The Effect of Temperature Variations on the Optical Properties of Tin Oxide Film with Doping Aluminum, Fluorine and Indium for Semiconductor Electronic Devices

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The Effect of Temperature Variations on the Optical Properties of Tin Oxide Film with Doping Aluminum, Fluorine and Indium for Semiconductor Electronic Devices

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Abstract. The manufacture of a thin layer of SnO_2: (Al + F + In) was carried out by using the sol-gel spin coating method on a glass substrate with various temperatures (25, 50, 100, 150, and 200 ^{0}C).The purpose of this study is to determine the optical properties of thin layers which include transmittance, absorbance, band gap energy and activation energy. The optical properties of the coating were characterized using a UV-Vis spectrophotometer with a wavelength of 200-1100 nm. The results showed that the absorbance value increased with increasing temperature at a wavelength of 300 nm. The absorbance values obtained for temperature variations were in the percentages of 95: 5% and 75: 25%, respectively 3.46-4.50 and 3.96-5.76. The transmittance value obtained increased, namely 73.00-86.30% and 74.20-99.30%. In addition, the energy band gap decreased from 3.60-3.41 eV and 3.57-3.31 eV for direct allowed, while 3.69-3.58 eV and 3.65-3.54 eV for indirect allowed. Activation energy decreased from 2.00-1.18 eV and 1.60-1.12 eV. In general, the absorbance and transmittance values increase with increasing ripening temperature and the addition of doping aluminum, fluorine, and indium, while the bandgap energy and activation energy values obtained decrease with increasing ripening temperature and increasing the doping percentage of aluminum, fluorine, and indium. The decrease in the value of the bandgap energy and the activation energy can make it easier for electrons to move from the valence band to the conduction band so that the material is slightly conductive and acts as a semiconductor.

Introduction

The Semiconductors are materials that are flexible, meaning that in certain circumstances they act as conductors and in other cases are insulators [1]. Various ways have been done by researchers to maximize the function of semiconductor materials, including modifying the material in the form of a thin layer.

The use of thin layers of semiconductor materials includes gas sensors, [2], LED (Light emited diode) [3], solar cells [4], TCO (transparent Conducting Oxide) which are used in transparent electrodes [5], LCD [6] and so forth. The types of materials that have been utilized in the synthesis of thin films are titanium dioxide [7], aluminum, tungsten disulfide [8], and tin oxide [9].

The level of sensitivity of a thin film material is influenced by its optical properties. The optical property referred to is the energy value of the thin layer band gap. The higher the bandgap energy value of the layer, the more difficult the material is to conduct current. The bandgap energy value of the tin oxide (SnO_2) thin layer is still quite high, around 3.72 eV [10], so it needs to be modified by adding donors or other atoms to the material. Several other atoms are added namely, ferrum [11], aluminum-zinc [12], indium [13] and fluorine [14]. In this study, the doping materials used are aluminum, fluorine, and indium with the hope that the layer transparency rate increases and the bandgap energy obtained is lower than the previous band gap energy.

Experiments

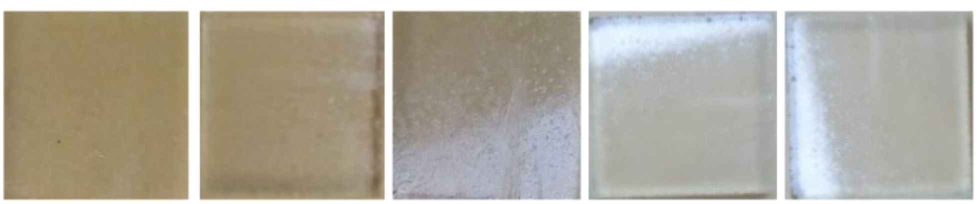
The stages of this research consisted of synthesis and characterization. The first stage, synthesis, is the process of making a thin layer using the sol-gel spin coating technique with a SnO_2: (Al + F + In) ratio of 95: 5% and 75: 25%. The synthesis consists of glass substrate preparation, sol-gel preparation, coating preparation, and curing [15]. Substrate preparation is done by cleaning the glass with detergent to remove all the dirt on the glass. Sol-gel making is done by dissolving SnO_2, aluminum, fluorine, and indium in ethanol (C_2H_5OH) using a magnetic stirrer until a thick white solution is formed, then left for 24 hours. The coating was made using a spin coater with a rotating time of 3 minutes. The thin layer that has been formed is then heated with temperature variations of 25, 50, 100, 150, and 200 ^{0}C using a furnace for 1 hour. The second stage, namely characterization of thin films using the UV-Vis Spectrophotometer Thermo Scientific Genesys 150 with a wavelength of 200-1100 nm.

Result and Discussion

The results obtained from the synthesis of a thin layer of SnO_2 with doping aluminum, fluorine and indium (SnO_2: Al + F + In) made the layer formed more transparent. This is shown in Figures 1 and 2, where a thin layer of SnO_2: (Al + F + In) with a doping concentration of 75: 25% (Figure 2) is more transparent than a thin layer of SnO_2: (Al+F +In) with a doping concentration of 95: 5% (Figure 1).

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

Figure 1. SnO_2 thin layer: (Al +F + In) (95: 5%) temperature variations (a) 25 ^{0}C, (b) 50 ^{0}C, (3) 100 ^{0}C, (d) 150 ^{0}C, (e) 200 ^{0}C.



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

Figure 2. SnO_2 thin layer: (Al + F + In) (75: 25%) temperature variations (a) 25 ^{0}C, (b) 50 ^{0}C, (3) 100 ^{0}C, (d) 150 ^{0}C, (e) 200 ^{0}C.

The next analysis is characterization of the optical properties of thin films using UV-Vis. The data obtained from the results of characterization of optical properties include absorbance, transmittance, band gap energy and activation energy.

Absorbance

Figure 3 shows the relationship between the wavelength and the absorbance of the SnO_2: (Al + F + In) thin film temperature variations.

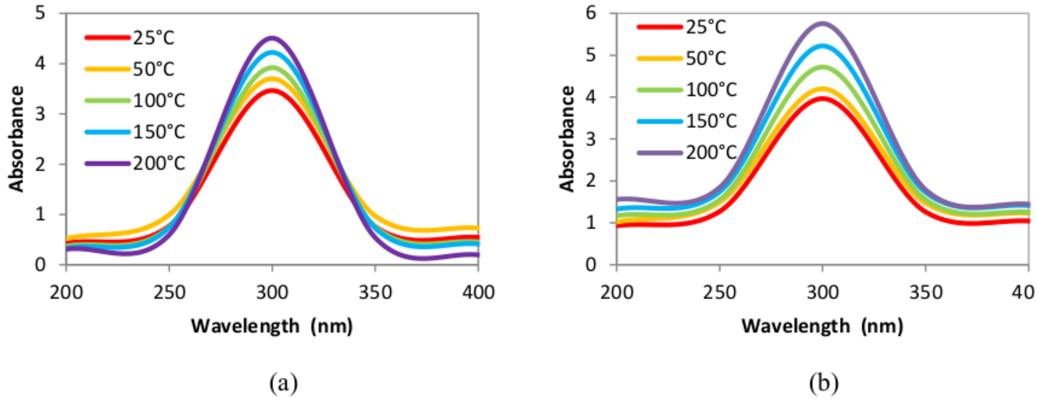


Figure 3. Graph of wavelength relationship with absorbance of thin layer SnO_2: (Al + F + In) temperature variation. (a) 95: 5%, (b) 75: 25%.

In Figure 3, it is clear that the absorbance value of the SnO_2: (Al +F + In) thin film absorbs temperature variations. The maximum absorbance values for temperature variations of 25, 50, 100, 150 and 200 ^{0}C for the percentages 95: 5% and 75: 25% at a wavelength of 300 nm are 3.46-4.50 and (Figure 3a) and 3.96-5.76 (Figure 3b), respectively. Based on Figure 3, it is clear that the higher the temperature, the resulting absorbance value increases, especially in the ultraviolet region with a wavelength of 300 nm.

Transmittance

The graph of the relationship between the wavelength and the transmittance of the SnO_2: (Al + F + In) thin layer variation is shown in the following figure.

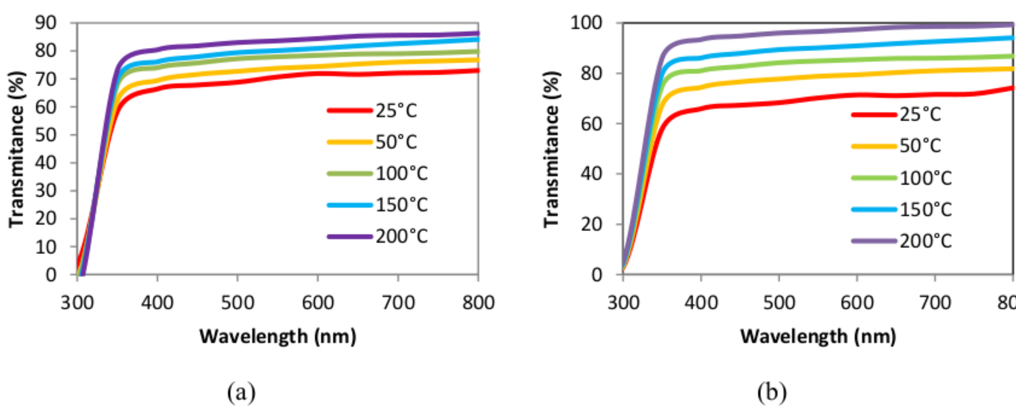


Figure 4. The graph of the wavelength relationship with the transmittance of the thin layer SnO_2: (Al + F + In) temperature variation (a) 95: 5%, (b) 75: 25%.

The transmittance value for temperature variations in the 300-800 nm wave range is shown in Figure 4.The transmittance values for temperature variations of 25, 50, 100, 150 and 200 ^{0}C are 95: 5% and 75: 25% respectively 73.00-86.30% (Figure 4a) and 74.20-99.30% (Figure 4b). This means that the transmittance value increases with increasing temperature. This is because the energy possessed by photons is smaller than the energy gap so that it is unable to excite electrons. This resulted in the photons being only transmitted [16].

Bandgap Energy

Bandgap energy consists of direct allowed bandgap energy and indirect allowed bandgap energy. Bandgap energy is obtained by graphing the photon energy with respect to $(\alpha h\upsilon)^r$. The amount of bandgap energy is shown by the slope of the photon energy graph with respect to $(\alpha h\upsilon)^r$. The amount of bandgap energy is obtained from equation 1 [17]. While the activation energy of the thin layer is obtained from 1/m or one per gradient of the photon energy graph with respect to $\ln \alpha$.

$$\alpha(h\upsilon)h\upsilon = K(h\upsilon - Eg)^r \quad (1)$$

Note: α is the absorbance coefficient, hυ is the incident energy of the photon, K is a constant, r = 1/2 for direct and r = 2 for indirect band-gap energy. Based on equation 1, it is obtained that the direct and indirect energy band gap allowed for the SnO2: (Al + F + In) layer with the tauc plot method is shown in Figures 5 and 6.

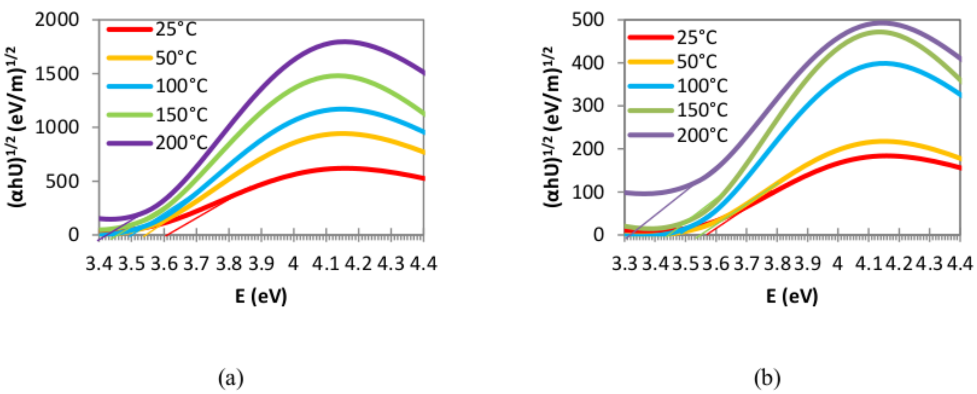


Figure 5. Energy band gap direct allowed SnO_2: (Al + F + In) thin layer. (a) 95: 5%, (b) 75: 25%.

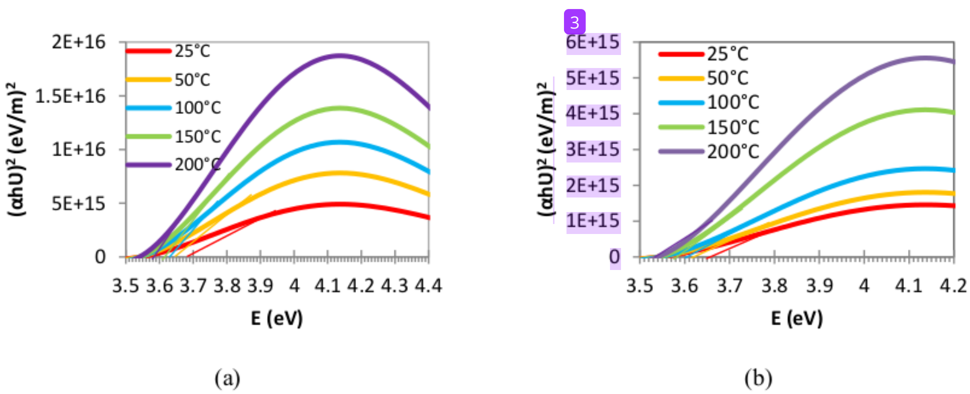


Figure 6. Energy band gap indirect allowed SnO_2: (Al + F + In) thin layer. (a) 95: 5%, (b) 75: 25%.

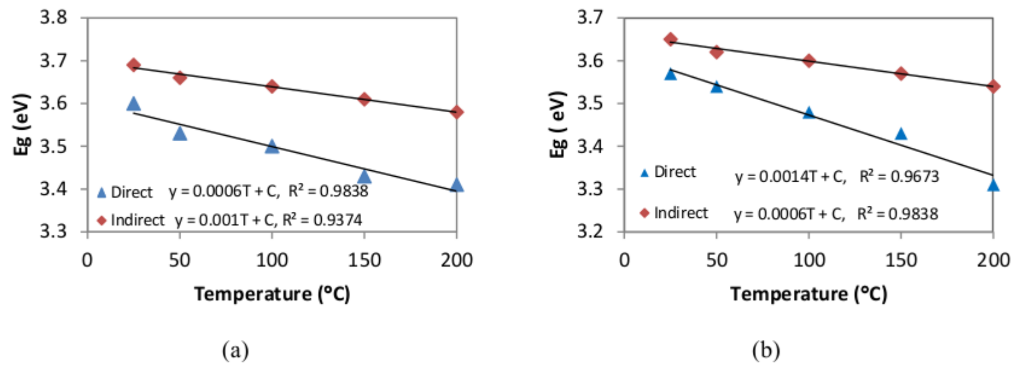


Figure 7. The relationship between temperature variations and the energy band gap of the SnO_2: (Al + F + In) thin layer. (a) 95: 5%, (b) 75: 25%.

Figure 7 shows that the band gap energy values for temperature variations. The band gap energy values for temperature variations of 25, 50, 100, 150 and 200 ^{0}C for a percentage of 95: 5% (Figure 7a) are 3.60, 3.53, 3.50, 3.43 and 3.41 eV for direct allowed, respectively, while for indirect allowed respectively 3.69, 3.66, 3.64, 3.61, and 3.58 eV, respectively. The energy value of the band gap for temperature variation for the percentage of 75: 25% (Figure 7b) is 3.57, 3.54, 3.48, 3.43, and 3.31 eV for direct allowed, respectively, while for indirect allowed the amount is 3.65, 3.62, 3.60, 3.57, respectively and 3.54 eV. The energy band gap obtained decreases with increasing ripening temperature and increasing the doping percentage of aluminum, fluorine, and indium [18, 19].

Activation Energy

Activation energy can be obtained from the slope of the straight line ln (α) versus photon energy (hυ). The value of ln (α) is obtained from the equation.

$$\alpha(\upsilon) = \alpha_0 \exp\left(\frac{E_f}{E_u}\right) \quad (2)$$

Where α (υ) = absorption coefficient, α_0= constant, E_f = photon energy, and E_u = Urbach energy. The values for Ln (α) and the activation energy are shown in Figures 8 and 9.

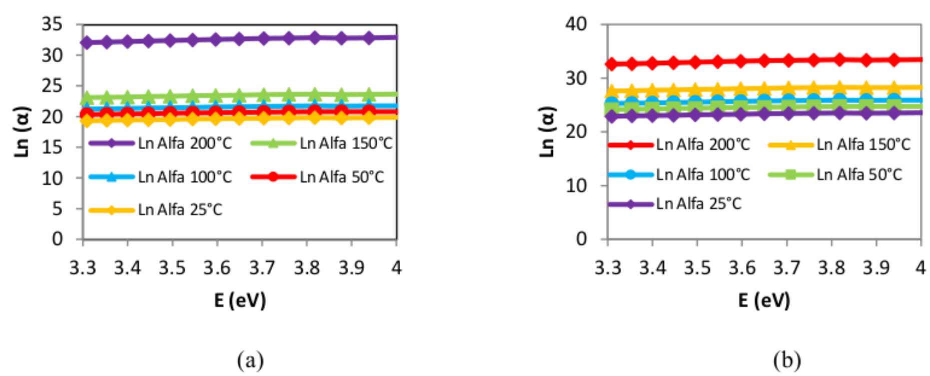
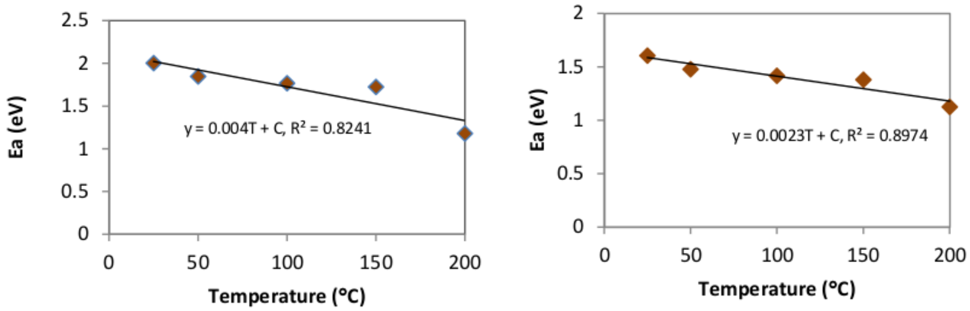


Figure 8. Graph of the relationship between photon energy and ln (α) of the SnO_2: (Al + F + In) layer variation. (a) 95: 5%, (b) 75: 25%.



(a) (b)

Figure 9. The relationship between temperature variations and the activation energy of the SnO_2: (Al + F + In) thin film. (a) 95: 5%, (b) 75: 25%.

Figure 9 shows that the activation energy for temperature variations of 25, 50, 100, 150 and 200 ^{0}C for a percentage of 95: 5% (Figure 9a) is 2.00, 1.84, 1.76, 1.72 and 1.18 eV, respectively, while for a percentage of 75: 25% 1.60, 1.47, 1.41, 1.37, 1.12 eV, respectively. In general, the activation energy decreases with increasing ripening temperature and the doping percentage of aluminum, fluorine, and indium. This shows that the movement of electrons increases so that the transfer of electrons from the valence band to the conduction band increases [20, 21].

Summary

The synthesis of SnO_2: (Al + F + In) thin films has been carried out using the sol-gel spin coating technique. The data obtained from the characteristics of the optical properties include absorbance, transmittance, band gap energy and activation energy. In the ultraviolet area with a wavelength of 300 nm, the absorbance value increases with the increase in ripening temperature and the addition of doping of aluminum, fluorine, and indium, while the transmittance value increases at a wavelength of 350 nm to 800 nm in the area (ultraviolet-visible) as the ripening temperature increases. and increasing amounts of aluminum, fluorine, and indium doping. In general, the absorbance and transmittance values increase with increasing ripening temperature and the addition of doping aluminum, fluorine, and indium, while the bandgap energy and activation energy values obtained decrease with increasing ripening temperature and increasing the doping percentage of aluminum, fluorine, and indium. This is because the energy possessed by photons is smaller than the energy gap so that it is unable to excite electrons and results in the photons being only transmitted. In addition, the bandgap energy and activation energy obtained decreased with increasing ripening temperature and increasing the doping percentage of aluminum, fluorine, and indium. The decrease in the value of the bandgap energy and the activation energy can make it easier for electrons to move from the valence band to the conduction band so that the material is slightly conductive and acts as a semiconductor.

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References

[1] A. Mandelis, Physics Today, 72(10), 68-69 (2019).

[2] C. L. Lu, S. J. Chang, T. C. Weng, and T. J. Hsueh, IEEE Electron Device Letters, 39 (8), 1223 – 1225 (2018).

[3] B. Kashyout, Fathy, Gad, Badr, and A. Bishara, Photonics, 6(2) (2019).

[4] F. Bittau, A. Abbas, K. L. Barth, J.W. Bowers, and J. M. Walls, Thin Solid Films, (633), 92-96 (2017).

[5] B. Sarma, D. Barman, and B. K. Sarma, Applied Surface Science, (479), 786-795 (2019).

[6] D. F. Andrade, F.M. Fortunato, and E. R. Pereira-Filho, Analytica Chimica Acta,(1061), 42-49 (2019).

[7] M.R. Panigrahi, and M. Devi, Journal of Physics: Conference Series, 1172, 012046 (2019).

[8] A. S. Pawbake, R. G. Waykar, D.J. Late, and S.R. Jadkar, ACS Applied Materials & Interfaces, 8(5), 3359–3365 (2016).

[9] M. A Yıldırım, S. T. Yıldırım, , E. F. Sakar, and A. Ates, Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 133, 60–65 (2014).

[10] D.L. Kamble, N.S. Harale, V.L. Patil, P.S. Patil, and L.D. Kadam, Journal of Analytical and Applied Pyrolysis, 127, 38–46 (2017).

[11] B. Beklesovas, V. Stankus, J. Link, R. Stern, Thin Solid Films, (708), 138-124 (2020).

[12] A. Doyan, Susilawati, N. Ikraman, and M. Taufik, Journal of Physics: Conference Series, 1011, 1-6 (2018).

[13] S. Hakim, A. Doyan, Susilawati, L. Muliyadi, Journal of Research in Science Education, 5 (2), 171-174 (2019).

[14] L. Muliyadi, A. Doyan, Susilawati, and S. Hakim, Journal of Research in Science Education, 5(2), 175-178 (2019).

[15] Susilawati, A. Doyan, L. Muliyadi, and S. Hakim, Journal of Research in Science Education, 6 (1), 1-4 (2019).

[16] Susilawati, A. Doyan, L. Muliyadi, S. Hakim, M. Taufik, and Nazarudin. Journal of Physics: Conference Series, 1397, 1-8 (2019).

[17] Susilawati, and A. Doyan, American Journal of Applied Science, 6 (12), 2071-2077 (2009).

[18] A. Doyan, Susilawati, A. Harjono, S. Azzahra, and M. Taufik, Materials Science Forum, 966, 30-34 (2019).

[19] M. S. Bannur, A. Antony, K. I. Maddani, P. Poornesh, A. Rao, and K.S. Choudhari, Physica E: Low-Dimensional Systems and Nanostructures, 103, 348–353 (2018).

[20] G. Bhatia, V. K. Gupta, M. M. Patidar, S.B. Srivasatava, D. Singh, M. Gangrade, and V. Ganesan, AIP Conference Proceedings 1953, 100084 (2018).

[21] A. Doyan, Susilawati, S. Hakim, L. Muliyadi, M. Taufik, Journal of Physics: Conference Series, 1397, 1-8 (2019).

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