Here I will discuss the influence of nanoscale morphology – bulk and interfacial - on the J-V characteristics and the efficiency of organic solar cells. In particular, I will discuss our past work on bulk-heterojunction PTB7:PCBM solar cells, where we observed increase in the short circuit current as a result of improved bulk morphology due to diiodooctance (DIO) treatment. We found that DIO treatment reduced trap-assisted recombination in these devices resulting in improved EQE. On the other hand, methanol treatment on similar devices resulted in an increase of the open circuit voltage ($V_{oc}$). Part of this increase in $V_{oc}$ could be explained as a result of improved charge extraction and reduced charge recombination caused by changes in electronic properties at the interface between the photoactive layer and the PEDOT:PSS. Using both spatial and temporal resolution of charge dynamics, we also found evidence for hole accumulation at the electrode on the nanosecond timescale, and show that this can limit charge transport through space charge effects at solar illumination condition.

In the end, I will briefly discuss our efforts in understanding nanoscale evolution of morphology in conjugated polymer thin films from single molecule and local exciton- coupled systems to bulk long-range ordered systems, whereby the photophysical properties such as energy and charge transfer change significantly.