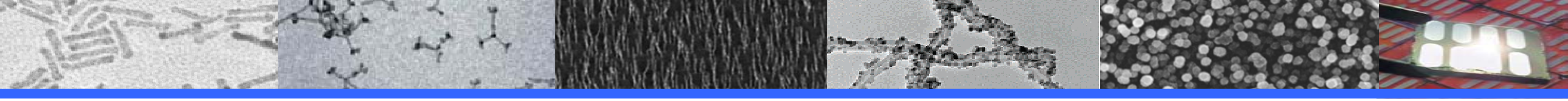

Nanostructures for Solar Cells

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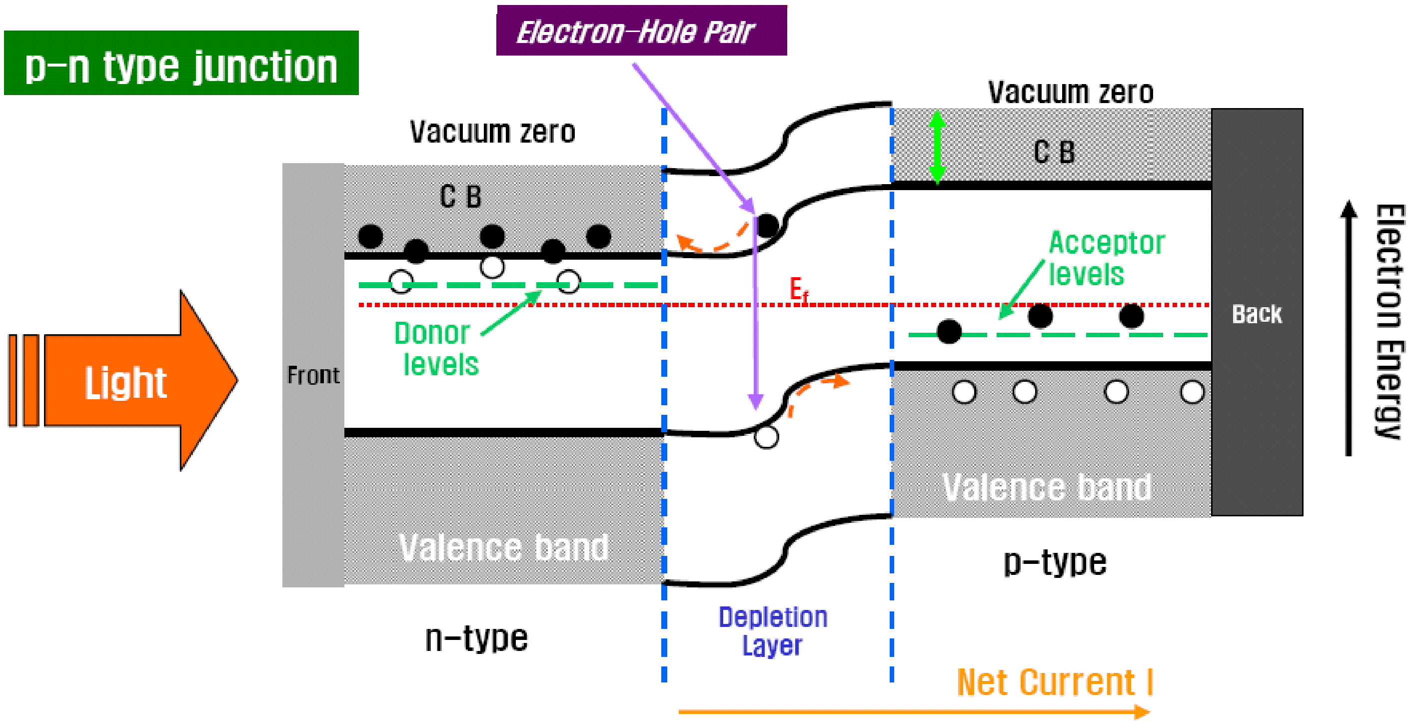
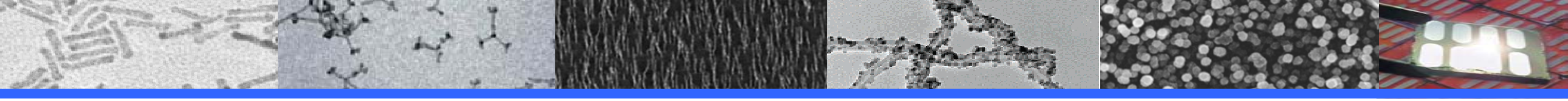
Contents

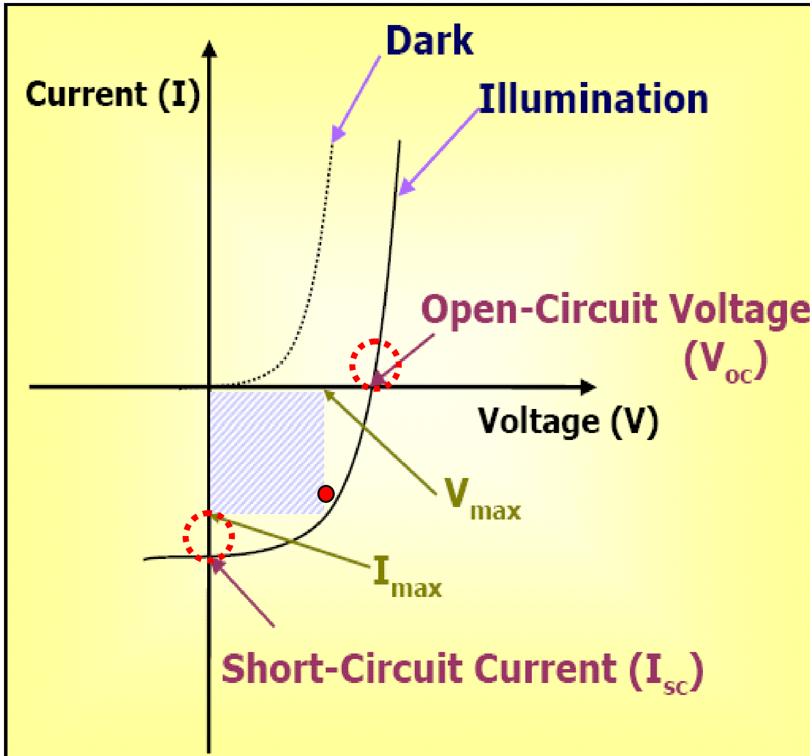
Semiconductor p-n junction



- Band gap enables photogeneration of carriers (ideal:1.34 eV)
- n and p type doping ⇒ asymmetric electrodes (exciton separation)



Solar cell characteristics



- **Short-Circuit Current** (I_{sc}) For V = 0, $I = I_{sc}$
- **Open-Circuit Voltage** (V_{oc}) For I = 0, $V = V_{oc}$
- **Fill Factor** (FF) = $(I_{max} \times V_{max}) / (I_{sc} \times V_{oc})$

  $= P_{max} / (I_{sc} \times V_{oc})$
- **Power Conversion Efficiency** (η)

  $= P_{max} / P_{in}$

  $= (I_{max} \times V_{max}) / P_{in}$

  $= FF \times \{ (I_{sc} \times V_{oc}) / P_{in} \}$

* P_{in} = 100 [mW/cm^2]

$$P_{sun} = \int b(E)E\,dE$$

Motivation

Silicon Solar Cell

- Power conversion efficiency up to 24% in lab.[1]
- High energy consumption at fabrication
- Cost-intensive fabrication

Organic Solar Cell

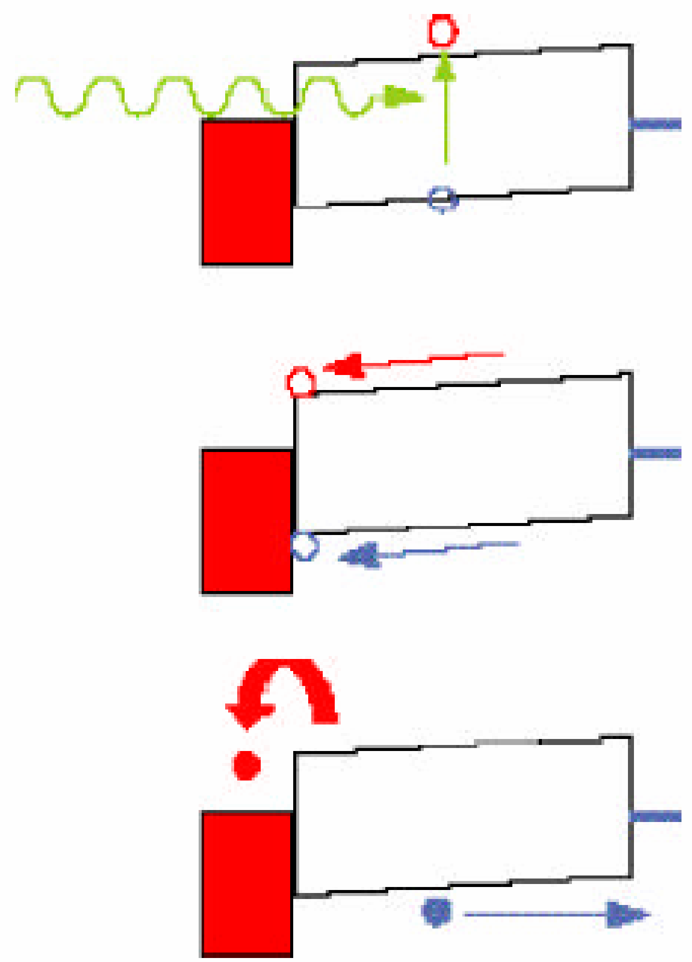
- Low energy consumption at fabrication
- Inexpensive fabrication
- Mechanically flexible on appropriate substrates
- Only 5% achieved in lab.[1]

Issues

To harvest more photons from a wide spectral range:
- Develop new absorber system that responds to IR

To improve the efficiency beyond the limit of 5%:
- Fabricate ordered nanostructures to improve photo-induced charge separation and transport

Issues in Organic Photovoltaics

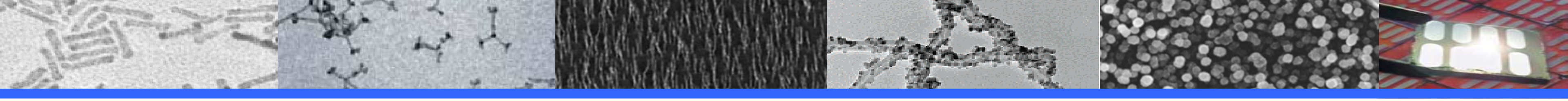


Photoabsorption
& exciton generation

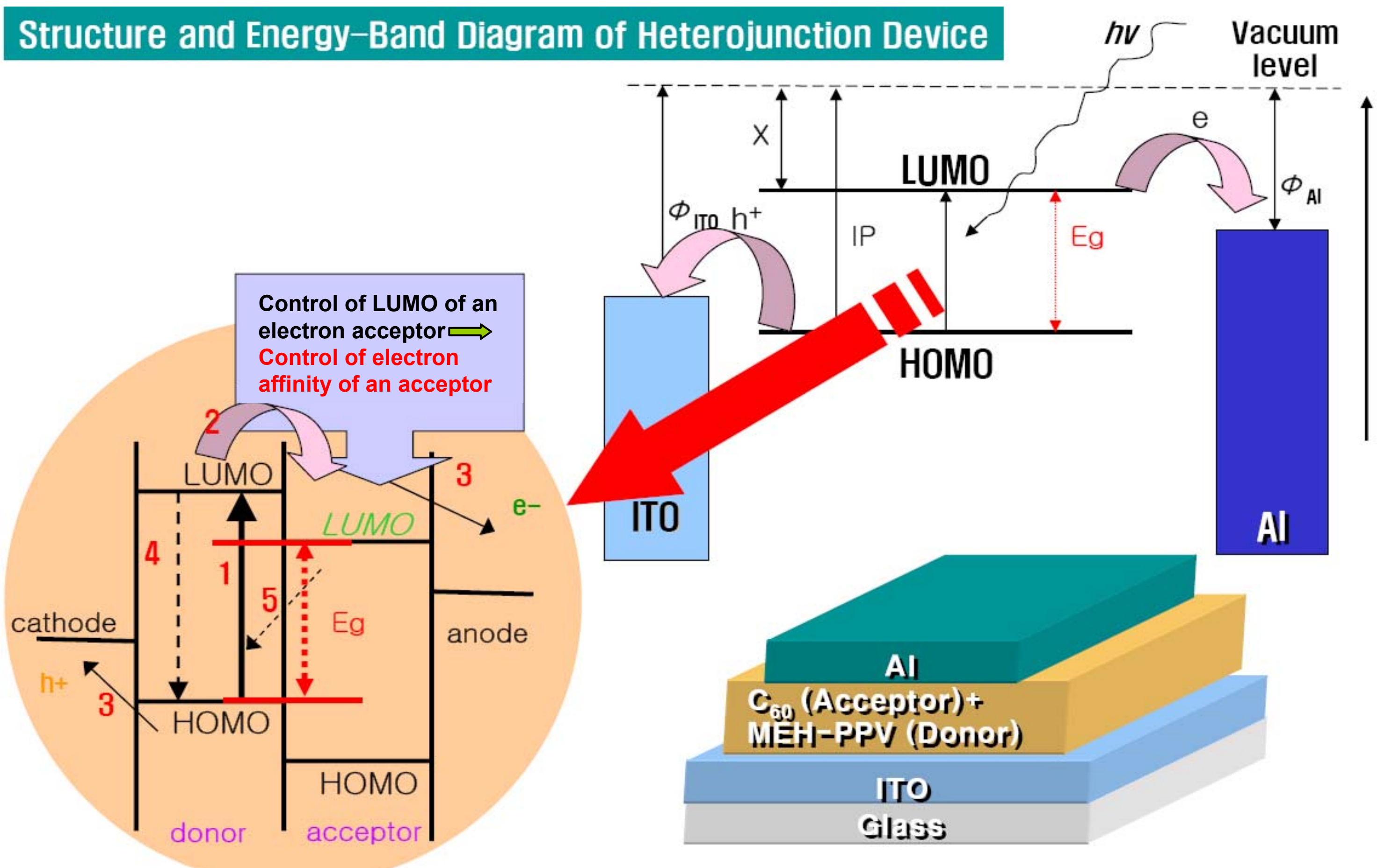
Exciton transport
& separation

Hole transport

J. Nelson, Materialstoday, May 2002, p20

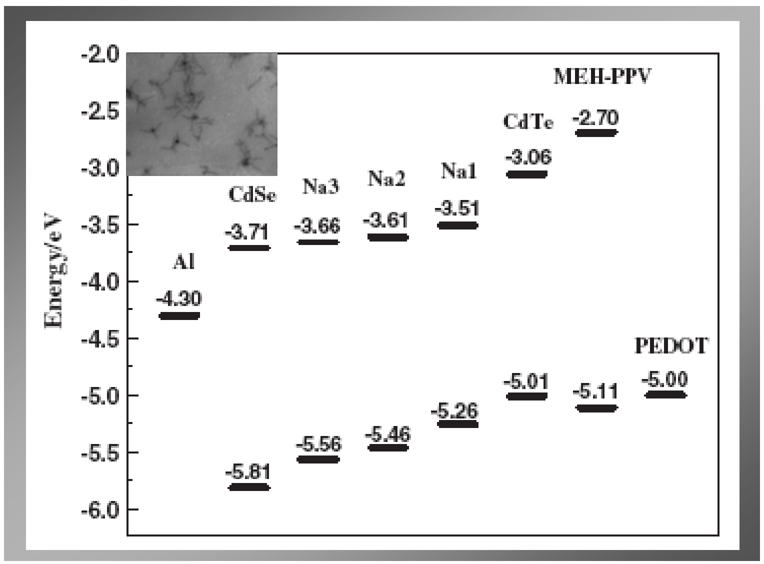


Organic photovoltaics



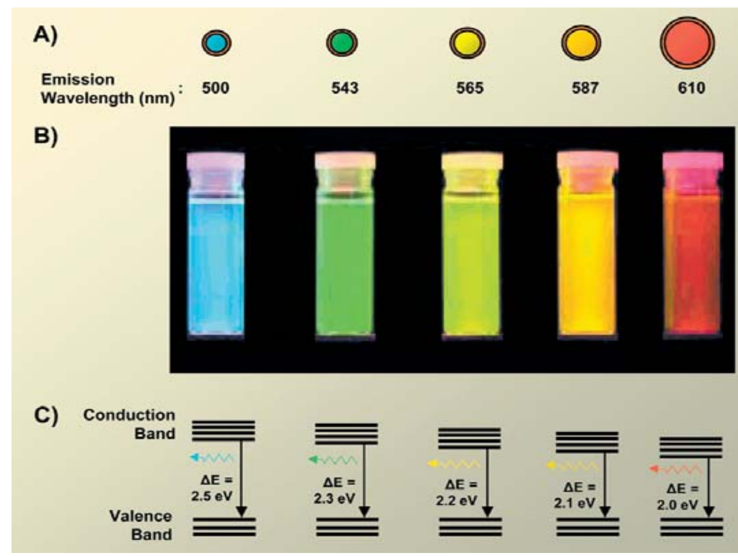
Unique properties of nanomaterials

- High electrical conductivity (10^4 S/cm for metallic (10,10) SWNTs[2]) and electron affinity (CdS, CdSe, CdTe, InP, GaAs etc.)
- 1-, 2- and 3-D assemblies
- Controlled electronic and surface properties by various components, morphologies, and chemical modifications[3,4]



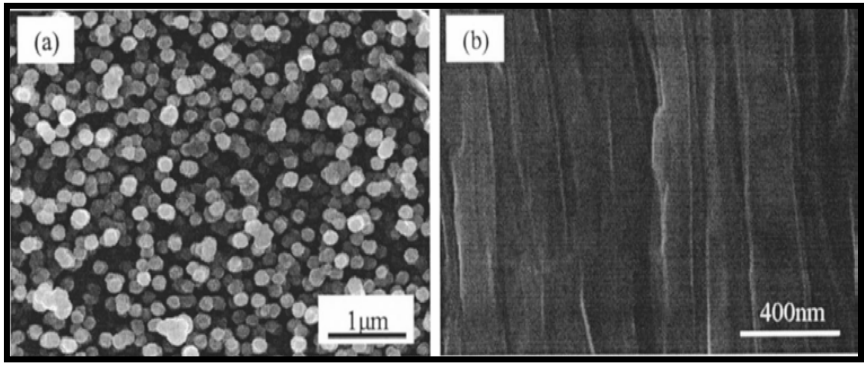
Samples	Na1	Na2	Na3
Molar ratio of Se/Te in the mixed precursors (Se + Te)	1/4 (0.25)	1/1 (1)	4/1 (4)
Molar ratio of Se/Te in the alloyed nanocrystals, determined by ICP	0.30	1.13	3.55
Se content in $CdSe_xTe_{1-x}$, x =	0.23	0.53	0.78

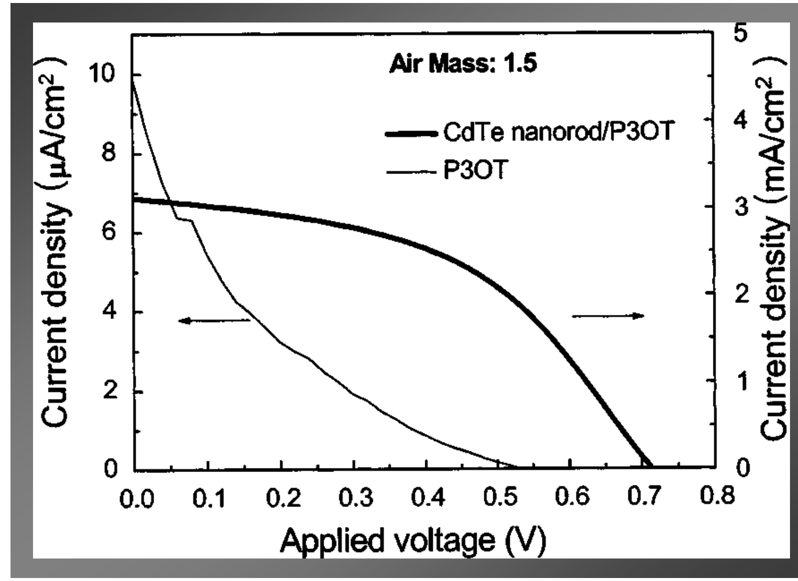
Electrical band gap energy of $CdSe_xTe_{1-x}$ tetrapodal nanocrystals[2]

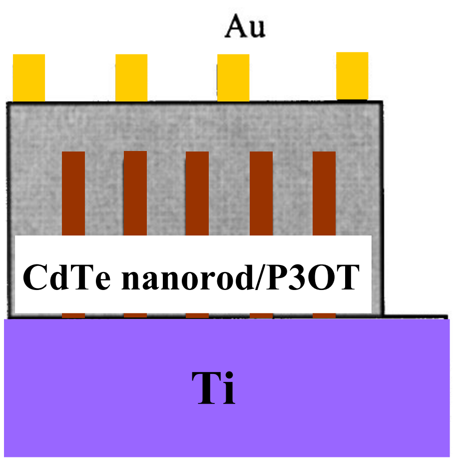


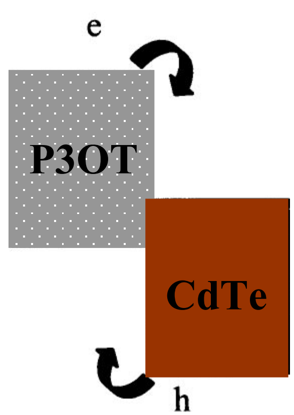
Optical property of CdSe quantum dots with different size[3]

Previous research

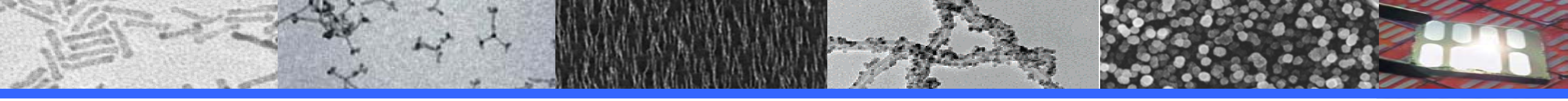


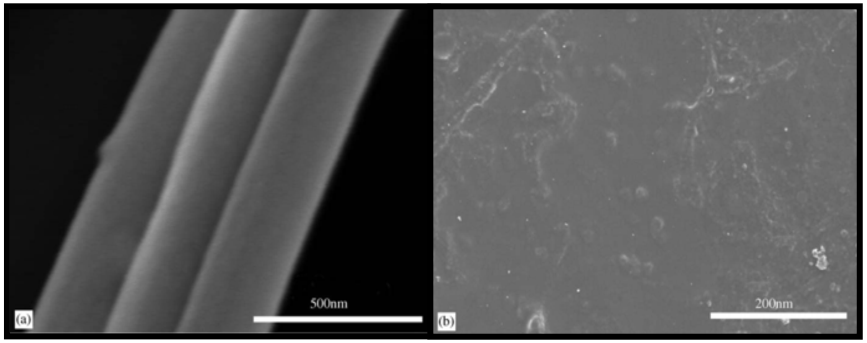


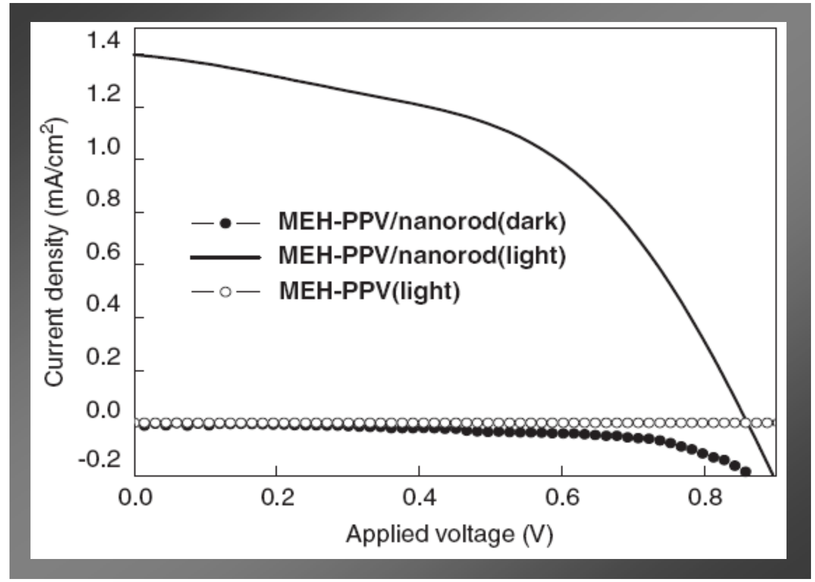


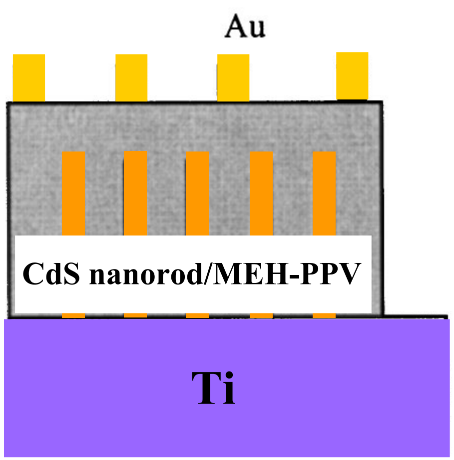


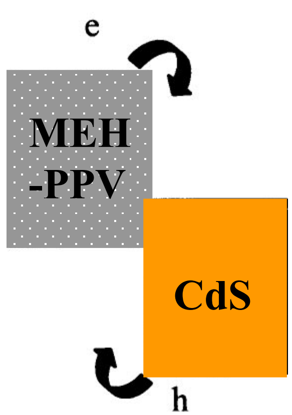
Short-circuit current (J_{SC}): 3.12 mA/cm^2
Open-circuit voltage (V_{OC}): 0.714 V
Fill factor (FF): 47.7 %
Power conversion efficiency (η): 1.06 %
under AM 1.5 conditions.[5]











Short-circuit current (J_{SC}): 1.40 mA/cm^2
Open-circuit voltage (V_{OC}): 0.858 V
Fill factor (FF): 49.6 %
Power conversion efficiency (η): 0.6 %
under AM 1.5 conditions.[6]

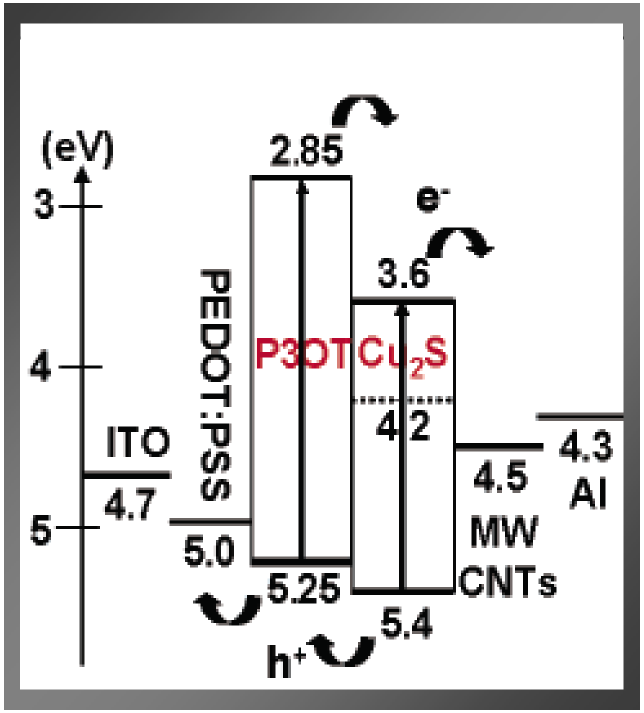
Hybrid nanostructures

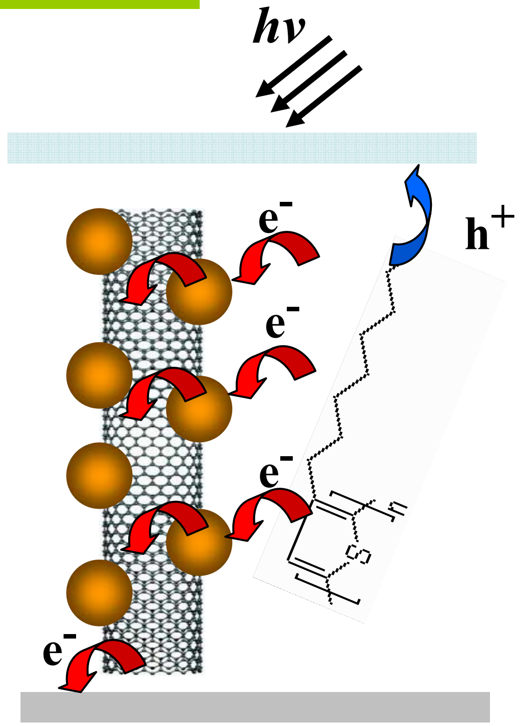
Quantum dots as charge separator and generator

Carbon nanotubes as the supporter to improve charge separation and transport

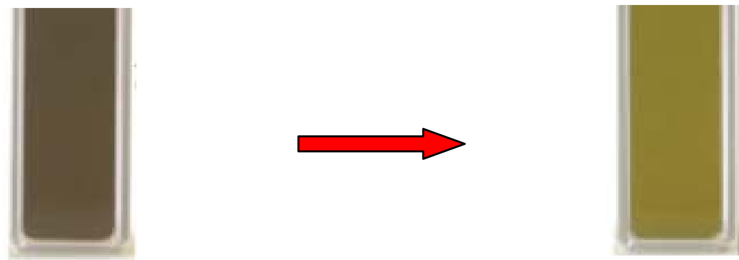
Direct assembly

Hybrid nanostructures[7]

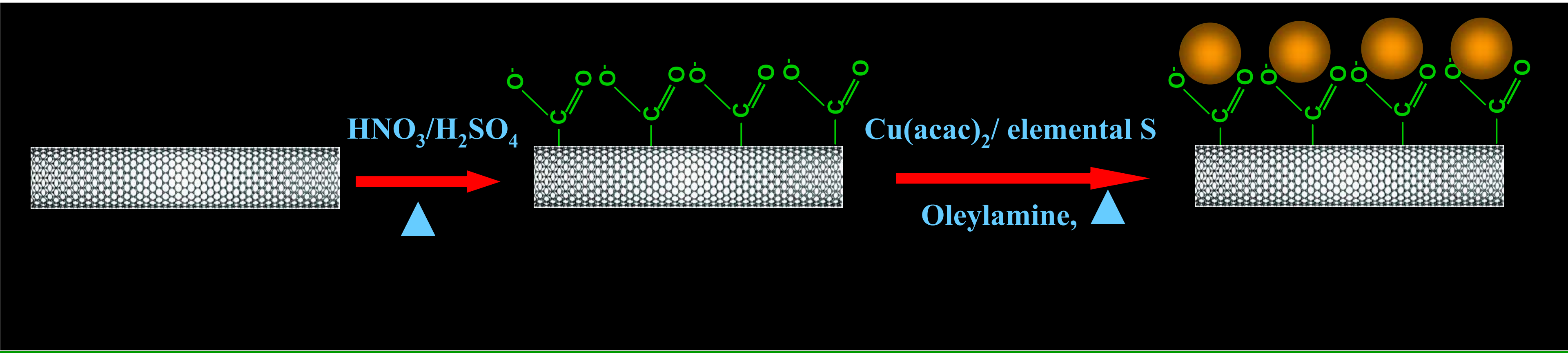


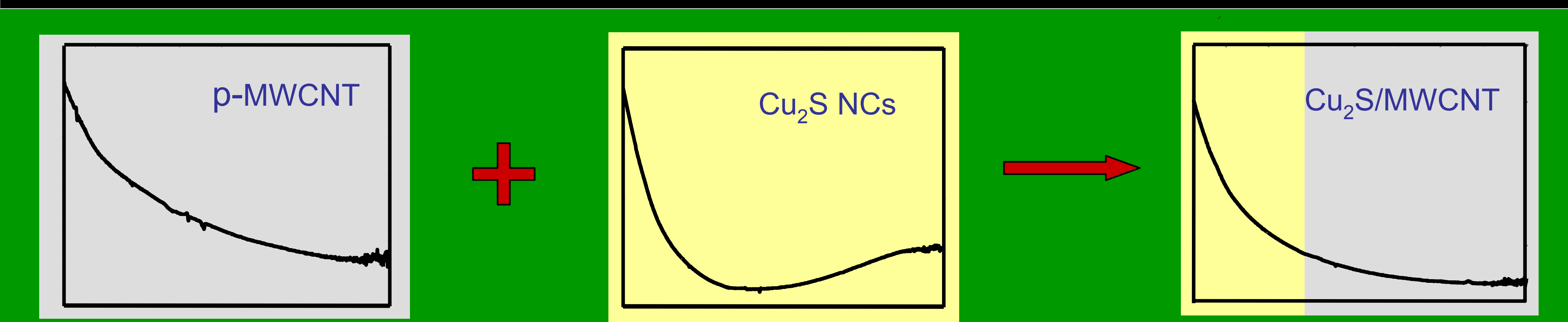


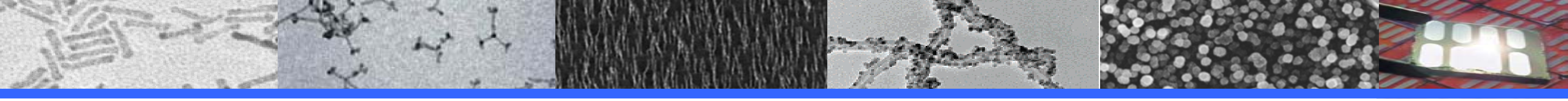
Material synthesis



p-MWCNT in EtOH → Cu_2S/MWCNT in $CHCl_3$







0.05M $Cu(acac)_2$

0.1M $Cu(acac)_2$

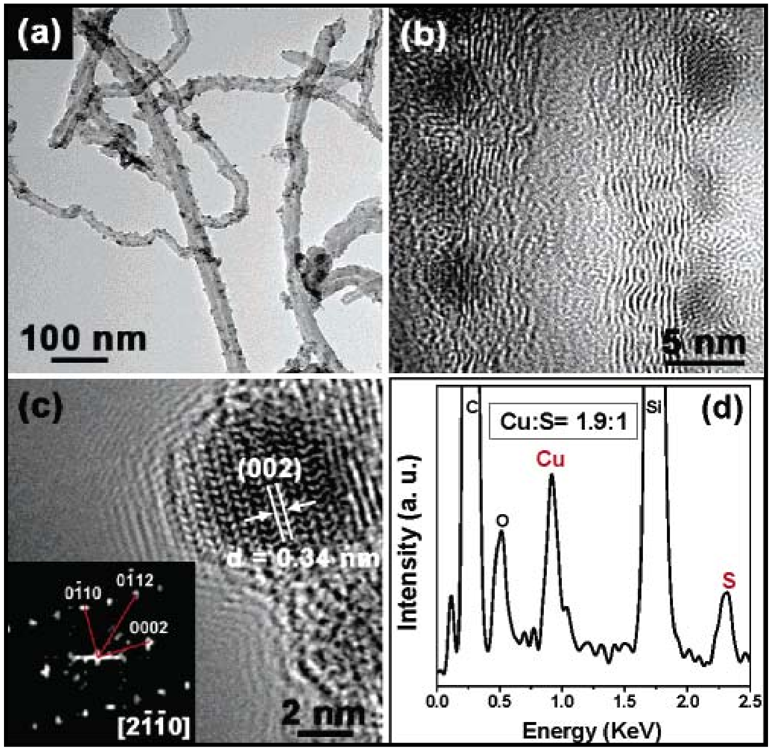


Fig.1

Hexagonal chalcocite β-Cu_2S (JCPDS no. 26-1116; *a* = 3.961 Å, *c* = 6.722 Å).

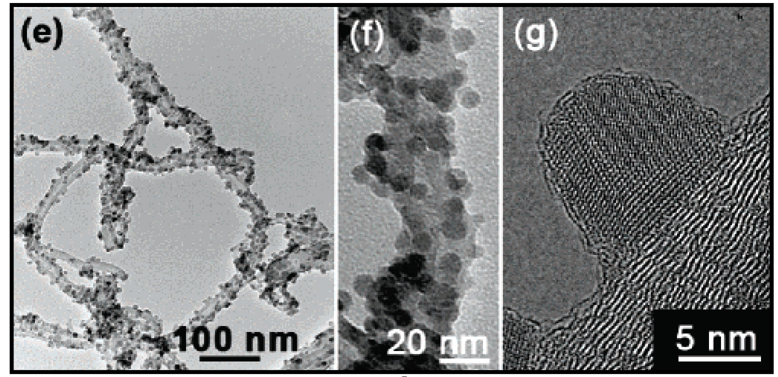


Fig.1

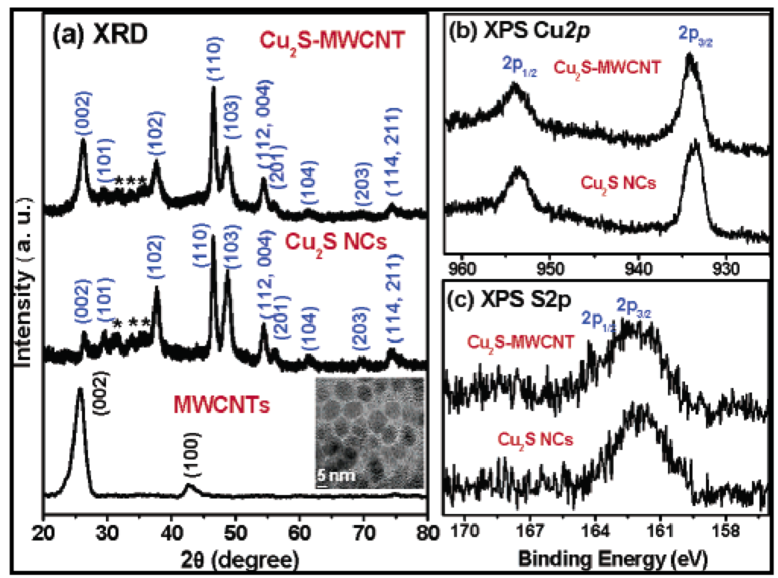
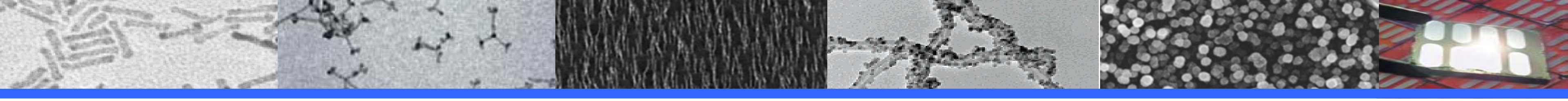


Fig.2



1.5M $Cu(acac)_2$

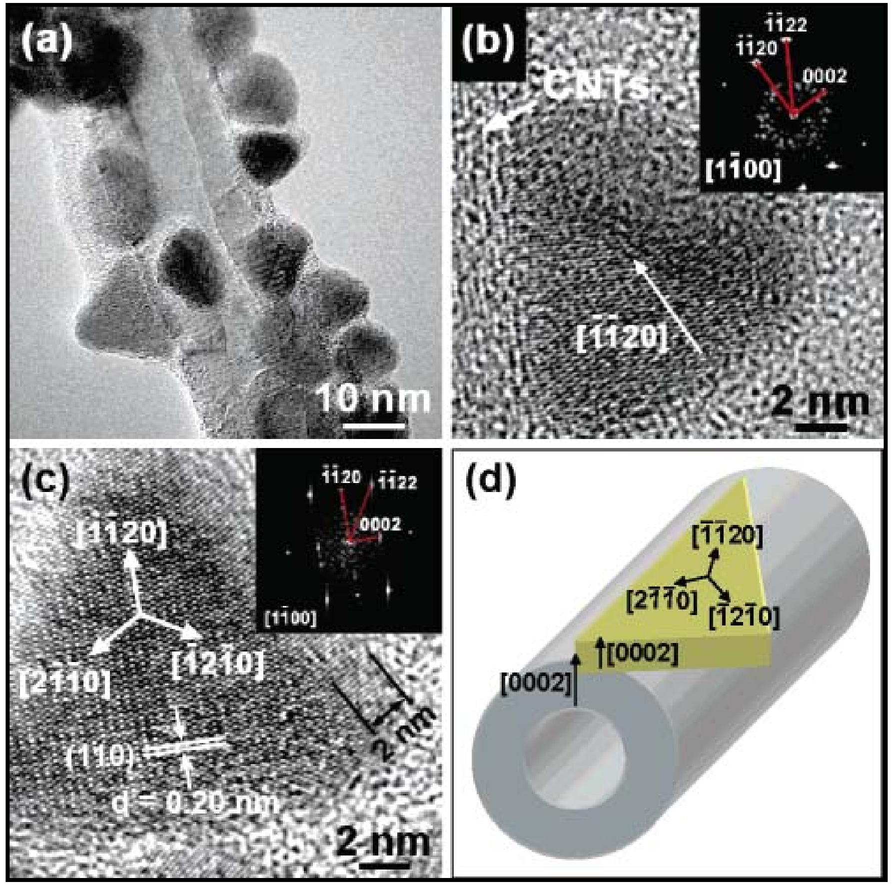


Fig.3

Solar cell fabrication

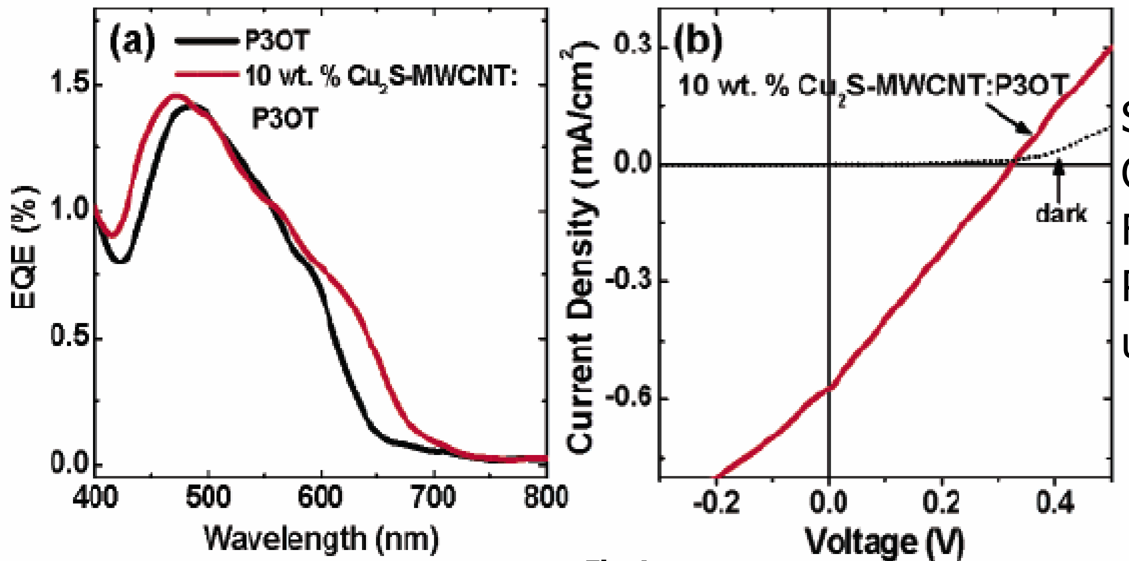
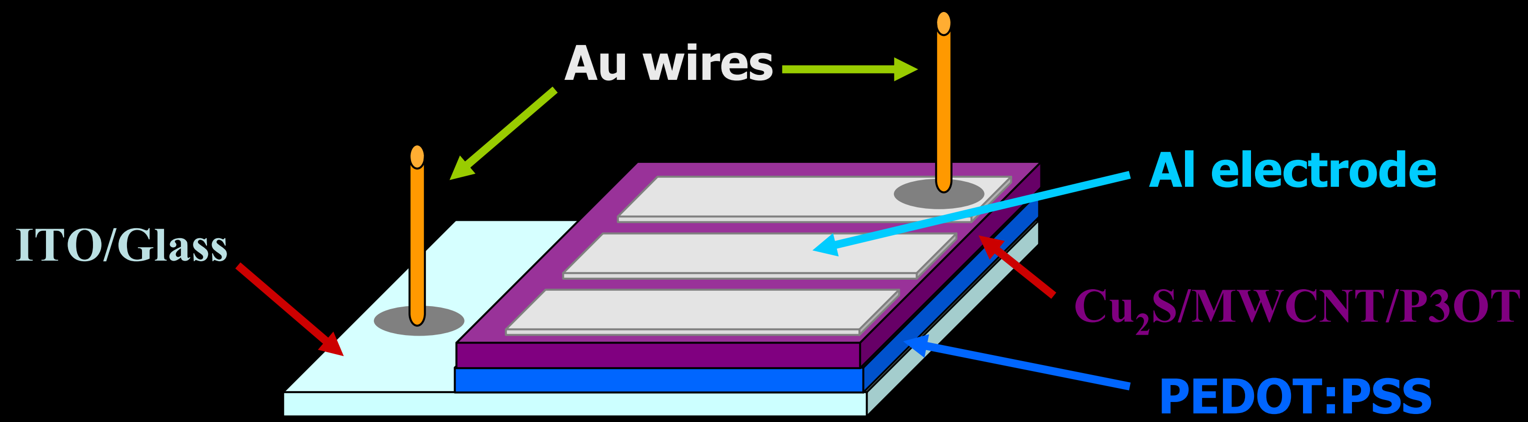


Fig.4

Short-circuit current (J_{SC}): 0.57 mA/cm^2
Open-circuit voltage (V_{OC}): 0.32 V,
Fill factor (*FF*): 44 %
Power conversion efficiency (η): 0.08 %
under AM 1.5 conditions.



Conclusion

1. Single-crystalline hexagonal-phase β-Cu_2S NCs were grown in situ on acid-functionalized MWCNTs by the solvothermal method.

2. The morphology of the Cu_2S NCs was varied from spherical particles (avg. size 4 nm) to triangular plates (avg. size 12 nm) by increasing the concentration of the precursors.

3. The lattice matching between the (002) planes of Cu_2S and the (002) planes of the MWCNTs is thought to be an important factor in the growth of the Cu_2S NCs on the surface of the MWCNTs.

4. The photovoltaic device fabricated from the blends of Cu_2S-MWCNT and P3OT responds more sensitively than those fabricated using Cu_2S NCs or MWCNTs alone.

5. The maximum power conversion efficiency was found to be 0.08%. Direct, efficient electron transport from the photoexcited Cu_2S NCs to the MWCNTs would enhance their photocurrents.

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