High Efficiency Nanocrystalline Organic Thin-Film Solar Cells

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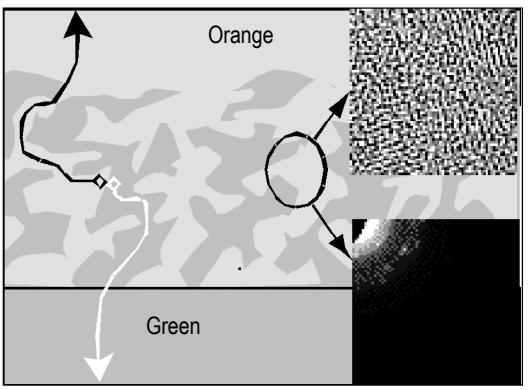
Efficiency increase in organic thin-film solar cells is achieved by applying novel nanostructures. The photogenerated excitons need to diffuse to the donor/acceptor (DA) interface where the abrupt energy change separates the excitons into electron-hole pairs. The free carriers then diffuse towards the electrodes where they are collected. A full-organic DA network formed by crystalline molecules is introduced to organic solar cells in this work. By controlling the organic crystallization during the deposition of ultra-thin multi-players, the donor material, copper phthalocyanine (CuPc) and the acceptor, C_{60} crystallize and form interconnected network. The crystalline structures of both phases are confirmed with high-resolution transmission electron microscopy and selected area electron diffraction, as shown in the right figure.

Photocurrent vs. voltage measurement confirms that the large interface area ensures effective carrier generation, while the continuous pathways formed in the network favors efficient carrier collection. The CuPc/C_{60} nanocrystalline solar cell has a power conversion efficiency, $\eta P = (4.6 \pm 0.2)\%$ under 100mW/cm^2, air mass 1.5 global illumination, which is more than 3 times of improvement compared to $\eta P = (1.4 \pm 0.1)\%$ in a similar CuPc/C_{60} cell with planar interface structure. Our work shows that the control over the heterointerface structure is the key in improving the efficiency of the organic solar cells. This project is supported by Global Photonic Energy Corp. (with University of Southern California) under award number Subscontract PO No. 111678.



Schematic structure of the organic nanocrystalline solar cell. The donor (green) and acceptor (orange) forms interconnected crystallite networks, where the carriers generate from the donor-acceptor interface and diffuses into the top and bottom contacts. Insets show the transmission electron micrograph of the crystalline phases, and the selected electron diffraction pattern of the donor, CuPc and acceptor C_{60}.