Type of presentation: Oral

MS-14-O-2804 Characterization of nanoscale morphology in photovoltaic polymer blends using energy-filtered scanning electron microscopy

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Modern organic solar cells typically have an active layer consisting of a semiconducting polymer and fullerene blended together in a thin (<100nm) film. In production this blend phase separates on a nanometre scale, producing donor and acceptor phases in the film. The nature of the resulting blend morphology has a huge effect on the efficiency of a solar cell device[1]. As such high-resolution tools for the characterisation of such morphologies are required. We are developing energy-filtered SEM (EFSEM) as a fast, easy-to-implement method to perform this task, building on previous work using the technique to characterise inorganic semiconductor devices[2].

During an SEM exposure, the secondary electrons (SE) emitted by a given material under irradiation by the primary beam have a well-defined energy spectrum[3]. We compare the energy spectra of the SE emitted from different phases in a P3HT:PCBM photovoltaic blend (see fig 1). At energies below 8eV, one phase is brighter than the other; however this contrast is reversed at energies above 8eV. Therefore if all SE are used to image the blend morphology, the contrast in SE emission between the different phases will be relatively small. It is thus very difficult to map such blend morphologies withstandard SEM techniques.

To negate this problem it is possible to place a low-pass energy filter on the SE detected by the through-lens detector in an SEM column. This is done by changing the strength of the electrodes that deflect electrons towards the scintillation detector in the through-lens detector (TLD) assembly of an FEI Sirion SEM[2]. We place our energy filter at 8eV and only image using SE with energies below this threshold. This results in a significantly larger contrast difference between the two blend components than when all electrons are detected, as it excludes the regime in which the contrast between the phases is reversed. Using EFSEM we find we can map the chemical distribution in organic solar cells with sub-nanometre resolution; a feat that is unprecedented with SEM equipment (see fig 2). In our data we see periodicity in our data on two length-scales, at approximately 8nm and 17nm, as displayed in figure 3. We believe that these values correlate to periodicity in the separation between different P3HT and PCBM domains. The ability to image the morphology of a photovoltaic blend with this level of detail could constitute a powerful tool for informing the development of future organic photovoltaic technology.

[1] A.J. Heeger, Adv. Mater. **26** (2014), p. 10
[2] C. Rodenburg et al, J. Phys. Conf. Ser. **241** (2010), p.012074
[3] D. Joy, M.S. Prasad and H.M. Meyer, J. Microsc. **215** (2004), p.77

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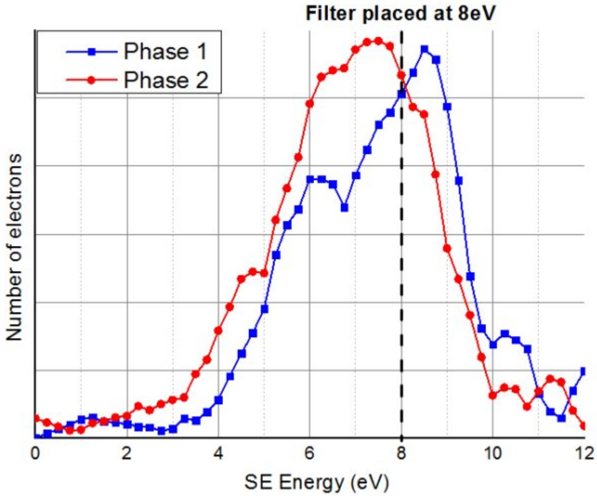

Fig. 1: Secondary electron spectra of 2 distinct phases seen whilst imaging a P3HT:PCBM blend. Placing a low-pass energy filter at 8eV results in images being taken only from the domain where phase 2 is significantly brighter than phase 1 – this improves the chemical contrast in our images

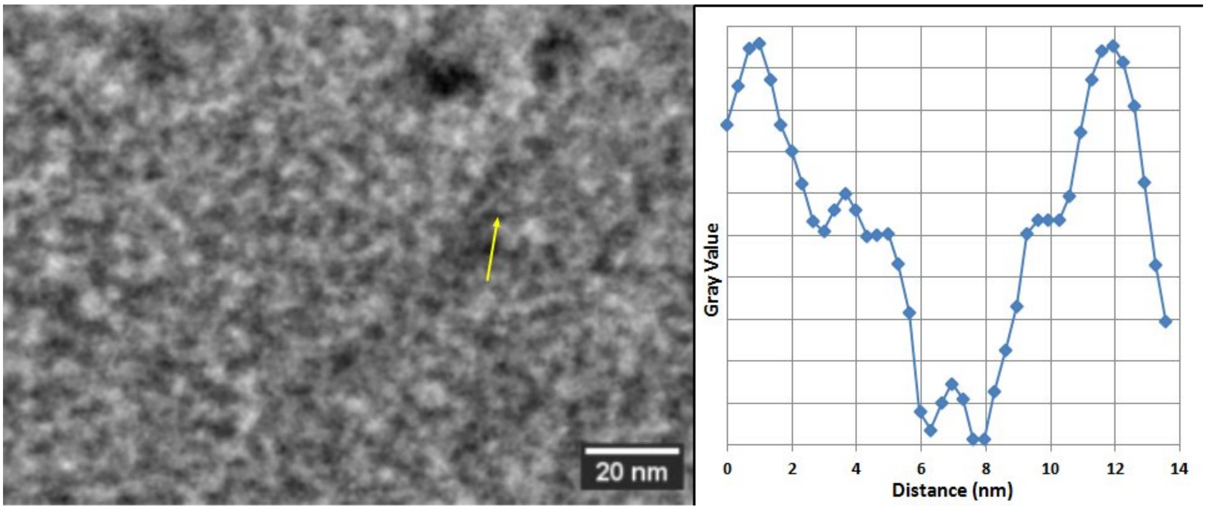

Fig. 2: EFSEM image of P3HT:PCBM photovoltaic blend, subject to a 5-minute plasma clean to remove surface layers. From previous work we believe the brighter regions to be P3HT-rich and the darker regions to be PCBM-rich. The plot shows a line profile from the image (see yellow arrow), showing the level of detail available.

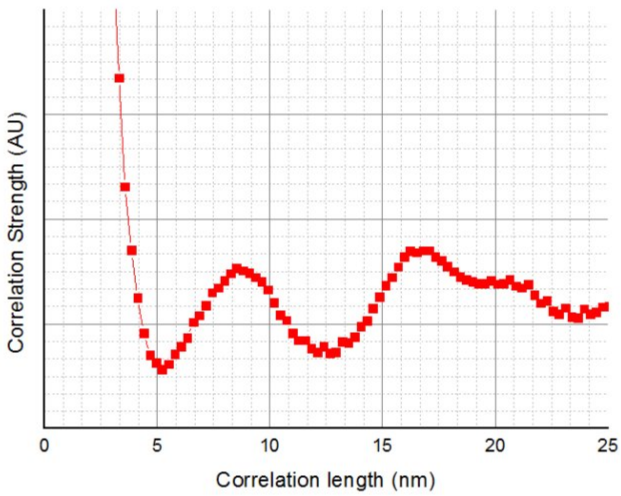

Fig. 3: Autocorrelation functions applied to our EFSEM images show a two-fold correlation in our data; we postulate that these correspond to periodicity in P3HT-rich and PCBM-rich domains. The equal strength of these peaks leads us to believe that they are two separate correlations, rather than two projections of the same correlation