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Optimizing Transport Carrier Free All-Polymer Solar Cells for Indoor Applications: TCAD Simulation under White LED Illumination

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Abstract: This work inspects the utilization of all-polymer solar cells (APSCs) in indoor applications under LED illumination, with a focus on boosting efficiency through simulation-based design. The study employs a SCAPS TCAD device simulator to investigate the performance of APSCs under white LED illumination at 1000 lux, with a power density of 0.305 mW/cm^2. Initially, the simulator is validated against experimental results obtained from a fabricated cell utilizing CD1:PBN-21 as an absorber blend and PEDOT:PSS as a hole transportation layer (HTL), where the initial measured efficiency is 16.75%. The simulation study includes an examination of both inverted and conventional cell structures. In the conventional structure, where no electron transportation layer (ETL) is present, various materials are evaluated for their suitability as the HTL. NiO emerges as the most promising HTL material, demonstrating the potential to achieve an efficiency exceeding 27%. Conversely, in the inverted configuration without an HTL, the study explores different ETL materials to engineer the band alignment at the interface. Among the materials investigated, ZnS emerges as the optimal choice, recording an efficiency of approximately 33%. In order to reveal the efficiency limitations of these devices, the interface and bulk defects are concurrently investigated. The findings of this study underscore the significance of careful material selection and structural design in optimizing the performance of APSCs for indoor applications.

Keywords: all-polymer; solar cells; indoor; LED; power conversion efficiency

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1. Introduction

Photovoltaics are one of the most effective renewable energy sources [1]. The role of photovoltaics in energy harvesting for a low-carbon society is increasingly recognized, with a particular focus on indoor photovoltaics (IPVs) as they harness photon energy derived from household lighting or dim ambient environments [2].

This growing interest can be attributed to several factors, including the emergence of efficient thin-film solar cells like organic and hybrid perovskites, the transition to solid-state white light emitting diodes (LEDs) and fluorescent lamps indoors, the rise of Internet of Things (IoT) technology, and the decreasing power requirements of wireless sensors [3,4].