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Bio-Inspired electro-photonic structure for organic and dye sensitized solar cells[1]

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A major challenge in solar cell technology dwells in achieving an efficient absorption of photons with an effective carrier extraction. In all cases, light absorption considerations call for thicker modules while carrier transport would benefit from thinner ones. This dichotomy is a fundamental problem limiting the efficiencies of most photovoltaics. One pathway to overcome this problem is to decouple light absorption from carrier collection. We present solutions to this problem applying bio-inspired nanostructures to two different types of systems: organic photovoltaic (OPV) and dye sensitized solar cells (DSSC). For OPV devices based on poly-3-hexylthiophene:[6,6]-phenyl-C61-butyric acid methyl ester (P3HT:PCBM), we describe a 2-D photonic crystal geometry that enhances the absorption of polymer-fullerene photonic cells $\sim$ 20% relative to conventional planar cells. Remarkably, the photonic crystal cell offers the possibility to increase photocurrents by improvements in optical absorption and carrier extraction simultaneously, and particularly through the excitation of photonic resonant modes near the band edge of organic PV materials. We also present an optical method to extract charge transport lengths from device photoactive layers. For DSSCs we introduce a new structural motif for the photoanode in which the traditional random nanoparticle oxide network is replaced by vertically aligned bundles of oxide nanocrystals. We have used a pulsed laser deposition system to ablate titanium oxide targets to obtain the porous and vertically aligned structures for enhanced photoelectrochemical performance. Absorption studies show that in optimized structures for titanium oxide, there is a 1.4 times enhancement of surface area compared to the best sol-gel films, Incident-Photon-Conversion-Efficiency values are better than 3 times thicker sol-gel films, and $\sim$ 92% Absorbed-Photon-Conversion-Efficiency values have been observed when sensitizing with the N3 dye (Ru(dcbpyH)2(NCS)2). The direct pathways provided by the vertical structures appear to indeed provide for enhanced collection efficiency for carriers generated throughout the device.

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