The University Of Sheffield.

EPSRC
Engineering and Physical Sciences Research Council

Organic Photovoltaic Solar Cells

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08 June 2010

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E-Futures

Outline

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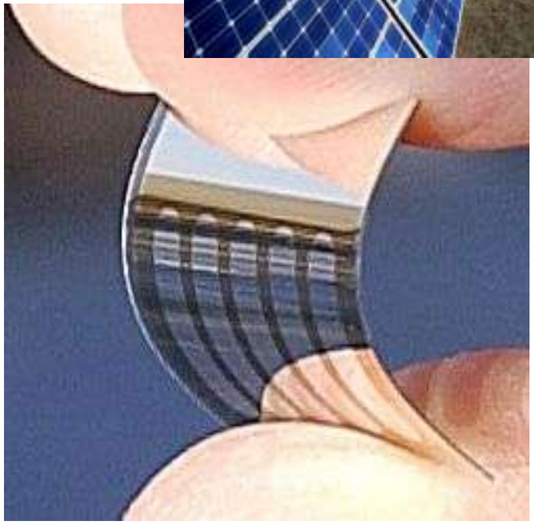
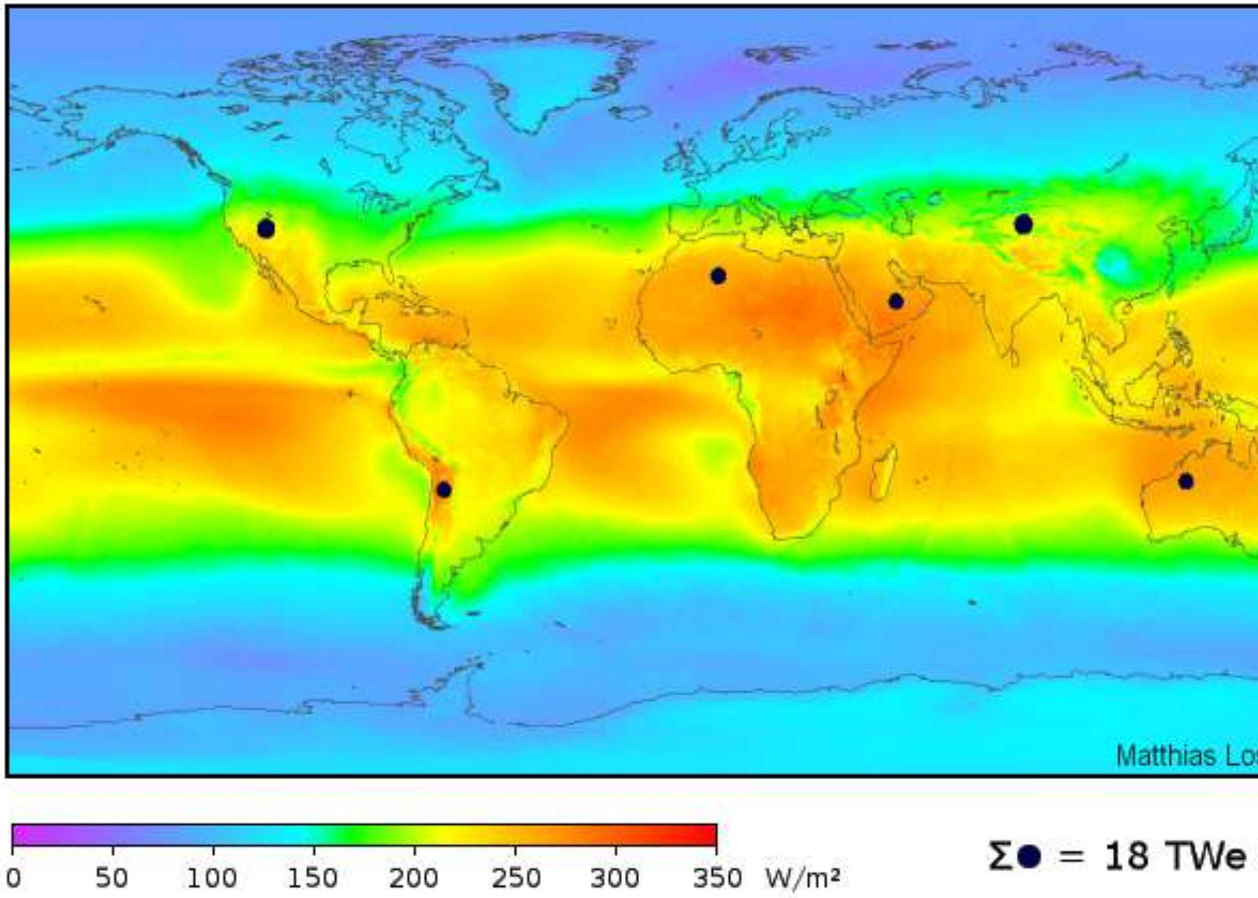
- Sheffield Solar Farm



Solar Power

- The sun provides most of the energy required to drive the Earth's natural systems.
- Most sources of energy come directly or indirectly from the sun
- The amount of energy intercepted from the sun at the outer limits of the atmosphere is 1367 W/m^2
- Due to clouds, particles, water vapour and pollution, only part of this will reach the Earth's Surface

Solar Power



Photovoltaic Technology

- Photovoltaic technology is a potential solution for decreasing the world's reliance on fossil fuels

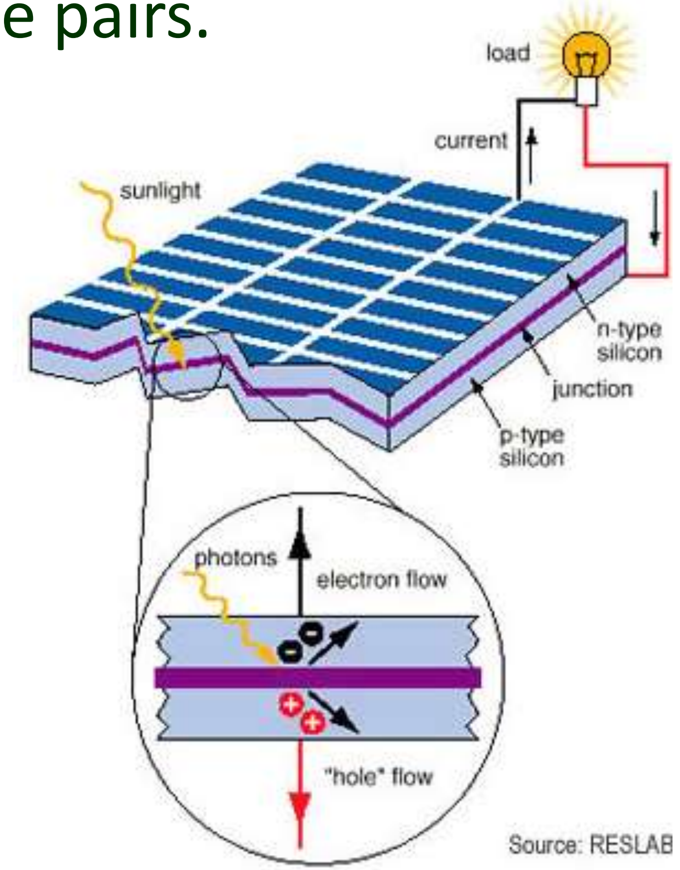
usgreenenergycenter.com

- Photovoltaics provide an efficient way to convert the energy from the sun directly into electricity

www.bp.com

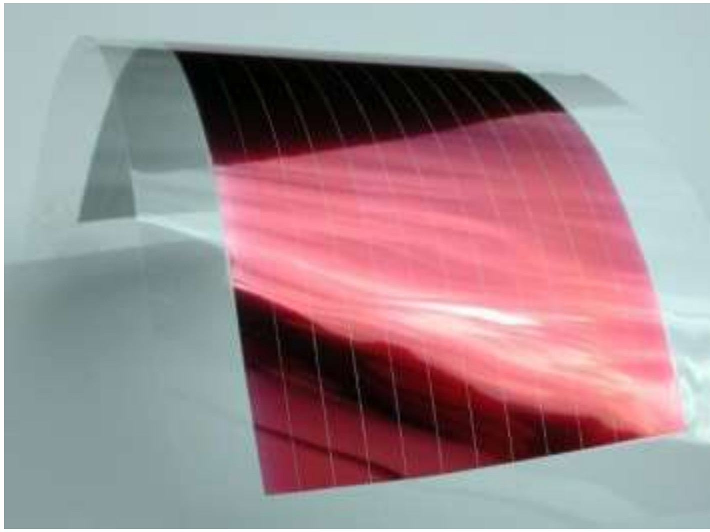
Photovoltaic Technology

- When photons from the sun hit a cell, they are absorbed and create electron-hole pairs.
- The electrons and holes are attracted to electrodes at opposite surfaces of the semiconductor, creating a potential difference, and electricity can be generated



Introduction to OPVs

Traditional solar panels are energy-intensive and costly to manufacture.



Pros

- Organic polymers cost-effective, flexible and lightweight
- Can be solution-processed – ultimate aim is roll-to-roll fabrication

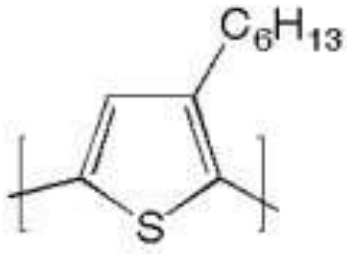
Cons

- Lifetime of OPVs is not yet established
- Need to increase speed of charge generation and extraction

Materials

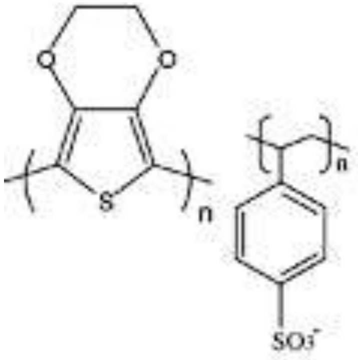
Materials commonly used in OPVs are:

- P3HT –electron donor, hole-transport material
- PCBM – electron acceptor, a fullerene derivative
- PEDOT:PSS – hole-transport (electron-blocking) layer



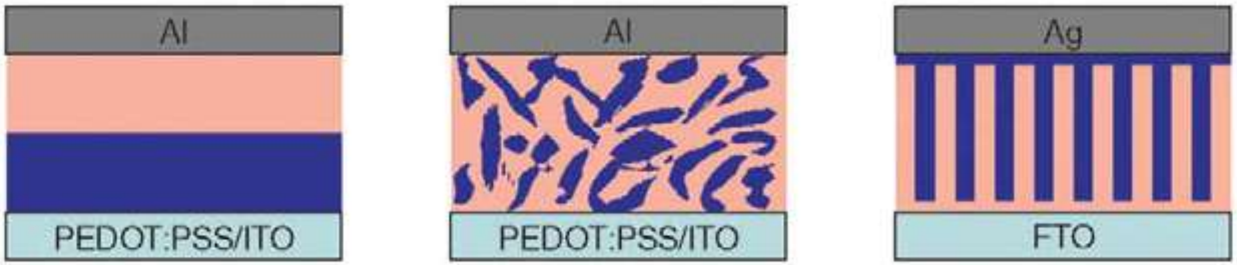
P3HT Poly(3-hexylthiophene)

PCBM [6,6]-phenyl-C61-butyric acid methyl ester



PEDOT:PSS Poly(3,4-ethylenedioxythiophene) : Poly(styrenesulphonate)

Junctions

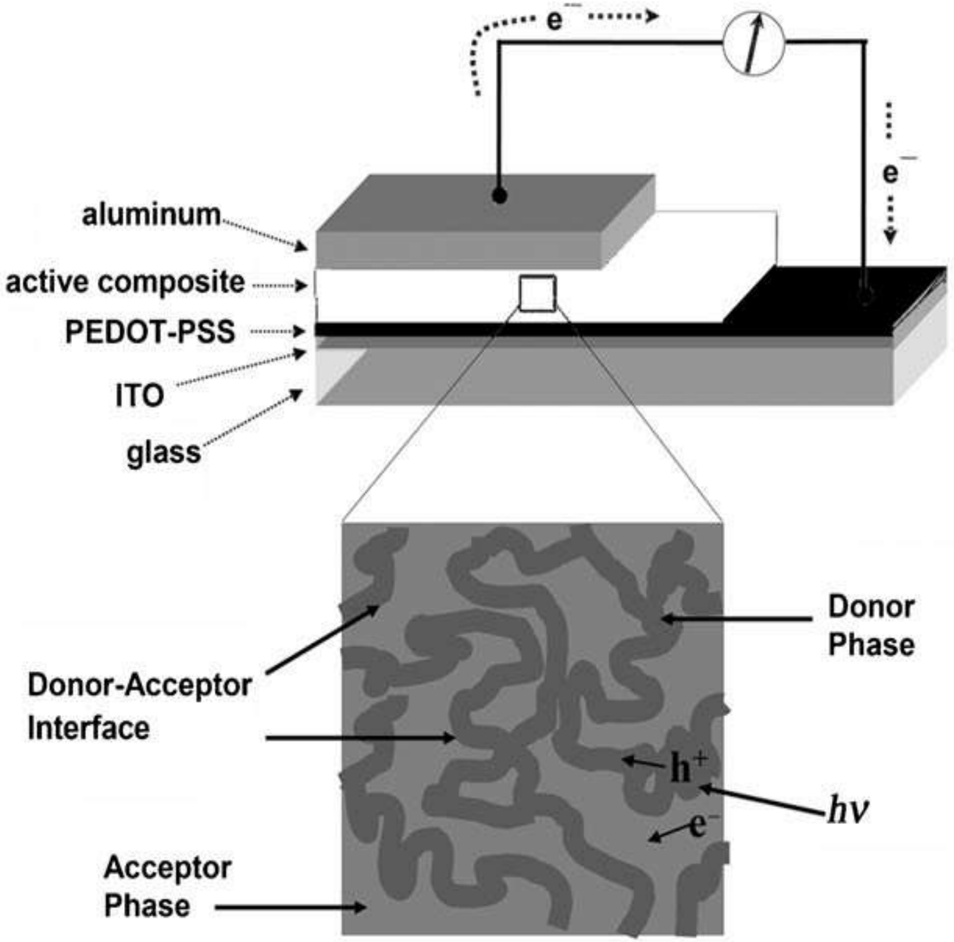


Planar Bulk Ordered

The distance between P3HT and PCBM is crucial to achieving a current.
A blended composite of P3HT and PCBM is used to create a bulk heterojunction.
The two components phase-segregate and allow charge transport pathways between electrodes.

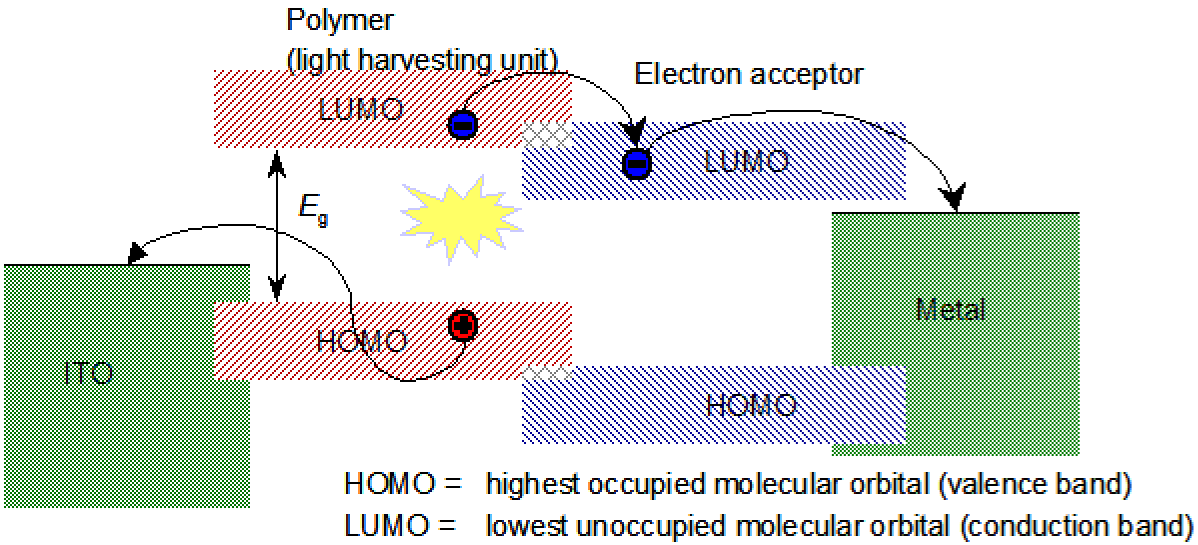
Cell Assembly

1. Remove protective photoresist from ITO-covered glass substrate.
2. Spin-coat with hole-transport layer (usually PEDOT:PSS, ~70 nm). Thermal anneal.
3. Spin-coat with active layer (P3HT:PCBM, 100-300 nm). Solvent anneal.
4. Deposit Aluminium cathode by evaporation.
5. Encapsulation.



Dopant Effect

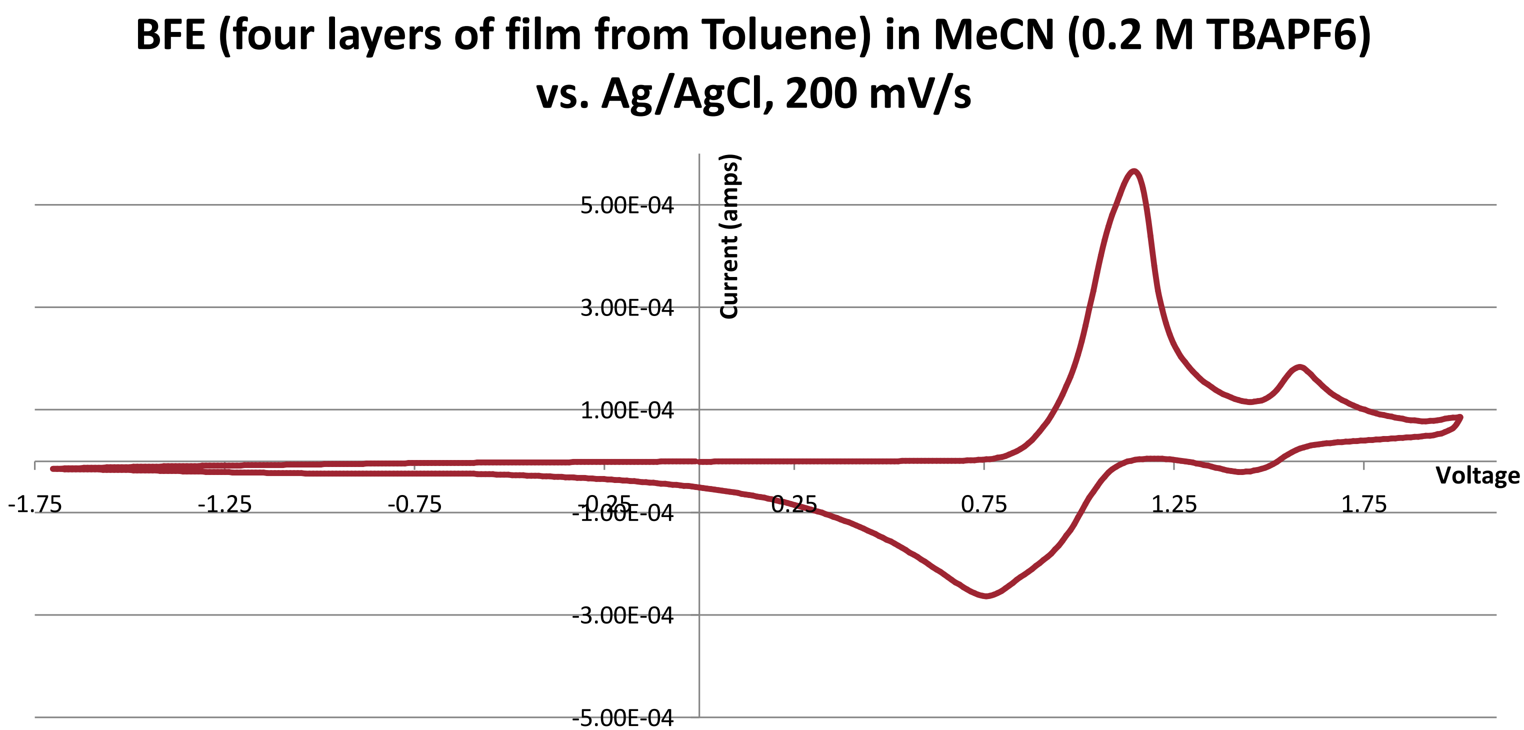
- Not always understood – conductivity increased accidentally with impurities!
- Fermi level – electronic equilibrium between materials in the cell.
- Dopant acts as electron acceptor.



http://www.chemphys.lu.se/research/projects/teratransport/

Cyclic Voltammetry

- Shows oxidation and reduction of compound
- Voltage at which oxidation occurs in polymer and dopant can be compared



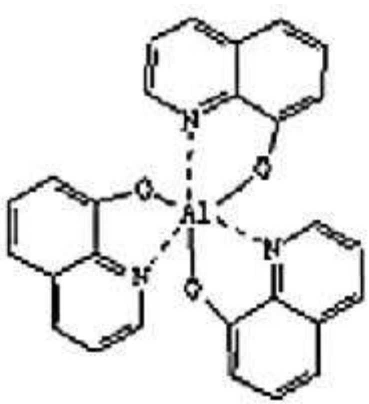
Current Dopants

<u>Metals</u>

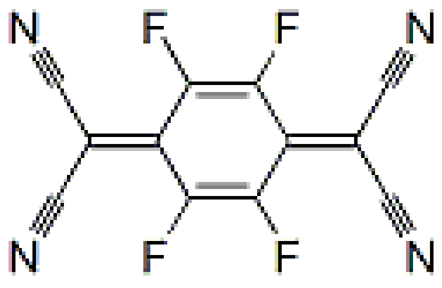
- Oxides: WO_3, MoO_3
- Alq_3
- insoluble
- vacuum deposition

<u>Organics</u>

- F4-TCNQ
- F2-HCNQ
- triarylamine derivatives
- volatile



Alq3

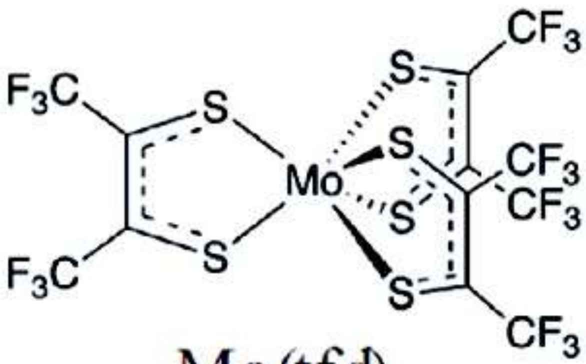


F4-TCNQ

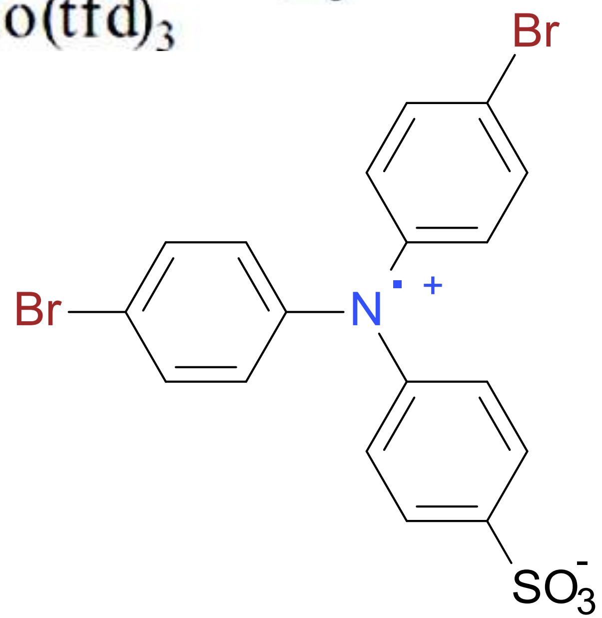
Future Work

<u>Dopant requirements:</u>

- Have widely controllable solubility
- Have potential to dope a range of polymeric semiconductors
- Should not react with the host polymer
- Neutral agent, incorporated as an inert, immobile counter ion in the film

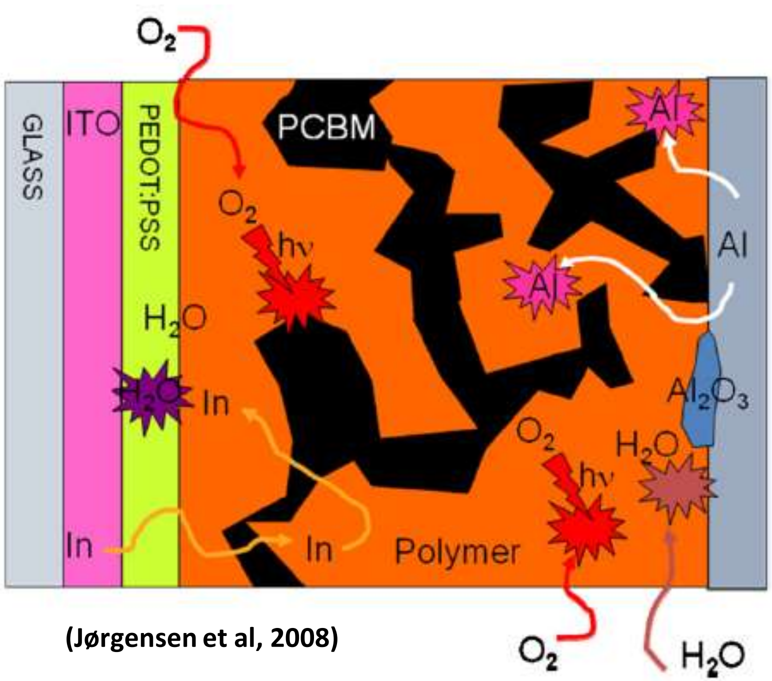


$Mo(tfd)_3$



Lifetime/Stability

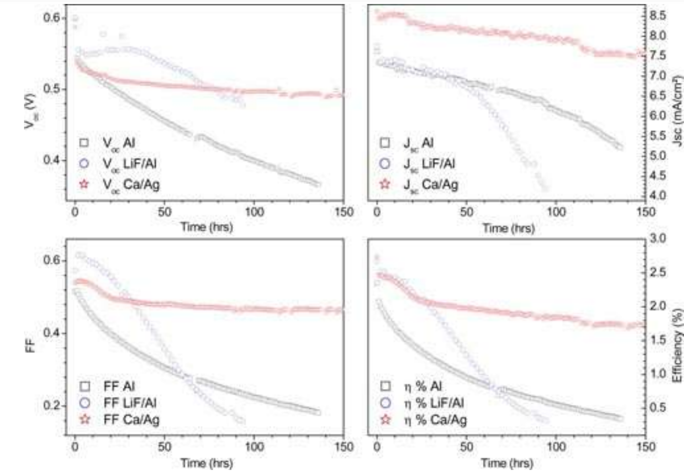
- Unfortunately OPVs currently have very short lifetimes
- Several possibilities for mechanism of degradation
  - Environmental and intrinsic factors
  - Light (photodegradation)
  - Temperature, humidity, presence of oxygen
  - Chemical composition, morphology
- Can be physical or chemical degradation



(Jørgensen et al, 2008)

Mechanisms for Degradation

- Composition of cathode
  - Reduction in I_{sc} over time
- Thermal Degradation of PEDOT:PSS layer
  - Irreversible structural changes
- Light induced degradation of active layer
  - Changes to UV-Visible spectrum and IR spectra
- Diffusion of oxygen and water



www.spie.org

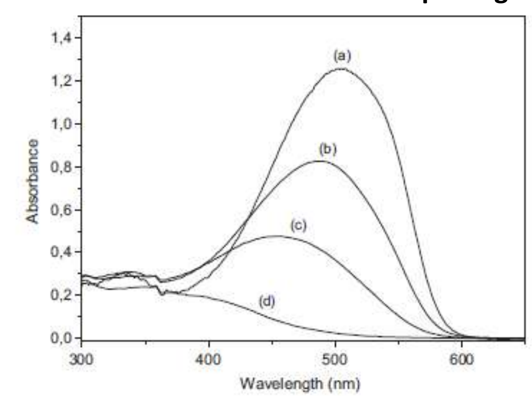
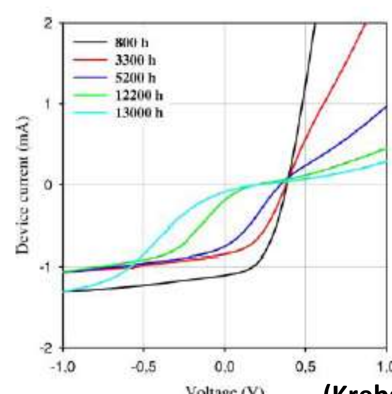


Fig. 1 Changes in the UV–visible spectrum of an MDMO-PPV thin film during photo-oxidation in the SEPAP 12/24 device: (a) 0 min; (b) 45 min; (c) 75 min; (d) 120 min.

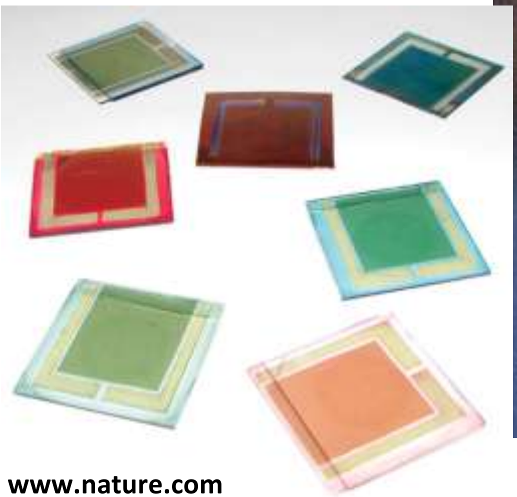
(Rivaton et al, 2010)



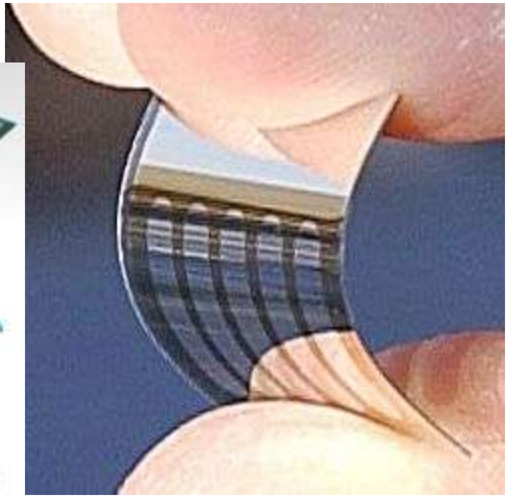
(Krebs, Norrman, 2007)

The Future

- OPV devices offer potential for commercialisation of solar cells
- Potential for large scale, low cost production
- Research efforts in:
  - Colour for building integration
  - Flexibility
  - Transparency
  - Increasing efficiency
  - Increasing stability
- Real-world testing



www.nature.com

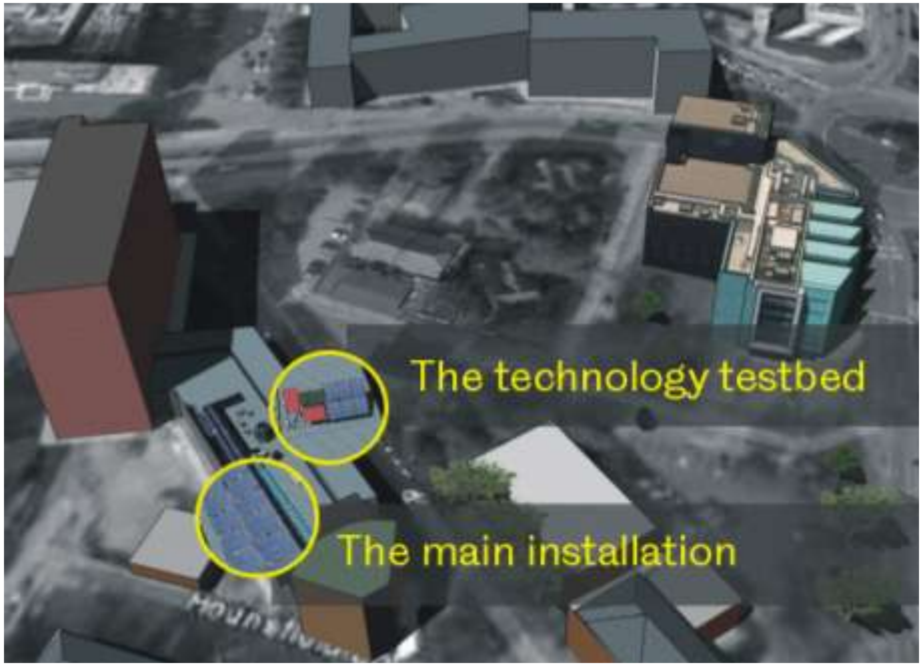


www.livescience.com

The Sheffield Solar Farm

- Primarily a 70m^2 silicon PV installation plus a technology testbed
- Comparison of new commercial and academic technologies and with standard laboratory based tests of efficiencies and lifetimes

- Lightweight flexible thin film photovoltaics for such as amorphous silicon, cadmium telluride and CIGS
- Dye-sensitised solar cells (Graetzel cells)
- Polymer photovoltaics, Bio-organic hybrid devices, and compound semiconductor devices



The Sheffield Solar Farm

- Pyranometer installed to provide live feed of both direct and diffuse radiation
- Allows analysis of performance related to actual ambient conditions

www.delta-t.co.uk

- Promotion of knowledge Transfer
- Real world testing

Sheffield

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