Surface Photovoltage Spectroscopy (SPS): A useful Tool for the Detection of Charge Carrier Injection Processes in Extremely Thin Absorber (ETA) solar cells

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INTRODUCTION

The concept of ETA solar cells is closely related to the concept of dye-sensitized solar cells. In dye-sensitized solar cells[1] the light absorption is achieved by a monolayer of a molecular dye (organic or metalorganic), adsorbed at the surface of a mesoporous n-type semiconductor film (typically TiO_2). In ETA solar cells[2] the molecular dye is replaced by an extremely thin (approx. 3-10 nm) layer of an inorganic pigment, such as Cu_2S or $CuInS_2$ (fig. 1a). The photovoltaic effect in this type of solar cell is due to charge carrier injection from the absorber layer into the contacting n- and p-type layers respectively (fig. 1b) upon excitation by incident photons. These injection processes can be considered as the heart of such type of injection solar cells. The investigation of charge carrier injection for a given interface is therefore crucial. In this contribution, we show that Surface Photovoltage Spectroscopy (SPS) can provide useful information on charge carrier injection at ETA-interfaces.

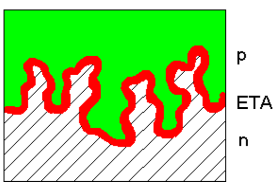


Fig. 1a: ETA-cell (schematic)[2]

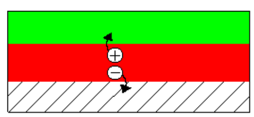


Fig. 1b: photovoltaic effect

METHOD

Kelvin probe (KP) and SPS are traditionally used for the characterization of semiconductors, yielding information about electrical properties such as work function, bandgap, semiconductor type and defects.
Recently we have shown that SPS can also be used for the detection of electron injection in dye-sensitized solar cells and this proved to be useful for the elucidation of mechanistic details of electron injection in these devices[3].

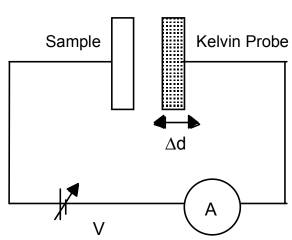


Fig. 2: Equivalent electronic circuit for KP-measurements

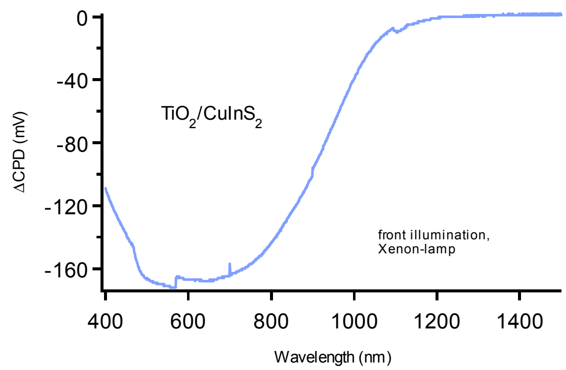
EXPERIMENTAL

Materials
- Nanocrystalline oxide films (~5µm):
  TiO_2 (100 m^2/g), ZrO_2 (120 m^2/g), SnO_2 (70m^2/g),
  Flat TiO_2 (sprayed) as model.
- Dye:RuL_2 $(NCS)_2$, L = 2,2'-bipyridyl-4,4'-dicarboxylic acid = N3
- Pigments: PbS (quantum sized)[4], $CuInS_2$[5]

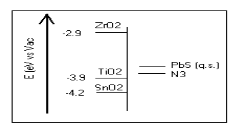
Measurement Parameters:
- Ambient conditions
- Front/back side illumination (as specified)
- Scan rate 1nm/s
- Xenon lamp 350 W or Tungsten-Halogen , 250 W (as specified)

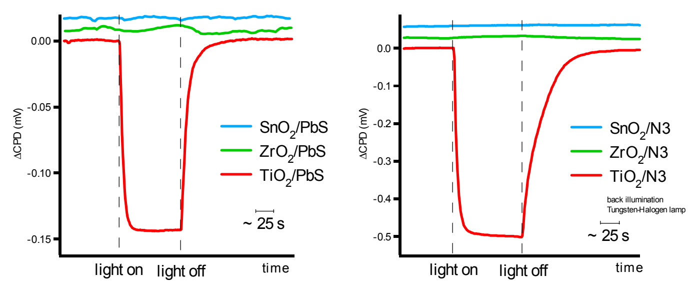
RESULTS

1) Determination of the spectral sensitivity using SPS



2) Monochromatic On/Off Measurements (at 600 nm)





DISCUSSION / CONCLUSIONS

- SPS can indeed be used for the detection of electron-injection at ETA-interfaces (for dye-sensitized interfaces this has been shown before[3]).
- $CuInS_2$ and PbS both appear to be suitable ETA-pigments for TiO_2, as can be concluded from the observation of the photovoltage signals in the SPS experiments.
- The possibility to detect electron injection by SPS depends both on the position of the relative energy levels of the involved materials and the interface kinetics.
- The evolution of the signals with time allows to extract information about charge carrier recombination dynamics across the interface.

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