MAR14-2013-020056

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Engineering polymer-fullerene thin films and solar cells with external fields

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Trace amounts of nanoparticles, including fullerenes, can impart stability to thin polymer films against dewetting by the combined effects of pinning the contact lines of dewetting holes and by effectively altering the polymer-substrate interaction. Polymer nanocomposite (meta)stable thin films can yield well-defined morphologies from uniform to spinodal-like, via spontaneous polymer-nanoparticle phase separation and crystallization. Confinement breaks the structural isotropy and generally causes (partial) segregation of components orthogonally to the film surface. Surface energy patterning can thus modulate composition and morphology, both in plane and normal to the surface. Further, UV-visible, and even background, light exposure, in both solutions and melts, is shown to tune the solution stucture and morphology of dewetting and phase separating polymer-fullerene thin films. Neutron reflectivity allows us to locate the various constituents within the film. We find a coupling of fullerene photo-sensitivity and both self-assembly processes which results in controlled pattern formation, and we illustrate the potential with a model polymer-fullerene circuit pattern. We then translate this approach into the directed assembly of energy harvesting bulk heterojunctions thin films. Indeed, a key challenge to the commercialization of organic solar cells remains the achievement of morphological stability, particularly under thermal stress conditions. The directed assembly a blend polymer:$PC_{60}BM$ solar cells via a simple light processing step results in a 10-100 fold increase in device thermal stability and, under certain conditions, enhanced device performance. The enhanced stability is linked to the light-induced oligomerisation of $PC_{60}BM$ that effectively hinders diffusion and crystallization in blends. This effect appears to be general and promises to be an effective and cost-effective strategy to optimize fullerene-based solar cell performance.