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Optoelectronic Device Modeling and Simulation of Selenium-Based Solar Cells under LED Illumination

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Abstract: Solar cells can be designed for indoor applications to provide a feasible solution for harnessing photon energy from indoor lighting. In this paper, we analyze the suitability of a selenium-based solar cell for gathering photon energy emitted by indoor light-emitting diodes (LEDs). The absorption band of selenium (Se) is found to be aligned with the LED spectrum, making it a promising contender for efficient indoor applications. In order to simulate the Se-based photovoltaic (PV) device, we started by calibrating the simulation model against a fabricated Se cell that was tested under AM1.5G. After the verification of the physical models and the technological key factors of the different layers incorporated in cell design, a systematic approach was performed to assess the operation of the Se solar cell under an LED light environment. We show an optimized power conversion efficiency (PCE) of 26.93% for the Se-based cell under LED illumination (311 $\mu W/cm^2$). This is achieved by providing an effective design that incorporates a double-ETL structure, which can significantly improve the band alignment between the different layers of the cell device. The simulation results presented in this work serve to judge the potential of Se solar cells as indoor PVs and offer an approach for providing indoor use specifically designed for internet-of-things (IoT) devices.

Keywords: thin film; selenium; CBO; double ETL; SCAPS simulation; power conversion efficiency

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1. Introduction

Photovoltaic (PV) technologies have emerged as a central renewable energy resource, portraying a fundamental role in addressing accelerating energy demands and environmental apprehensions. The capability of solar cells to collect sun energy and convert it into electricity has acquired immense interest worldwide because of their immaculate and sustainable nature [1,2]. By harnessing solar energy, these devices contribute to reducing reliance on fossil fuels. Thin-film solar cells (TFSCs) have undergone overwhelming advances due to their potential for lightweight structures, high absorption coefficient, and ease of incorporation into several applications [3–5]. TFSCs notably offer significant benefits over traditional crystalline silicon-based solar cells, such as lower processing costs and enhanced versatility in material selection [6,7].

While solar cells are widely credited for their outdoor applications, their ability to be used indoors has received interest recently. Indoor applications involve a diverse range of settings, including commercial establishments and portable electronic devices. By capturing