

# Excitonic Solar Cells: $\text{Sb}_2\text{S}_3$ and lead halide perovskite heterojunction solar cells

Lioz Etgar

Institute of Chemistry, The Harvey M. Krueger Family Center for Nanoscience and Nanotechnology, Casali institute of applied chemistry, The Hebrew University of Jerusalem, Israel.

Conventional p-n junction solar cells, currently employed for energy production, face unavoidable efficiency limits, due to thermodynamic and optical constraints; some of these limits are reduced by thin-film and tandem cells<sup>i</sup>, but with a considerable increase in production costs. The so-called third generation solar cells, researched since the mid 1990s and presently tested in some benchmark applications, exploit an entirely different approach.<sup>ii</sup>

In excitonic solar cells (XSCs), when light is absorbed, it results in the production of localized excited state that cannot thermally dissociate (binding energy  $kT$ ) in the chemical phase in which it was formed.<sup>iii</sup> The thermodynamic requirement for an exciton to dissociate at an interface is that the band offset must be greater than the exciton binding energy. XSCs include molecular semiconductor solar cells, conducting polymer solar cells, dye-sensitized solar cells (DSSCs), and quantum dot solar cells. In all these, the photoconversion mechanism is fundamentally different from that in conventional solar cells. In some respects, XSCs closely resemble DSSCs<sup>iv</sup> (or Grätzel-type solar cells). DSSCs are based on mesoscopic injection devices that mimic the principles used by photosynthesis throughout the past 3.5 billion years in solar conversion, separating the two functions of solar light harvesting and charge carrier transport (whereas conventional cells perform both operations simultaneously, with stringent demands on the purity of materials and much higher production costs).

## **Effect of Interfacial Engineering in Solid-state nanostructured $\text{Sb}_2\text{S}_3$ heterojunction solar cells.**

Solid-state nanostructured inorganic-organic heterojunction solar cells were made using  $\text{Sb}_2\text{S}_3$  as a light-absorber layer on nanoporous  $\text{TiO}_2$  film, while Poly-3-hexylthiophene (P3HT) was used as an organic hole-transporting material. It was observed that surface treatment by Decyl-phosphonic acid (DPA) could reduce the recombination inside the  $\text{Sb}_2\text{S}_3$  heterojunction solar cell. The DPA effect was studied

by impedance spectroscopy, the recombination resistance shows a clear increase in the DPA treated cells while the capacitance stays nearly unchanged. The inorganic-organic heterojunction solar cell produces a short circuit photocurrent ( $J_{sc}$ ) of 14.2 mA/cm<sup>2</sup>, an open circuit photovoltage ( $V_{oc}$ ) of 0.51 V and a fill factor (FF) of 0.53, corresponding to a light to electric power conversion efficiency ( $\eta$ ) of 3.9% under 1 sun intensity.

### **Mesoscopic CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub>/TiO<sub>2</sub> heterojunction solar cells**

Lead halide perovskites have direct band gap, large absorption coefficients and high carrier mobility which present good potential for their use as light harvesters in mesoscopic hetero-junction solar cells.

Hole conductor-free mesoscopic methylammonium lead iodide CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub>(perovskite)/TiO<sub>2</sub> heterojunction solar cell, produced by deposition of perovskite nanoparticles from a solution of CH<sub>3</sub>NH<sub>3</sub>I and PbI<sub>2</sub> in  $\gamma$ -butyrolactone on a 400nm thick film of TiO<sub>2</sub> (anatase) nanosheets exposing (001) facets. An Au film was evaporated on top of the CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub> as a back contact. Importantly, the CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub> nanoparticles assume here simultaneously both the role of light harvester and hole conductor, rendering superfluous the use of an additional hole transporting material. The simple mesoscopic CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub>/TiO<sub>2</sub> heterojunction solar cell shows impressive photovoltaic performance with short circuit photocurrent ( $J_{sc}$ ) of 16.1 mA/cm<sup>2</sup>, an open circuit photovoltage ( $V_{oc}$ ) of 0.631 V and a fill factor (FF) of 0.57, corresponding to a light to electric power conversion efficiency (PCE) of 5.5% under standard AM 1.5 solar light of 1000 W/m<sup>2</sup> intensity. At a lower light intensity of 100W/m<sup>2</sup> a PCE of 7.3 % was measured. The advent of such simple solution processed mesoscopic heterojunction solar cells paves the way to realize low cost, high-efficiency solar cells.

---

<sup>i</sup> Colsmann, A.J., J.; Kayser, C.; Uli Lemmer. Organic tandem solar cells comprising polymer and small-molecule subcells. *Appl. Phys. Lett.*, 2006. 89: p. 203506.

<sup>ii</sup> Graetzel, M. Dye sensitized solar cells. *Journal of Photochemistry and Photobiology C: Photochemistry Reviews*, 2003. 4: p. 145-153.

<sup>iii</sup> Brian A. Gregg. Excitonic Solar Cells. *J. Phys. Chem. B* 2003, 107, 4688-4698

<sup>iv</sup> Grätzel, M. Photoelectrochemical cells. *Nature*, 2001. 414.