



REVIEWER'S REPORT

Manuscript No.: IJAR-56665

Title: Optimization of Electron Affinity in In₂S₃ Buffer Layers for CIGS Solar Cells: A SILVACO ATLAS Simulation Study

Recommendation:

Accept

Rating	Excel.	Good	Fair	Poor
Originality	Yes			
Techn. Quality		Yes		
Clarity		Yes		
Significance		Yes		

Reviewer Name: Dr. Ashish Yadav

Detailed Reviewer's Report

Reviewer's Comment for Publication.

Acceptance Comment are mentioned below suitable for the paper titled "Optimization of Electron Affinity in In₂S₃ Buffer Layers for CIGS Solar Cells: A SILVACO ATLAS Simulation Study"

Reviewer Comments: Accept

Reviewer Comments –

1. Introduction

The manuscript addresses an important issue in the advancement of thin-film photovoltaic technologies within the field of Photovoltaics by investigating the optimization of electron affinity in indium sulfide (In₂S₃) buffer layers for Copper Indium Gallium Selenide solar cells. The introduction effectively explains the need to replace the conventional toxic CdS buffer layer with environmentally friendly alternatives while maintaining high device performance. The authors highlight the advantageous properties of In₂S₃, including its wide bandgap, high optical transparency, and tunable electron affinity that allows control of heterojunction band alignment. The motivation for using numerical simulation to analyze the effect of electron affinity on photovoltaic parameters is clearly presented, establishing a solid foundation for the research problem and its significance in developing Cd-free high-efficiency solar cells.

2. Literature Review

The literature review provides an overview of previous research related to buffer layers in CIGS solar cells and the importance of band alignment at the heterojunction interface. Earlier studies investigating CdS alternatives and the role of conduction band offset in determining device performance are appropriately referenced. The authors discuss the advantages of In₂S₃ as a non-toxic and efficient buffer layer material and explain how its electronic properties can influence carrier transport and recombination at the interface. While the review establishes the scientific context of the study, it would benefit from a slightly broader discussion of recent simulation and experimental works on Cd-free buffer layers.

REVIEWER'S REPORT

Nevertheless, the section adequately justifies the need for a systematic optimization of electron affinity to achieve improved photovoltaic efficiency.

3. Solution Approach / Methodology

The authors employ numerical simulation using the SILVACO ATLAS device simulator to analyze the effect of electron affinity on the performance of CIGS solar cells with an In_2S_3 buffer layer. The modeling framework involves solving Poisson's equation together with the carrier continuity and drift-diffusion transport equations under standard AM1.5G illumination conditions. By varying the electron affinity of the In_2S_3 buffer layer within the range of 4.0–4.8 eV, the study examines its influence on key photovoltaic parameters such as short-circuit current density, open-circuit voltage, fill factor, and conversion efficiency, along with parasitic resistances. This simulation-based approach is appropriate for evaluating heterojunction band alignment and understanding the relationship between conduction band offset and interfacial recombination mechanisms in thin-film solar cells.

4. Results and Discussion

The results clearly demonstrate the strong influence of electron affinity on band alignment and overall device performance. The optimal configuration occurs at an electron affinity of 4.0 eV, corresponding to a conduction band offset that forms a moderate spike at the heterojunction interface. This band alignment effectively suppresses interfacial recombination while maintaining efficient carrier transport, resulting in a high conversion efficiency of 22.96% and an open-circuit voltage close to 0.99 V. The study also shows that increasing electron affinity can significantly reduce series resistance and improve the fill factor; however, this change simultaneously leads to a considerable reduction in open-circuit voltage, which ultimately decreases overall efficiency. These findings highlight the delicate balance required in tuning the electronic properties of the buffer layer and emphasize that precise control of band alignment is critical for maximizing CIGS solar cell performance.

5. Conclusion

The manuscript successfully demonstrates that optimizing the electron affinity of the In_2S_3 buffer layer plays a crucial role in determining the efficiency of CIGS solar cells. The simulation results confirm that a narrow electron affinity window provides optimal band alignment, minimizing interfacial recombination while preserving efficient charge transport. The study also highlights that the open-circuit voltage is the dominant factor governing overall device efficiency. By identifying the optimal electron affinity and corresponding conduction band offset conditions, the research contributes valuable insights for the design of high-performance Cd-free CIGS solar cells and supports the development of environmentally sustainable photovoltaic technologies.