Hybrid TiO_2/polymer Solar Cells made with functionalized Single Wall carbon Nanotube (SWNT)

P.A.Amalraj, K.Balashangar, and P.Ravirajan#
Department of Physics, University of Jaffna, Sri Lanka
*p_ravirajan@jfn.ac.lk, pravirajan@gmail.com

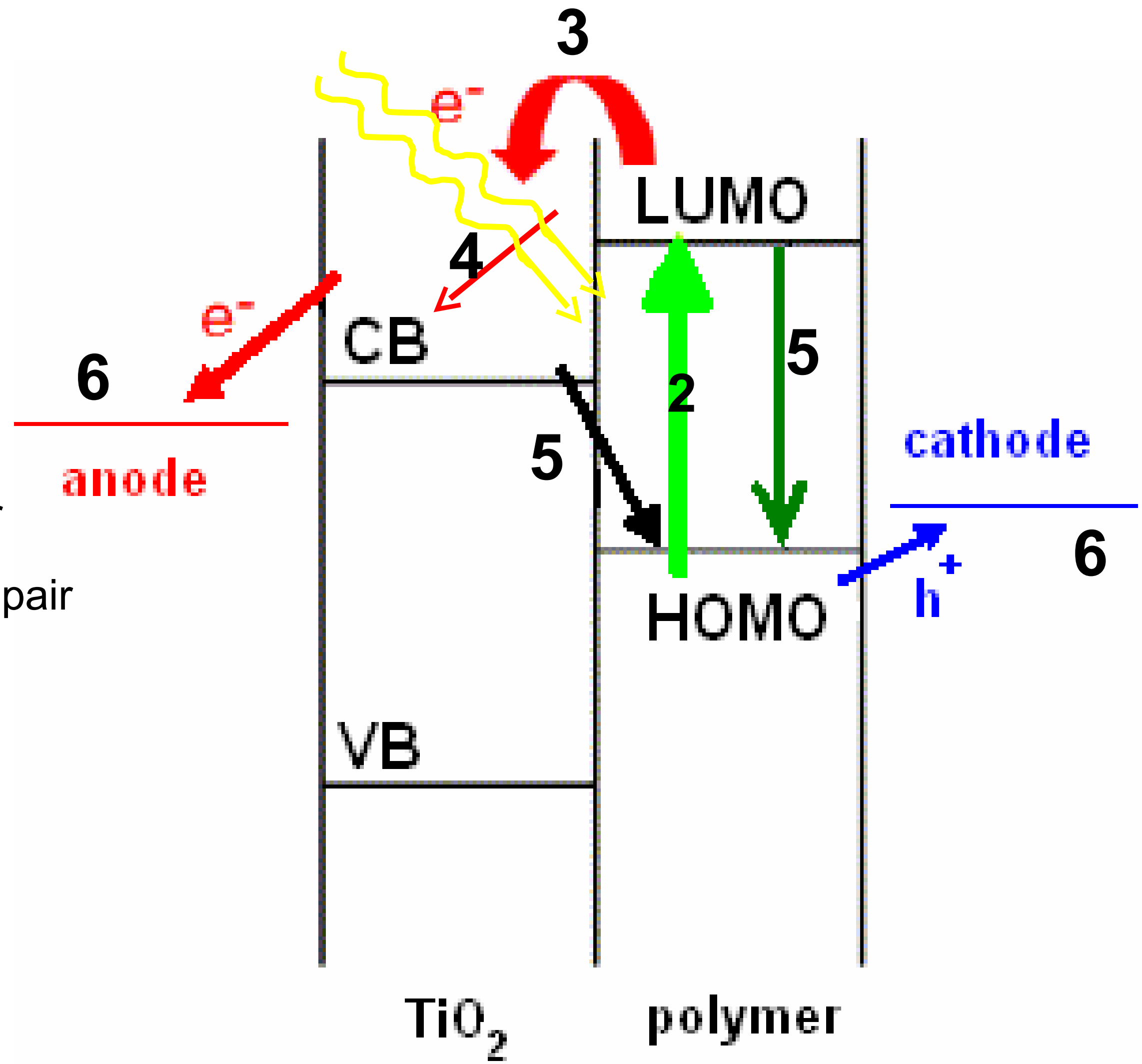
First National Nanotechnology Conference - 2012
24 – 25 August 2012

Acknowledgement

NRC
National Research Council
of Sri Lanka

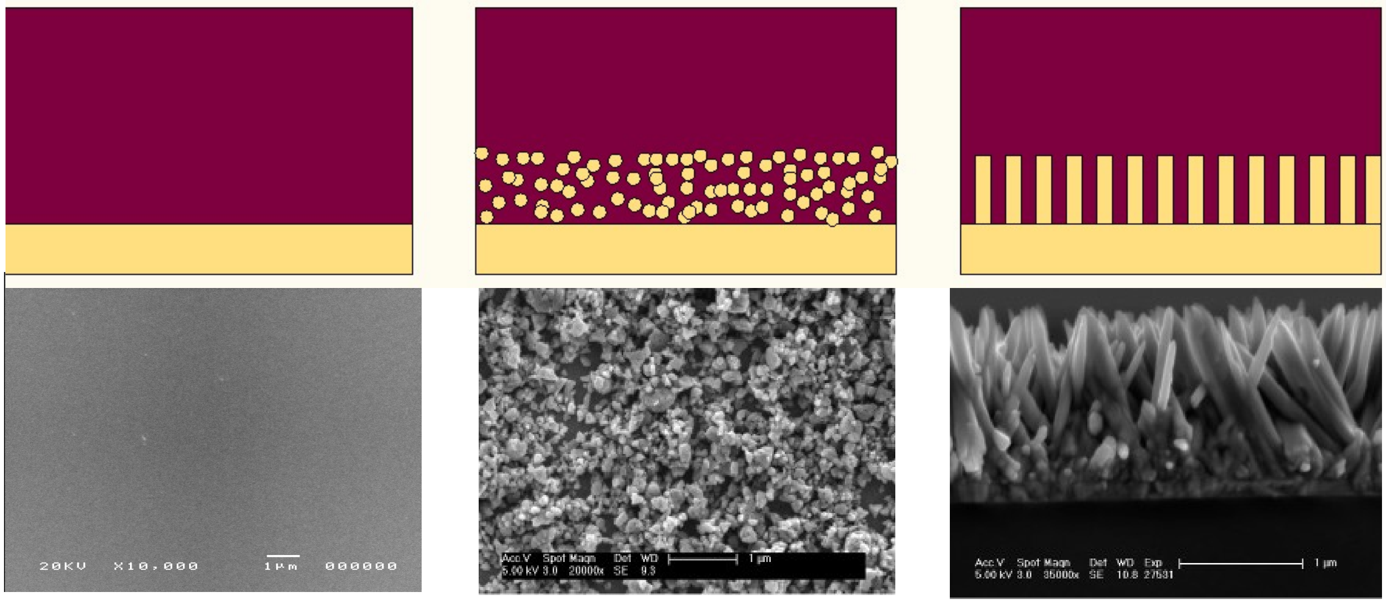
P.R & K.B Thanks NRC for funding to purchase Equipments and K.B Thanks for Studentship

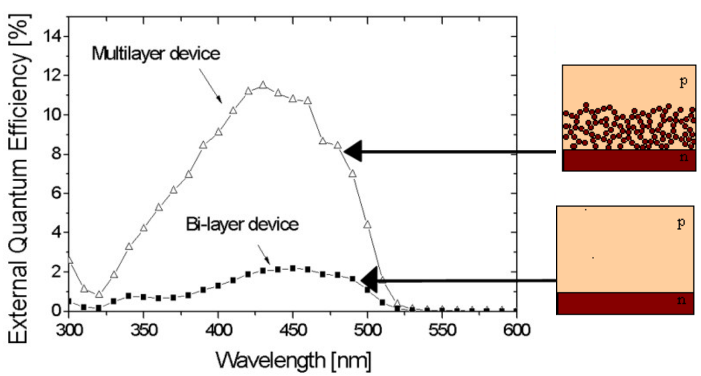
Photovoltaic effect in donor-acceptor heterojunction

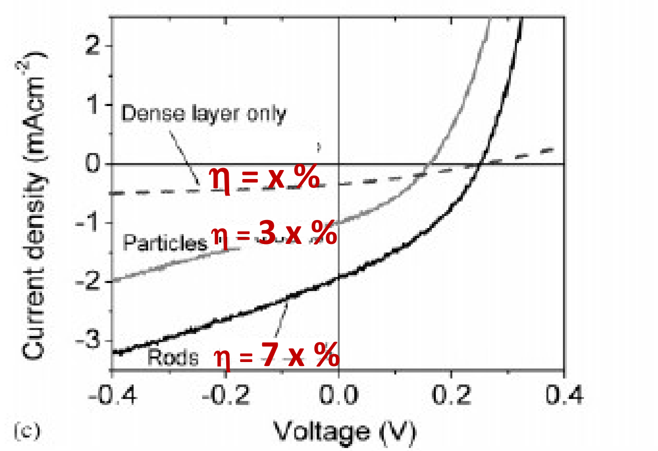


1. Absorption of light
2. Creation of electron-hole pair
3. Dissociation of electron-hole pair
4. Transport of charges
5. Recombination of charges
6. Collection of charges

Nanofilms – Nanoparticles – Nanorods for solar cells



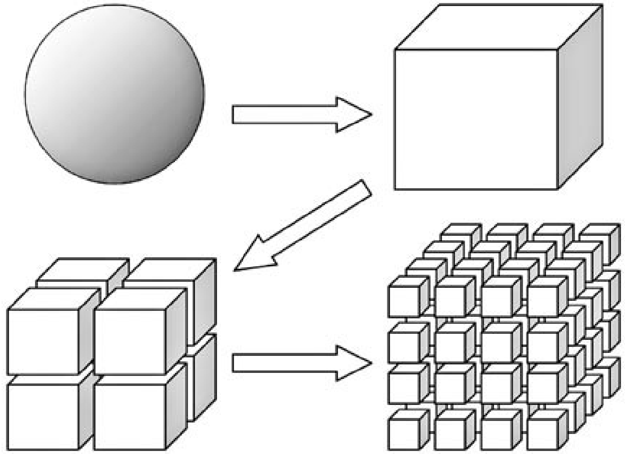


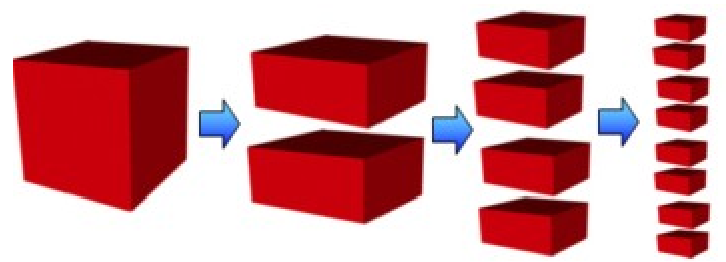


P.Ravirajan *et. al*, J. Appl. Phys. **95**, (3), 2004
Cited 94 times

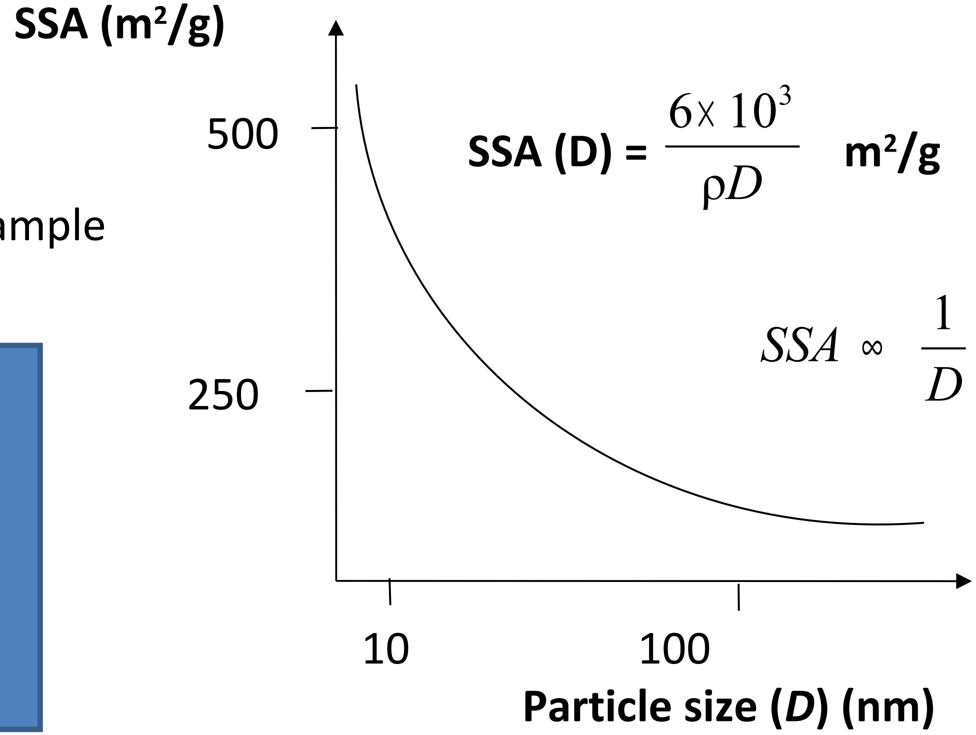
P.Ravirajan *et. al*, J. Phys. Chem. B, **2006**, 110, 7635-7639 **Cited 275 times**

How does Nanotechnology help?





$$SA = \frac{\text{area}}{\rho \times \text{volume}} = \frac{A}{\rho V}$$

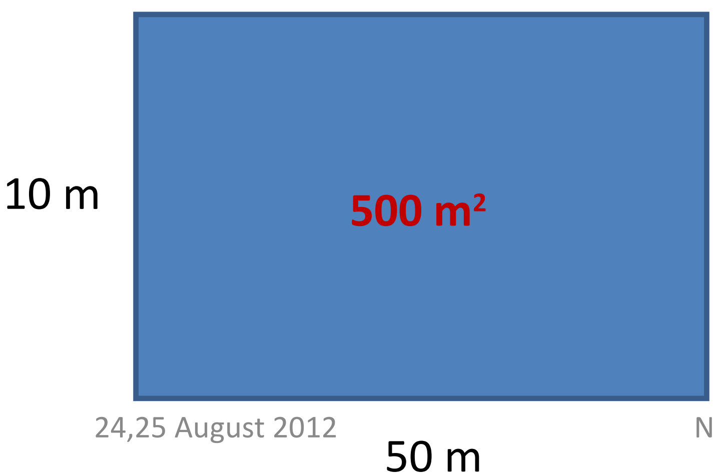


SSA (D) = $\frac{6 \times 10^3}{\rho D}$ **m²/g**

$$SSA \propto \frac{1}{D}$$

Specific Surface Area (SSA) vs Particle size

Surface area of 1 g nanoparticle sample can be upto 500 m^2 **!**



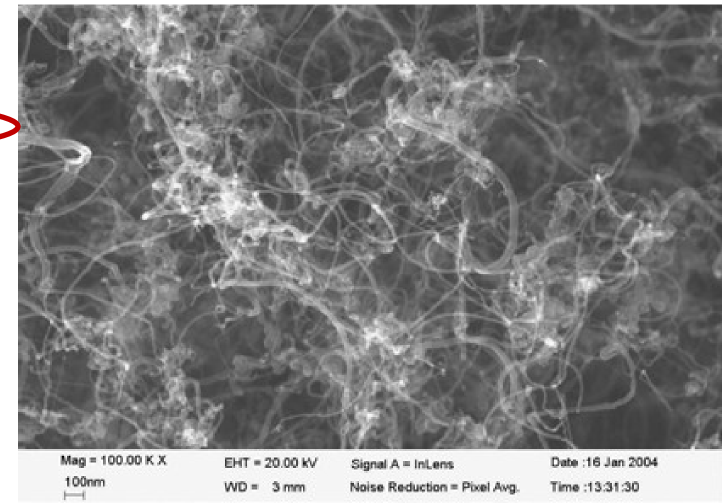
SWNT purchased from

nanothinx

Nanotubes, Etc.

Nanomaterials and Nanotechnology R&D

SWNT	
Production method	CCVD
Available form	Black powder
Diameter	0.8-1.4 nm
Length	≥5 μm
Bundles	15-30
Nanotubes purity	60%< x < 65% (raw: NTX8) ≥85% (purified: NTX9)
Metal particles	40% > x > 35% (NTX8) ≤15% (NTX9)
Amorphous carbon	< 1 %
Surface area	500-600 m^2/g (NTX8) ~900 m^2/g (NTX9)



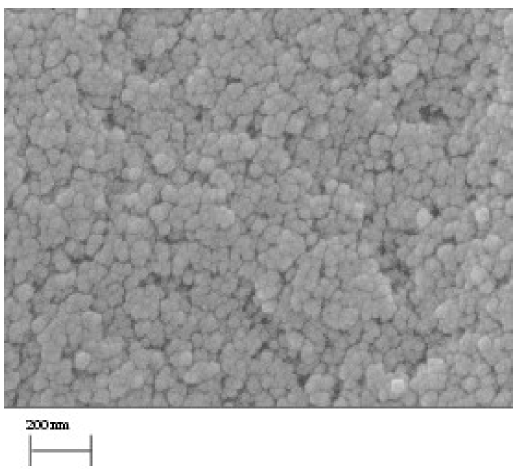
SEM image of SWNT

Strategies to increase the interfacial area By introducing SWNT in the active layer

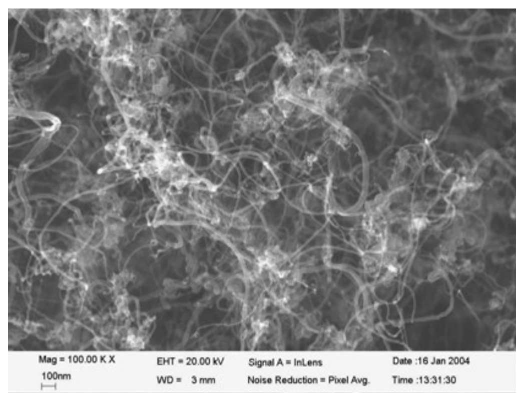
Depositing SWNT blended TiO2 layer

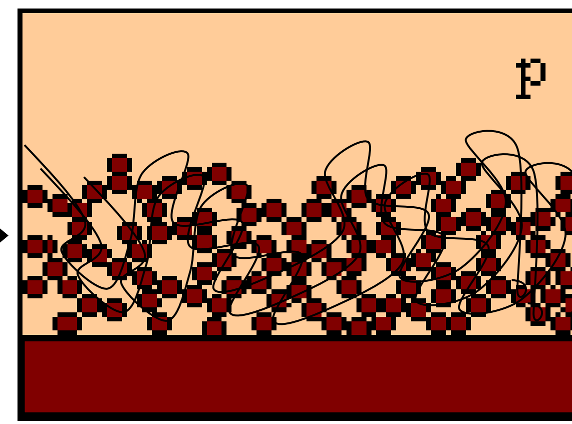
K. Balashangar et.al, International conference on solar energy materials, Solarcells and Solar energy Applications. (Solar Asia 2011), Kandy, Srilanka.

Dipping Porous TiO_2 layer in SWNT Solution



&



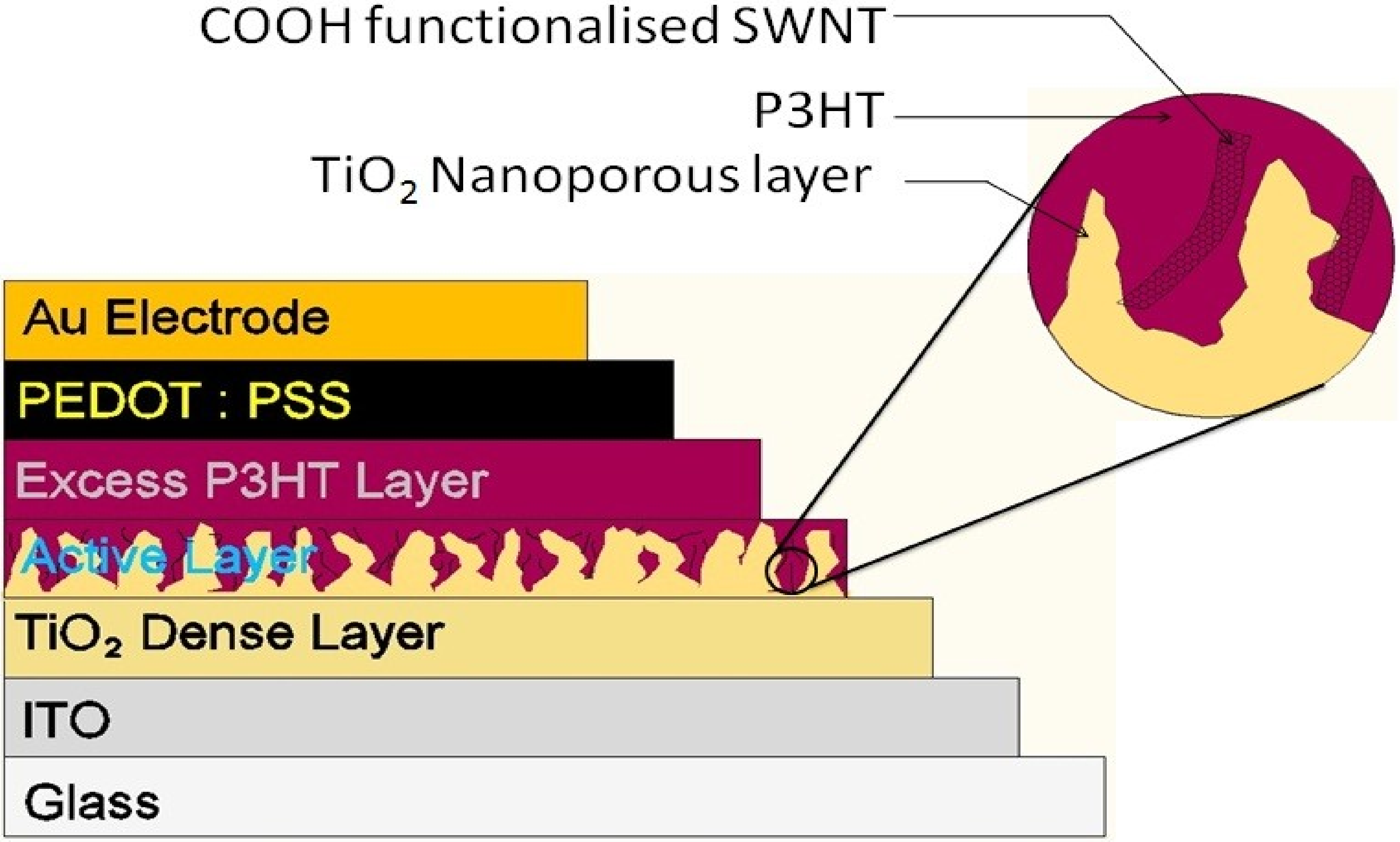


Pore sizes of TiO_2 film ~ 10-20 nm

Diameter of SWNT ~ 1 nm

The Device Structure

TiO_2 nanoporous layer was dipped in SWNT-COOH solution and it was used as an active layer



Device Preparation

1. Cleaning ITO substrates
2. Covering ITO with a dense TiO_2 layer by the spray pyrolysis technique at 450°C
3. Depositing 180mg/ml TiO_2 on THF on each substrate using spin casting at selected rpm (1250) for 30sec
4. Dipping substrates into SWNT-COOH solution
5. Dipping substrates into 1mg/ml P3HT solution for 18 hours at 110 ^{0}C

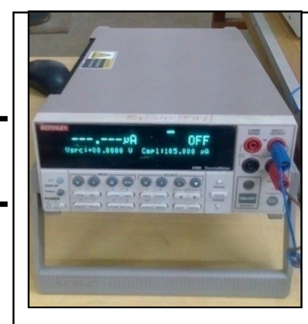
6. Spin casting 30µl of 25 mg/ml concentrated P3HT solution onto these substrates at 1250 rpm for 30sec
7. Spin casting 60 of PEDOT: PSS onto the substrate at 4000 rpm for 30sec.
8. Depositing gold contacts onto the PEDOT by thermal evaporation at a pressure better than 5×10^{-6} Pa.

Optical Measurement

Jenway UV-Vis Spectrometer

I-V Measurement

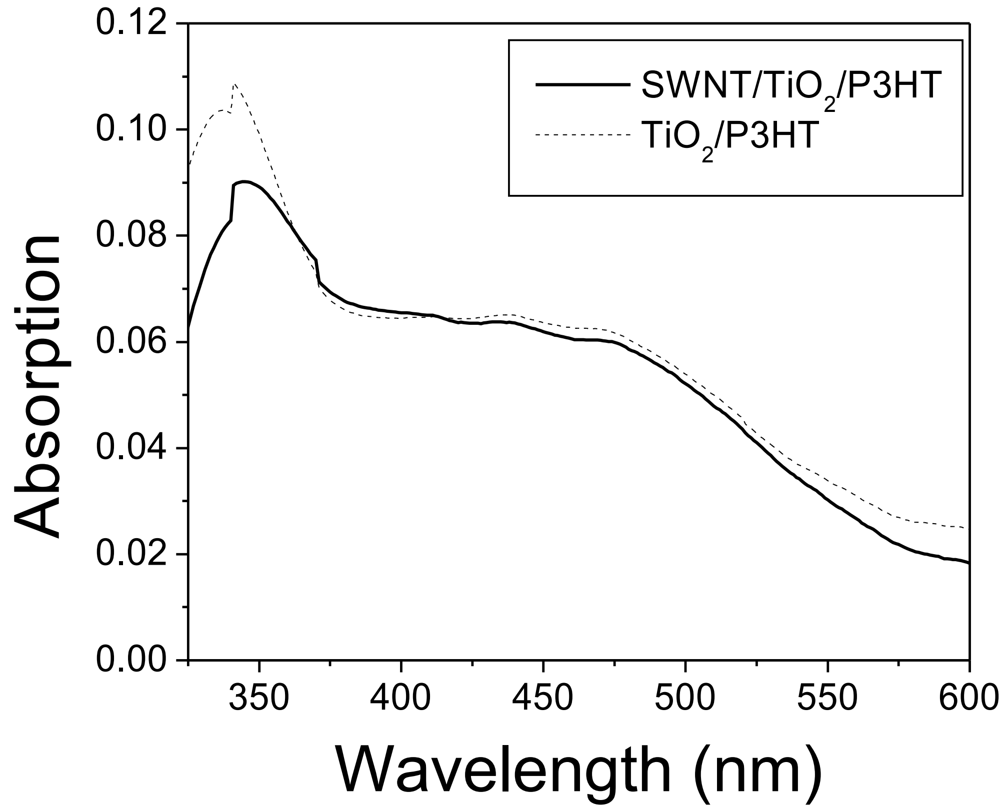
Prepared solar cell
in device holder



Keithley

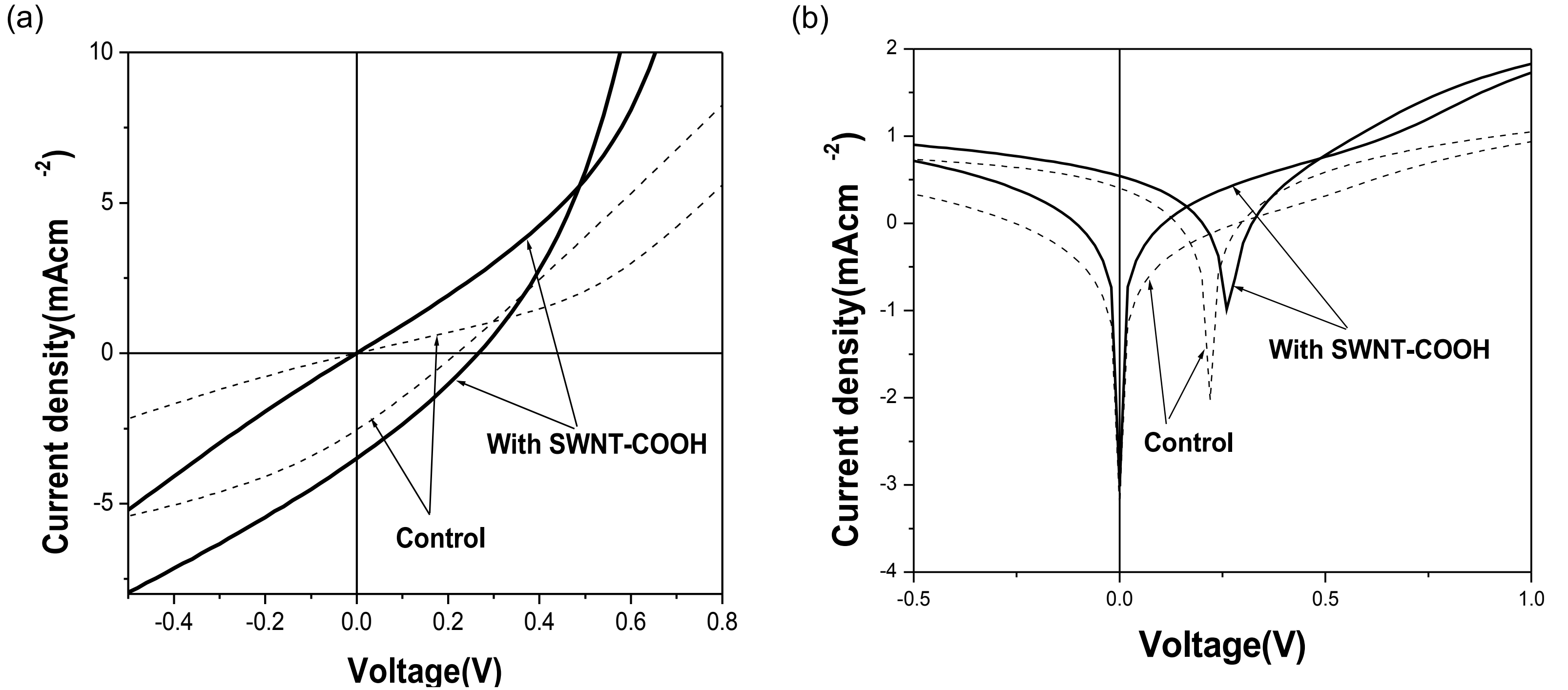
Computer

Absorption Spectra



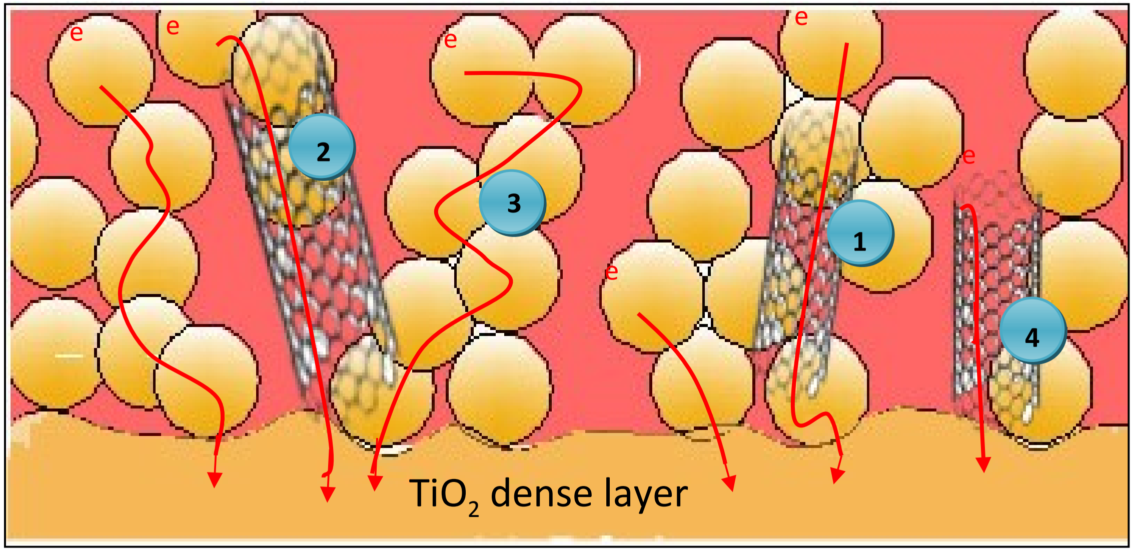
SWNT-COOH doesn't make any observable change of the absorption spectrum of TiO_2/P3HT in the visible range

J–V characteristics under Solar simulator



(*a*)*Current density (J)–Voltage (V) characteristics of the SWNT-COOH dip and control hybrid* TiO_2 */P3HT solar cells in dark and under AM 1.5 illumination from a solar simulator with 70 mWcm*$^{-2}$ *intensity (b) and its corresponding logarithmic plot.*

Power conversion efficiency of the SWNT incorporated device is 70% higher in comparison with its control



Possible electron transport after the exciton dissociation occurred at TiO_2/Polymer interface

(1)By Scaffolding

(2)By freeing from dead zones, supported by SWNT-COOH

(3)Through nanoporous TiO_2.

(4)The electron transport through SWNT--COOH, if there is a possibility for exciton dissociating at SWNT-COOH/Polymer interface

Conclusion

- SWNT-COOH was successfully incorporated at the TiO_2/polymer interface
- J_{SC} of over 3 mA/cm^2 is obtained under illumination of 0.7 sun for TiO2/polymer device having SWNT-COOH .
- This may be due to
  - reduced series resistance,
  - reduced recombination and back direction electron transport
  - SWNT-COOH scaffolding
  - reduction in dead ends and incomplete pathways.
- The hybrid polymer–metal oxide composites provide an excellent model system to study the effects of interface properties and film morphology on the performance of bulk heterojunction photovoltaic devices

Thank you