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Toward the design of monolithic 23.1% efficient hysteresis and moisture free perovskite/c-Si HJ tandem solar cell: a numerical simulation study

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Abstract

In recent years, research and development of high-efficiency perovskite solar cells (PSCs) have gained momentum. However, the inherent issues of high-temperature stability and hysteresis have constrained the device from commercial feasibility. Researchers have proposed different electron transport layer (ETL) based PSCs to minimize the aforesaid issues. Recently, reduced cerium oxide/[6,6]-phenyl-C61-butyric acid methyl ester (CeO_x/PCBM ETL) based PSC device is developed with power conversion efficiency (PCE) of 16.85% and improved stability. In the present work, CeO_x/PCBM ETL based PSC device is simulated and calibrated to provide the scope for further improvement in terms of the overall conversion efficiency of the device. The device is further optimized by parametric variation such as doping and thickness of CeO_x/PCBM ETL layers. The optimized device with added carbon nanotubes CNTs (to enhance moisture stability) is employed in the monolithic tandem solar cell, and the efficiency potential of a monolithic, hysteresis and moisture free perovskite/crystalline silicon heterojunction (c-Si HJ) tandem solar cell is investigated. Silicon-based, i.e. hydrogenated p-type microcrystalline silicon oxide (μc-$Si_{1-x}O_x$:H) and hydrogenated n-type amorphous silicon tunnel junction (TJ) is used to model the TJ between two diodes. Comprehensive analysis and optimization of the tandem device are done in terms of optical and electrical performance with different thicknesses of perovskite and c-Si. The tandem device proposed in this work yielded a maximum PCE of 23.08%.

Keywords: solar cell, Perovskite, c-Si, Tandem solar cell, heterojunction, electron transport layer

(Some figures may appear in colour only in the online journal)

1. Introduction

Crystalline silicon (c-Si) solar cells have dominated the photovoltaic (PV) energy market since the last two decades with maximum recorded PCE of 26.6% which is close to its theoretical Auger efficiency of 29.4% [1–4]. The maximum efficiency limit is mainly due to thermalization loss. To make solar power generation competitive with conventional energy sources, the PCE of solar cells needs to be enhanced. One viable approach to improve PCE at a reasonable cost is to fabricate tandem devices by stacking absorbers of wide tunable bandgap over a narrow tunable bandgap [3, 5, 6] which reduces thermalization losses. Literature reports tandem solar cells incorporating various technologies such as amorphous silicon & microcrystalline silicon solar cells, dye-sensitized solar cells, organic solar cells/silicon solar cells [7–10]. However,

