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Synthesis Thin Films $SnO_2$with Doping Indium by Sol-Gel Spin Coating

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Abstract: This research is an experimental study that aims to support the temperature and variation of doping in making thin films. The temperature variations at room temperature annealing, 50, 100, 150, and 200ºC, and doping variations of 0, 5, 10, 15, 20, and 25%. The method used in this study is sol-gel spin coating. The results showed that thin films at low temperatures were more transparent than higher temperatures and the increase percentage doping causing thin films to be more transparent.

Keywords: Thin Films; SnO_2; Indium, Sol-gel, Spin Coating.

Introduction

Semiconductor materials have been widely used for technological development. Semiconductor materials are not only used in electronic materials such as diodes, capacitors, transistors, IC (integrated circuit). But it is more widely developed into more sophisticated nanotechnology such as solar cells, gas sensors (Rebholz, *et al.*2015), LCD projectors, electronic LCD TVs, ATM machines, touch screens (Doyan, *et al.*2018), and transparent conductive electrodes (Zhao, *et al.*2015).

The thin film can be made from various semiconductor materials, one of which is SnO_2 (Doyan, *et al.*2016). A thin film of SnO_2 (tin oxide) was found that the energy band gap it possessed was high enough for semiconductor materials ranging from 3.75 eV to 3.8 eV (Muthuraja, *et al.*2015),(Selvi, *et al.* 2017).

Indium is one of the doping materials that has a high enough conductivity so that it can reduce resistivity, increase optical transparency (Hammad, *et al.*2011), and good response to sensor applications (Zoubir, *et al.*2016). The use of Indium as a dopant of SnO_2 thin films, because in the manufacture of thin films of indium does not require high temperatures (Ma, *et al.* 2018).

A thin film of SnO_2 with Indium as a material doping to growth films can be performed by a variety of methods or techniques as like as reactive magnetron sputtering (Angarita, *et al.* 2017), rf Plasma enhanced Reactive Thermal Evaporation (Patel, *et al.*2013), Dc and RF Sputtering (Xu, *et al.*2016) whose process is quite complicated, because it requires RF radio frequency with high electrical power (Velumani, *et al.*2017), dip coating (Doyan, *et al.*2018), and Spin-Coating techniques (Yongvanich, *et al.*2018). The simplest methods above are the Spin-Coating method.

Spin-Coating method is one simple method that utilizes centrifugal force to spread thin film sol-gel evenly on the surface of the preparation and its thickness can be controlled with spin speed (Ng, *et al.*2014), has a short crystallization process, it can synthesis at low temperatures, nano particles, pure results. Despite the simple method, the thin film produced is of high quality (Pertiwi, *et al.*2015).

Methods

The method used in making thin films is the sol-gel spin coating method. The sol gel method is a method used to make a solution that can stick to the glass substrate. Calculate of 1 Molar concentration of SnO_2 and Indium materials with variations in doping concentration using equations.

$$(100-n)\% = \frac{(m_t SnCl_2{\cdot}2H_2O)\ x \frac{1}{Mr\ SnCl_2{\cdot}2H_2O})}{(m_t InCl_3{\cdot}4H_2O)\ x \frac{1}{Mr\ InCl_3{\cdot}4H_2O}} \quad \text{.... (1)}$$

$$(n)\% = \frac{(m_t InCl_3{\cdot}4H_2O)\ x \frac{1}{Mr\ InCl_3{\cdot}4H_2O})}{(m_t SnCl_2{\cdot}2H_2O)\ x \frac{1}{Mr\ SnCl_2{\cdot}2H_2O}} \quad \text{.... (2)}$$

In order for the sol-gel coating the glass to be spread evenly on the glass surface, a spin coating is carried out. The process of spin coating applies a centrifuge force which arises during the playback

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process, with the centrifuge force the sol-gel which is injected on top of the glass substrate spread evenly on the glass surface.

The glass substrate used is colorless or transparent glass. The use of transparent glass because with transparent glass there be a clear difference in the appearance of thin films formed by variations in different doping concentrations. The use of doping in thin films aims to increase the color transparency of the thin film.

In addition to the concentration of doping, the transparency color of the thin film is also influenced by the heating temperature or the maturation of the thin film. So that in this study, the maturation stage of the thin film using varied ripening temperatures ranging from ripening without heating, and ripening by heating at temperatures of 50, 100, 150, and 200 ^oC which was done for one hour using a furnace.

Result and Discussion

The stages are carried out in making thin films in general through four stages. Started from washed the substrate, making sol-gel, grow up thin films on the substrate with spin coating techniques, and the annealed process.

Substrate washed use detergent solution. The glass substrate is soaked in detergent solution and vibrated using a shaker so that the stains stick to the glass substrate apart and the glass surface becomes sterile from the dirt. After the glass is shaker, the glass substrate is then rinsed using pure water (distilled water) until the detergent foam is clean. Besides being clean from stains and foam, the glass substrate must also be sterile from bacteria, so the glass substrate is immersed in alcohol and then the glass substrate is dried.

Preparation of Indium SnO_2 doped sol-gel composition $SnCl_2.2H_2O$ and $InCl_3.4H_2O$ dissolved ethanol (Doyan, *et al*. 2017). SnO_2: In thin layer material dissolved in 20 ml ethanol at concentration 1 M.

Table 1. Mass Comparison composition thin films of SnO_2:In.

Doping Persentage(%)	$SnCl_2.2H_2O$ (gram)	$InCl_3.4H_2O$ (gram)
100:0	4.5125	0
95:5	4.2869	0.2932
90:10	4.0613	0.5865
85:15	3.8356	0.8797
80:20	3.6100	1.1730
75:25	3.3844	1.4662

The growth of a thin film on the glass substrate is done by the screening process or commonly called spin coating. The spin coating technique applies the principle of centrifuge force arising from rotation. The centrifuge force causes sol-gel to be injected over the surface of the glass substrate. The spin coating process at a speed of 2000 rpm for 3 minutes causes sol-gel to spread evenly on the glass surface, resulting in a high-quality thin film.

The production of sol-gel from the base material of SnO_2 with Indium doping variation made the thin film produced look different. This difference in the thin films shows that the difference in treatment of variations in doping or anneal temperature will cause differences in the yield of thin films.

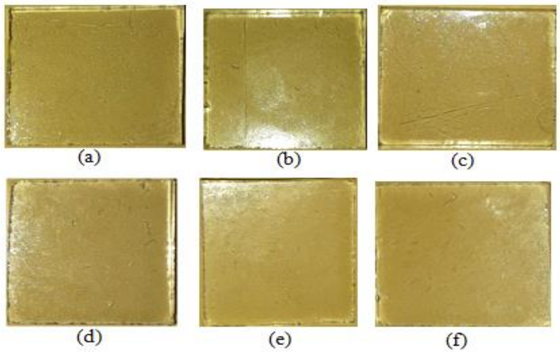

Figure 1. Thin film with temperature anneal 200 ^oC. Variation of SnO_2:In (a) 100: 0%, (b) 95: 5%, (c) 90: 10%, (d) 85: 15%, (e) 80: 20%, (f) 75: 25%.

In figure 1 shows that, the film with 0% doping Indium surface is no more transparent. The thin film with the highest to lowest transparent colors is 25, 20, 15, 10, 5, and 0% doping Indium respectively.

The effect of varying temperature of the thin film maturation causes the surface of the thin film to have a different level of transparency. The increase of anneal temperature, cause the transparent color level of the thin film decreases.

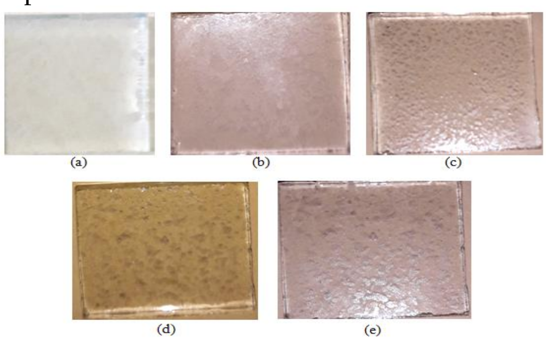

Figure 2. Thin Films SnO_2:In with variation anneal temperature (a) room temperature, (b) 50 ^oC, (c) 100 ^oC, (d) 150 ^oC,(e) 200 ^oC.

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In figure 2, anneal at a temperature of 50, 100, 150, 200 °C shows that the thin film with a temperature of 50 °C surface is the most transparent, followed by 100, 150, and 200 °C respectively. The higher anneal temperature, the more visible white spots on the thin films.

Conclusion

The process of making sol-gel can be done at room temperature because SnO_2 and In ingredients can mix homogeneously. The spin coating technique is quite simple, but can produce a thin film spread evenly over the glass surface.

The surface of the thin film is influenced by the concentration of doping (SnO_2: In), the higher the doping In percentage, the transparent color of the thin film produced increases. In accordance with the effect of increasing temperature. The higher anneal temperature, make the transparent color of thin films are decrease.

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