Electron Beam Enhanced Thermal Stability of Polymer Photovoltaic Blends

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Polymer/fullerene blends are subject to considerable interest due to their potential for organic electronic applications including solar cells, bipolar and light-emitting transistors and dark-current photo-detectors. The performance of the devices depends on the fine details of the microstructure that develops during processing of the films from solution. However, the microstructure further develops during subsequent thermal annealing steps taking place as part of the fabrication procedure and during normal operation conditions. The microstructure consists of a bicontinuous network providing paths for electron acceptors (fullerene) and donors (polymer) to the electrodes. In solar cells, the incoming light generates excitons that charge separate at the interfaces between the polymer and fullerene providing the individual charge carriers. The exciton diffusion length is relatively short, i.e. on the nanometer scale, and it is therefore crucial that the length scale of the phase separation is of the order of a few dozen nm. Previous work has shown that annealing at temperatures of about 150 °C results in coarsening of the microstructure that degrades the power conversion efficiency.

This talk addresses studies of the effect of thermal annealing of polymer/fullerene (TQ1/PCBM [1]) films and the use of the electron beam in a transmission electron microscope (TEM) to enhance the thermal stability of the microstructure. The films were studied in a FEI G2 Tecnai TEM. The in situ heating experiments were performed using a DENSsolutions single tilt heatingholder with High Temperature EMheaterchips. The annealing temperature was 150 °C and the patterned windows were used to expose the films to different total annealing times and electron beam exposure at different stages of thermal anneal. The effect of increased thermal annealing time is illustrated in Fig. 1. The characteristic length scale of the phase separation increases with increasing annealing time. The effect of electron beam exposure is illustrated in Fig. 2. The length scale of the microstructure is the same before and after thermal annealing. The effect of the electron beam exposure is to enhance the microstructural stability with respect to thermal annealing. It was also found that the acceleration voltage influences the microstructural evolution.

[1] Bäcke, C. Lindqvist, A. Diaz de Zerio Mendaza, S. Gustafsson, E. Wang, M. R. Andersson, C. Müller and E. Olsson, "Mapping Fullerene Crystallization in a Photovoltaic Blend: An Electron Tomography Study", in manuscript.

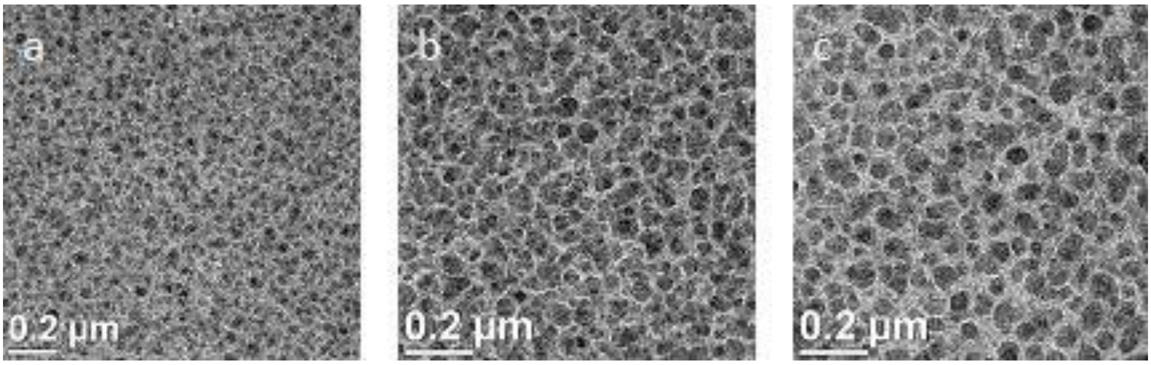

Fig. 1. TEM bright field images of the TQ1/PCBM film (a) before anneal, (b) after anneal at 150 °C for 10 min, (c) after a total anneal of 30 min.

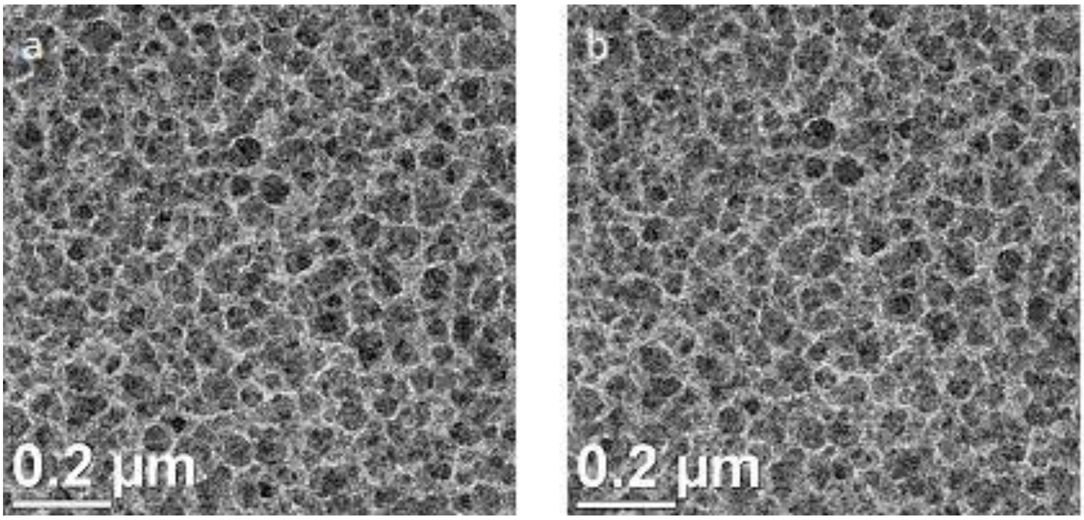

Fig. 2. TEM bright field images of the film; (a) corresponds to Fig. 1b. (b) the same area after annealing at 150 °C for a total time of 20 min .