Potential Fabrication Processes for Inverted Organic Solar Cells

"Quick and easy polymer solar cells – Maybe?"

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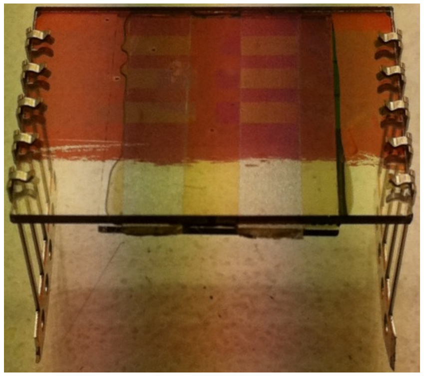


Contents

1. Introduction to basic principles of Organic Solar Cells (OSCs)
2. Outline current OSC fabrication
3. Reasons for creating inverted devices
4. Explain single and dual substrate approach
5. Highlight interaction issues between organic polymers
6. Explore possible solutions
7. Suggested future work
8. Questions?

Introduction/Basic Principle

Silicon based solar cells use a P-N junction to create charge instability

A photon excites an electron and promotes it from the valence band to the conduction band and uses the P-N junction to separate it from its respective hole

The increase in energy that electron has is able to be utilised to provide power

OSCs use a Bulk Heterojunction (BHJ) – Polymer : Fullerene Derivative Blend

The BHJ allows charge separation to take place and in turn the utilisation of excited electrons

The BHJ composition is relatively unknown, but post processing techniques are shown to enhance the performance of such devices

Current OSC Fabrication

Current OSC devices are made up of multiple layers

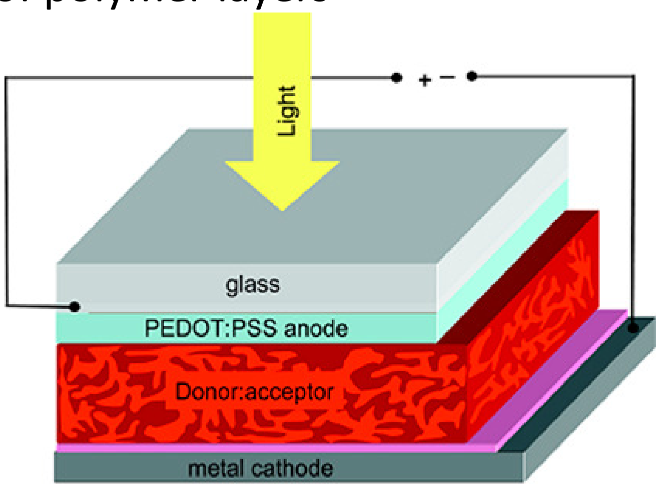
Commonly Indium-Tin-Oxide (ITO) coated glass substrates are used as the base layer

Polymer layers are spin cast on to the substrate followed by evaporating a low work function metal acting as the cathode – typically Aluminium

Varying rotational speeds give varying thicknesses of polymer layers

Devices are thermal annealed and solvent annealed to enhance performance

ITO – Transparent Electrode (Anode)
PEDOT:PSS – Hole Transport Layer
P3HT : PCBM – Active Layer
Aluminium – Metal Cathode



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Why Inverted?

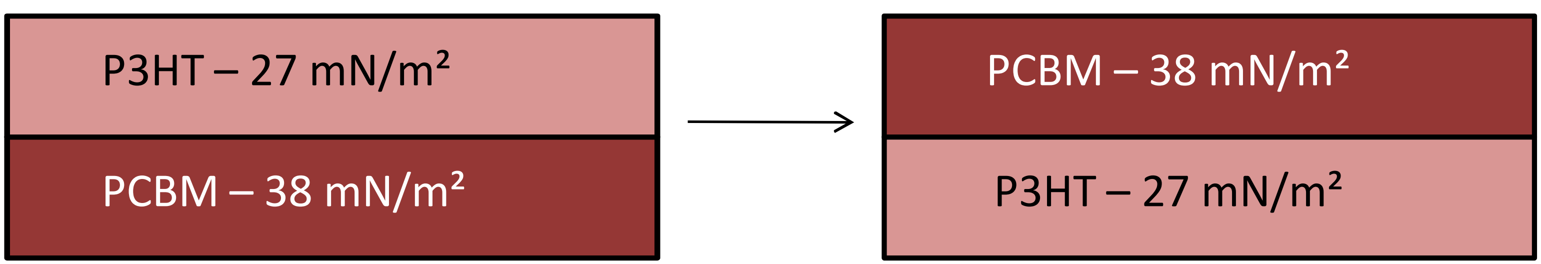
The BHJ in this case is made up of P3HT and PCBM

Conjugated polymers tend to phase separate vertically according to surface energies

The lower surface energy polymer tends to segregate towards the air interface and the higher surface energy tending towards the solid substrate

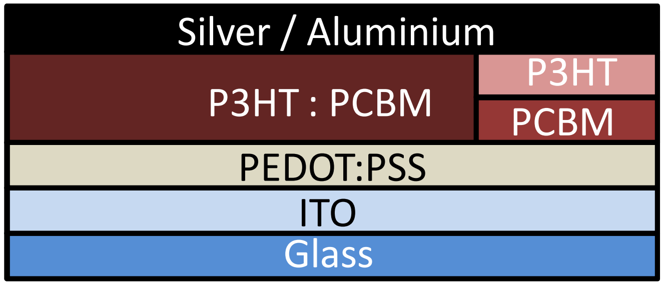
However, what naturally occurs is the inverse of what is desired

If the P3HT layer is adjacent to the metal cathode, the degree of recombination is increased and thus brings about decreased photovoltaic performance

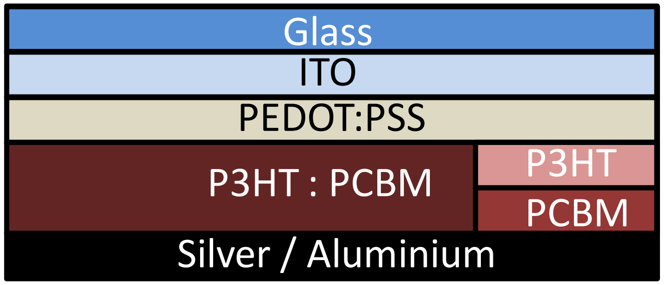


Single Substrate Approach

Proposed to fabricate devices starting with metal cathode rather than glass substrate



Standard orientated device



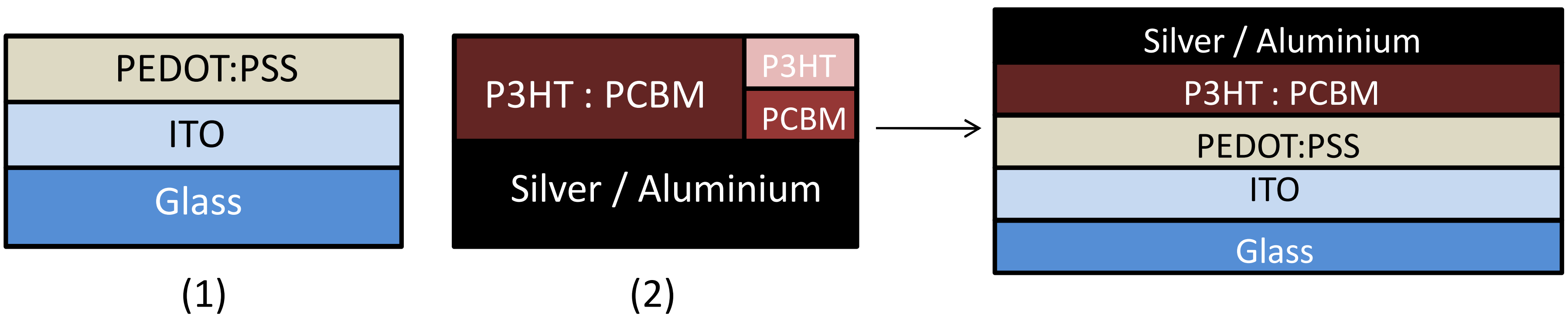
Inverted device

By starting with a metal cathode as the base substrate, naturally occurring vertical phase separation is proven to be favourable

P3HT is adjacent to PEDOT:PSS layer and similarly PCBM is adjacent to cathode layer reducing the likelihood of recombination

Dual Substrate Approach

Another way to generate the desired BHJ structure is to use TWO substrates



Spin coating a glass / ITO substrate with PEDOT:PSS forming (1)

And spin coating an aluminium / silver substrate with the P3HT : PCBM forming (2)

The desired vertical phase separation will take place with a higher concentration of PCBM sitting at the aluminium / silver interface

Interaction Issues with Single Substrate

The P3HT : PCBM blend was shown to interact favourably with the aluminium substrate, forming a uniform layer

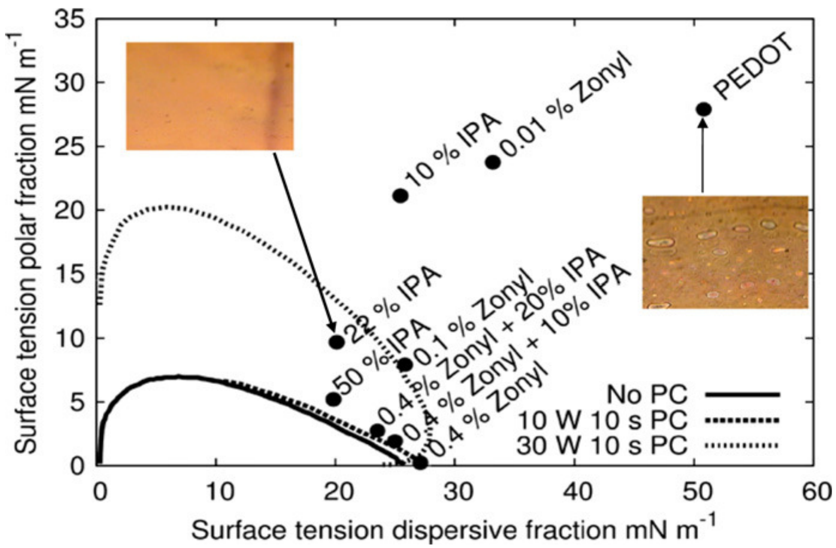
However, PEDOT:PSS was shown to not interact favourably with P3HT : PCBM, forming noticeable beads and not sufficiently wetting the active layer

Due to hydrophilic nature of PEDOT:PSS and hydrophobic nature of P3HT : PCBM, PEDOT:PSS lies outside the wetting envelope

Further treatment of PEDOT:PSS layer is needed in order to interact successfully

Fluorosurfactant, oxygen plasma, IPA

Single substrate approach is not shown to be viable



Interaction Issues with Dual Substrate

Dual substrate approach looks to be more favourable

Both substrates are able to be fabricated without complications

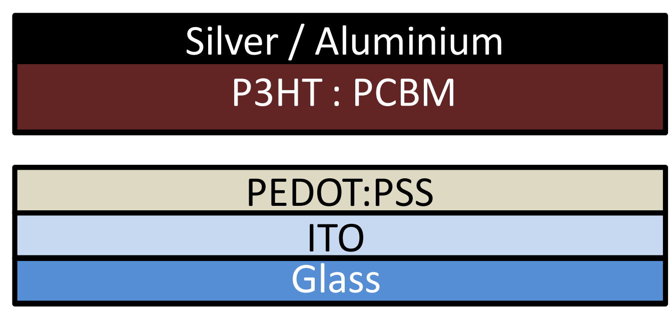
P3HT : PCBM layer interacts favourably with silver nanoparticle cathode strips

PEDOT:PSS interacts favourably with ITO coated glass

However, the two separate substrates do not interact together favourably

Various techniques were tried to enhance the interaction

Thermal annealing, solvent annealing, clamping, compression



Conclusion

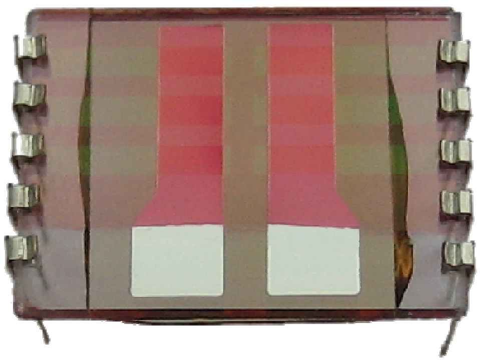
Unfortunately neither the single or the dual substrate approach has shown to produce any coherent results

In large part due to the unfavourable interactions between polymer layers

Need to ensure intimate interface between layers to ensure good photovoltaic performance

Standard devices are fabricated in a similar process, followed by evaporating a layer of aluminium acting as the device cathode

Aluminium film holds and intimate interface with the P3HT : PCBM layer which is vital



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Future Work

The feasibility of the dual substrate approach looks to be low on account of the unfavourable interaction between the two substrates

Further research into methods of enabling a successful interaction between P3HT : PCBM and PEDOT:PSS could be carried out - it is possible as stated earlier

Then need to look at ITO deposition techniques and processes

And following that, producing a way of encapsulating the devices with a glass layer to protect the devices from atmospheric levels of oxygen and moisture

A true inversion using a single substrate looks to be the most feasible way of producing inverted devices, but many more processes need to be explored before it is fully realised

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