Materials, Electronics and Renewable Energy

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• Nanostructured solar cells
• Beyond the Shockley-Queisser limit
‘Dispersed Interface’ Photovoltaics

‘mixed’ polymers generally phase-separate due to low entropy of mixing – spinodal decomposition

Fine structure in F8BT-PFB blends:

High Resolution Atomic Force Microscopy

Structure on many length scales

Sub-20nm structure most important for device operation
Dye-sensitised solar cells

Dye = Ru(dcbpy)$_2$(NCS)$_2$
Carboxylates result in self-assembly as monolayer on TiO$_2$ film.
Current DSSC Status:

- Best lab device efficiency 12%
- Stable devices 5-8%
- Trade off between efficiency, stability and processability
  - Replacing liquid electrolyte with less volatile materials (polymer electrolytes, molecular hole semiconductors, ionic liquids)
  - Interface engineering: redox cascades, barrier layers etc.

Fabrication on metal foils for consumer products
First factory (30 MWp/yr) on line early 2007 in Cardiff, UK
[http://www.g24i.com/](http://www.g24i.com/)

Prototype building integrated DSSC
Toyota, Japan

Inorganic Semiconductor Nanoparticles

Luminescence
(CdSe with ZnS shells)

Increasing diameter
- Quantum confinement
- Particle-in-a-box

- Use as electron acceptor in polymer solar cell
Nanocrystal shape control

- Best power conversion efficiencies ~ 3%

Beyond the Shockley-Queisser Limit:

Tandem cells:

Use stack of cells, grading band-gap from highest at incident light surface (with highest $V_{oc}$) to lowest at back of cell. Practical structures require diodes to be wired in series, so balancing photocurrents from these tandem cells is necessary.

Best results with III-V semiconductors, with demonstrated efficiencies above 33%

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Lattice-matched III-V semiconductor growth reduces defects at boundaries.

Example: 2-cell stack [Takamoto et al, Appl. Phys. Lett. 70, 381 (1997)]

$In_{0.5}Ga_{0.5}P$ top cell – band gap near 1.9 eV

GaAs bottom cell – band gap 1.45 eV

Note: expensive to make – ok for space satellites….

Also possible (easier?) with organics – see J. Y. Kim et al., Science 317 222 (2007)
Beyond the Shockley-Queisser Limit:

**Multiple charge pair generation:**

One photon to produce multiple e-h pairs? Very inefficient in bulk materials, due to energy and momentum conservation. Possible in nanoparticles, where k conservation is relaxed?

**Multiple exciton generation in quantum dots:** Evidence for multiple exciton generation in nanocrystals of e.g. PbS


Not yet proven that the extra carriers can be extracted in a solar cell.