Nanoscale Evaluation of Organic Solar Cells by Light-Modulated Scanning Tunneling Microscopy

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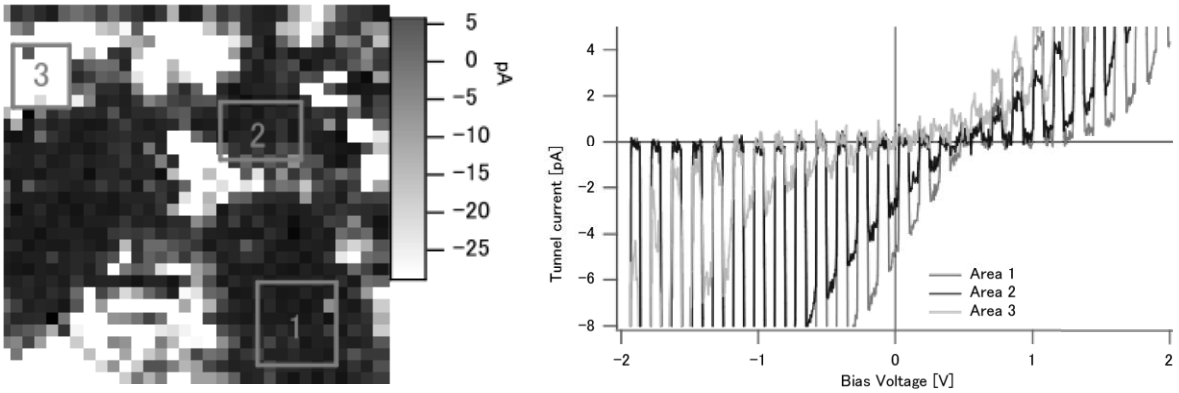
Unlike conventional single-crystal silicon cells, the next-generation solar cells, such as organic paint solar cells and CIGS and other thin-film cells, have highly inhomogeneous structures on the microscopic scale. Thus, some regions of such a cell have larger power-conversion efficiency than other regions. The inhomogeneous regions are, however, all connected in parallel when they operate. So, in order to increase the external efficiency of such cells, understanding and controlling the microscopic inhomogeneity is essential.

It is shown that the light-modulated scanning tunneling spectroscopy (LM-STS) method [1] is superior for investigating the inhomogeneity in local band characteristics and local power-conversion efficiency of the next-generation solar cells. As a first demonstration, [6,6]-PCBM and MDMO-PPV bulk-hetero-junction cells were investigated. In the LM-STS measurement, the sample surface under STM observation is intermittently illuminated by a super-bandgap laser light (400 nm), which is periodically switched on and off at ~100 Hz, while the conventional STS measurement is done. The obtained STS spectra show rectangular-wave-like oscillation reflecting the period of dark and illuminated conditions. By smoothly tracing the top and bottom envelop of the oscillating spectra, we can obtain two STS spectra corresponding to the dark and illuminated 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 efficiency. In particular, the tunnel current at zero bias voltage corresponds to the short circuit current and the bias voltage at which tunnel current becomes zero corresponds to the open-circuit voltage of the local region. At the presentation, we discuss the relationship between the local efficiency measured by LM-STS and the external efficiency of the cell device.

[1] O. Takeuchi, S. Yoshida and H. Shigekawa, Appl. Phys. Lett. 84, 3463 (2004).



Left: Tunnel current image under dark condition clearly shows the PCBM clusters floating in the MDMO-PPV matrix. Right: Three LM-STS spectra are shown which correspond to the three areas in the left image.