

**PENGARUH WAKTU MILLING TERHADAP KARAKTERISTIK BAHAN
CZTS SEBAGAI LAPISAN ABSORBER PADA SEL SURYA**

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disusun untuk memenuhi salah satu syarat memperoleh Gelar Sarjana Sains
Program Studi Fisika Departemen Pendidikan Fisika kelompok bidang
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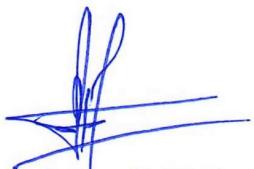


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ABSTRAK

CZTS merupakan bahan lokal yang mudah ditemukan, tidak beracun, dan biaya murah yang dapat dijadikan sebagai sel surya yang potensial untuk menggantikan sel surya berbahan silikon. Sintesis dengan berbagai metode seperti *sputtering*, penguapan termal, *pulsed laser deposition*, dan sebagainya telah dilakukan. Pada penelitian ini metode sintesis yang akan dilakukan yaitu dengan menggunakan ball milling. Variasi waktu penggilingan CZTS dilakukan pada penelitian ini yaitu 2 jam, 4 jam, dan 6 jam dengan tambahan sampel pembanding yaitu tanpa dilakukannya penggilingan. Film tipis CZTS dibuat dengan metode sol-gel dan diendapkan menggunakan *spin coating*. Setiap sampel telah dilakukan karakterisasi struktur kristal menggunakan *X-Ray Diffraction* (XRD), struktur mikro menggunakan *Scanning Electron Microscope* (SEM), sifat optik menggunakan *UV-Vis Spectrometry* dan sifat listrik menggunakan *I-V* meter. Hasil karakterisasi menunjukkan bahwa ukuran kristalit dari sampel berkisar 11.4-29.3 nm. Sampel 2 jam dan 6 jam memiliki ukuran kristalit yang hampir sama dan begitu pula untuk sampel tanpa penggilingan dan 4 jam memiliki ukuran kristalit yang hampir sama. Hasil karakterisasi SEM menunjukkan pada ketebalan sampel tidak ada perbedaan yang begitu signifikan. Nilai absorbansi maksimum berada pada kisaran panjang gelombang 300-374 nm dengan nilai *Light Harvesting Efficiency* LHE berkisar 93-99%. Nilai energi bandgap berkisar 1.2-1.6 eV. Nilai efisiensi semakin meningkat ketika waktu penggilingan semakin lama yaitu 7.17%. Hasil yang didapatkan ini menunjukkan bahwa metode sintesis ini dapat dijadikan salah satu alternatif metode untuk mensistesis bahan CZTS lokal sebagai lapisan absorber pada sel surya.

Kata Kunci: Solar Sel, Sintesis, CZTS, Ball mill, Absorbansi.

**THE EFFECT OF MILLING TIME ON THE CHARACTERISTIC OF CZTS
MATERIALS AS ABSORBER LAYERS IN SOLAR CELLS**

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ABSTRACT

CZTS is a local material that is easy to find, non-toxic, and low-cost which can be used as a potential solar cell to replace silicon-based solar cells. Synthesis by various methods such as sputtering, thermal evaporation, pulsed laser deposition, and so on has been carried out. In this research, the synthesis method that will be carried out is by using ball milling. CZTS milling time variations were carried out in this study, namely 2 hours, 4 hours, and 6 hours with the addition of a comparison sample, namely without milling. The CZTS thin films were prepared by the sol-gel method and deposited using a spin coating. Each sample has been characterized by crystal structure using X-Ray Diffraction (XRD), microstructure using Scanning Electron Microscope (SEM), optical properties using UV-Vis Spectrometry, and electrical properties using I-V meter. The characterization results showed that the crystallite size of the sample ranged from 11.4 to 29.3 nm. The 2-hour and 6-hour samples had almost the same crystallite size and similarly the unmilled and 4-hour samples had almost the same crystallite size. The results of SEM characterization show that there is no significant difference in the thickness of the sample. The maximum absorbance value is in the wavelength range of 300-374 nm with the value of Light Harvesting Efficiency LHE ranging from 93-99%. Bandgap energy values range from 1.2-1.6 eV. The efficiency value increases when the milling time is getting longer, namely 7.17%. The results obtained indicate that this synthesis method can be used as an alternative method for synthesizing local CZTS material as an absorber layer in solar cells.

Keywords: Solar Cells, Synthesis, CZTS, Ball mill, Absorbance.

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DAFTAR PUSTAKA

- Abdullah, M. (2009). *PENGANTAR NANOSAINS* (1st ed.). Penerbit ITB.
- Agawane, G. L., Vanalakar, S. A., Kamble, A. S., Moholkar, A. V., & Kim, J. H. (2018). Fabrication of Cu₂(Zn_xMg_{1-x})SnS₄ thin films by pulsed laser deposition technique for solar cell applications. *Materials Science in Semiconductor Processing*, 76(May 2017), 50–54. <https://doi.org/10.1016/j.mssp.2017.12.010>
- Ahmoum, H., Chelvanathan, P., Su'ait, M. S., Boughrara, M., Li, G., Al-Waeli, A. H. A., Sopian, K., Kerouad, M., & Amin, N. (2020). Impact of preheating environment on microstructural and optoelectronic properties of Cu₂ZnSnS₄ (CZTS) thin films deposited by spin-coating. *Superlattices and Microstructures*, 140(January). <https://doi.org/10.1016/j.spmi.2020.106452>
- Atowar Rahman, M. (2021). Enhancing the photovoltaic performance of Cd-free Cu₂ZnSnS₄ heterojunction solar cells using SnS HTL and TiO₂ ETL. *Solar Energy*, 215(January), 64–76. <https://doi.org/10.1016/j.solener.2020.12.020>
- Awallyyah, A., Ikhwan, H., Nugiasari, V., Zainul, R., Padang, U. N., Padang, U. N., Kimia, L., Padang, U. N., Fisika, L., Padang, U. N., & Milling, F. (2018). Prinsip Dasar Milling. *Laboratorium Kimia, FMIPA, Universitas Negeri Padang, Indonesia*, 21.
- Azanza Ricardo, C. L., Su'Ait, M. S., Müller, M., & Scardi, P. (2013). Production of Cu₂(Zn,Fe)SnS₄ powders for thin film solar cell by high energy ball milling. *Journal of Power Sources*, 230, 70–75. <https://doi.org/10.1016/j.jpowsour.2012.12.045>
- Das, S., & Mandal, K. C. (2015). *Performance Limiting Factors of Cu₂ZnSn (S_xSe_{1-x})₄ Solar Cells Prepared by Thermal Evaporation*.
- Ennaoui, A., Lux-Steiner, M., Weber, A., Abou-Ras, D., Kötschau, I., Schock, H. W., Schurr, R., Hölzinger, A., Jost, S., Hock, R., Voß, T., Schulze, J., & Kirbs, A. (2009). Cu₂ZnSnS₄ thin film solar cells from electroplated precursors: Novel low-cost perspective. *Thin Solid Films*, 517(7), 2511–2514. <https://doi.org/10.1016/j.tsf.2008.11.061>
- Fraas, L. M. (2014). Low-cost solar electric power. *Low-Cost Solar Electric Power*,

- 9783319075, 1–181. <https://doi.org/10.1007/978-3-319-07530-3>
- Gu, Y., Yin, X., Han, J., Zhou, Y., Tai, M., Zhang, Q., Zhou, Y., Li, J., & Lin, H. (2019). All-Layer Sputtering-Free Cu₂Zn_{1-x}Cd_xSnS₄ Solar Cell with Efficiency Exceeding 7.5%. *ChemistrySelect*, 4(19), 5979–5983. <https://doi.org/10.1002/slct.201900520>
- Katagiri, H., Jimbo, K., Maw, W. S., Oishi, K., Yamazaki, M., Araki, H., & Takeuchi, A. (2009). Development of CZTS-based thin film solar cells. *Thin Solid Films*, 517(7), 2455–2460. <https://doi.org/10.1016/j.tsf.2008.11.002>
- Katagiri, H., Saitoh, K., Washio, T., Shinohara, H., Kurumadani, T., & Miyajima, S. (2001). Development of thin " lm solar cell based on Cu ZnSnS thin " lms. 65, 141–148.
- Li, Q., Hao, Y., Cui, Y., Wang, J., Du, J., Wang, M., Hu, J., Shen, T., Duan, L., Wang, S., Sun, K., & Gao, S. (2021). Effect of Sulfurization Temperature on the Preparation of Cu₂ZnSnS₄ Thin Films for Solar Cells via a Nanoink Coating Method. *International Journal of Electrochemical Science*, 16, 1–12. <https://doi.org/10.20964/2021.05.14>
- Nguyen, D. C., Ito, S., & Dung, D. V. A. (2015). Effects of annealing conditions on crystallization of the CZTS absorber and photovoltaic properties of Cu(Zn,Sn)(S,Se)2 solar cells. *Journal of Alloys and Compounds*, 632, 676–680. <https://doi.org/10.1016/j.jallcom.2015.01.258>
- Pawar, S. M., Pawar, B. S., Moholkar, A. V., Choi, D. S., Yun, J. H., Moon, J. H., Kolekar, S. S., & Kim, J. H. (2010). Electrochimica Acta Single step electrosynthesis of Cu₂ZnSnS₄ (CZTS) thin films for solar cell application. *Electrochimica Acta*, 55(12), 4057–4061. <https://doi.org/10.1016/j.electacta.2010.02.051>
- Prima, E. C., Nuruddin, A., Yuliarto, B., Kawamura, G., & Matsuda, A. (2018). Combined spectroscopic and TDDFT study of single-double anthocyanins for application in dye-sensitized solar cells. *New Journal of Chemistry*, 42(14), 11616–11628. <https://doi.org/10.1039/c8nj01202d>
- Prima, Eka Cahya, Wong, L. H., Ibrahim, A., Nugraha, & Yuliarto, B. (2021). Solution-processed pure Cu₂ZnSnS₄/CdS thin film solar cell with 7.5% efficiency. *Optical Materials*, 114(March), 110947.

<https://doi.org/10.1016/j.optmat.2021.110947>

Ravindiran, M., & Praveenkumar, C. (2018). Status review and the future prospects of CZTS based solar cell – A novel approach on the device structure and material modeling for CZTS based photovoltaic device. *Renewable and Sustainable Energy Reviews*, 94(December 2017), 317–329.
<https://doi.org/10.1016/j.rser.2018.06.008>

Sawant, J. P., & Kale, R. B. (2020a). CZTS counter electrode in dye-sensitized solar cell: enhancement in photo conversion efficiency with morphology of TiO₂ nanostructured thin films. *Journal of Solid State Electrochemistry*, 24(2), 461–472. <https://doi.org/10.1007/s10008-019-04452-w>

Sawant, J. P., & Kale, R. B. (2020b). Surfactant mediated TiO₂ photoanodes and Cu₂ZnSnS₄ counter electrodes for high efficient dye sensitized solar cells. *Materials Letters*, 265, 127407. <https://doi.org/10.1016/j.matlet.2020.127407>

Setyo, H., Refantero, G., Luh, N., Septiani, W., Iqbal, M., Marno, S., Abdullah, H., Cahya, E., & Yuliarto, B. (2022). Journal of Industrial and Engineering Chemistry A progress review on the modification of CZTS (e) -based thin-film solar cells. *Journal of Industrial and Engineering Chemistry*, 105, 83–110. <https://doi.org/10.1016/j.jiec.2021.09.010>

Tanaka, K., Fukui, Y., Moritake, N., & Uchiki, H. (2011). Chemical composition dependence of morphological and optical properties of Cu₂ZnSnS₄ thin films deposited by sol-gel sulfurization and Cu₂ZnSnS₄ thin film solar cell efficiency. *Solar Energy Materials and Solar Cells*, 95(3), 838–842. <https://doi.org/10.1016/j.solmat.2010.10.031>

Todorov, T. K., Reuter, K. B., & Mitzi, D. B. (2010). High-efficiency solar cell with earth-abundant liquid-processed absorber. *Advanced Materials*, 22(20), 156–159. <https://doi.org/10.1002/adma.200904155>

Trisnayanti, N. P. (2020). Metode sintesis nanopartikel. *Universitas Indonesia*, 3, 1–4.

Wang, Y., Li, C., Yin, X., Wang, H., & Gong, H. (2013). Cu 2 ZnSnS 4 (CZTS) Application in TiO 2 Solar Cell as Dye . *ECS Journal of Solid State Science and Technology*, 2(7), Q95–Q98. <https://doi.org/10.1149/2.005307jss>

Washio, T., Shinji, T., Tajima, S., Fukano, T., Motohiro, T., Jimbo, K., & Katagiri,

- H. (2012). 6% Efficiency Cu₂ZnSnS₄-based thin film solar cells using oxide precursors by open atmosphere type CVD. *Journal of Materials Chemistry*, 22(9), 4021–4024. <https://doi.org/10.1039/c2jm16454j>
- Winkler, M. T., Wang, W., Gunawan, O., Hovel, H. J., Todorov, T. K., & Mitzi, D. B. (2014). Optical designs that improve the efficiency of Cu₂ZnSn(S,Se)₄ solar cells. *Energy and Environmental Science*, 7(3), 1029–1036. <https://doi.org/10.1039/c3ee42541j>
- Woo, K., Kim, Y., Yang, W., Kim, K., Kim, I., Oh, Y., Kim, J. Y., & Moon, J. (2013). Band-gap-graded Cu₂ZnSn(S_{1-x},Se_x)₄ solar cells fabricated by an ethanol-based, particulate precursor ink route. *Scientific Reports*, 3, 1–7. <https://doi.org/10.1038/srep03069>