Electron tomography [1] plays an essential role in the study of three-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 [2, 3]. 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 [4], since high power conversion efficiency (PCE) of 9.2% has been reported for devices based on this mixture [5]. Unfortunately, little is known about the nanoscale organisation of PTB7:PC71BM blends beyond some 2D imaging. In this work, we use electron tomography (ET) [1] to investigate the 3D organisation of such blends. Different electron microscopy and atomic force microscopy (AFM) methods to determine bulk structure of PTB7:PC71BM film. In particular, energy filtered electron tomography [6] was performed with TEM Tecnai T20 (FEI) operated at 200 kV using thin cross-sections through the blend cut using a FIB (Nova Nanolab, FEI). Three-dimensional Reconstruction was performed using the simultaneous iterative reconstructive technique (SIRT) using IMOD. The volume rendering visualisations of the reconstructions are shown in Figure (2). Orthoslices through the reconstructions are shown in Figure (3).

EFTEM results clearly show that domains in the blend are PC71BM-rich (i.e. contain more carbon). 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. The fine structure inside domains and matrix was observed by TEM and AFM (Solver P47H and Next, NT-MDT). Evolution of (photo) current distribution measured by AFM equipped with conductive probe on surface of PTB7:PC71BM blend was studied. We also used plasma etching of blend to study internal structure of this film by AFM.

References

Acknowledgement: The work of A.Aleef, P.C, I.M, and S.M was supported by Kelvin Smith scholarship -University of Glasgow. Work of A.A., G.J.H. and I.D.W.S. was supported by the EPSRC (grant number EP/l013288/1).
Fig. 1: background estimation image produced from two pre-edge EFTEM images. This background estimation is subtracted from the B) Post-edge image to obtain an C) Elemental map.

Fig. 2: Orthoslice through SIRT 3D reconstruction, the y-direction labelled is parallel to the tilt axis, x-direction is perpendicular and z-direction is parallel to the optic axis. E) Volume rendering of reconstruction, F) A domain is selected G) to be visualized by rotating to H) 45 I) 90 Degrees around the tilting axes.

Fig. 3: Cross-sections (Orthoslices) through 3D reconstruction of PTB7:PC70BM.