Inorganic nanostructured solar cells

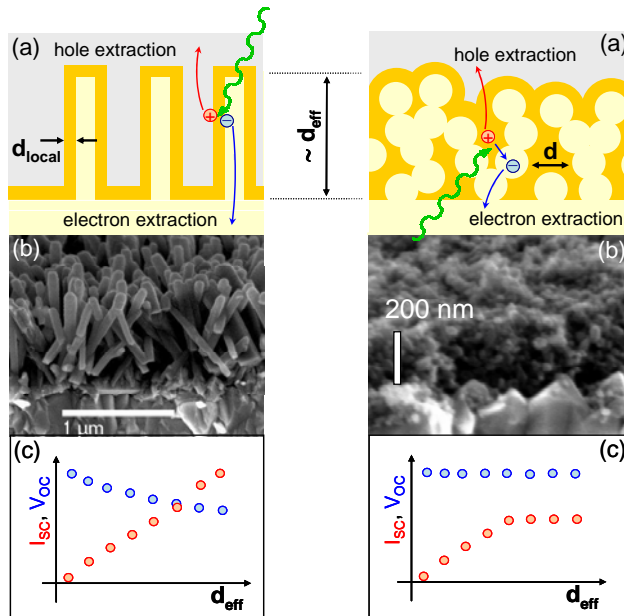Th. Dittrich[*], M. Lux-Steiner

Helmholtz-Centre Berlin for Materials and Energy, Glienicker Str. 100, D-14109 Berlin, Germany,
e-mail: dittrich@helmholtz-berlin.de
* Corresponding author.

Abstract – The realization of low-cost solar cells depends on the realization of low processing temperatures. The diffusion length of photo-generated charge carriers in the absorber material is one of the most important parameters for solar cells. Low temperature processes result usually in very low diffusion lengths of inorganic absorbers. Nanostructures can help to overcome problems with the diffusion length. Here we compare the concepts of inorganic solid state solar cells with extremely thin absorber and ultra-thin nanocomposite absorber on the examples of ZnO-nanorod/In_2S_3/CuSCN and nanoporous-TiO_2/In_2S_3/CuSCN systems.

Figures 1(a) and 2(a) show the schematic cross sections of solar cells with extremely thin absorber (eta) and with ultra-thin nanocomposite absorber, respectively. The extremely thin absorber is folded following the morphology of a template, for example the surface of a ZnO nanorod array (fig.1(b)). The nanocomposite absorber consists of a nanoporous matrix, for example of interconnected TiO_2 nanoparticles (fig.2 (b)), with an absorbing material filling the pores completely. The local absorber layer thickness (d_{local}) has to be larger than the tunneling length between the electron and hole extracting contacts but less than the transport or diffusion length of photo-generated charge carriers. The pore size of the nanoporous matrix has to be less than half of the transport length in the absorbing material. The nanocomposite absorber can be considered as an effective absorber layer with its own diffusion length. The diffusion length of the nanocomposite absorber can be much larger than the transport length of the absorber material due to local charge separation and separate percolating transport paths for electrons and holes. The short circuit current (I_{SC}) of the eta solar cell scales with the surface area of the template, i.e. d_{eff} (fig.1.(c)). I_{SC} of the nanocomposite absorber solar cell is limited by the diffusion length, i.e. I_{SC} saturates for large values of d_{eff} (fig.2(c)). Recombination increases with increasing area of the limiting contact. Therefore, the open circuit voltage (V_{OC}) may not increase or even decrease with increasing d_{eff} for eta solar cells or solar cells with nanocomposite absorbers (fig.1 (c), 2 (c)).

Small area solar cells with extremely thin In_2S_3 absorber based on ZnO nanorod-arrays [1,2] and with ultra-thin TiO_2/In_2S_3 nanocomposite absorbers [3] as model systems were realized to demonstrate the basic dependencies of I_{SC} and V_{OC} on d_{local} and on d_{eff}. CuSCN was used as the hole extracting contact. The transport length of the wet chemically prepared In_2S_3 absorber was of the order of 20-30 nm whereas the diffusion length of the nanocomposite absorber increased by about one order of magnitude. The hole extracting contact is the critical one in the investigated systems. Possible measures to increase the energy conversion efficiency as well as the opportunity to implement absorbing semiconductor nanoparticles will be discussed.

Figure 1: a) Schematic cross section of a solar cell with extremely thin absorber. **b)** Electron microscopy cross section of a ZnO nanorod array with a 30 nm thick In_2S_3 coating. **c)** Principle dependencies of the short circuit current and of the open circuit voltage on the effective layer thickness.

Figure 2: a) Schematic cross section of a solar cell with ultra-thin nanocomposite absorber. **b)** Electron microscopy cross section of a nanoporous TiO_2 layer. **c)** Principle dependencies of the short circuit current and of the open circuit voltage on the effective layer thickness.

References

[1] D. Kieven, T. Dittrich, A. Belaidi, J. Tornow, K. Schwarzburg, N. Allsop, and M. Lux-Steiner, Appl. Phys. Lett. 92 (2008) 153107.
[2] A. Belaidi, T. Dittrich, D. Kieven, J. Tornow, K. Schwarzburg, and M. Lux-Steiner, phys. stat. sol. (RRL) 2 (2008) 172.
[3] C. Herzog, A. Belaidi, A. Ogacho, and T. Dittrich, submitted to Energy & Environmental Science.