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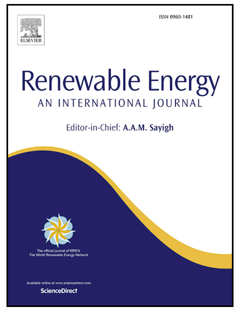

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Efficiency evaluation for triple-junction solar cells in five tandem configurations

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Abstract

For triple-junction solar cells (3J SCs), five tandem configurations have been successively put forward, including two-terminal serial, six-terminal, parallel/serial, bottom-cell-independent and top-cell-independent configurations. However, comprehensive studies on efficiencies of 3J SCs in the five configurations are few, and comparisons of the above five configurations are scarcer. This work evaluates efficiencies of 3J SCs in all the five configurations, and meanwhile analyzes the strong and weak points of the five configurations in spectral robustness and efficiencies. The limiting efficiencies for 3J SCs with three direct-bandgap subcells are firstly calculated based on the detailed balance theory. Previous works mainly provided the highest efficiencies and the corresponding subcell bandgaps. In this work, along with the highest efficiencies, efficiency contour plots for all the five configurations are offered. Then the emphasis is focused on 3J SCs with a crystalline silicon (c-Si) bottom cell. Organic cation lead halide perovskite materials have shown a huge development potential in photovoltaic field. Possessing the wide tunable bandgap ranges, perovskite materials are promising candidates for the top and middle cells. Hence, simulations and recommendations for practical approaches of the perovskite/perovskite/c-Si 3J SC are given, where the perovskite subcells have appropriate bandgaps according to the above calculated results.

Keywords: Triple-junction solar cells; Five tandem configurations; Efficiency; Spectral robustness

1. Introduction

The appropriate bandgap for single-junction solar cells (SCs) is estimated to be 1.1~1.4 eV [1]. A lager bandgap of SC material brings about a blue shift of absorption edge, which inevitably narrows down the light absorption waveband of SC module. A smaller bandgap incurs more severe thermalization loss, which means more energy of high-energy photons transforms into the waste heat. Tandem architecture of SCs are constituted of a series of subcells with different bandgaps, which broadens the light absorption region of the whole tandem SC module, and at the same time reduces the thermalization loss, thus enhancing the efficiency effectively. Theoretically, Brown et al.[2] predicted the efficiency limits for SCs with one to six subcells are nearly 33%, 45%, 51%, 55%, 57% and 59%. The efficiency improvement from single-junction SCs to dual-junction SCs is significant. After the triple-junction (3J) SCs, efficiency has a slow growth as the number of subcells increases. Experimentally, Spectrolab fabricated a direct semiconductor bonded five-junction SC with a record efficiency of 38.8% under one-sun illumination [3]. The InGaP/GaAs/InGaAs 3J SC with a certified efficiency of 37.9% [4], which was developed by Sharp Corporation, is second only to it. The above two efficiencies have been certified by National