A Photonic Nano-Structuring Approach to Increase Energy Harvesting for Organic Photovoltaic Cells

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EXTENDED ABSTRACT
To enhance photo-conversion efficiency (PCE) for organic photovoltaic (OPV) cells it is important to optimize the photon harvesting provided the such devices suffer from a short exciton diffusion length and, in particular, a low mobility of charged carriers which prevent the use of thick materials for a more effective photon absorption. From an optical perspective, such organic solar cells can be seen as a stack of several layers with different refractive index. At each interface between any of these layers there is a significant reflection that prevents the most effective photon harvesting. If such reflection can be minimized, the external quantum efficiency (EQE), defined as the ratio between current and incoming photons, approaches the internal one, which is the ratio between current and absorbed photons.

Here, we will show experimentally that for an inverted organic cell it is possible to find a combination of layer thicknesses such that when the active layer thickness is 91 nm, optical interference leads to an EQE that, as shown in Fig. 1, amounts to 91% of the internal quantum efficiency (IQE). We observe that the total reflectivity is close to its minimum possible value in a wavelength range of more than 100 nm. In that range the EQE closely matches the IQE. In a model developed to determine the role played by optical interference in the light harvesting efficiency we confirmed that the EQE can closely match the IQE for that wavelength range. Additionally, we observed that a similar cell with an active material 151 nm thick, close to 2 times thicker than the previous case, exhibited a lower PCE. The poor photon harvesting in the later cell configuration is confirmed by an EQE that amounts only to 72% of the IQE.

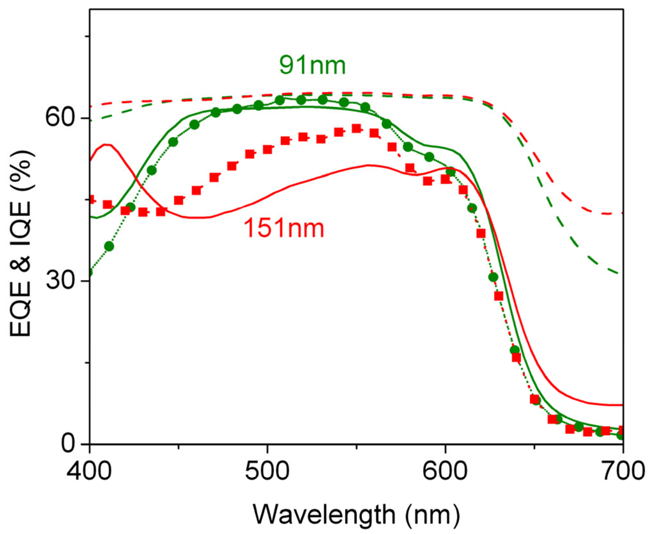

Figure 1. Experimentally measured EQE and numerically determined EQE & IQE.

However, such optical interference approach can have a positive effect over a limited bandwidth. At the longer wavelength region where photon absorption by the active material is smaller, the effect of an optimized optical absorption by manipulating the relative thicknesses of all layers is rather limited. I will discuss alternative approaches using several different forms of nano-photonics to enhance energy harvesting in the infrared region.

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