Fabrication and characterisation of high efficiency carbon nanotube based organic solar cells

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Outline

- Introduction: Why organic solar cells
  Properties of CNTs
- Project description
- Methodologies
- Sample results
- Conclusion

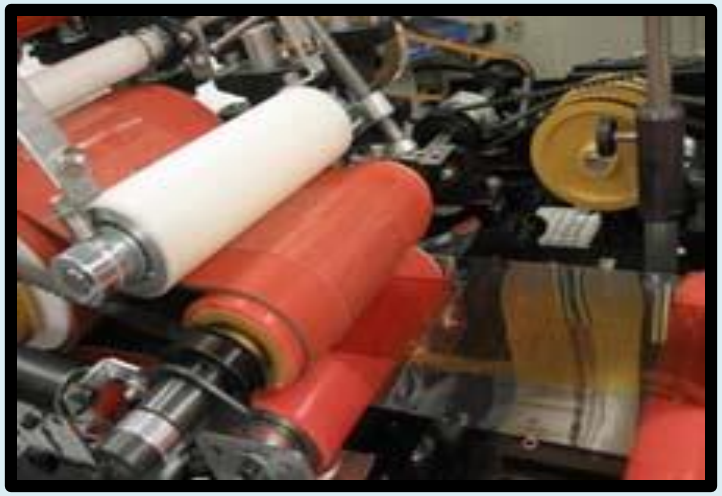
Introduction

- Global view: Energy deficit – still have 1.1 billion people with no access to electricity!
- UN-World Bank initiative: Sustainable Energy for All
  - ✓ SE4All 2030
  - » Universal access to electricity and clean cooking fuels.
  - » Double the share of renewable energy.
  - » Double the energy efficiency improvement.
- E…M
- Acceleration of current initiatives!

- Why organic solar cells[OSCs]?

  (Organic Photovoltaics[OPVs])?

- Possibility - lightweight, flexible and versatile device fabrication schemes which can ultimately lead to low cost large-scale industrial production.



- High optical absorption coefficients – very thin film production processes.
- Easily integrated into consumer products.

- OPV mechanism

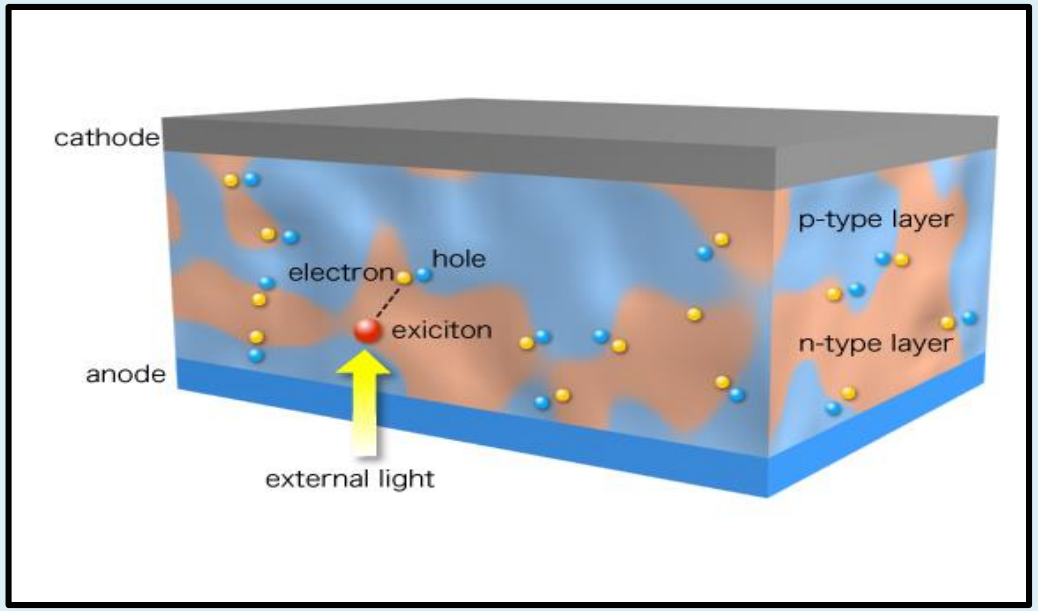
➢ Photoexcitation
  - Absorption of light and creation of exciton.

➢ Exciton diffusion
  - Movement towards donor/acceptor interface.

➢ Exciton dissociation
  - Separation of electrons and holes.

➢ Charge transport
  - Movement of free

charges towards electrodes.



- CNTs properties ideal for OPVs
  - Mechanically strong and chemically stable
  - High carrier mobilities (~100,000 $cm^2/(V.s)$
  - Large surface areas (~1600 $m^2\ g^{-1}$)
  - High optical absorption
  - Very large current carrying capability – 10^9 A cm^{-2}

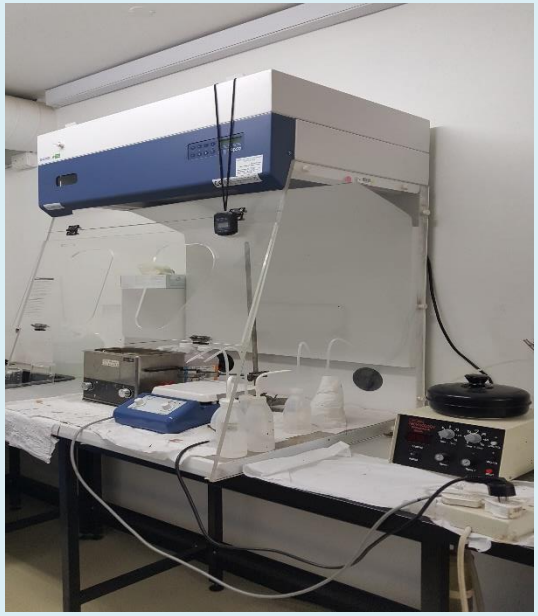
Project description

- The aim of this project is to enhance the scientific knowledge and understanding of how to optimise the fabrication and characterisation of OPV devices. To refine and adopt methodologies that lead to the incorporation of carbon nanotubes, into fabricated devices, for the realisation of high efficiencies.

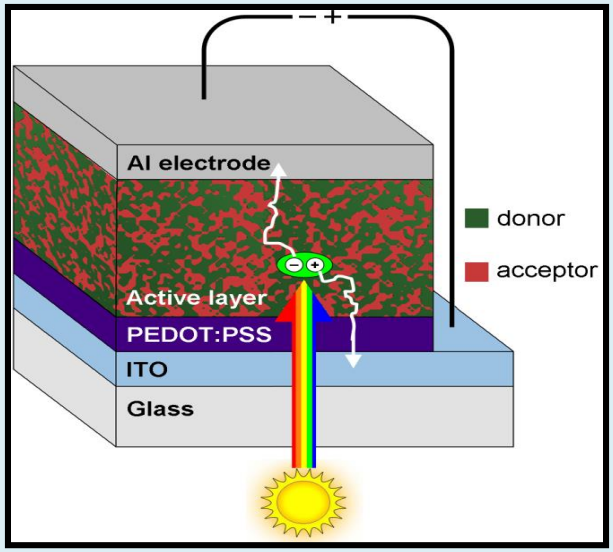
Methodologies

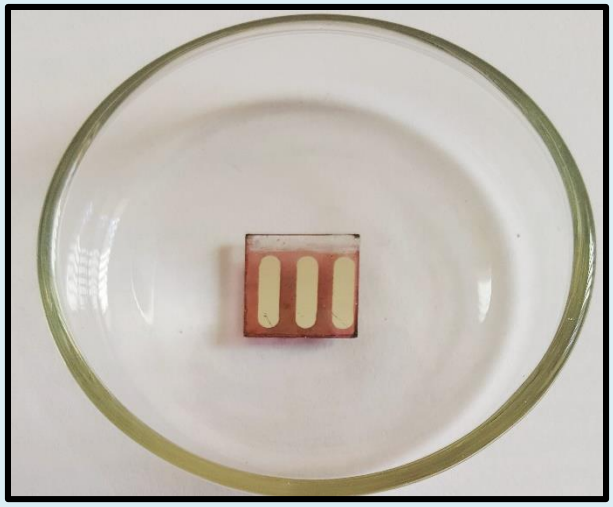
- Basic OPV device materials:-
  - electron donor[**P3HT**]-poly(3-hexyl thiophene) and electron acceptor [**PC71BM**] –phenyl C71-butyric acid methyl ester) – active layer materials. **PC61BM**
  - Electrodes – **ITO**(indium tin oxide), **Aluminium**
  - Hole conducting polymer[**PEDOT:PSS**] - poly(3,4-ethylenedioxythiophene) polystyrene sulfonate
- CNTs

The process…

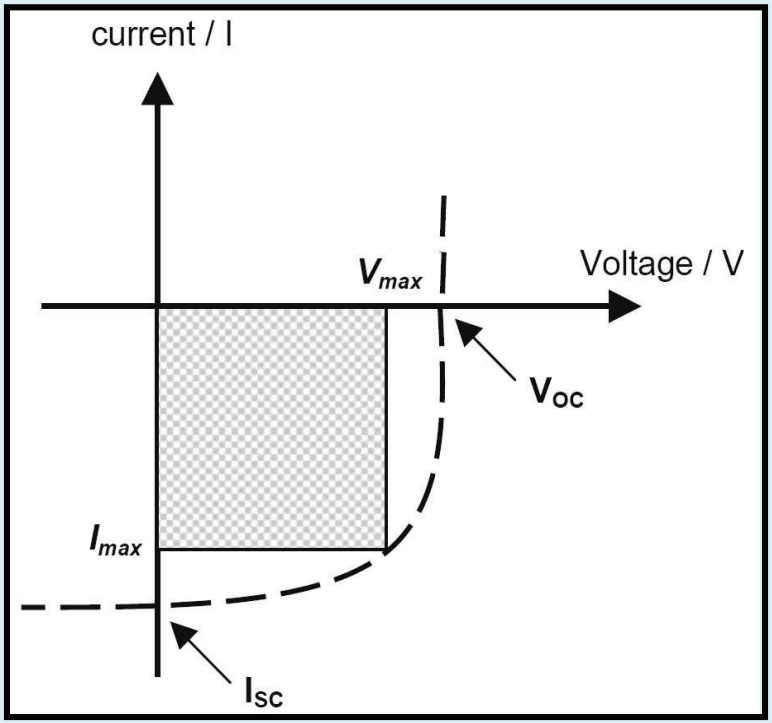


- Typical OPV structure





- Typical I-V curve of an OPV cell



Verploegen, E.; Mondal, R.; Bettinger, C.; Sok, S.; Toney, M.; Bao, Z.,Advanced Functional Materials 2010, 20, 3519-3529.

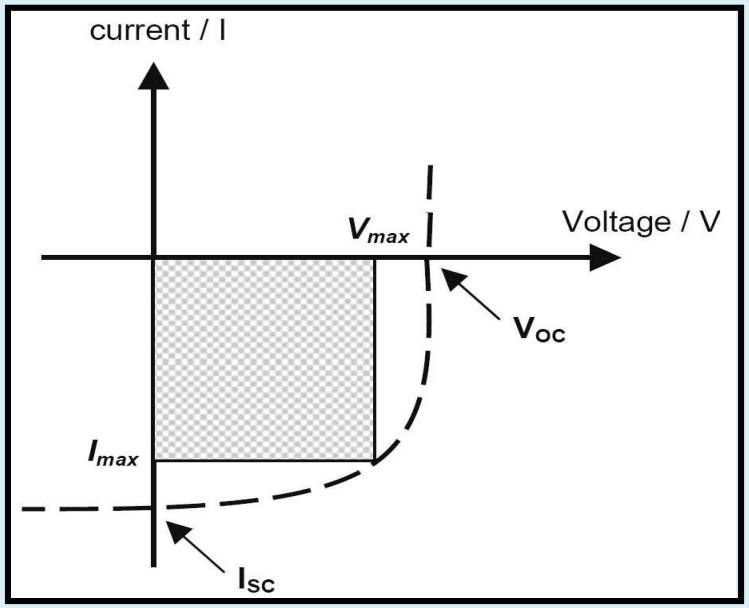
- Device performance parameters of OPV devices are obtainable from measured I-V curves: short circuit current (I_{sc}) and open circuit voltage (V_{oc})

- I-V measurements using AM1.5 solar simulator

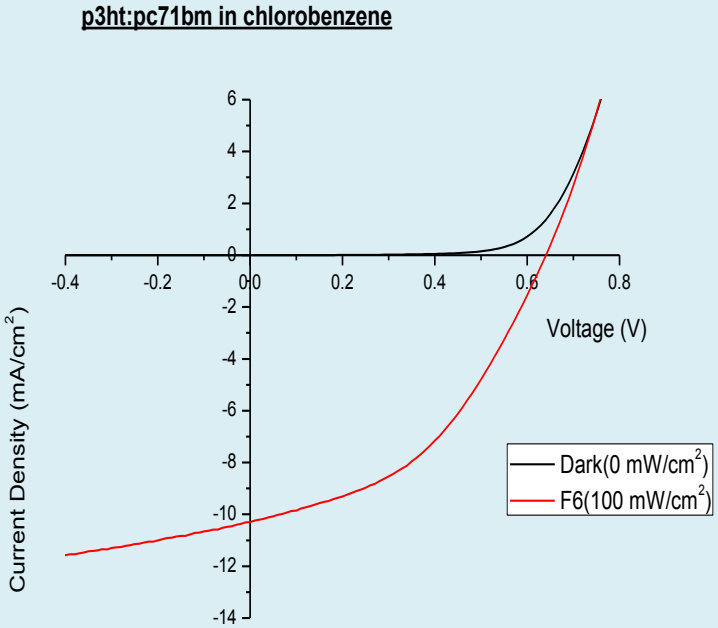
- Power conversion efficiency (PCE)

$$PCE = \frac{V_{oc} \times I_{sc} \times FF}{P_{input}}$$

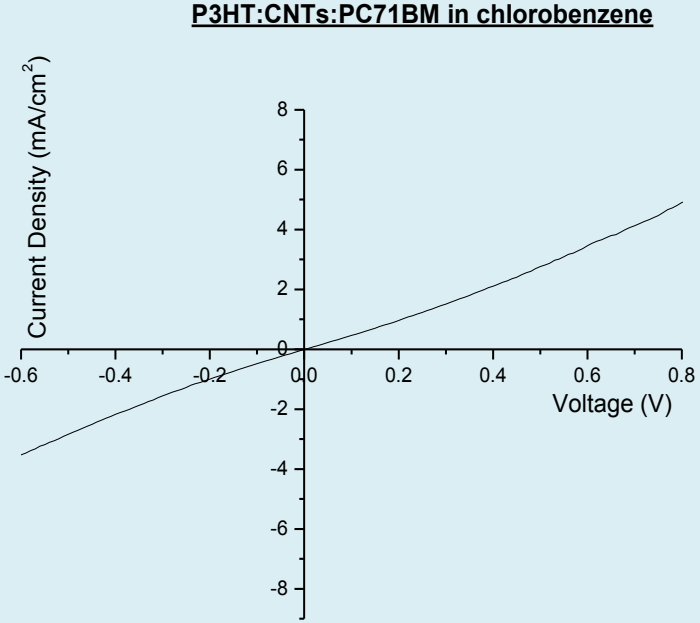
$$FF = \frac{I_{\max} \times V_{\max}}{I_{sc} \times V_{oc}}$$



Sample results



Measured J-V characteristics without CNTs



Measured J-V characteristics with CNTs

- Further characterisation

UV-Vis	Electronic structure, optical properties
Photoluminescence	Electronic structure, degree of quenching
Raman spectroscopy	Chemical structure
AFM, SEM, TEM	Device morphology

Conclusion

- We can now routinely fabricate OPV devices with efficiencies of about 3%.

- We have not had much success with incorporating CNTs into fabricated devices.
  - CNTs are shorting devices

- Outlook
  - Source optimised CNTs
  - Incorporate PLASMONS

Thank you