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Optimizing CBTSSe solar cells for indoor applications through numerical simulation

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Abstract

Solar cell technologies are pivotal in the transition towards sustainable energy sources. This paper delves into the design and optimization of CBTSSe solar cells for efficient indoor energy harvesting. The tunable bandgap nature of CBTSSe aligns well with the emission spectra of indoor LED lighting, making it a promising candidate for such applications. Our investigations in this paper commence with the design validation of a solar cell device structure, in line with experimental work, ensuring the accuracy of our models and simulation software. Through systematic simulations, we explore the dependence of absorber bandgap on the indoor LED color temperature. The study progresses into a multi-step optimization process, targeting crucial aspects of solar cell design. Investigating interface parameters, we analyze the interplay between the conduction band offset and surface recombination velocity. Subsequently, the influence of absorber layer properties on efficiency is examined, uncovering substantial improvements by optimizing thickness and bulk defect density. Further, we scrutinize the impact of electron transport layer thickness and doping, presenting avenues for performance enhancement. Quantitative results underscore the potency of our approach. Under warm and cool LED illumination, the proposed optimizations elevate the power conversion efficiency from 10.05 to 25.58% and 9.08 to 25%, respectively, validating the effectiveness of our strategies. These findings not only underscore the viability of earth-abundant CBTSSe-based solar cells for indoor applications but also pave the way for tailored, high-efficiency low-cost energy harvesting in various indoor environments.

Keywords CBTSSe · Indoor LED · SCAPS-1D · CBO · Power conversion efficiency

1 Introduction

The rising global energy necessity and growing concerns about environmental impact impose the exploration of renewable and clean energy sources. Solar energy, among several renewable options, holds substantial prospective, where photovoltaic (PV) technology has emerged as an efficient way of directly converting solar energy into electricity (Green et al. 2023; Petrović-Ranđelović et al. 2020). Silicon (Si) solar cells currently

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