

TIME-DEPENDENT PROPERTIES OF ZnIn₂S₄ THIN FILMS DEPOSITED FROM POWDER

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Zinc indium sulfide (ZnIn₂S₄) is a promising ternary chalcogenide semiconductor for optoelectronic and energy applications due to its tunable bandgap and favorable charge carrier dynamics. Its performance in photocatalysis, photodetectors, and solar conversion is highly dependent on film stoichiometry, crystal structure, and surface morphology. This work investigates the influence of deposition duration and multi-stage temperature ramping on the quality of ZnIn₂S₄ thin films deposited via thermal evaporation from a powder source.

The films were deposited onto substrates using a precision-controlled temperature ramp to optimize nucleation and growth kinetics. To address initial elemental imbalances, as-deposited films underwent thermal annealing in a sulfur-rich atmosphere. This post-deposition treatment was critical for refining the grain structure and ensuring the structural integrity of the ternary phase.

Initial as-deposited films exhibited an amorphous structure and significant sulfur deficiency. While the thermal evaporation process yielded uniform, continuous films with complete coverage, post-deposition sulfurization was necessary to eliminate vacancies and achieve a near-ideal 1:2:4 stoichiometry. Experimental results indicate that increasing evaporation duration and employing a multi-step thermal profile positively correlate with stoichiometric ratio. Films deposited over extended durations reached a near-ideal ratio of 1:2:3.97. In contrast, rapid "shock" deposition resulted in highly non-stoichiometric films (e.g., 1:1.49:3.15 and 1:2.16:4.2). This improvement is attributed to the exhaustive evaporation of the source material and the mitigation of thermal shock, ensuring a stable deposition pathway.

Structural analysis via X-ray diffraction (XRD) and Raman spectroscopy confirmed the formation of the crystalline ZnIn₂S₄ phase after annealing. Scanning Electron Microscopy (SEM) revealed well-defined growth patterns in the optimized films. Optical characterization demonstrated high transparency, with transmittance reaching 92% in the visible spectrum. These results showed that obtained ZnIn₂S₄ thin films are promising candidates for high-performance, transparent optoelectronic applications.

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- [1] J. Wang et al., "A review: Synthesis, modification and photocatalytic applications of ZnIn₂S₄," *Journal of Material Science and Technology*, vol. 78, pp. 1–19, Nov. 2020, doi: 10.1016/j.jmst.2020.09.045.
- [2] Z. Jing, Q. Wang, C.-M. Fan, X.-F. Yang, P.-Y. Tang, and B. Li, "ZnIn₂S₄-based heterostructure photocatalysts for solar energy conversion: a comprehensive review," *Journal of Materials Chemistry A*, vol. 13, no. 24, pp. 18253–18282, Jan. 2025, doi: 10.1039/d5ta02501j.
- [3] A. Khan, M. Danish, U. Alam, S. Zafar, and M. Muneer, "Facile Synthesis of a Z-Scheme ZnIn₂S₄/MoO₃ Heterojunction with Enhanced Photocatalytic Activity under Visible Light Irradiation," *ACS Omega*, vol. 5, no. 14, pp. 8188–8199, Apr. 2020, doi: 10.1021/acsomega.0c00446.