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Structural characterization of polymer solar cells, from high resolution to high through-put

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The structure and architecture of polymer solar cells on scales from nm to mm have crucial impact for the device performance. With standard X-ray scattering techniques, we may determine donor and acceptor domain sizes in polymer solar cells, crystalline structure and characterize the dimensionality of the interface, but to quantify the capability of the nanostructure for separating electron-hole pairs and for transporting free charges, we need access to the 3D structure on the nm scale. X-ray ptychography has the potential to allow these investigations, and has the further advantage that it is a reasonably mild technique, due to the weak interaction of X-rays with the material, as compared to electron and soft X-ray transmission microscopy, where dose loads are much higher. We have carried out very promising studies at cSAXS, where we with reasonable ease approach a 100 nm spatial resolution, and with clear pathways for improving resolution.
In a completely different type of experiment, synchrotron X-rays were used to probe active materials for polymer solar cells on flexible polyester foil. The active material was coated onto the flexible 130 micron thick polyester foil using roll-to-roll differentially pumped slot-die coating and presented variation in composition, thickness and additives. The coated foil was passed through the synchrotron X-ray beam on a small unit comprising unwinder and winder for the foil roll, an X-ray probe station and a barcode reader for sample registration. Foil lengths of 8 meters were probed and yielded X-ray scattering data for every- 1 cm along the foil that presented linear variations in processing and coating parameters along the foil length. We demonstrate a synchrotron X-ray based characterization method that is compatible with roll-to-roll coating methods in terms of speed and that provides detailed information on morphology and the effect of processing parameters on the same scale and in the same volume as the manufacturing method. We found that X-ray characterization is possible at web speeds of up to 6 m min-1. We found a distinctive morphological effect of changing the donor/acceptor blend ratio and of introducing chloronaphthalene as a processing additive.

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