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EFFECTIVENESS OF DIETHANOLAMINE (DEA) ADDITION ON BAND GAP VALUE OF SnO2 BY USING SOL-GEL METHODS

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Abstract

The need for electrical energy is increasing with the increase in the economy and population in Indonesia. Fossil energy sources are used as fuel to produce electrical energy and will run out if used continuously. Fossil energy sources can be replaced by using New Renewable Energy (NRE) to meet national electrical energy needs. The purpose of adding additives in this study is to observe the effectiveness of the addition of DEA on the band gap value, crystal phase, and surface morphology on SnO2. In this study using the sol-gel method for the synthesis of SnO2. The sol-gel method is the conversion of monomers into colloidal solutions (sol) which serve as precursors for integrated networks (gels) either discrete particles or network polymers. SnO2 nanomaterials will be characterized by UV-DRS Spectrophotometer. The results of characterization of SnO2 nanomaterials with the addition of Diethanolamine additives as much as 1.5 mL have obtained a band gap value of 3.60 eV.

Keywords : Diethanolamine ; SnO2 Nanomaterial ; Sol-gel

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INTRODUCTION

The need for electrical energy is increasing with the increasing economy and population in Indonesia (Adistia et al., 2020). Information that has been obtained from Databoks.id in 2023 shows that Indonesia consumed electricity per capita of 1,089 kWh per capita in 2020 and an increase in 2021 of 1,123 kWh per capita. Electricity consumption in Indonesia was recorded in 2022 to have reached 1,173 kWh per capita. Fossil energy sources are used as fuel to produce electrical energy and will run out if used continuously (Ryanuargo et al., 2013). Fossil energy sources can be replaced by using New Renewable Energy (EBT) to meet national electrical energy needs (Adistia et al., 2020). One of the New Renewable Energy (EBT) that can be developed is semiconductors. One of the uses of semiconductors in Indonesia is the production of electronic devices that use Lithium ions as semiconductor materials (Brunner, 2021). Lithium ion batteries are sensitive to high temperatures and can burn when exposed to extreme heat and the production of lithium ion batteries is expensive, making it less accessible to consumers (Shobana, 2019). The use of Lithium ion batteries can be replaced by using other semiconductor alternatives.

Semiconductors are materials that can conduct electricity within a certain range. The electrical and optical properties of semiconductors have a major impact on the performance of solar cells, photo electrocatalysts and photo catalysts (Wang et al., 2021). Semiconductors have several advantages, namely that they can be processed by low-temperature deposition, have a smooth / grainy coating, manufacture large areas on glass and lack of long-range regularity making plastic substrates flexible (Kim et al., 2018). Semiconductor applications include solar cells, batteries, and transparent electrodes as well as gas sensors and catalysts (Patel et al., 2021). Some semiconductor materials that can be applied such as TiO_2, ZnO, CoO, CdO, $LiCoO_2$, and SnO_2 (Shobana, 2019).

Tin dioxide (SnO_2) is an n-type oxide semiconductor with a band gap of 3.6 eV that has good electrical conductivity (Kose et al., 2015). Basically tin oxide exists in the form of SnO, SnO_2, Sn_3O_4, and Sn_2O_3. Tin oxide in the form of SnO is less stable so that through oxidation it is converted to SnO_2. The advantages of SnO_2 are good transparent conductor stability because it has high electrical conductivity and is transparent to visible light. In addition, SnO_2 does not experience corrosion and the tin element is easily available so that production is cheaper. The wide optical band gap of SnO_2 and transparency to visible

wavelengths make SnO_2 suitable for several applications such as solar cells, gas sensors, catalysts, batteries, transistors, and transparent electrodes (Patel et al., 2021).

Several methods in the synthesis of SnO_2 materials, such as magnetron sputtering method (Ning et al., 2009), chemical coprecipitation method (Liu et al., 2012), function theory (Isherwood et al., 2015), hydrothermal method (Borhade et al., 2019) and sol-gel method (Kim et al., 2018). The sol-gel process is the conversion of monomers into colloidal solutions (sols) that serve as precursors for integrated networks (gels) of either discrete particles or network polymers (Ansari et al., 2018). The sol-gel method has advantages, namely good product homogeneity, easy to control the composition, uses relatively low temperatures, large coating areas, low equipment costs, has good optical properties (Ilican et al., 2008), simple, and low energy and material consumption levels (Saini et al., 2007).

Arini, et al, have conducted research on SnO_2 synthesis without using additives to produce SnO_2 morphology that looks smooth with a particle size of 71.5 nm (Arini et al., 2021). Research by Aziz, et al, using polyethylene glycol additives in the synthesis of SnO_2 produced a smoother morphology with a smaller particle size of about 22-31 nm (Aziz et al., 2012). The use of additives can affect the morphology of SnO_2 material so that the optimum material is obtained. Additives can produce a homogeneous material (Ningsih, 2016), stabilizers (Suchanek et al., 2018), and can increase thermal stability and oxidation resistance in semiconductors (Widodo, 2020). The synthesis of oxide compound nanoparticles requires the use of additives as capping agents to improve the properties and semiconductor applications of these nanoparticles (Fathia, 2018). One of the additives that can be used as a capping agent is Diethanolamine (DEA).

Diethanolamine (DEA) is an organic compound with the formula $C_4H_{11}NO_2$. DEA can act as both base and acid (amphoteric). In semiconductor synthesis, the use of DEA has advantages such as increasing electrical conductivity, resistance to oxidation and optical properties in semiconductors (Rahayu et al, 2020) so that the use of DEA as an additive is needed in the synthesis of SnO_2 using the sol-gel method to produce materials with high homogeneity (Kasuma et al., 2020).

METHODS

The tools used were beakers, measuring cups, vaporizer cups, watch glass, measuring pipettes, desiccators, mortar and pestle, magnetic stirrer, stirrer bar, furnace, and UV-Diffuse Reflectance (UV-DRS) spectrophotometer (Thermoscientific Genesys 30).

$SnCl_2.2H_2O$ was dissolved with 50 ml of methanol solvent with varying concentrations of 0.8 mmol, 1 mmol and 1.2 mmol, covered with plastic wrap, and homogenized with a magnetic stirrer for 40 minutes. Added 1.5 ml, 2 ml, and 2.5 ml of DEA to each solution, stirring for ± 1 hour. Then sonication was carried out on the solution for 30 minutes at 45 W so that a homogeneous solution (sol) was obtained and allowed to stand for 1 x 24 hours to stabilize the sol. Next, the sample was dried in an oven at 110°C for ± 1 hour. The gel obtained was calcined with a furnace at a temperature of 350 ° C for ± 3 hours to obtain SnO_2. The sample is stored in a desiccator, after cooling the sample is crushed using a mortar and pestle so that the sample can be characterized (Kasuma et al., 2020). UV-DRS functions to determine optical properties (Mugundan et al., 2015) at wavelengths of 200-800 nm (Borhade et al., 2019). The band gap energy and wavelength can be identified from the UV-DRS spectrum (Mugundan et al., 2015).

RESULTS AND DISCUSSION

1. Effect of Precursor Concentration Variation

UV-DRS spectrophotometer is used to determine the band gap value resulting from the synthesis of SnO_2. In this study, UV-DRS Spectrophotometer measurements were taken at a wavelength of 185-1100 nm. In the synthesis of SnO_2, several variations in the concentration of $SnCl_2.2H_2O$ precursors were carried out to determine the optimum band gap value of SnO_2 that had been synthesized. In this study using variations in precursor concentrations of 0.8 mmol, 1 mmol, and 1.2 mmol. The band gap value on SnO_2 is calculated using the Kubelka-munk equation (Sanjaya et al., 2018). The following are the results of band gap measurements with variations in precursor concentration can be seen in table 1.

Table 1. Band gap Energy with Effect of Precursor Concentration

Precursor Concentration	Band gap Value (Eg)
0.8 mmol Without DEA	6.29 eV
0.8 mmol + 1.5 mL DEA	3.70 eV
1 mmol + 1.5 mL DEA	3.60 eV
1.2 mmol + 1.5 mL DEA	4.17 eV

Based on table 1, it can be seen that the band gap value at a concentration of 0.8 mmol without the addition of DEA additives has a band gap value of 6.29 eV which indicates that SnO_2 nanomaterials are insulators. This is in accordance with the reference which states that the insulator has a large band gap value of > 4 eV (Costa et al., 2016). SnO_2 nanomaterial with a concentration of 0.8 mmol with the addition of 1.5 mL DEA obtained a band gap value of 3.70 eV. This shows that the addition of DEA additives can reduce the band gap value of SnO_2 nanomaterials. At a concentration of 1 mmol there is a decrease in band gap value of 3.60 eV then an increase in band gap value at a concentration of 1.2 mmol of 4.17 eV.

The difference in band gap value is due to a decrease in crystallite size resulting in an increase in band gap value towards the conductor (Rahmawati & Nazriati, 2022). According to Ningsih, et al, in 2021 stated that the bandgap value increases between the valence band and the conduction band with a decrease in particle size so that the reaction occurs faster in the visible light region (Ningsih et al., 2021). According to Ningsih et al, the decrease in band gap value is caused by the interaction between the electron band and the delocalization of electrons in transition ions so that metal ion substitution is formed (Ningsih et al., 2021). In addition, the reduced band gap value causes the distance between the valence band and the conduction band to get closer and electron excitation becomes faster so that less photon energy is needed for electron excitation from the valence band to the conduction band (Ningsih et al., 2019). This shows that the greater the band gap value to the insulator, the greater the photon energy required for electron excitation from the valence band to the conduction band. Based on table 1, the optimum band gap value has been obtained at a concentration of 1 mmol with a value of 3.60 eV because the band gap value obtained is smaller than other concentrations. This shows the distance between the valence band and the conduction band is closer and the particle size is smaller with a larger surface area and higher reactivity. The band gap value of SnO_2 with a precursor

concentration of 1 mmol is in accordance with the reference which states that the band gap value of SnO_2 nanoparticles is 3.60 eV (Al-saadi et al., 2019).

2. Effect of Addition of Diethanolamine (DEA) Additive

In the synthesis of SnO_2, variations in the addition of diethanolamine (DEA) additives were carried out to obtain the optimum band gap value in SnO_2 synthesis. In this study, variations in the volume addition of DEA additives were carried out with variations of 1.5 mL, 2 mL, and 2.5 mL. UV-DRS Spectrophotometer measurements were taken at a wavelength of 185-1100 nm. The following are the results of band gap measurements using a UV-DRS Spectrophotometer on variations in the volume of DEA additives in table 2.

Table 2. Band gap Energy with Effect of DEA

Volume of DEA (mL)	Band gap Value (Eg)
1.5	3.60 eV
2	3.62 eV
2.5	3.79 eV

Table 2 shows that the band gap value with variation of DEA additive volume has been obtained with values ranging from 3.60 eV - 3.79 eV. The smallest band gap value is at the addition of 1.5 mL DEA volume with a band gap value of 3.60 eV while the largest value is at the addition of 2.5 ml DEA volume with a band gap value of 3.79 eV. This shows that the band gap value is directly proportional to the addition of DEA volume in SnO_2 synthesis. The greater the addition of DEA volume, the greater the band gap value obtained in SnO_2 synthesis. The increasing band gap value is due to the non-uniform microstrain resulting from the relaxation of the grain surface and unsaturated bonds on the surface of the nanoparticles which can change the energy level thus affecting the band gap value (Wang et al., 2017). The optimum band gap value is obtained at the addition of 1.5 mL DEA volume because it has the smallest band gap value of 3.60 eV which is in accordance with the reference which states that SnO_2 has a band gap of 3.60 eV (Al-saadi et al., 2019). This small bandgap value has a small particle size and large surface area so that its reactivity increases in visible light (Ningsih et al., 2021).

CONCLUSION

The effect of the addition of DEA additives on the synthesis of SnO_2 is the more the addition of DEA volume, the higher the band gap value of SnO2 nanomaterials. The effect of $SnCl_2.2H_2O$ precursor concentration on SnO_2 synthesis is at a concentration of 0.8 mmol to 1 mmol there is a decrease in band gap value and then an increase in band gap value at a concentration of 1.2 mmol. The difference in band gap value occurs due to differences in particle size which can affect the band gap value of SnO_2.

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