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Design considerations of CdSe solar cells for indoor applications under white LED illumination

Marwa S. Salem [a,b], Ahmed Shaker [c,*], Mohamed Okil [d], Luying Li [e], Chao Chen [e], Arwa N. Aledaily [f], Kawther A. Al-Dhlan [f], Abdelhalim Zekry [g]

[a] Department of Computer Engineering, College of Computer Science and Engineering, University of Ha'il, Ha'il, Saudi Arabia
[b] Department of Electrical Communication and Electronics Systems Engineering, Faculty of Engineering, Modern Science and Arts University (MSA), Cairo, Egypt
[c] Department of Engineering Physics and Mathematics, Faculty of Engineering, Ain Shams University, Cairo, Egypt
[d] Department of Basic Engineering Sciences, Benha Faculty of Engineering, Benha University, Benha, Egypt
[e] Wuhan National Laboratory for Optoelectronics (WNLO) and School of Optical and Electronic Information, Huazhong University of Science and Technology (HUST), Wuhan, China
[f] Department of Computer Science and Information, College of Computer Science and Engineering, University of Ha'il, Ha'il, Saudi Arabia
[g] Electronics and Electrical Communication Department, Ain-Shams University, Cairo, 11535, Egypt

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A B S T R A C T

This work sheds light on the potential of Cadmium Selenide (CdSe) solar cells for indoor applications. CdSe boasts a wide direct bandgap, high carrier mobility, and a high absorption coefficient, making it an attractive candidate for harnessing ambient indoor light. Our study centers around an experimental solar cell architecture composed of FTO/CdSe/PEDOT:PSS/CuI/ITO, which exhibits a power conversion efficiency (PCE) of 6.00 %. Through a meticulous analysis of the core technological aspects of this cell, we successfully replicate the measured current-voltage characteristics and other experimental data, affirming the validity of our simulation modeling approach. Moving forward, we delve into the design and optimization of CdSe-based solar cells under white LED illumination. We emphasize the pivotal role of a double-hole transport layer (HTL) configuration over a single HTL, with a focus on optimizing the alignment between the HTL/back contact and HTL/absorber interfaces. The strategic incorporation of a heavily doped p-type HTL material, boasting both a deep valence band maximum (VBM) and a shallow conduction band minimum (CBM), is identified as paramount, especially for a deep VBM absorber like CdSe. Adding double HTL materials also facilitates efficient hole collection within the CdSe thin film while mitigating undesirable electron-hole recombination at the critical interface between the hole collection layer and the electrode. The implementation of a double HTL configuration based on CuI/ZnTe:Cu or CuI/BCS significantly enhances performance, resulting in a PCE in the order of 20 % under 200 lux and 2900 K LED illumination. Moreover, we introduce the single HTL design to provide other alternatives for efficiency boosting. Upon increasing the work function of the front contact, it is found that the valence band offset between the HTL and the absorber can be engineered, resulting in a PCE above 21.5 %.

1. Introduction

Photovoltaic (PV) technology has emerged as a central solution in mitigating the worldwide energy demand. In this regard, PV cells have become a keystone of renewable energy systems, playing a fundamental role in lowering dependence on fossil fuels usage. Among numerous solar cell technologies, Si-based cells have dominated the market due to their reliability and accepted power conversion efficiency (PCE) [1,2]. However, the pursuit of higher efficiencies has driven research studies to explore alternative materials and innovative designs. Within this context, thin film solar cells (TFSCs) have appeared as promising alternatives. TFSCs have a lot of advantages, including reduced material consumption, lightweight properties, and potential for flexible applications [3–6]. These attributes have motivated researchers to investigate novel materials to further improve the performance of TFSCs. One such material of interest is CdSe. CdSe is an II-VI semiconductor compound with a direct bandgap above 1.7 eV, high carrier mobilities and excellent light-absorbing properties [7,8]. Its energy band structure and

* Corresponding author.
E-mail address: ahmed.shaker@eng.asu.edu.eg (A. Shaker).

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