Loss Analysis of a Perovskite/Perovskite/Silicon Solar Cell

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Abstract

Perovskite/perovskite/silicon triple junction solar cells are a rather new architecture that offer a potentially cost-effective and highly efficient solution. Additional junctions reduce thermalization losses, yielding a detailed balance limit of 49.6% for this cell architecture. Simulations aid in identifying factors contributing to efficiency loss, guiding developers to improve specific layers. Current key challenges include achieving stable perovskite compositions at the right bandgap, as well as finding suitable hole and electron extraction and recombination layers. In this work, we first analyze the optical efficiency of a perovskite/perovskite/silicon triple junction solar cell. Our simulation is validated on experimental data, which we regard a representative cell for the current cells of this architecture. For this triple junction cell design, we identify the most impactful loss by the current mismatch between the cells, which is a loss of approximately 4 mA/cm^2. By using perovskites with optimized bandgaps and/or adjustments of the perovskite layer thicknesses, this can be resolved. Reflection causes 10% of the incoming light to be lost. A textured front surface can mitigate this. Also, the interlayers absorb 8% of the incoming photocurrent parasitically, which can be lowered by using the thinnest layers possible. By implementing the mentioned improvements, we predict a short-circuit current of 14.1 mA/cm^2 and an open-circuit voltage of 3.48 V with an efficiency of 44.3%, assuming idealized electrical properties. To assess the electrical losses, the top and middle perovskites are investigated as individual single-junction cells. With an opto-electrical model, we can investigate the internal processes and parameters and analyze the impact on the power conversion efficiency (PCE) with band diagrams and *J-V* curves. These internal parameters are validated by several different experiments. We investigate carrier lifetimes, surface recombination velocities, band alignments, series resistances, and the impact of preconditioning.

Keywords

Simulation, Sentaurus, Perovskite, Silicon, Multijunction