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Structural characterization of SnS thin films prepared by vacuum evaporation technique

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ABSTRAK

Tin Sulfide (SnS) thin films were fabricated using vacuum evaporation techniques under a pressure of approximately 2×10^{-5} mbar. Cleaned microscope glass substrates were utilized, with a substrate temperature maintained at 300 K. The deposition of the SnS thin films was conducted by placing spacers between the substrate and the source at distances of 10 cm, 15 cm, and 25 cm. The study of SnS thin films included X-ray diffraction (XRD), scanning electron microscope (SEM), and energy dispersive analysis X-ray (EDX). The XRD patterns of the SnS thin films revealed good crystallization and confirmed the presence of an orthorhombic crystal structure with lattice parameters for sample 1 (10 cm spacer): a = 4.308 Å, b = 11.142 Å, c = 4.132 Å; sample 2 (15 cm spacer): a = 4.305 Å, b = 11.101 Å, c = 4.217 Å; and sample 3 (25 cm spacer): a = 4.081 Å, b = 11.135 Å, c = 4.292 Å. The preferred orientation was along the (0 4 0) planes for all films. Lattice parameters, grain size, and microstrain in the films were calculated from XRD patterns and correlated with the substrate spacer. Grain size distributions were derived from SEM micrographs, revealing a grain size of approximately 0.5 µm. EDX analysis indicated the chemical composition of the sample, with elements Sn = 37.86% and S = 13.58%.

Keywords: Tin Sulfide (SnS), thin film, Solar cell, Evaporation technique

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INTRODUCTION

In the present years, most of the energy sources used to supply the necessities of life use conservative energy sources. The energy source comes from fossil fuels such as crude oil and coal. Fossil fuels are non-renewable fuels because they were formed through the process of decaying animals and other living things that died thousands or even millions of years ago. Therefore, it is necessary to develop alternative energy sources that can meet human needs. These alternative sources are renewable energy sources such as solar power, hydropower, wind power and others (Baz et al., 2021).

Solar cells are a renewable alternative energy source by utilizing solar energy. Solar energy is an abundant source of energy and can be used effectively and efficiently. Tropical countries, especially Indonesia, have the potential to develop solar cell technology. Technology that can convert solar energy into electrical energy is called solar cells or photovoltaics. Solar cells are devices for converting solar energy into electrical energy. Electrical energy is obtained from solar cells that receive light directly from the sun and produce photovoltaic effects (Ikpesu et al., 2020).

SnS is considered a promising compound due to its low cost and an optimal band gap energy of approximately 1.5 eV, ideal for solar cell applications (Norton *et al.*, 2021). The characteristics of SnS thin films, including crystal structure, optical band gap, and electrical properties, are influenced by the preparation methods. Several deposition techniques for thin film growth have been explored, such as chemical bath deposition, electrodeposition, vacuum evaporation and chemical vapor deposition (CVD). Among these methods, vacuum evaporation has been used to grow SnS thin films due to its ability to produce high-quality films through a simple and cost-effective process (Aparna et al., 2023).

In this study, evaporation technique with semiconductor Tin Sulfide (SnS) material to prepared the thin film was used. This technique is carried out because it has several advantages, including being able to prepare using temperature or evaporation temperature in the form of stability of the structure of a fixed material, the preparation results evenly on the surface of the substrate and others. But the weakness of this method is that we must determine the right filament temperature in preparing the material to produce a quality thin film (Balakarthikeyan et al., 2021).

The materials were prepared using vacuum evaporation technique. Vacuum evaporation is a method of making thin films by evaporating material in a vacuum. In the evaporation system there is a heating source to evaporate the desired material. The heater is passed by a high enough current until a temperature is obtained where the vapor pressure is sufficient to force the vapor out of the source material. The evaporated source material then moves away from the heat source in the form of gas. Then the coating process occurs with a condensation process on each surface of the substrate that is overwritten by atoms. Next, SnS powder and substrate are prepared. Then the material in the form of SnS powder is placed in a cup. The SnS powder is then deposited using the evaporation technique. Evaporation is carried out at a pressure of 5×10-5 mBar and the substrate is heated at a temperature of 600°C (Jain et al., 2023). To find out information on the quality of the preparation, one can use several techniques, including the X-Ray difraction (XRD) technique to determine the crystal structure, to examine the surface morphological structure and chemical composition quantitatively, scanning electron microscope-energy dispersive analysis X-Ray (SEM)-(EDX) was used.

RESEARCH METHODS

SnS thin films were synthesized using a vacuum evaporation method on glass substrates, employing a low-pressure diffusion pump. Tin and sulfur, in a 2:1 molar ratio, were used as the starting materials (Kumar et al., 2023). These materials were heated to approximately 600°C in a molybdenum boat crucible. Glass substrates, measuring 1.5×2 cm^2, served as the base for the SnS thin films. A spacer was placed between the source and the substrate, with distances of 10, 15, and 25 cm. A rotary pump, capable of reaching pressures of 5×10^{-2} mBar, was used initially and then connected to a diffusion pump that reduced the evaporator chamber pressure to 5×10^{-5} mBar. An electrical power supply was connected to the crucible holding the materials, which was placed on a spacer connected to electrodes. These electrodes were linked to the power supply to control the substrate temperature. Ultimately, SnS from the crucible was deposited onto the glass substrates. The microstructural properties of the SnS thin films were analyzed using an XRD and their morphology was examined with an SEM-EDX.

RESULTS AND DISCUSSION

SnS Crystal Structure with XRD

The data generated from XRD characterization is in the form of a diffractogram, which is a graph of the relationship between the scattering angle (2θ) and the intensity (I) of the peak of the spectrum (crystal). After XRD analysis, the distance between (d_{hkl}) fields can be known.

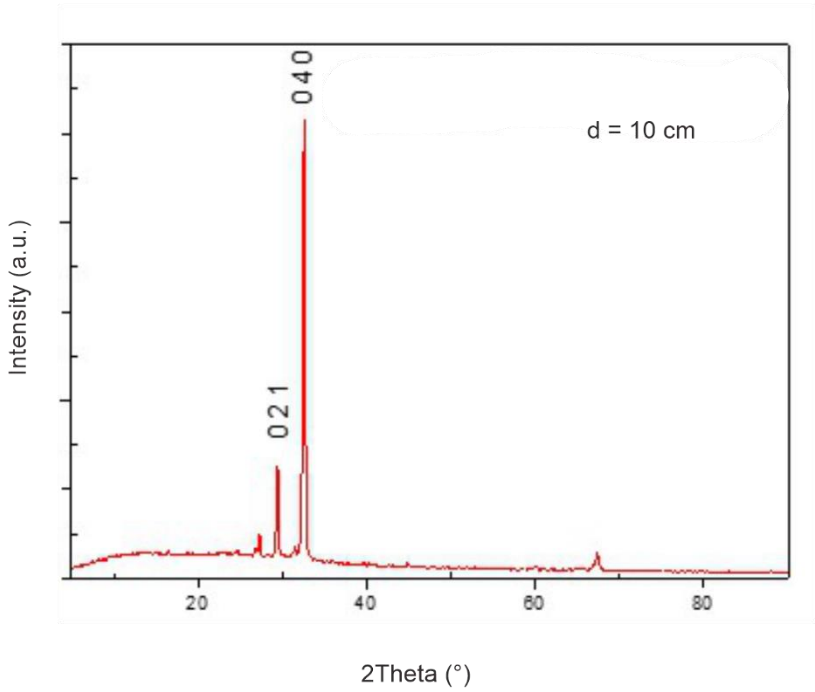


Figure 1. XRD pattern of sample 1 SnS thin layer with a buffer distance of 10 cm

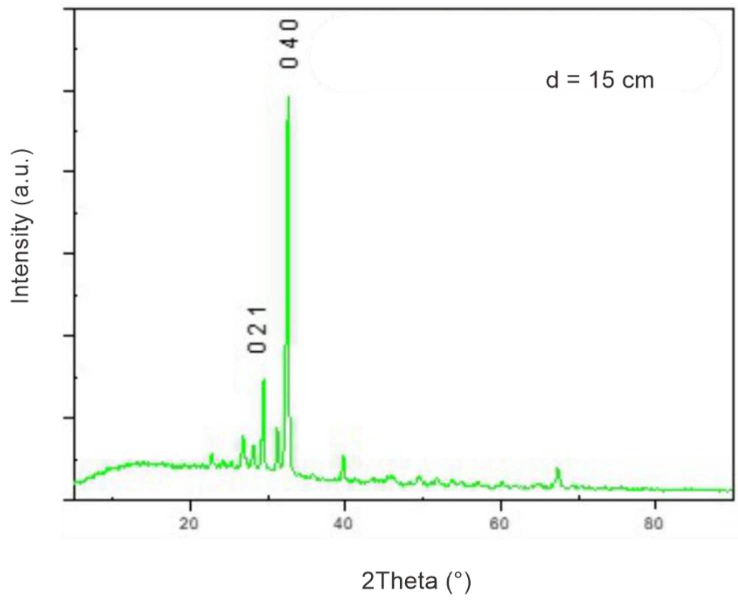


Figure 2. XRD pattern of sample 2 SnS thin layers with a buffer distance of 15 cm

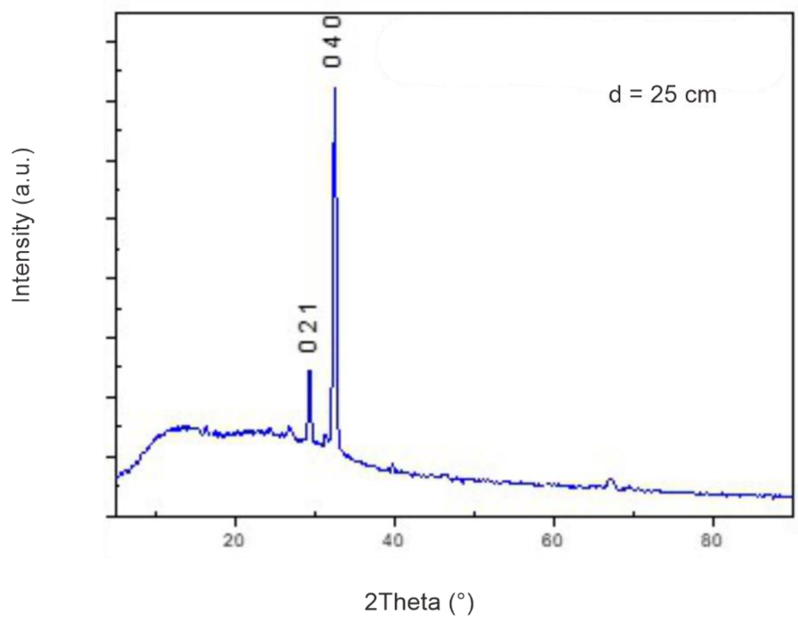


Figure 3. XRD pattern of sample 3 thin SnS layers with a buffer distance of 25 cm

Based on the analysis of XRD results, it can be seen that the thin layer of SnS formed from the results of preparation by evaporation technique at a buffer distance of 10 cm, 15 cm, and 25 cm is shown (atoms shown) in Figures 1, 2 and 3. By comparing the yield data XRD from SnS thin layer with JCPDS (Join Committee on Powder Diffraction Standard) from SnS, obtained polycrystalline orthorhombic structure with comparison of lattice parameters as shown in table 1 (Sánchez et al., 2024).

Table 1. Comparison of SnS crystal lattice parameters with JCPDS SnS data.

Sample	Lattice parameter			Crystall structure
	a	b	c	
Experiment	4,30 Å	11,09 Å	4,06 Å	orthorhombic
d = 10 cm	4,31 Å	11,08 Å	4,16 Å	orthorhombic
d = 15 cm	4,01 Å	11,08 Å	4,15 Å	orthorhombic
d = 25 cm	4,32 Å	11,19 Å	3,98 Å	orthorhombic
JCPDS SnS	4,30 Å	11,09 Å	4,06 Å	orthorhombic

From the results of the above analysis, the SnS thin film sample which will be further characterized by SEM and EDX is the first sample because it has the lattice parameter values that are closest to the JCPDS data (Noguchi *et al.*, 1994).

Surface morphology of SnS thin film by using SEM

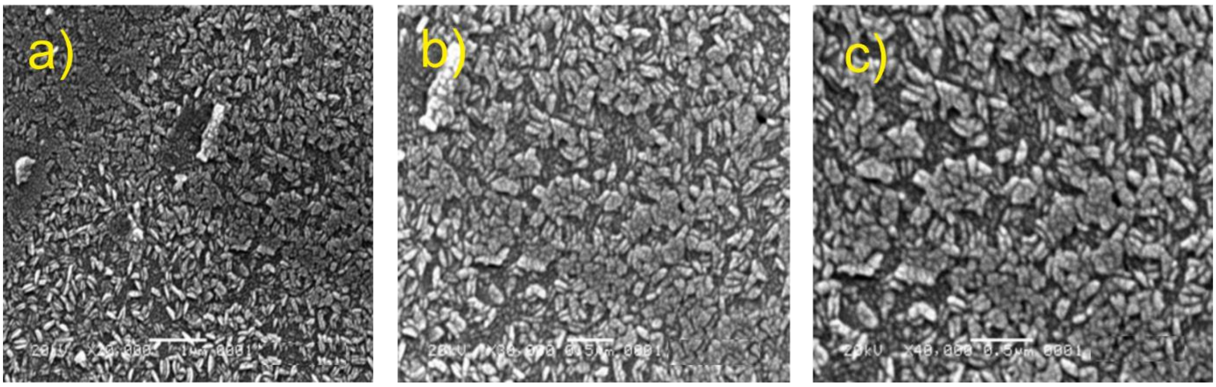
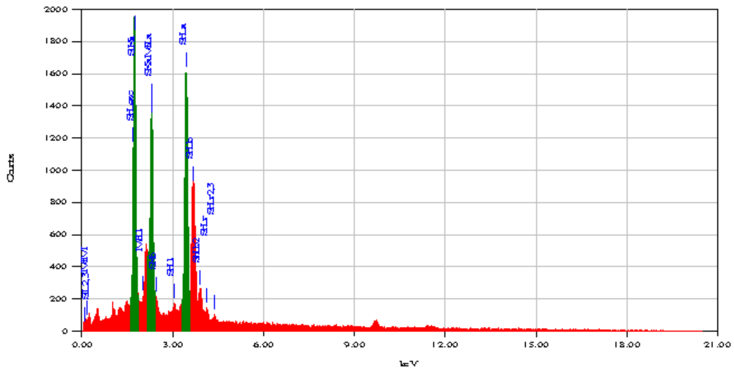


Figure 4. Photograph of the surface morphology of SnS material with magnification a) 20,000x, b) 30,000x, c) 40,000x

The SEM results, which are in the form of photographs of crystal surfaces are shown in Figure 4. Both pictures show that the SnS crystal has formed. The formation of these crystals is characterized by the appearance of scattered grains. As well as having a smooth texture of the surface morphology in the sample (grain) of crystals so that the magnification of the photo can be known the size of the granules formed on the SnS material that is 0.5 μm (Kafashan et al., 2024).

Chemical Composition of SnS thin films with EDX



Element	(keV)	mass%	Error%	At%	Compound	mass%	Cation	K
Si K	1.739	12.06	0.20	31.93			10.9963	
S K	2.307	5.94	0.36	13.78			7.3560	
Mo L	2.293	19.81	1.13	15.35			19.5477	
Sn L	3.442	62.18	0.80	38.95			62.1000	
Total		100.00		100.00				

Figure 5. Graph of the relationship between Energy and Intensity resulting from EDX characterization of SnS thin films prepared by evaporation techniques.

The EDX measurement results show the composition of each material shown in Figure 5. The characterization results showed that the SnS thin film sample contained the element Tin (Sn) with a percentage of 38.95% and the element Sulfide (S) with a percentage of 13.78% (Matyszczak et al., 2021).

CONCLUSION

From the results of the X-Ray Difraction (XRD) analysis, there is a shift in the angle causing a difference in the lattice parameter values obtained with the lattice parameter values in the JCPDS, namely: a = 4.32 Å, b = 11.19 Å and c = 3, 98 Å. However, the angular shift does not affect the SnS crystal structure that is formed. The sample that was further analyzed is the first sample because it has the lattice parameter value that is closest to the JCPDS data. In the analysis of the characterization of the scanning electron microscopy (SEM) the first sample showed that the surface morphology of the thin layer of Tin Sulfide (SnS) formed in the form of crystalline, with a fine texture and grains (grains) measuring 0.5 µm. In the energy dispersive analysis X-Ray (EDX) characterization analysis, the first sample obtained is a tin sulfide (SnS) thin layer sample having a chemical composition, namely the element Tin (Sn) = 38.95% and Sulfide (S): 13.78%.

REFERENCES

Aparna, N., Philip, R. S., & Mathew, M. (2023). Deposition of SnS thin films on various substrates at room temperature. *Applied Surface Science Advances*, 18, 100510. https://doi.org/10.1016/j.apsadv.2023.100510.

Balakarthikeyan, R., Santhanam, A., Khan, A., El-Toni, A. M., Ansari, A. A., Imran, A., Shkir, M., & AlFaify, S. (2021). Performance analysis of SnS thin films fabricated using thermal evaporation technique for photodetector applications. Optik, 244, 167460. https://doi.org/10.1016/j.ijleo.2021.167460.

Baz, K., Cheng, J., Xu, D., Abbas, K., Ali, K., Ali, H., & Fang, C. (2021). Asymmetric impact of fossil fuel and renewable energy consumption on economic growth: A nonlinear technique. Energy, 226, 120357. https://doi.org/10.1016/j.energy.2021.120357.

Ikpesu, J. E., Iyuke, S. E., Daramola, M., & Oyetunde, O. A. (2020). Synthesis of improved dye-sensitized solar cell for renewable energy power generation. Solar Energy, 206, 918-934. https://doi.org/10.1016/j.solener.2020.05.002.

Jain, D., Jain, G., Pal, A., Agarwal, S., & Kumar, S. (2023). Mixed phase formation of SnS-SnO2 on air-annealed thermally evaporated SnS thin films. Thin Solid Films, 780, 139973. https://doi.org/10.1016/j.tsf.2023.139973.

Kafashan, H., & Baboukani, A. R. (2024). Electrochemically deposited nanostructured Cd-doped SnS thin films: Structural and optical characterizations. Ceramics International, 50(3), 5717-5727. https://doi.org/10.1016/j.ceramint.2023.11.354.

Kumar, P., & Rao, G. K. (2023). Synthesis and characterization of sulfate precursor based SnS thin films using SILAR technique at elevated solution temperature. Materials Today Communications, 35, 106194. https://doi.org/10.1016/j.mtcomm.2023.106194.

Matyszczak, G., Jóźwik, P., Polesiak, E., Sobieska, M., Krawczyk, K., Jastrzębski, C., & Płociński, T. (2021). Sonochemical preparation of SnS and SnS2 nano and micropowders and their characterization. Ultrasonics Sonochemistry, 75, 105594. https://doi.org/10.1016/j.ultsonch.2021.105594.

Noguchi, H., Setiyadi, A., Tanamura, H., Nagatomo, T., & Omoto, O. (1994). Characterization of vacuum-evaporated tin sulfide film for solar cell materials. *Solar Energy Materials and Solar Cells*, 35, 325-331. https://doi.org/10.1016/0927-0248(94)90158-9.

Norton, K. J., Alam, F., & Lewis, D. J. (2021). A Review of the Synthesis, Properties, and Applications of Bulk and Two-Dimensional Tin (II) Sulfide (SnS). *Applied Sciences*, 11(5), 2062. https://doi.org/10.3390/app11052062.

Sánchez, F. D. B., Nair, M. T. S., & Nair, P. K. (2024). Insights to the production of SnS-cubic thin films by vacuum thermal evaporation for photovoltaics. Semiconductor Science and Technology, 39, 015003. https://doi.org/10.1088/1361-6641/ad0f4c.