Some Perspectives on Quantum Dot Sensitized Solar Cells

Iván Mora-Seró*

Photovoltaic and Optoelectronic Devices Group, Departament de Física, Universitat Jaume I, 12071 Castelló, Spain.

*Corresponding author: sero@fca.uji.es

With energy conversion efficiencies in continuous growth, quantum dot sensitized solar cells (QDSCs) are currently under an increasing interest. The current efficiencies of semiconductor-sensitized solar cells (SSCs) have reached over 6% efficient, under full 1 sun illumination, which makes inorganic semiconductor materials a serious alternative to molecular sensitizers. QDSCs using a liquid electrolyte as hole conductor, have reached 6.54% efficiency.[1] The efficiencies of liquid sensitized solar cells remain sensibly lower than their counterparts using molecular dye sensitizers (DSCs) with 12% efficiency, but the former presents a much faster increase than the later. On the other hand, for all-solid sensitized devices the gap between QDSCs and DSCs has been exceeded, showing in both cases efficiencies around 6%.[2, 3] It is expected that these efficiencies are overcome in the near future as there is still plenty room to increase QDSCs performance, as they are not fully optimized.[4, 5] The design of these cells have followed the previous designs on dye sensitized solar cells, but the charge of the light absorbing material requires a new paradigm.

Here, we compile some perspectives for further development of QDSCs in order to attain higher efficiency and stability. We will focus on alternative hole conductor materials as sulfide/polysulfide based ionic liquids[6] and all-solid semiconductor sensitized solar cells.[7, 8] Further development of QDSCs will require long-term stability. We report a robust S^{2-}/S_n^{2-} electrolyte that has been specifically designed for compatibility with CdSe quantum dots in sensitized solar cells. The new pyrrolidinium ionic liquid reaches 1.86% efficiency and a short-circuit current close to 14 $mA \cdot cm^{-2}$ under air-mass 1.5 global illumination and improves the device lifetime with good photoanode stability over 240 h. Photovoltaic characterization showed that the solar cell limitations relate to poor catalysis of regeneration at the counter electrode and high recombination. Further improvement of these factors in the robust electrolyte configuration may thus have a significant impact for advancing the state-of-the-art in QDSCs.

All-solid SSCs present the highest potentiality for this kind of devices, but there is an absence of a complete model for these cells. We have analyzed all-solid SSCs using the promising Sb_2S_3 semiconductor as light absorbing material. We have analyzed cells with different hole conductor material (CuSCN and P3HT), studying the hole transport and cell recombination processes and how they affect the cell performance. The current limitations of these devices are determined and further ways to enhance cell performance discussed. The recombination rate of the nanostructured TiO_2/Sb_2S_3/CuSCN cell is much higher than the blank TiO_2/CuSCN cell, indicating an active role of Sb_2S_3 in the recombination process. In liquid cells, the Sb_2S_3 also shows higher recombination rate than bare TiO_2, or TiO_2 sensitized with CdS semiconductor or the

N719 molecular dye. The improvement of the quality of Sb_2S_3 coating, the use of alternative structures for the TiO_2 electrodes, or the application of surface treatments could be some options reduce such recombination loss.[7]

The high extinction coefficient of inorganic semiconductor absorber should allow the reduction of the film thickness, improving the photovoltage. Here we present all-solid semiconductor sensitized solar cells. Flat and nanostructured cells, Fig. 1a and b, have been prepared and analyzed, developing a cell performance model, based on impedance spectroscopy results, that allows us to determine the impact of the reduction of metal oxide film thickness on the operation of the solar cell. Decreasing the effective surface area toward the limit of flat samples produces a reduction in the recombination rate, increasing the open circuit potential, Voc, while providing a significant photocurrent, Fig. 1c. However, charge compensation problems as a consequence of inefficient charge screening in flat cells increase the hole transport resistance, lowering severely the cell fill factor. The use of novel structures balancing recombination and hole transport will enhance solid sensitized cell performance.

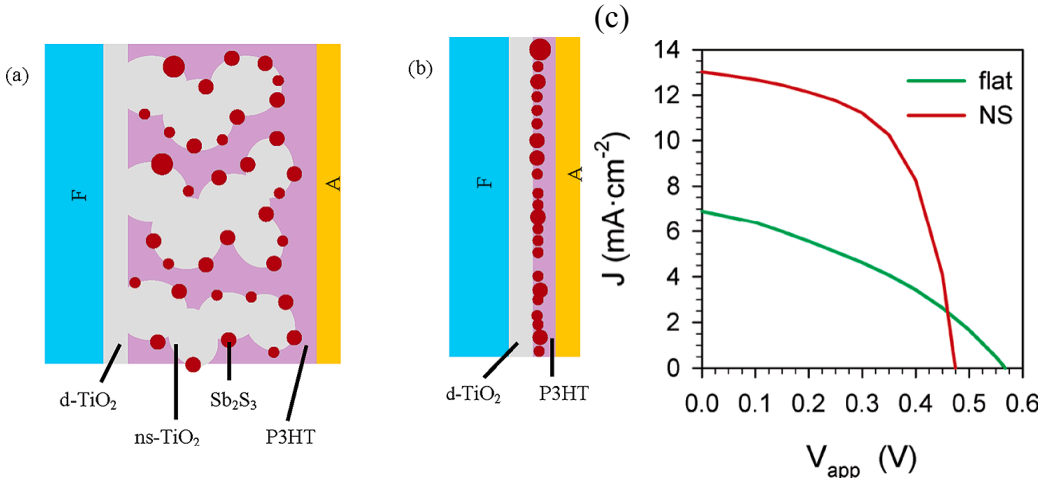

Fig. 1: Schematic illustration of device structures for (a) nanostructured and (b) flat cell. Abbreviations: d, dense; ns, nanostructured; P3HT, poly-3-hexylthiophene. (c) Current_voltage curve extracted from impedance spectroscopy measurements for flat and nanostructured configurations, under 1 sun (1.5 a.m. G) illumination.[8]

On the other hand, the use of different absorbing materials at the same time in a single sensitized electrode is also analyzed. The potentialities of these absorber combination are described, as the increase of the light absorption range and the recombination reduction by a synergic coupling between absorbers.

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