

Some problematic practical aspects of semiconductor-sensitized, nanoporous solar cells

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Semiconductor-sensitized, nanoporous solar cells are the semiconductor-sensitized analogue of the dye-sensitized solar cell (DSC). The extremely Thin Absorber (ETA) cell is commonly used for solid state versions of these cells. The nanoporous electron conductor is normally TiO_2 or (commonly-used for ETA cells) ZnO ; a range of semiconductor absorbers; and usually CuSCN as the solid hole conductor or a range of electrolytes for liquid junction cells. Solar conversion efficiencies of between 3 - 4% have been measured for several different cell types.

There are a number of issues that often arise in these cells that, while poorly understood at present, are important both in obtaining good cells and in meaningful measurement of their performance.

ETA cells using different absorbers on TiO_2 often require a solution treatment with an aqueous SCN^- salt before CuSCN deposition: In the absence of this treatment, the cells are invariably much poorer than with it [1-3]. We have also recently found this treatment to be important for $\text{ZnO}/\text{CdS}/\text{CuSCN}$ cells. I-V measurements clearly show that the SCN^- treatment reduces the cell resistivity, but the mechanism of this effect is not understood, although it is believed to be associated with the CuSCN hole conductor.

The cells also usually improve with aging (storage), although the details of this improvement depend on the cell structure. Again, although the mechanism of the aging is not known (some possibilities have been suggested by O'Regan et al. for CuSCN -based dye cells [4]), it may well be connected with the CuSCN .

Because of the nanoporous structure of the cells, particular care has to be taken with both current-voltage and spectral response measurements. RTA cells are often completed by evaporating a small, area-defined Au contact on the hole conductor. However, the relatively high (in some cases, very high) lateral conductivity that can occur in these cells means the real area of the cell can be larger than the Au contact. As an extreme example of this, for $\text{TiO}_2/\text{Cu}_2\text{S}/\text{CuSCN}$ cells, with a 2 mm diameter Au contact, the current extracted from that Au contact was over 20 times greater than when the cell was measured with a mask the size of the contact. Scribing the cell around the Au contact, which disconnects the scribed portion from other parts of the cell (except for the conducting glass contact), solves this problem. Small but sometimes appreciable inaccuracies can arise from waveguiding of scattered light through the side of the relatively thick (2.2 mm) conducting glass; this is most relevant for real sunlight measurements where there is considerable scattered light, and the effect will be greater as the cell size decreases.

While these geometric and optical effects on cell measurements can be well understood, this is much less the case for quantum efficiency measurements (in contrast to most conventional solar cells). Expected short circuit currents in sunlight can, in principle, be calculated from spectral response quantum efficiency data. However, we find that often there is no correlation between the two measurements. Part of this can be attributed to light intensity dependences of the photocurrent. A well-known example of this for nanoporous TiO_2 is that electron transport rate in the TiO_2 increases as the light intensity increases and traps are

gradually filled. This effect can be minimized by DC (white light) illumination and low frequency monochromatic light chopping. However, even with these precautions, inconsistencies between spectral response and full illumination measurements can occur.

Finally, some consideration will be given to common measurement errors in liquid junction cells (both 2-electrode and 3-electrode cells) which can either underestimate or overestimate the real efficiencies, sometimes by a factor of many times. These errors apparently occur due to a lack of understanding of basic electrochemistry and should be readily preventable.

References

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