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Structural measurements of polymer-fullerene blend films for organic photovoltaics

DEAN DELONGCHAMP, NIST

Organic photovoltaic (OPV) technology has the potential to greatly lower the cost of solar cell fabrication by enabling ink-based deposition of active layers. In bulk heterojunction (BHJ) OPV devices, the power conversion efficiency critically depends on the distribution of the polymer absorber and the fullerene electron acceptor (e.g., the blend morphology). I will describe measurement methods to probe the structure of OPV devices, with a focus on the morphology of the BHJ layer. For example, the vertical distribution of absorber and electron acceptor in BHJ films follows segregation behavior similar to that of miscible polymer blends. The top (air) interface becomes rich in the polymer absorber, whereas the bottom interface composition depends on the substrate surface energy. Thin film transistors fabricated from BHJs can therefore exhibit ambipolar or hole-only transport depending on the dielectric, because of different interfacial segregation. We extend these results to practical photovoltaic devices by comparing BHJs cast upon hole transport layers that have similar work functions but different surface energies. This study includes the application of variable angle spectroscopic ellipsometry (VASE) to BHJ films, and emphasizes the importance of absorber anisotropy and vertical heterogeneity in the optical model. Additional results will describe the nanometer-scale structure in the BHJ interior. The application of solid-state nuclear magnetic resonance (SS-NMR) can reveal details about the segregation of absorber and acceptor in a BHJ film. Nanoscale BHJ morphology information can also be collected using tomographic transmission electron microscopy (TEM). Together these measurements allow us to reveal a detailed picture of BHJ morphology, explain how the morphology originates from materials and processing choices, and relate the morphology to device performance and stability.