Electron tomography of polymer solar cells using Compressed Sensing

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Recently, the single layer polymer solar cell (PSC) based on bulk heterojunction (BHJ) blend of two materials: fullerene derivative [6,6]-phenyl-C71-butyric acid methyl ester (PC71BM) and a polymer with alternating units of thieno{3,4–b} thiophene and benzodithiophene (PTB7) has received significant attention [1], since high power conversion efficiency (PCE) of 9.2% has been reported for devices based on this mixture [2]. Unfortunately, little is known about the nanoscale organisation of PTB7:PC71BM blends beyond some 2D imaging. In this work, we extends our previous study in [8] electron tomography (ET) [3] and a new ET image reconstruction method, DLET, to investigate the 3D organisation of such blends using. ET plays an essential role in the study of 3 dimensional (3D) nanostructures. It involves reconstructing 3D objects from a series of 2D images by sequential tilting of the sample about a single axis. This technique, although originally designed for use in the life sciences, has also been applied to the study of polymer blends using bright-Field TEM (BFTEM) as in [4]. We used energy filtered electron tomography [5] using thin cross-sections through the blend cut using a FIB (Nova Nanolab, FEI). Three-dimensional reconstruction was performed using a new compressed sensing based algorithm, DLET [6,7], which enables high-fidelity, low-noise reconstruction from relatively few projections and minimizes artifacts from the missing wedge in the tilt data. The result from DLET is also compared with traditional methods such as Weighted back projection (WBP) and simultaneous iterative reconstructive technique (SIRT). The volume rendering visualisations of the reconstructions are shown in Figure (1). EFTEM results clearly show that domains in the blend are PC71BM-rich (i.e. contain more carbon as in Fig.1(b)). The EFTEM tomography clearly reveals that these ellipsoids and are not spherical. TEM and SEM measurements of device cross-section show existence of thin skin layer covering domains.

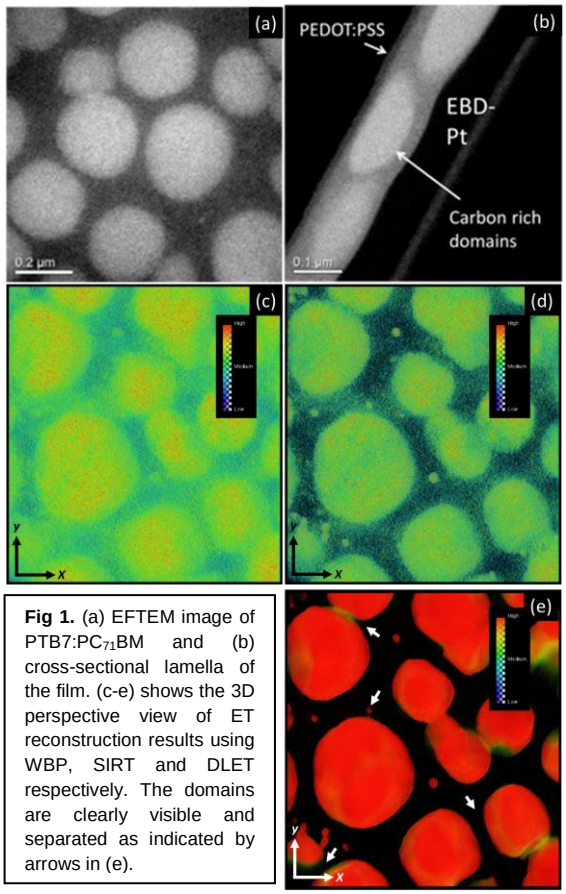

Fig 1. (a) EFTEM image of PTB7:$PC_{71}BM$ and (b) cross-sectional lamella of the film. (c-e) shows the 3D perspective view of ET reconstruction results using WBP, SIRT and DLET respectively. The domains are clearly visible and separated as indicated by arrows in (e).

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