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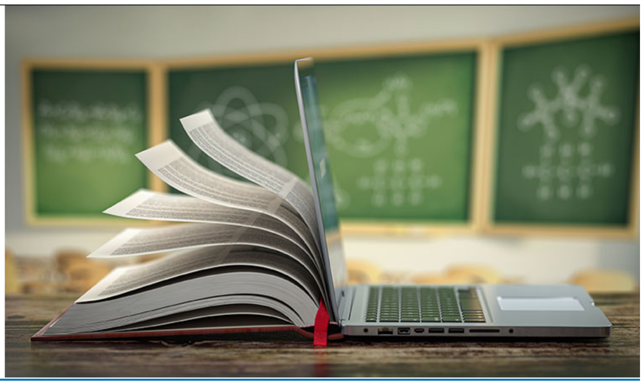
To cite this article: A Doyan *et al* 2021 *J. Phys.: Conf. Ser.* **1816** 012114



The effect of dopant material to optical properties: energy band gap Tin Oxide thin film

A Doyan[1,2], Susilawati[1, 2], L Muliyadi[1], S Hakim[1], H Munandar[1] and M Taufik[2]

[1]Master of Science Education Program, University of Mataram, Lombok, West Nusa Tenggara, Indonesia
[2]Physics Education, FKIP, University of Mataram, Lombok, West Nusa Tenggara Indonesia

E-mail: aris_doyan@unram.ac.id

Abstract. The synthesis of the SnO_2 thin film with doped materials of aluminum, fluorine, indium, a combination of aluminum and indium, a combination of aluminum and fluorine, and a combination of the three doping agents, namely aluminum, fluorine, and indium have been successfully carried out. The purpose of this synthesis is to determine the effect of the various doping materials on the resulting bandgap energy value. The thin layer was synthesized using the sol-gel spin coating technique with the ratio of the base material and doping material used were 95: 5% and 85: 15%. The results showed that the higher the doping material concentration, the resulting bandgap energy value decreased. In addition, the highest bandgap energy value is found in the SnO_2 thin film with indium doping, namely for direct 3.62 eV (95: 5% percentage) and 3.59 eV (percentage 85: 15%), while the indirect bandgap energy value is 3, 92 eV (percentage 95: 5%) and 3.67 eV (percentage 85: 15%). The lowest energy band gap value is found in the SnO_2 thin film with a combination of the three doping aluminum, fluorine, and indium, namely for direct 3.50 eV (95: 5% percentage) and 3.41 eV (percentage 85: 15%), while the energy band gap value is indirect. namely 3.81 eV (percentage 95: 5%) and 3.55 eV (percentage 85: 15%). All the energy band gap range in semiconductor materials.

1. Introduction

The increase in various types of technology in the industrial era 4.0 is inseparable from the hard work of scientists. This development cannot be denied that the developing technology requires supporting materials such as semiconductor materials. The semiconductor is a material which in certain circumstances acts as an insulator and in other circumstances acts as a conductor [1]. One of the materials used as a semiconductor is SnO_2.

Tin oxide (SnO_2) is a semiconductor material that is unique with an energy bandgap of about 3.6 eV and is sensitive to the presence of surrounding gases [2]. Based on these properties SnO_2 is widely applied to diodes [3], transistors [4], liquid crystal displays [5], capacitors [6], solar cells [7], gas sensors [8], and other optoelectronic devices [9]. This shows that the role of SnO_2 as a semiconductor material is very much.

The nature of SnO_2 itself can be substituted or added to other elements to change the properties according to needs. SnO_2 is usually added to other elements such as fluorine [10], aluminum [11], indium [12], antimony [13], and zinc [14]. Also, SnO_2 can be doped with a combination of antimony and zinc [15], a combination of aluminum and zinc [16], a combination of aluminum and indium [17], and a combination of aluminum and fluorine [18].

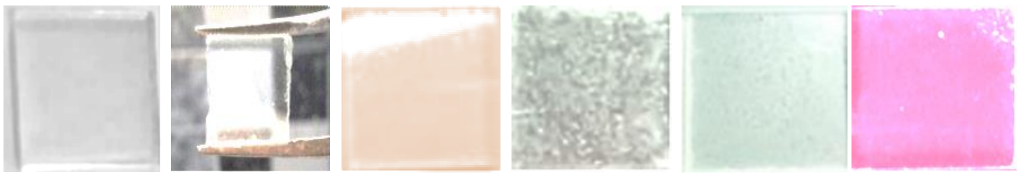
This study aims to determine the optical properties of the SnO_2 thin layer doping with aluminum, fluorine, indium, a mixture of aluminum and indium, a mixture of aluminum and fluorine, and the three doping mixtures, namely aluminum, fluorine, and indium. The optical property referred to in this study is the energy bandgap. With the addition of various types of doping, it is hoped that the bandgap energy produced by the thin layer will decrease or be less than 3.6 eV.

2. Method

The stages of this research include two processes, namely synthesis, and characterization. The synthesis process starts from the preparation of the glass substrate, the manufacture of sol-gel, coating the glass substrate with a sol-gel solution for coating growth, and finally the heating process. The second process is the characterization of thin films using thermoscientific Uv-Vis to obtain the optical properties of the coating. The SnO_2 thin film was synthesized using a sol-gel spin coating technique with doping materials for aluminum, fluorine, indium, a combination of aluminum and indium, a combination of aluminum and fluorine, and a combination of the three doping agents, namely aluminum, fluorine, and indium. The ratio of basic ingredients and doping materials used is 95: 5% and 85: 15%. The sol-gel material that has adhered to the glass surface is then heated for 60 minutes using a furnace at a temperature of 150 ^{o}C [19]. The finished sample was then characterized to obtain a thin layer optical value, namely the bandgap energy.

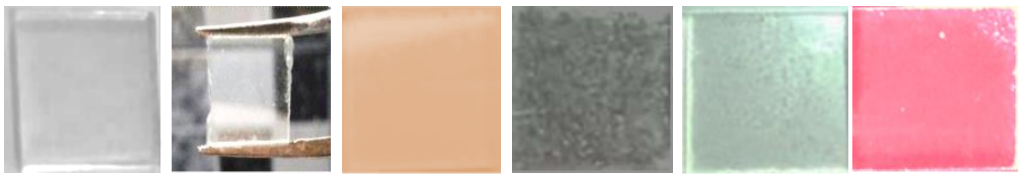
3. Result and Discussion

The synthesis of the SnO_2 thin film with dopants, namely aluminum, fluorine, indium, a combination of aluminum and indium, a combination of aluminum and fluorine, and the combination of the three aluminum, fluorine, and indium dopants produces a transparent film. The higher the number of dopants, the higher the level of transparency that is formed. Figures 1 and 2 show a thin film of SnO_2 for various types of dopant materials.



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

Figure 1. SnO_2 thin film: dopant material (95:5%). (a) SnO_2:In, (b) SnO_2:Al, (c) SnO_2:F, (d) SnO_2:(Al+In), (e) SnO_2:(Al+F), (e) SnO_2:(Al+F+In).



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

Figure 2. SnO_2 thin film: dopant material (85:15%). (a) SnO_2:In, (b) SnO_2:Al, (c) SnO_2:F, (d) SnO_2:(Al+In), (e) SnO_2:(Al+F), (e) SnO_2:(Al+F+In).

The optical properties of thin films obtained from the characterization results include absorbance and transmittance. The absorbance value is used to obtain the energy band gap value. The energy value of the thin film bandgap is classified into two, namely the direct energy bandgap and the indirect energy bandgap. The energy gap value is obtained through equation 1 [20].

$$\alpha(hv)hv = C(hv - Eg)^m \quad (1)$$

Note: α is the absorbance coefficient, hv is the incident energy of the photons, C is the constant, m = 1/2 for direct band-gap energy, and m = 2 for indirect band-gap energy.

The method of graphing the relationship between $(\alpha hv)^m$ photon energy can also be used to determine the energy value of the bandgap. Based on equation 1, the bandgap energy is obtained as shown in Figure 3, Figure 4, Figure 5, and Figure 6.

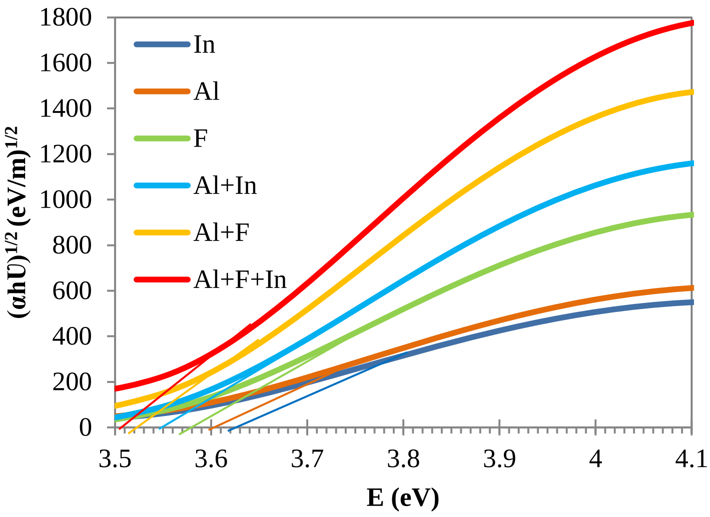


Figure 3. The energy band gap direct allowed a thin film of SnO_2 with a variety of dopant materials (95: 5%).

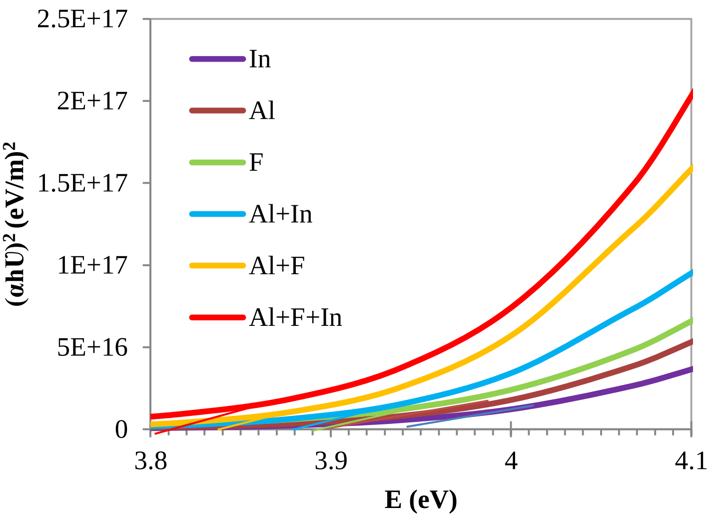


Figure 4. The energy band gap indirect allowed a thin film of SnO_2 with a variety of dopant materials (95: 5%).

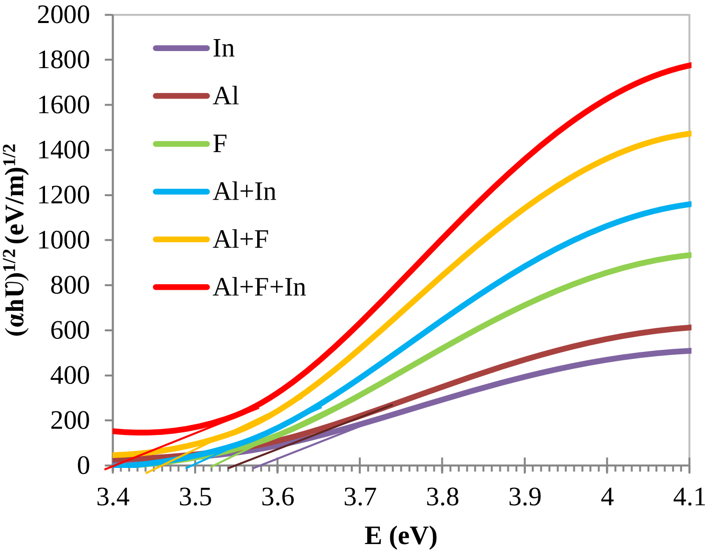


Figure 5. The energy band gap direct allowed a thin film of SnO_2 with a variety of dopant materials (85: 15%).

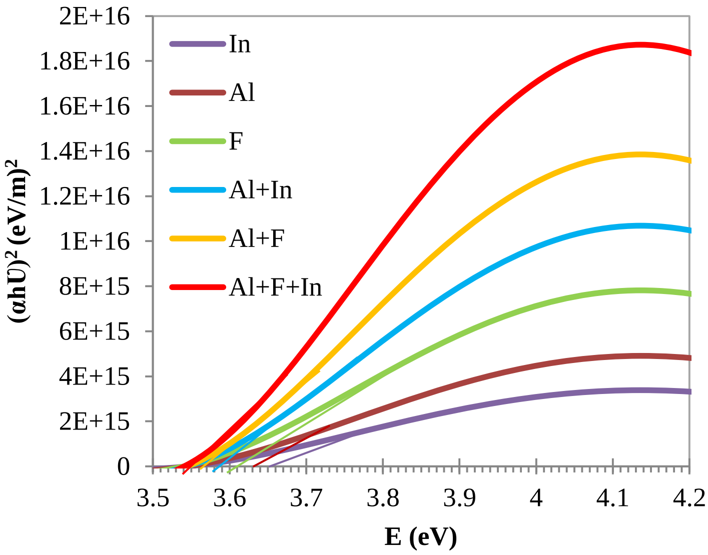


Figure 6. The energy band gap indirect allowed a thin film of SnO_2 with a variety of dopant materials (85: 15%).

The energy band gap values of direct allowed and indirect allowed are shown in Figure 7 and Figure 8.

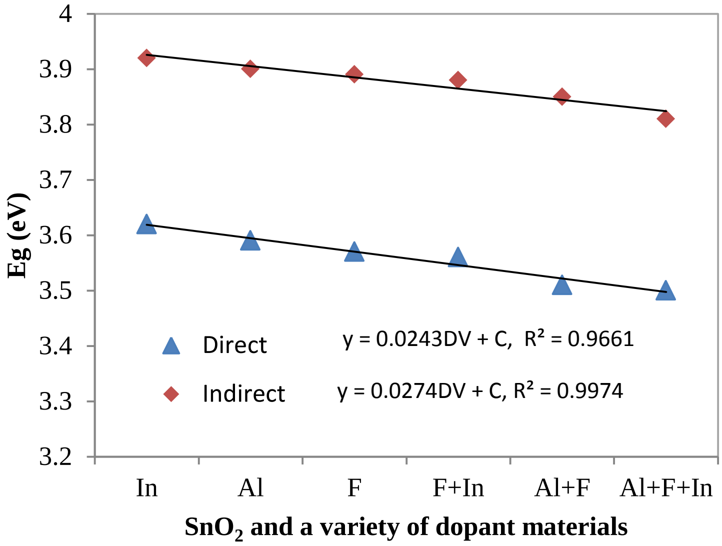


Figure 7. Graph of energy band gap direct and indirect allowed a thin film of SnO_2 variation of dopant material (95: 5%).

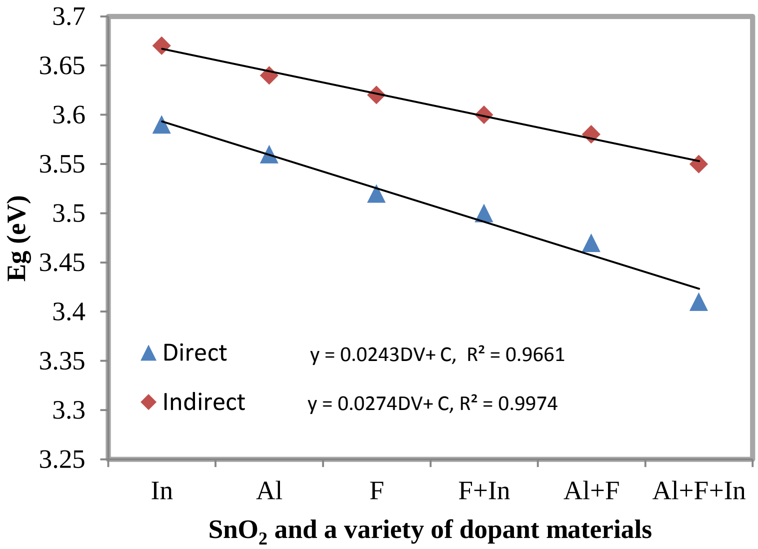


Figure 8. Graph of energy band gap direct and indirect allowed a thin film of SnO_2 variation of dopant material (85: 15%).

Figures 7 and 8 show the bandgap energy values for the dopant material variations. The energy value of the dopant bandgap for aluminum, fluorine, indium, a combination of aluminum and indium, a combination of aluminum and fluorine, and a combination of aluminum, fluorine, and indium dopants for a percentage of 95: 5%, respectively 3.62; 3.59; 3.57; 3.56; 3.51; and 3.50 eV for direct allowed, while for indirect allowed respectively 3.92; 3.90; 3.89; 3.88; 3.85; and 3.81 eV.

Energy band gap for the percentage of 75: 25% respectively 3.59; 3.56; 3.52; 3.50; 3.47 and 3.41 eV for direct allowed, while for indirect allowed respectively 3.67; 3.64; 3.62; 3.60; 3.58; and 3.55 eV. This shows that the higher the dopant material concentration, the resulting bandgap energy value decreases. Also, the highest bandgap energy value was found in the SnO_2 thin film with indium dopant, while the lowest bandgap energy value was found in the SnO_2 thin film with a combination of the three dopants, namely aluminum, fluorine, and indium.

This reduction in the energy bandgap is due to the presence of Indium in the SnO_2 structure which induces the formation of new recombination centers with lower emission energies [21]. Also, the presence of fluorine dopants causes the bandwidth built up by localization conditions in each film to be greater [22]. The decrease in the energy band gap value is also influenced by the presence of aluminum in the SnO_2 structure. This is because aluminum is a type of metal that is a good conductor of electricity [23]. The smaller the bandgap energy value possessed by the thin film, the easier it will be for electrons to move from the valence band to the conduction band [24, 25]. This results in the quality of a film being better used as a semiconductor material [26, 27, 28].

4. Conclusion

The optical properties of the SnO_2 thin film of various dopant materials for aluminum, fluorine, indium, a combination of aluminum and indium, a combination of aluminum and fluorine, and a combination of the three dopants namely aluminum, fluorine, and indium have been successfully carried out. The results showed that the higher the dopant concentration, the resulting bandgap energy value decreased. In addition, the highest bandgap energy value is found in the SnO_2 thin film with indium dopant, namely for direct 3.62 eV (95: 5% percentage) and 3.59 eV (percentage 85: 15%), while the indirect bandgap energy value is 3, 92 eV (percentage 95: 5%) and 3.67 eV (percentage 85: 15%). The lowest energy band gap value is found in the SnO_2 thin film with a combination of the three dopants, namely aluminum, fluorine, and indium, namely for direct 3.50 eV (95: 5% percentage) and 3.41 eV (percentage 85: 15%), while the energy band gap value indirect, namely 3.81 eV (percentage 95: 5%) and 3.55 eV (percentage 85: 15%). This shows that the three doping mixtures, namely aluminum, fluorine and indium, are very well used to produce a thin layer with a small bandgap energy.

Acknowledgments

The author would like to thank the Analytical Laboratory of the University of Mataram, the Integrated Labolaturium of Diponegoro University, the Ristekdikti PTM Skim and all those who helped the realization of this article.

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