Novel Automated Next-Generation Multijunction Quantum Dot Solar Panel Designs Using Monte Carlo-Based Modeling

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Solar spectral losses account for 50+% of efficiency loss in conventional solar panels, due to inherent conflict between maximizing quantity of photons absorbed and energy obtained from each photon. Multijunction solar cells could simultaneously address both issues. Quantum dots, or semiconductor nanoparticles, are ideal: quantum confinement allows bandgap tuning. However, despite leading status in quantum dot solar cells, lead sulfide (PbS) quantum dots are rarely studied in higher-efficiency multijunction solar cells. This work investigated quantum dot/photon interactions in multijunction solar cells and identified fundamental limiting factors of solar cell efficiency, utilizing computational quantum physics and solar optics to design improved-efficiency multijunction quantum dot solar cells. Absorption spectra associated with PbS quantum dots as low as 1-nm diameter, obtained with quantum mechanical cloud-computation, were incorporated into JAVA-programmed stochastic Monte Carlo simulations implementing novel algorithms. Simulations assumed 10 million incoming photons and were conducted for permutations of quantum dot stacks in 1, 2, 3, 5, and 9-stack multijunction quantum dot solar cells. Spectral changes due to absorption were tracked as photons progressed through quantum dot stacks to understand energy absorption and electricity conversion at each stack to calculate aggregate results. Analytical procedures were developed and executed to maximize synergistic effects between photon absorption and electricity conversion. Results indicated that intrinsic efficiency was increased from 36.63% in a single-stack quantum dot solar cell to 52.77%, 60.69%, 69.77%, and 79.09% in 2, 3, 5, and 9-stack multijunction quantum dot solar cells designed in novel and automated ways.

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