STM Light Emission Spectroscopy on P3HT:PCBM Solar Cell

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Organic thin film solar cells (OSCs) are expected to be light-weighted, flexible, design friendly and cost efficient. Thus, it gathers attention in the development of sustainable energy sources. To maximize the active region for photoelectric conversion, a number of OSCs have complex bulk-hetero junction (BHJ) structures, where the interface between *p*-type and *n*-type semiconductor regions is heavily corrugated during the self-organizing phase separation. In an OSC device, the organic film with BHJ structure is sandwiched by a metal electrode and a transparent electrode. Thus, although the nanoscale corrugation of *p*-*n* interface results in the nanoscale variation of conversion efficiency, all the parts with different efficiency in an OSC are electrically connected in parallel with each other by the outer electrodes. Thus, such nanoscale variations are not observable by an external measurement. To understand the nanoscale variation, however, is crucial for further improvement of conversion efficiency of OSC devices.

To investigate such nanoscale variation of efficiency in OSCs, we applied scanning tunneling microscopy light emission spectroscopy (STM-LES) on a naked OSC thin film without the metal electrode. In our experiment, instead of the planar metal electrode, STM metal tip works as the metal electrode. We inject electrons from the STM tip and holes from bottom transparent planar electrode to investigate the reverse process of an OSC, i.e. light emission by the recombination of electrons and holes in the organic thin film. With STM apparatus, we regulate injection current during measurement. Thus, measured emission intensity distribution reflects emission efficiency, which is supposed to reflect the density of nonradiative carrier recombination sites.

The figure shows the typical STM-LES result on P3HT:PCBM BHJ OSC. The sample is created by spin coating P3HT:PCBM mixed solution in chloroform onto a PEDOT-PSS film on an ITO thin film on a glass substrate and then annealed at 110°C for 10 min in dry nitrogen. Grains with several hundred nanometers dimension found in the STM topograpy are known as P3HT crystals. The emission intensity distribution tends to show smaller intensity at the boundary of the grains. We discuss the origin of the dark spots which are expected also to degrade OSCs' conversion efficiency with recent results at the presentation.

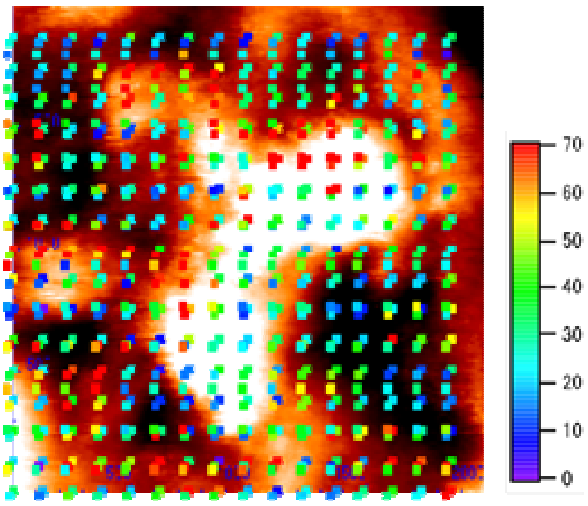

Figure: STM topography and light emission intensity on P3HT:PCBM organic solar cell, 2μm×2μm, emission intensity is in arbitrary unit.