Structure-Property Approach to Diffusion in Bilayer Organic Solar Cells

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At present, most efficient organic photovoltaic (OPV) cells are based on the bulk heterojunction (BHJ) architecture. A key requirement for high performance BHJ cells is achieving a good 'blending' between the electron donor and acceptor organic semiconductor materials [Nature Materials, 7, 158-164 (2008); Advanced Functional Materials, 20, 1458 – 1463 (2010)] and this has presented significant challenges in controlling the nanoscale morphology. To date, BHJ OPV cells based on a blend of poly(3-hexylthiophene-2,5-diyl) (P3HT, the donor) and [6,6]-penyl-C61-butyric-acid-methyl-ester (PCBM, the acceptor), a fullerene derivative, have shown good results [Advanced Materials, 21, 1323–1338 (2009)].

A simpler approach would be to use the 'bilayer' architecture, which only requires stacked planar layers. Recent work by Ayzner et al. demonstrated an all-solution-processed P3HT/PCBM bilayer OPV cells with performance approaching those of a BHJ [J. Phys. Chem. C, 113, 20050–20060 (2009)]. This has been surprising as the thickness of the donor and acceptor layers in the bilayer device were significantly larger than the exciton diffusion length. In their work, they attributed this improvement to being able to optimise the processing condition for each layer, and hence being able to increase the crystallinity (and hence the mobility) of the electrons through the PCBM.

We have also fabricated bilayer OPV cells by using an all-solution processing technique. By using a structure-property approach, we have performed material characterisation studies concurrently with the electrical testing of our bilayer OPV cells. This has allowed us to gain a deeper insight into the mechanisms responsible for the improved performance. We have already conducted analysis using X-ray Photoelectron Spectroscopy (XPS) and this has revealed that PCBM does not form a distinct layer on the top surface. Further studies of the morphology helps to account for the performance that we have observed.