

Interface Engineering and Absorber Quality Control in Tin Sulfide-Based Hybrid Photovoltaic Devices

Abdessamad El Kanouny^{1,2,3,*}, Viorica Stancu¹, Ahmed El Manouni², Sara Laafar¹, Andrei Gabriel Tomulescu¹, Lucia Nicoleta Leonat¹, Abdelmajid Almaggoussi^{3,4}, Cristina Besleaga¹, Aurelian Catalin Galca^{1,5}

¹Laboratory of Complex Heterostructures and Multifunctional Materials (HeCoMat), National Institute of Materials Physics, Atomistilor 405A, 077125 Magurele, Romania

²Laboratoire de Mathématiques et Sciences Physiques Appliquées aux Sciences de l'Ingénieur (MSPASI), Faculté des Sciences et Techniques, Université Hassan II, 28806 Mohammedia, Morocco

³IMED-Lab, Faculté des Sciences et Techniques, Université Cadi Ayyad, Av. Abdelkarim Khattabi, 40000 Marrakech, Morocco

⁴Applied Chemistry & Engineering Research Centre of Excellence (ACER CoE), Mohammed VI Polytechnic University (UM6P), Lot 660 – Hay Moulay Rachid, 43150 Benguerir, Morocco

⁵International Centre for Advanced Training and Research in Physics, Atomistilor 409, 077125 Magurele, Ilfov, Romania

***Email:** abdessamadelkanouny@infim.ro

Abstract: The development of photovoltaic technologies based on earth-abundant and environmentally benign materials is essential for enabling sustainable and large-scale solar energy deployment. Chalcogenide absorbers such as tin monosulfide (SnS) have attracted significant attention due to their suitable band gap, high absorption coefficient, and compatibility with low-cost thin-film processing routes. Nevertheless, the performance of these emerging photovoltaic devices is often limited by challenges related to thin-film crystallization control, unfavorable morphology, interfacial recombination, and inefficient charge transport [1,2].

In this work, hybrid photovoltaic devices incorporating solution-processed absorber layers are investigated with particular emphasis on the role of the electron transport layer (ETL) and absorber–ETL interface engineering. The optimization of ETL properties is shown to strongly influence absorber growth behaviour, crystallographic orientation, surface morphology, optical absorption, and interface quality. These improvements lead to enhanced charge extraction and reduced recombination losses, resulting in significant device performance enhancement.

Through optimized heterojunction design and thin-film growth control, power conversion efficiencies exceeding 3% under standard solar illumination conditions are achieved. Comprehensive structural, morphological, optical, and interfacial analyses provide insight into the relationship between material properties and device operation. This study highlights the critical importance of interface engineering and absorber quality for advancing scalable photovoltaic technologies based on emerging earth-abundant materials.

Keywords: Molecular ink; Interface engineering; Thin-film solar cells; Earth-abundant photovoltaics

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