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Characterization Thin Film Nano Particle of Aluminum Tin Oxide (AlTO) as Touch Screen

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Abstract. The aims of this research are to synthesis Aluminum Tin Oxide (AlTO) thin films have been deposited on glass substrates. The Tin (II) chloride dihydrate as precursor, ethanol as solvent, and $AlCl_3$ as dopant substance, the film was done by spin coating technique. Then to characterization the properties of the thin film as the Structural and morphological analysis was carried out by X-Ray Diffraction (XRD) measurement and Scanning Electron Microscope (SEM). The Optical characteristics were analyzed from the study of transmission and absorption spectrum data obtained by UV-Vis Spectrophotometer. The Result from XRD measurement, there were crystal system alterations. They were confirmed that SnO_2 and SnO_2 doped Aluminum have cubic structure (by material phase classification of Al_2O_4Sn) because of the substrate compositions contained Aluminum. The XRD pattern shows that grain size of thin film decreased just after the Aluminum dopant was added. EDX analysis confirms the presence of SnO_2. The Optical characteristics were analyzed from the study of transmission and absorption spectrum data obtained by UV-Vis Spectrophotometer. The Aluminum was added by various concentrations (5, 10, and 15)%. Transmissions of visible light were better on the little concentrations of Al, but absorptions were lower too. The range of band gap energy value (3.52 – 3.47) eV was decreased by increasing the Aluminum concentration. It show that semiconductor range used touch Screen.

1. Introduction

Nano technology continuous to be developed and prioritized in science and technology. Thin film is one form of this nanotechnology. A thin film is made of organic or inorganic material, metal or metal-organic mixture (thickness in the scale of nanometers to millimeters) and has the properties of a conductor, semiconductor, or insulator. Since 1850, this thin film technology has been introduced by M. Faraday, W.Grove, T.A. Edison and continues to experience growth in terms of the materials used, method of manufacture, and its application in life [1]. In material science, there are some metal oxide materials are often used in thin film technology, both pure and doped with other materials.

Studies on the synthesis and characterization of thin film has always attracted the attention of researchers for extensive application in everyday life, both in the field of decoration-construction and electronics. In the field of electronics, thin film was used to make semiconductors. The application of thin films for semiconductors are developed in the form of transparent conductive oxide (TCO), capacitors, diodes, transistors and sensors. Application of TCO develops rapidly and has been applied to electronic devices such as LCD TVs, Plasma TVs,

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and organic electroluminescence, for example, touch screen monitors on authomatic teller machine (ATM), ticket vending machines installed in train stations, car navigation systems, handheld game consoles, mobile phones and electrodes in solar cells [2].

Excess thin film of SnO_2 which causes this material is interesting to develop is its transparancy (the energy gap approximately 3.6 eV) [3], electricity resistance is low, and has high chemical stability [4], the price is cheap, responsive to a number of gases, durable, and requires only a simple electronic device in its application. This research is used to determine the thin film characteristics of SnO_2 by adding various concentration of dopant Al on glass substrate.

2. Experimental

The synthesis was done by using sol-gel spin coating with variations in dopant concentrations of Al (in %) of 5; 10; and 15 and an increase in the annealing temperature of 200°C to 400°C. Materials used are $SnCl_2.2H_2O$ as precursors, C_2H_5OH as solvent and $AlCl_3$ as dopant. Research stages are as follows : Compute and weigh the ingredients needed, Dissolving 0.902 g $SnCl_2.2H_2O$ in the 40 ml C_2H_5OH using a hot plate magnetic stirrer for 15 minutes (or until the solution looks homogeneous) to obtain samples SnO_2 without doping. Dissolving 0.027, 0.053 and 0.08 g $AlCl_3$ respectively in the previous solution to obtain a dopant concentration (in %) 5, 10, and 15 at temperature 80°C for 15 minutes. Marking solutions, then the solution A was SnO_2 without doping, solution B, C, and D are solution of SnO_2 with dopant Al 5%, 10%, and 15% respectively. Aging the solution for 24 hours. Each solution labeled A, B, C and D will be used as a coating material on a glass substrate. Dropping the solution onto a glass substrate and rotate with a speed of 2000 rpm for 3 minutes. Perform characterization using a UV-Vis Spetrophotometer, XRD and SEM-EDX.

3. Results and Discussion

This The following figure 1. Show that SnO_2 thin film without dopant, SnO_2 with 5, 10 and 15 (in %) dopant Aluminum (Al) respectively.

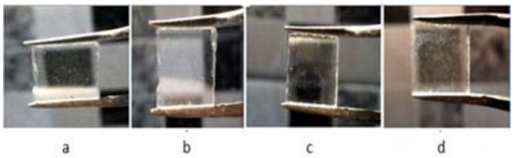


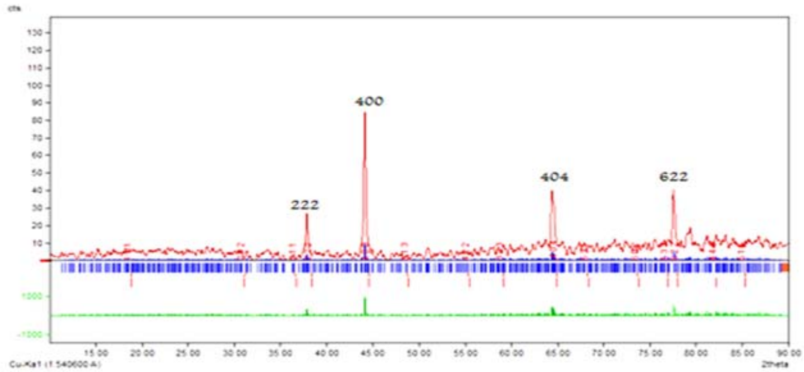
Figure 1. (a) Pure SnO_2; (b)SnO_2:Al 5 %; (c) SnO_2:Al 10 %; (d) SnO_2:Al 15 %

3.1 Tests using XRD instrument

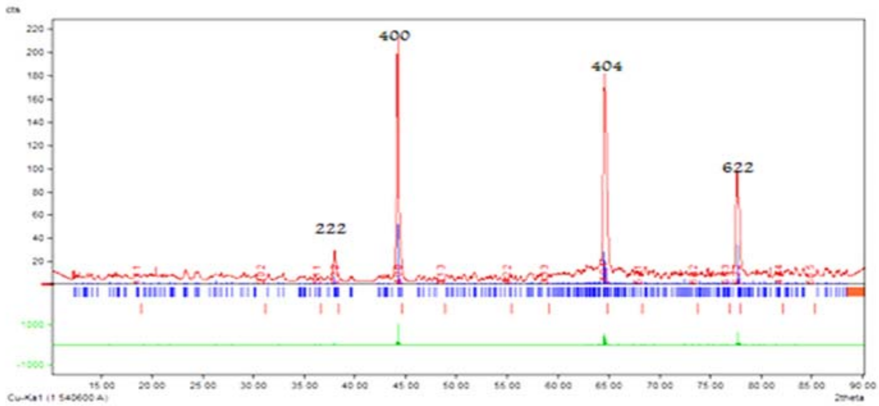
Measurements were performed using an X-Ray Diffraction (XRD-7000) Shimadzu brand Maxima, which is operated at a voltage of 30 kV and current of 30 mA with a target Cu (λ = 1.54060 Å). Figure 2 shows the diffraction pattern for SnO_2 samples with dopant concentrations of 0 % and 5 % and the annealing temperature 400°C. Based on the results of XRD, the structure formed is cubic with the identity of a = b = c = 8.1200 Angstroms with $\alpha = \beta = \gamma = 90°$, referring to the crystallographic open database (COD). These results indicate that the addition of aluminum dopant increases the intensity peak at an angle (2θ) of about 44° and does not eliminate the constituent elements of SnO_2 thin film, that is the element of tin (Sn) and oxygen (O). Average crystal size can be obtained by Scherrer equation as follows :

$$D = \frac{k\lambda}{\beta cos\theta} \quad (1)$$

Original crystal size of SnO_2 is 55.95 nm, and after the addition of dopant Al 5 %, the crystal size becomes smaller at 48.45 nm. For each samples, the position of constituent particles in thin film showed a regular pattern, which indicates crystalline solids. Here is XRD diffraction patterns for SnO_2 without doping and SnO_2 doped 5 % aluminum on a glass substrate.



(a)



(b)

Figure 2. XRD diffraction pattern for the thin films : (a) SnO_2 without doping and (b) SnO_2:Al 5 % on a glass substrate

3.2 Tests using SEM – EDX

Tests using SEM (Scanning Electron Microscopy) was conducted to determine the structure of the material surface morphology of thin films. This tool is integrated with detector energy dispersive X-ray (EDX) that can be used to analyze the composition of materials. Figure 3 shows the result of morphology observation on SnO_2 without doping, and Figure 4 shows the surface morphology of SnO_2:Al 5% deposited on a glass substrate respectively with 20000x magnification.

The contrast in the resulting image is the result of differences in reflectivity in a wide range of nanostructured area.The resulting image is different each other because of their differences in the orientation of the crystal surface. SnO_2 samples deposited on a glass substrate has pattern like grain resembling that united to form a unique pattern, with the grain boundary are clearly visible. Grain boundaries of SnO_2 with 5% aluminum is not clearly visible.

Characteristics of glass substrate that are less resistant to high temperatures cause porosity in thin films as a result of the rapid evaporation process. The SEM-EDX analysis is used to confirm the presence of constituent components in thin film. Here is the identification result of the material components distribution of SnO_2 and SnO_2:Al 5% deposited on a glass substrate (Figure 5).

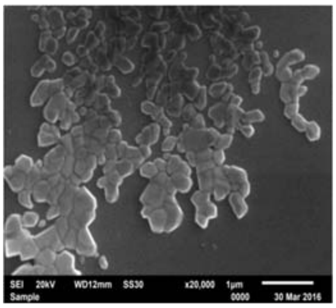


Figure 3. The morphological structure of SnO_2 deposited on a glass substrate

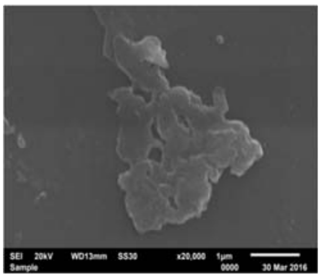
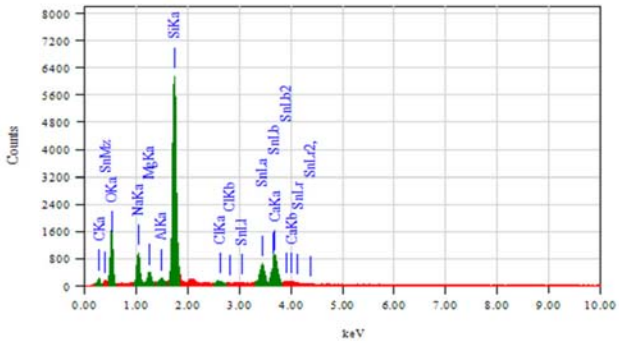
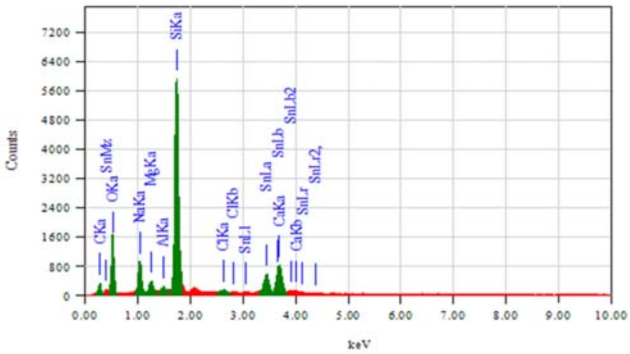


Figure 4. The morphological structure of SnO_2 :Al 5% deposited on a glass substrate

From EDX integrated with SEM, it was obtained fact that the presence of the element tin (Sn), oxygen (O) and aluminum (Al) can be identified. In addition to the elements Sn, O and Al, other elements identified is in part derived from the components of the solution deposited on a glass substrate (eg. C and Cl), and the others are part of the glass substrate itself (eg. SiO_2 and Al_2O_3).



(a)



(b)

Figure 5. The identification result of the material components distribution of SnO_2 and SnO_2:Al 5% deposited on a glass substrate

3.3 Test Using UV-Vis Spectrophotometer

Figure 6 shows the absorption of the energy of light to each thin film sample of SnO_2 on glass substrates, either pure or doped with 5%, 10% and 15% aluminum, each of them started to increase absorption at the wavelength of the beginning of 220 nm. The increase in this value keeps going until it reaches its top position, then drops exponentially. Peak of absorption for the pure SnO_2 sample, and SnO_2 doped aluminum 5 %, 10 %, 15 % respectively were 0.63 at a wavelength of 259 nm, 1.39 at a wavelength of 275 nm, 1.62 at a wavelength of 299 nm, and 1.64 at a wavelength of 277 nm. In the wavelength range of visible light, minimum absorption value constantly occurs at wavelength of 320 nm to 800 nm, with absorption reaches 0. In these graphs, the highest absorption occurred in the SnO_2 samples doped aluminum 15 %, and the lowest absorption occurred in pure SnO_2 samples. The Optical phenomenon that occurs in the thin film of solid material involves an interaction between the electromagnetic radiation of light with atoms, ions, or electrons. Two of the most important part of this interaction are electronic polarization and energy transition of electrons. One of the components of an electromagnetic wave is the electric field which fluctuates rapidly. For the frequency range of visible light, the electric field interacts with the electron cloud around each atom in a trajectory that causes electronic polarization or a shift relative to the electron cloud of an atomic nucleus. Two consequences of this polarization are (1) light radiation energy is absorbed and (2) the light wave is slowed when crosses medium [5].

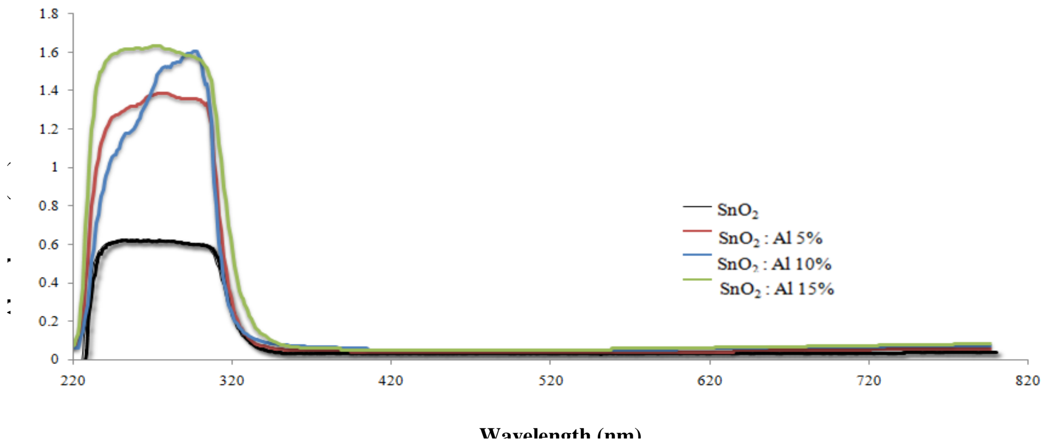


Figure 6. Relationship between wavelength and absorbance of SnO_2 with various Al concentrations (5%, 10%, and 15) on a glass substrate

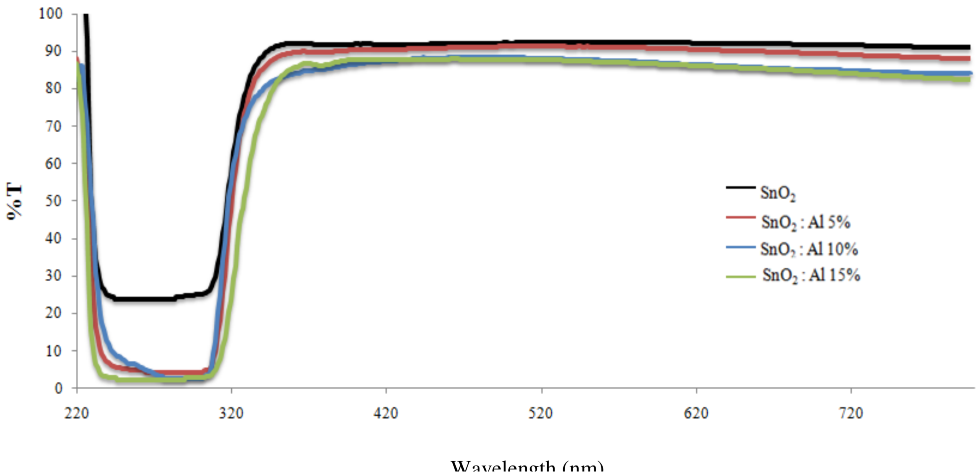


Figure 7. Relationship between wavelength and transmittance of SnO_2 with various Al concentrations (5%, 10%, and 15) on a glass substrate

Based on the analysis of UV-Vis Spectrophotometer of SnO_2 without doping and SnO_2 with various dopant Al, a thin film transparency will decrease when the concentration of dopant added. Absorption and emission of light wave radiation involves the transition of electrons from one energy level to another energy level. When light is imposed on a transparent glass coated with a thin film of SnO_2 materials, the electrons in the sample absorb the energy of the light. 15 % aluminum doped on SnO_2 has the highest absorbance due to the high concentration of dopant which causes more light energy is absorbed by electrons of the aluminum dopant. The higher absorption is caused by electrons from a material that requires energy to move to a higher energy level. Besides absorbance, other parameters measured in this study is the transmittance. The highest transmittance is 92.6 % in pure SnO_2, followed by SnO_2 doped 5 % aluminum (91.3 %), SnO_2 doped 10 % aluminum (88.5 %), and the last is SnO_2 doped 15 % aluminum (87.8 %). The optical characteristics are influenced by the concentration of aluminum dopant given.

The higher the concentration of aluminum, results in decreased levels of transmittance. Aluminum is a type of metal that is light and strong. The melting point of aluminum reaches 660.3°C, and the melting point of tin 231.9°C. In this study, elevated temperature used is 200°C and then to 400°C. When tin components melt and form a tin oxide at a temperature of 231.9°C, aluminum has not reached the melting point, so cannot melt perfectly. This causes a reduction in the transmitted light.Transmittance of the glass substrate also influences the transmittance of the sample. Glass is a solid material with irregular atomic structure, thus affecting the transmittance percentage.

There are electrons which occupy each trajectory in solid material atoms. If there is an external electromagnetic radiation (in this case the light) with a specific energy of the electrons in a material, there will be absorption and emission of electromagnetic radiation. Absorption and emission of electromagnetic radiation would involve the transition of an electron from one energy level to another energy level. Changes experienced by the electron energy is equal $\Delta E = h\nu$, so that only photons with a frequency corresponding to ΔE experiencing energy by atomic absorption through the transition of electrons [6].

The electrical characteristics can be determined by the width of the gap between the valence band and the conduction band. It can be known by calculating the width of the energy gap (band gap energy) related to the absorption of energy from ultraviolet light and visible light. Increased energy (in units of eV) causes the electrons vibrate and move from its original energy level to higher energy level.

The graphical trend that increase exponentially. From the data obtained, the decline in the value of energy gap occurs after the addition of aluminum dopant concentration. This indicates that when the width of the energy gap is reduced, it is allowing more electrons undergo electronic transitions from the valence band to the conduction band so that a thin film is more conductive. It is also confirmed that aluminum is a type of metal that is a good conductor.

The relationship between photon energy ($h\nu$) and absorption coefficient (α) is expressed in the equation :

$$(\alpha h\nu)^{\frac{1}{n}} = A(E - E_g) \quad (2)$$

Where α is a constant, $E = h\nu$ is the photon energy and E_g is the band gap optics. Exponent n depends on the type of optical transitions. The value of n for direct optical transitions is equal to 1/2, to indirect optical transitions by 2 and a direct optical transitions forbidden is 3/2 [7].

The figure 8 of energy gap for SnO_2 without doping and with doping aluminum 5 %, 10 % and 15 % on a glass substrate.

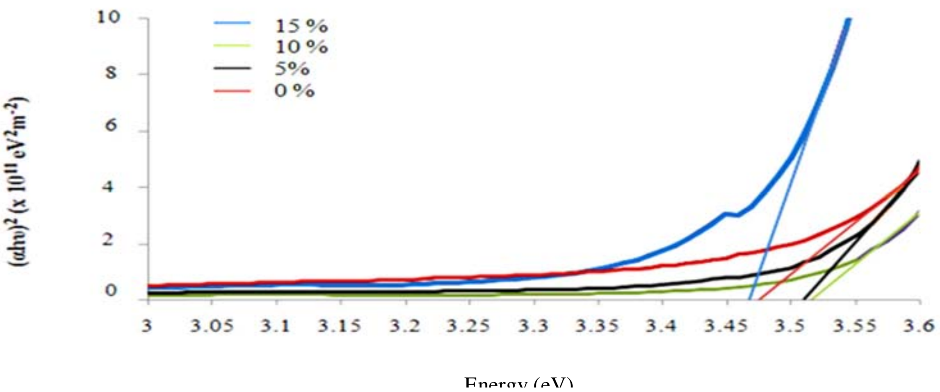


Figure 8. Energy gap SnO_2 and SnO_2 doped with 5%, 10%, and 15% Al on glass substrate

Table 1. Comparison of energy gap of SnO_2 on various Al concentration deposited on a glass substrate

Thin Film Materials	E_g (eV)
SnO_2: Al 0%	3.52
SnO_2 : Al 5%	3.51
SnO_2 : Al 10%	3.48
SnO_2 : Al 15%	3.47

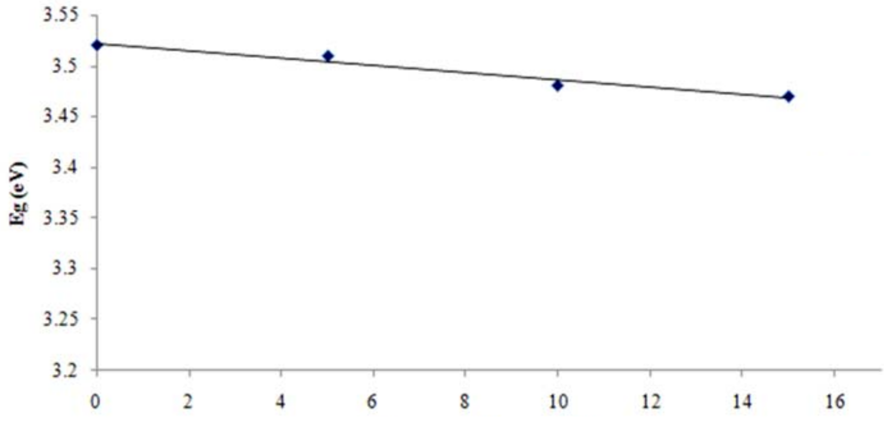


Figure 9. Relationship between dopant Al with gap energy of SnO_2 on glass substrate

4. Conclusions

Based on the results of research and discussion, it can be concluded as follows: The percentage of transmittance of thin films is reduced by the addition of aluminum dopant concentration. The energy gap of ATO decreases as the addition of aluminum dopant concentration that causes the material is more conductive. The XRD characterization showed the identification of crystals have cubic crystal system. The presence of dopant reduces the size of the crystal grain. The Tin Oxide (SnO_2) and ATO (SnO_2:Al) can be applied as a basic ingredient material Transparent Conductive Oxide (TCO) in terms of transparency (> 90%) and its energy band gap (3.52 – 3.47)eV used as touch screen.

5. Acknowledgement

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