Local Characteristics of P3HT:PCBM Bulk-hetero Junction Organic Solar Cell by Light-Modulated STM/AFM

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Organic Solar Cells (OSCs) have attracted attention because they have advantages such as low production cost, high flexibility, and light weight. A number of OSCs have highly inhomogeneous structures on the microscopic scale, so-called bulk-hetero junction (BHJ) structures. To realize highly power-conversion efficient OSCs, many researchers study solar cells with BHJ structure. In order to further proceed such studies, characterization of BHJ cells on the nanoscale is necessary.

In this study, we applied Light-Modulated I-V spectrum measurement by STM and conductive AFM to a P3HT:PCBM BHJ OSC. This technique is superior for investigating the inhomogeneity in local band characteristics and local power-conversion efficiency of OSCs. For spectrum measurement, the sample is illuminated by a green laser (λ = 532 nm). The laser is electrically chopped synchronously with the STM/AFM scan under the control of a microcomputer. A typical Light-Modulated I-V spectrum is shown in Figure 1. During the I-V curve measurements, the laser illumination is chopped at 100Hz. Therefore, the "raw" I-V curve (red line) oscillates with amplitude, which reflects the alternative half periods under dark and illuminated conditions. By smoothly tracing the top and bottom envelops of the oscillating spectra, we obtain two spectra corresponding to the dark (green curve) and illuminated (blue curve) conditions at the same time at the same position of the sample. Obtained two IV curves reflects the local sample band characteristics and power-conversion efficiencies. In particular, the tunnel current at zero bias voltage corresponds to the short circuit current (Isc) and the bias voltage at which tunnel current becomes zero corresponds to the open-circuit voltage (Voc) of the local region. Figure 2 shows Voc distribution measured by STM and figure 3 shows Isc distribution measured by AFM. It can be seen that Voc and Isc varies with spatial length scale ~100nm. Isc also varies with ~0.5μm (similar to scale of topographic corrugations). In observing OSCs, advantage of contact AFM over STM is capability of keeping the tip-sample distance constant regardless of surface property. Indeed, Isc measurement by STM is affected by variety of tip-sample distance to some extent. On the other hands, advantage of STM over contact AFM is capability of a non-contact measurement. Indeed, soft OSC surface can easily be worn away during a contact AFM measurement. For accurate characterization of BHJ cells on nanoscale, we have to combine the advantages of the two methods.

Ref.: O. Takeuchi, N. Takeuchi, T. Ochiai, H. Kato, S.Yoshida, H. Shigekawa, Appl. Phys. Express 7, 021602 (2014)

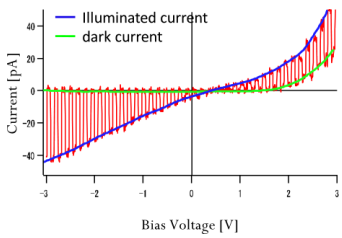

Figure 1: Typical Light-Modulated I-V spectrum.

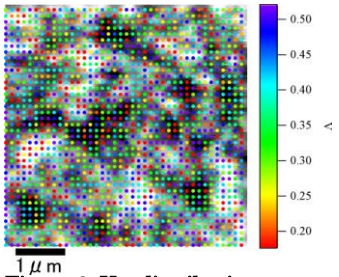

Figure 2: Voc distribution measured by Light-Modulated STM.

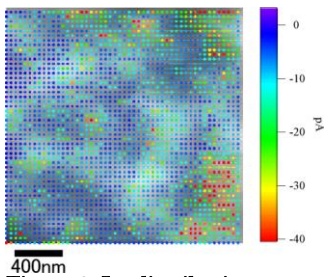

Figure 3: Isc distribution measured by Light-Modulated AFM.