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Direct Observation of Space Charge Dynamics in an Oxide Based Solar Cell Using Kelvin Probe Force Microscopy

The way of charge carrier generation and trapping processes are a subject of intense research in many third-generation solar cell materials.[1] Charge transfer dynamics at interfaces of the active layers inside the solar cell are essential to know the mechanism of photovoltaic processes. The internal potential in solar cell devices depends on the basic processes of photovoltaic effect, such as charge carrier generation, separation, transport, recombination etc. Here we report the direct observation of the surface potential depth profile over the cross-section of the ZnO nanorods/Cu_2O based solar cell at different wavelengths of light using Kelvin probe force microscopy. It is a well-established technique used to characterize the nano-scale electronic/electrical properties of metal/semiconductor surfaces and semiconductor devices.[2-3] The topography and phase images across the cross-section of the solar cell are also observed, where the interfaces of the different layers in the device are well defined in nanoscale range. We have plotted the contact potential difference (CPD) profiles across the cross-section of the device and correlated the measured potentials with the material interface positions in the device. The potential profiling results demonstrate that under white light illumination, the photo induced electrons in Cu_2O inject into ZnO due to the interfacial electric field resulting to the large difference in surface potential between two active layers. Whereas, under a single wavelength (UV, Green and Red) illumination condition, the charge carrier generation, separation and transport processes between two active layers are limited which affect on the surface potential images and corresponding potential depth profiles (shown in Figure 1).[4] These results provide the clear idea about the charge carrier distribution inside the solar cell in different conditions and show the perfect illumination condition for large carrier transport in a high performance solar cell.

References

[1] D. Bozyigit, W. M. M. Lin, N. Yazdani, O. Yarema, V. Wood, Nat. Commun., 6 (2015) 6180(1-10).

[2] C. Maragliano, S. Lilliu, M. S. Dahlem, M. Chiesa, T. Souier, M. Stefancich, Sci. Rep, 4 (2014) 4203-4209.

[3] J. B. Li, V. Chawla, B. M.Clemens, Adv. Mater. 24 (2012) 720-723.

[4] S. Panigrahi, T. Calmeiro, R. Martins, D. Nunes, E. Fortunato, ACS Nano 10 (2016) 6139–6146.

Figures

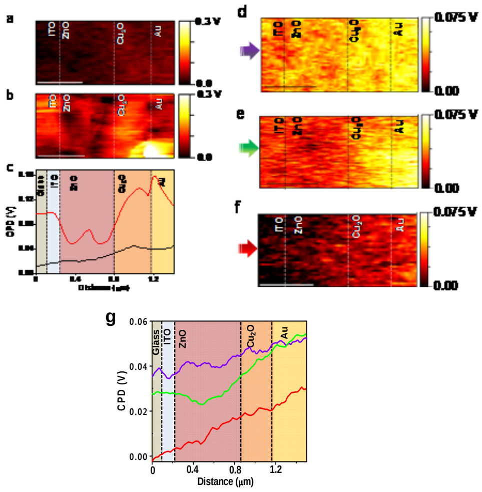

Figure 1: Surface potential images of the ITO/ZnO/Cu_2O/Au device under (a) dark and (b) white light illumination, respectively (Scale bar, 500 nm). (c) Potential depth profiles of the device under dark (black line) and white light illumination (red line), respectively. Surface potential images of the device under (d) UV (λ = 365 nm), (e) green (λ = 505 nm) and (f) red (λ= 660 nm) light illuminations, respectively (Scale bar, 500 nm). (g) Potential depth profiles of the device under UV, green and red light illuminations, respectively.