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Strategies for morphological control in organic photovoltaic devices

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While inorganic solar cells enjoy a level of success, high manufacturing costs and bulky modules limit their broad applicability. In contrast, organic photovoltaic (OPV) devices employ flexible thin-films of organic small molecules or polymers as the photoactive layer. OPV could provide a low-cost alternative to traditional PV, and a system of solution processing coupled with roll-to-roll printing of lightweight, flexible solar cells is envisioned.

One complication of organic photovoltaic technology is the heavy dependence on the active layer morphology obtained by the component donor and acceptor materials. The optimal morphology will maximize the donor/acceptor interface to insure free charge generation but must also conduct charges efficiently, which requires pure and crystalline percolation pathways oriented relative to the electrodes. These qualities are often at odds with each other, and their interplay and the resultant photovoltaic performance are of great importance to the OPV field.

Here we discuss two routes we have taken towards understanding and controlling morphology in OPV thin films. In the first system, the modulation of bulky substituents in nematic liquid-crystalline small molecules was investigated as a means of controlling their orientation, phase separation, and crystallinity in films. In these novel p-type materials, it was demonstrated through depth-dependent grazing-incidence wide-angle X-ray scattering (GIWAXS) studies that the degree of crystallinity and the distribution of crystallite orientations throughout the films is determined by solubility and can have a large effect on device performance. In the second system, we have employed a bottom-up approach to morphological control by covalently linking the donor and acceptor materials to form amphiphilic block copolymers. Using GIWAXS in conjunction with resonant soft X-ray scattering, these block copolymers were shown to spontaneously self-assemble into well-defined and crystalline domains in thin films. The results of both systems demonstrate the value of careful molecular design for the morphological control of organic photovoltaic active layers.

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