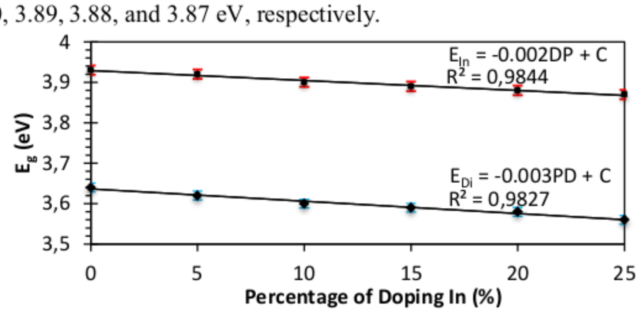


Figure 5. Comparison of *Direct* (◆) and *Indirect* (■) Energy Gap of Thin Films SnO_2: In.

Figure 5 shows that the comparison direct and Indirect energy gap indicate that direct energy gap lower than indirect energy gap. The increasing doping concentration from 0 to 25%, obtained direct energy gap which decreased from 3.64 to 3.57 eV for the band's direct optical gap. While the indirect value of the energy gap decreased from 3.92 to 3.87 eV.

The direct energy gap the position of the valence band and its conduction is in the phase, for the energy gap indirect the valence band and its conductivity are at a different phase. The direct energy gap, the mobility of electron from the valence band to the conduction band with a straight path so that electrons reach the conduction band faster, whereas in the indirect energy gap there is an electron leap from the valence band to the conduction band in a direction that is not straight so that the arrival of electrons to the conduction band becomes longer and requires more energy. It causes direct bandgap energy smaller than indirect bandgap energy. This decrease in energy bandgap is due to the presence of impurity indium in the SnO_2 structure, which induces the formation of new recombination centers with lower energy emissions [27].

3.3. Optical Activation Energy

Optical activation energy is obtained by first finding the value of $\ln(\alpha)$ (α: absorbance coefficient). The magnitude of activation optical energy is obtained from the value of the gradient or slope of the line (m) of the graph of photon energy versus $\ln(\alpha)$. Optical activation energy $E_a = 1/m$ [28].

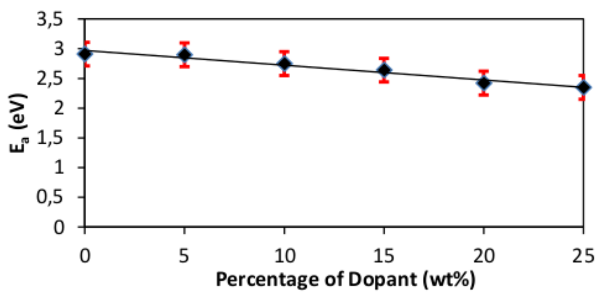


Figure 6. The graph of the percentage of doping versus activation energy of Thin Films SnO_2: In.

The graph gradients m of each doping percentage (0, 5, 10, 15, 20, and 25%), namely 0.343, 0.344, 0.363, 0.378, 0.413 and 0.425, respectively. From the value of the gradient, optical activation energy obtained in Figure 6 is 2.91, 2.90, 2.75, 2.64, 2.42 and 2.35 eV. The reduced activation energy makes the electron rate from the valence band to the conduction band increasingly toward the semiconductor properties [29, 30].

4. CONCLUSION

The addition of the indium doping percentage to the thin films of SnO_2 causes thin-film absorbance and transmittance to increase. The energy band gap of thin films SnO_2 decreases with Indium doping increase. The reduced energy gap from 3.64 to 3.57 eV and the activation energy 2.91 to 2.35 eV, it makes the thin films be high-quality.

References

[1] Aziz, M. Abbas, S. S. Baharom, W. R. W. 2013 *Size-controlled synthesis of SnO₂ nanoparticles by sol-gel method. Journal. Materials Letters 91 (2013) 31–34.*

[2] Erken, Ö, Gümüş, C. 2018 *Determination of The Thickness and Optical Constants of PolycrystallineSnO2 Thin Film by Envelope Method. Adıyaman University Journal of Science dergipark.gov.tr/adyusci 8 (2) (2018) 141-151.*

[3] Doyan, A. Susilawati, Imawanti, Y. D. Gunawan, E. R. Taufik, M. 2018 *Characterization Thin Film NanoParticle of Aluminum Tin Oxide (AlTO) as Touch Screen. IOP Conf. Series: Journal of Physics: Conf. Series 1097 (2018) 012009.*

[4] Degler, D. Barz, N. Dettinger, U. Peisert, H. Chassé, T. Weimar, U. Barsan, N. 2016 *Extending the toolbox for gas sensor research: Operando UV-vis diffuse reflectance spectroscopy on SnO_2-based gas sensors*. *Journal*. *Sensors and Actuators B 224 (2016) 256–259*.

[5] Rahal, Achour. Benramache, Said. Benhaoua, Boubaker. 2013 *Preparation of n-type Semiconductor SnO_2 Thin films*. *Journal of Semiconductors Vol. 34 No. 8*.

[6] Doyan, A., Susilawati, Imawanti, Y. D. 2017 *Synthesis and Characterization of SnO_2 Thin Layer with a Doping Aluminium is Deposited on Quartz Substrates*. *AIP Conference Proceedings 1801, 020005*. *DOI 10.1063/1.4973083*.

[7] Ikraman, N. Doyan, A. Susilawati. 2017 *Growth of SnO_2 Films with Al-Zn Doping Using the Dip-Coating Sol-Gel Technique*. *Jurnal Penelitian*. *Jurnal Pendidikan Fisika dan Teknologi Vol. 3, No. 2. (ISSN. 2407-6902).*

[8] Kaviyarasu, K. Manikandan, E. Kennedy, J. Ladchumananandasiivam, R. Gomes, U.U. Maaza, M.Mola, G. T. 2017 *Improved, Photon Conversion Efficiency of (SnO_2) Doped Cesium Oxide (Cs) Nanofibers for Photocatalytic Application Under Solar Irradiation*. *Springer International Publishing AG 2017A.Y. Oral and Z.B. Bahsi Oral (eds.), 3rd International Multidisciplinary Microscopy and Microanalysis Congress (InterM), Springer Proceedings in Physics 186*.

[9] Muliyadi, L. Doyan, A. Susilawati. Hakim, S. 2019 *Synthesis of SnO_2 Thin Layer with a Doping Fluorine by Sol-Gel Spin Coating Method*. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, 5 (2) 2019: 175 -178. DOI: 10.29303/jppipa.v5i2.257.

[10] Benouis, C. Benhaliliba, M. Yakuphanoglu, F. Juarez, A. S. 2011 *Physical Properties of Ultrasonic Sprayed Nanosized Indium Doped SnO_2 Films*. *Journal Elsevier Synthetic Metals 161 (2011) 1509-1516*.

[11] Ramanathan, G. Murali, K. R. 2015 *Characteristics of Tin Doped IndiumOxide Films*. *International Journal of ChemTech Research*. Vol. 8. (8). 260-264.

[12] Erik Anderson, C. Ekstrand. 2019 *IndiumProperties, Uses, Market and Economy, Recovery, and Environmental Impacts*. Colorado School of Mines.

[13] Seiler, W. Nistor, M. Hebert, C. Perrière, J. 2013 *Epitaxial undoped indium oxide thin fi lms: Structural and physical properties*. *Journal Solar Energy Materials & Solar Cells 116 (2013) 34–42*.

[14] Beatriceveena. T. V. Prabhu, E. Jayaraman, V. Gnanasekar, K. I. 2018 *X-ray photoelectron and Hall studies on nanostructured thin films of PbS grown by pulsed laser deposition*. *Journal Materials Letters (2018), DOI: https://doi.org/10.1016/j.matlet.2018.12.038*.

[15] Kaur, M. Dadhich, B. Singh, R. Ganpathi, K. Bagwaiya, T. Bhattacharya, S. Debnath, A.K. Muthe, K. P. Gadkari, S.C. 2017 *RF sputtered SnO_2: NiO thin films as sub-ppm H2S sensor operable at room temperature*. *Sensors and Actuators B: Chemical http://dx.doi.org/10.1016/j.snb.2016.11.054.*

[16] Patel, P. Karmakar, A, Chetan Jariwala, C. Ruparelia, J. P. 2013 *Preparation and Characterization of SnO_2 Thin Film Coating using rfPlasma Enhanced Reactive Thermal Evaporation*.

[17] Angarita, G. Palacio, C. Trujillo, M. Arroyave, M. 2017 *Synthesis of Alumina Thin Films Using Reactive Magnetron Sputtering Method*. *IOP Conf. Series: Journal of Physics: Conf. Series 850 (2017) 012022*.

[18] Xu, B. Ren, X. G. Gu, G. R. Lan, L. L. Wu, B.J. 2016 *Structural and Optical Properties of Zn-doped SnO2 Films Prepared by DC and RF Magnetron Co-Sputtering*. *Superlattices and Microstructures*.

[19] Velumani, M. Meher, S. R.. Alex, Z. C.. 2017 *Impedometric humidity sensing characteristics of SnO_2 thin films and SnO_2-ZnO composite thin films grown by magnetron sputtering*. *Journal of Material Science: Material in Electronics*.

[20] Doyan, Susilawati, Ikraman, Taufik, 2018 *Characterization of SnO_2 Film with Al-Zn Doping Using Sol-Gel Dip Coating Techniques*. *The International Conference on Theoretical and*

Applied Physics. *IOP Conf. Series: Journal of Physics: Conf. Series 1011 (2018) 012015*.

[21] Yongvanich, N. Thongkaew, K. Yuanlae N. Sae-ung, S. Suwanchawalit C.. 2018 *Influence of Copper Doping in Nanostructured ZnOThin Films by Spin Coating*. *IEEE TRANSACTIONS ON NANOTECHNOLOGY, VOL. 17 (6)*.

[22] Ariyakkani, P. Lakshmikanthan, S. Balakrishnan, S. 2016 *Investigation of the structural, optical and magnetic properties of Fe doped ZnO thin films coated on glass by sol-gel spin coating method*, *Journal of Alloys and Compounds (2017), DOI: 10.1016/j.jallcom.2016.12.011*.

[23] Thirumoorthi, M. Prakash, J. T. J. 2015 *A study of Tin doping effects on physical properties of CdO thin films prepared by a sol-gel spin coating method*. *Journal of Asian Ceramic Societies xxx (2015) xxx–xxx*.

[24] Hakim, S. Doyan, A. Susilawati. Muliyadi, L. 2019 *Synthesis Thin Films SnO_2 with Doping Indium by Sol-gel Spin coating*. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, 5 (2) 2019: 171 -174. DOI: 10.29303/jppipa.v5i2.254.

[25] Susilawati. Doyan, A. 2009 *Dose-response and optical Properties of Dyed Poly Vinyl Alcohol-Trichloroacetic Acid Polymeric Blends Irradiated with Gamma-Rays*. *American Journal of Applied Science* 6 (12): 2071-2077, 2009.

[26] Pati, S. Banerji, P. Majumder, S. B. 2015 *Properties of Indium doped nanocrystalline ZnO thin films and their enhanced gas-sensing performance*. *Journal Royal Society of Chemistry (2015) DOI: 10.1039/C5RA10919A*.

[27] Lekshmy, S. S. Joy, K. 2013 *Structural and optoelectronic properties of Indium doped SnO_2thin films deposited by sol-gel technique*. *Journal Mater Sci: Mater Electron DOI 10.1007/s10854-014-1781-x*.

[28] Bakr, N. A., Salman, S. A. N. Ali, M. N. 2016 *Effect of Fluorine Doping on Structural and Optical Properties SnO_2 Thin Films Prepared by Chemical Spray Pyrolysis Method. Advances in Materials.* 5 (4):23-30.

[29] Sundaram, B. Veeravazhuthi, V. Meena, P. Selvan, K. 2004 *Thin Film Technique, and Applications*. Mumbai: Allied Publishers PVT. Limited.

[30] Mo, Y. W., Kleiner, J., Webb, M. B., & Lagally, M. G. 1991 *Activation energy for surface diffusion of Si on Si(001): A scanning-tunneling-microscopy study*. *Physical Review Letters*, 66(15), 1998–2001.doi:10.1103/physrevlett.66.1998.

The Effect of Indium Doped SnO2 Thin Films on Optical Properties Prepared by Sol-Gel Spin Coating Technique

ORIGINALITY REPORT

10%	7%	7%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	ir.uitm.edu.my Internet Source	2%
2	Submitted to University of Greenwich Student Paper	2%
3	Submitted to University of Leeds Student Paper	1%
4	Wasan A. Al-Taa'y, Saad F. Oboudi, Emad Yousif, Mohammed Abdul Nabi, Rahimi M. Yusop, Darfizzi Derawi. "Fabrication and Characterization of Nickel Chloride Doped PMMA Films", Advances in Materials Science and Engineering, 2015 Publication	1%
5	Sugamata, Ryuichi, Akihiro Sugawara, Tomokazu Nagao, Koya Suzuki, Tomoyasu Hirose, Ki-ichi Yamamoto, Masamichi Oshima, Kazuo Kobayashi, Toshiaki Sunazuka, Kiyoko S Akagawa, Satoshi Ōmura, Toshinori Nakayama, and Kazuo Suzuki. "Leucomycin A3, a 16-	1%

membered macrolide antibiotic, inhibits influenza A virus infection and disease progression", The Journal of Antibiotics, 2014.
Publication

6	Submitted to Universiti Kebangsaan Malaysia Student Paper	1%
7	"TMS 2014: 143rd Annual Meeting & Exhibition", Springer Science and Business Media LLC, 2016 Publication	1%
8	aip.scitation.org Internet Source	1%
9	Submitted to University of Al-Qadisiyah Student Paper	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		