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Light Trapping in Colloidal Quantum and Silicon Nanowire Solar Cells

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Abstract

Light utilization in thin film solar cells such as colloidal quantum dot solar cells and amorphous/nanocrystalline silicon solar cells remains relatively low due to a tradeoff between low carrier transport lengths and longer infrared photon absorption lengths. Here, we discuss two different methods for increasing light absorption: plasmonic nanostructured back-reflectors in colloidal quantum dot solar cells, and core-shell silicon nanowires in thin film Si solar cells. The effect of plasmonic back-reflector nanostructure on absorption is modeled by finite difference time domain (FDTD) simulations. Nanostructured back-reflectors based on the simulations are fabricated in colloidal quantum dot solar cells and shown to exhibit broadband absorption enhancement over the wavelength range λ= 600 to 1100 nm. The solar cell short-circuit current improved by 31% compared to an approximately equal volume planar device. The second method of light trapping involves the use of disordered silicon nanowires to lower the reflectance of incident light on thin film Si solar cells. Fabrication of p-i-n thin film Si shells around silicon nanowires lowered the total reflectance to values <4% over a broad wavelength range of 400 nm < λ < 650 nm. The lower reflectance and enhanced absorption in the infrared led a short-circuit current enhancement of 15% compared to an amorphous Si solar cell. The challenge of incorporating plasmonic nanostructures and core-shell nanowires into solar cells without affecting the electrical properties is also discussed. For example, the open-circuit voltage (V_{OC}), was observed to decrease from by about 0.1 V, which was attributed to higher recombination at the p/i interface in the high surface area nanowire solar cells.