Nanotechnology Pathways to Next-Generation Photovoltaics

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This tutorial will set the stage for understanding and appreciating the latest advances and central challenges in photovoltaics research. Over the long term, nanotechnology is expected to enable improvements throughout the energy sector, but the most striking near- to mid-term opportunities may be in lower-cost, higher-efficiency conversion of sunlight to electric power. Nanostructures in solar cells have multiple approaches by which they can improve photovoltaic performance: (1) New physical approaches in order to reach thermodynamic limits; (2) Allow solar cells to more closely approximate their material-dependent thermodynamic limits; and (3) Provide new routes for low-cost fabrication by self-assembly or design of new materials. We focus primarily on the first two approaches which have the goal of increasing efficiency. Several different approaches will be described that circumvent long-held physical assumptions and lead beyond first- and second-generation solar cell technologies. Special emphasis will be on a novel nanostructure-based devices based on advanced concepts such as hot carrier cells, intermediate band and multi-exciton generation, which have the theoretical basis to realize high efficiency energy conversion. We also discuss the role nanotechnology in improving light trapping and the light collection properties of solar cells. We also focus on the effects that surfaces and interfaces play in nanostructured solar cells, and how to reduce parasitic carrier recombination effects through passivation.