Nanophotonic design of grating perovskite solar cell

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Abstract

The development of Perovskite Solar Cells (PSCs) represents one of the most promising pathways toward reducing the cost of photovoltaic electricity. This emerging and rapidly advancing technology uniquely combines low-cost fabrication with high power conversion efficiencies. This growth is motivated by numerous demonstrations of high record laboratory PSCs fabricated using simple solution-based or physical evaporation methods. The purpose, here, is the enhancement of the current design of planar PSCs through nanophotonic engineering. Specifically, one show how Photonic-Crystal (PC) structuring of absorber layer improves sunlight harvesting, especially at band-edge where optical absorption falls down. The study is limited to Methylammonium lead iodide CH3NH3PbI3 (MAPbI3) as typical perovskite material, but may be easily generalized to other perovskites. Therefore, full electromagnetic-wave methods were used to model sunlight interaction with multilayer PSC including subwavelength patterns. Therefore, the Finite Difference Frequency Domain (FDFD) and Fourier Modal Method (FMM) were employed to model resonant coupling and sunlight absorption in the absorber layer. The FMM calculated absorptance spectra of two PC patterns, holey membrane and nanorod array, show clear absorption improvement around band-edge, ~800 nm for $MAPbI_3$. Moreover, short-circuit current density limit, deduced from absorptance, of the optimized structures show a relative enhancement of more than 24% when compared to the unpatterned structure. The feasibility of implementing the proposed designs using electron-beam lithography, UV lithography, nanoimprint lithography, or self-assembly techniques was also discussed. Finally, a brief analysis of the sustainability and lifecycle assessment of perovskite solar cells was presented.