Probing Nanostructures and Optoelectronic Properties of Organic Solar Cells by Conductive and Photoconductive AFM

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Organic solar cells have obtained much attention in both academia and industry because they have the potential to produce low-cost plastic devices for alternative energy sources. In these devices, the performance depends strongly on the nanoscale film morphology and optoelectronic properties; therefore, it is important to control the nanoscale morphology and to probe these properties and correlate to the bulk measurements. We combine conducting and photoconductive atomic force microscopy (c-AFM and pc-AFM) to study nanoscale morphology and device physics of bulk heterojunction solar cells based on small molecules and low band gap conjugated polymers blended with [6,6] phenyl-C71-butyric acid methyl ester. In c-AFM, the conducting probe makes contact with the sample (the tip acts as a nanoelectrode) and measures dark- or photo-current as a function of applied voltage either at certain points on a surface or maps out a current image at a fixed bias. We demonstrated that substantial insight at the nanoscale can be obtained by using the c-AFM: 1) Nanoscale charge carrier transport, 2) Photocharge generation, 3) Assigning donor and acceptor phase separation domains, 4) Mapping donor-acceptor networks, both laterally and vertically, 5) Surface charge distributions, 6) Film quality by examining charge mobility distribution, and 7) Device physics. C-AFM is also employed to study inorganic and peroskite solar cells. The results demonstrate that c-AFM and pc-AFM are powerful techniques to characterize solar cell materials and can be used to understand the bulk performance.