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Simulating Nanoscale Optics in Photovoltaics with the S-Matrix Method

Dalton Chaffee, Xufeng Wang, and Peter Bermel
Department of Electrical Engineering, University of Purdue

ABSTRACT

In the push to build high-efficiency solar cells with less materials usage, thin-film solar cells have attracted an increasing amount of interest. Thin films are particularly attractive if they could exhibit light trapping and photon recycling capabilities exceeding those of traditional wafer-based cells. Recent work by Alta Devices demonstrating a record single-junction efficiency of 28.8% with a gallium arsenide thin film cell shows the potential. However, most existing simulation tools do not handle these properties well -- particularly photon recycling. In this work, we develop an improved solar cell simulation tool to accurately predict thin-film performance. It is based on a fast layered wave-optical module coupled to a drift-diffusion electronic model. The S-matrix method was used to solve for light absorption at any point in a solar cell given the depths and refractive indices of each layer; these results are then used to calculate initial and recycled photon generation profiles, and coupled self-consistently to an existing solar cell simulator, ADEPT 2.0, available on nanoHUB.org -- an open-access science gateway for cloud-based simulation tools and resources in nanoscale science and technology. In general, this improved simulation technique produced more accurate carrier distributions and a higher open-circuit voltage than predicted by standard models, which has also been observed in experiment. Preliminary results are presented that indicate this approach is also capable of accurately modeling the effects of anti-reflection coatings (ARCs) and various back reflectors. This new capability will be made available through a revised version of ADEPT 2.0.

KEYWORDS

Photovoltaics, thin film, transfer matrix method

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