Nanomorphology controls in colloidal nanocrystal – polymer bulk heterojunction solar cells based on non-toxic inorganic acceptors and functional block copolymers

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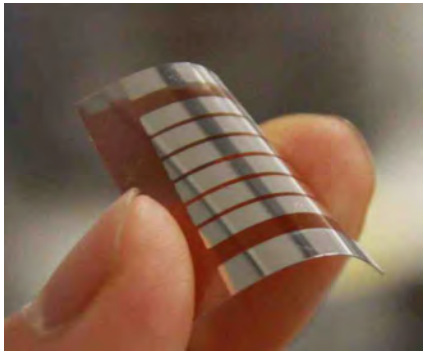
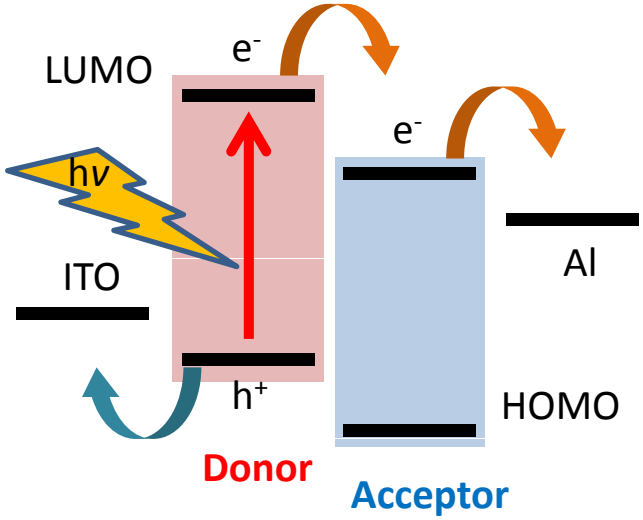
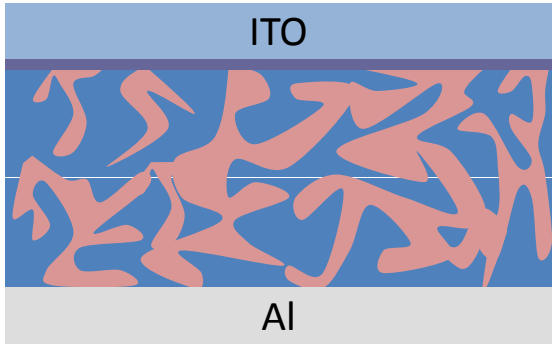
Organic Solar Cells







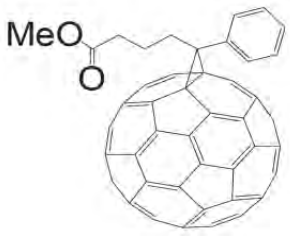
Bulk heterojunction structure

Hiramoto et al., *Appl. Phys. Let.*, **1991**, *58*, 1062.
Yu et al., *Science* **1995**, *270*, 1789.

Donor (p-type)

P3HT

Acceptor (n-type)

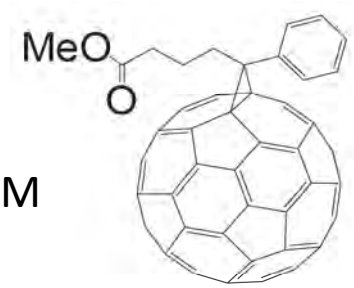


PCBM

Advantages

Low cost, Flexibility, Light weight

Hybrid Solar Cells

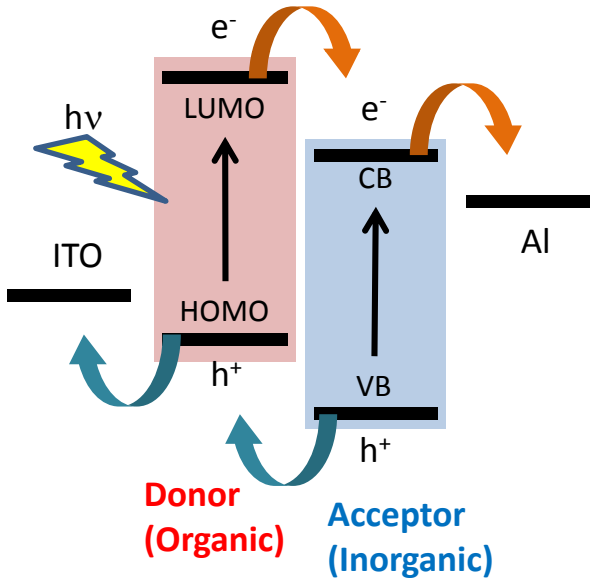


PCBM

- Weak Absorption in Visible
- Poor Electron Mobility

Hybrid Solar Cells

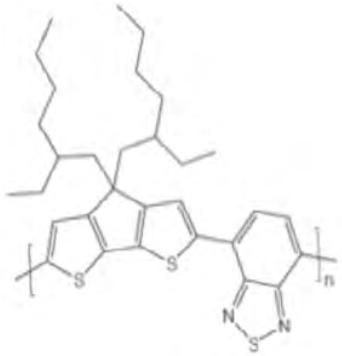
Inorganic Materials as Electron Acceptors



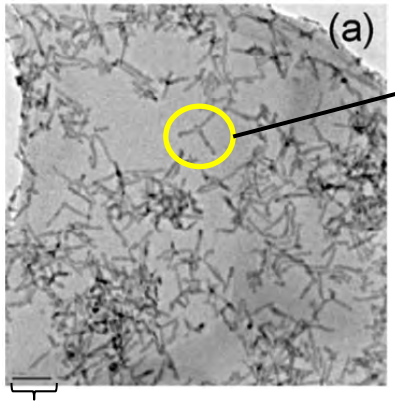
Advantages

- Absorption of visible light
- High electron mobility

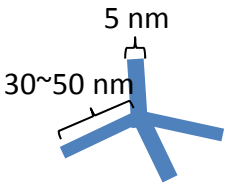
Hybrid Solar Cells

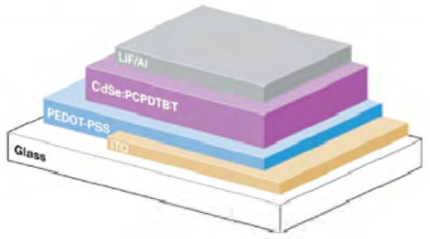


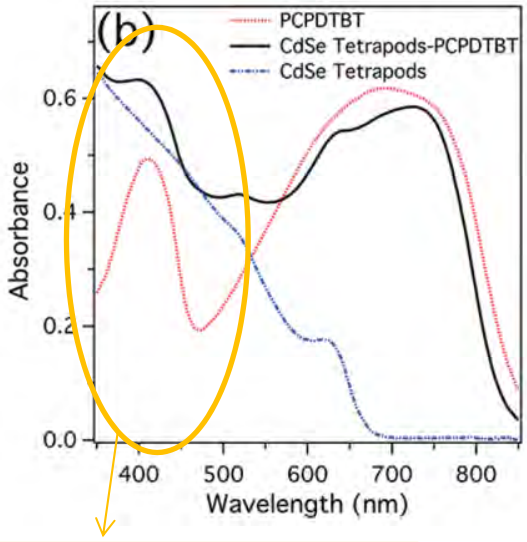
PCPDTBT
(Low bandgap polymer)



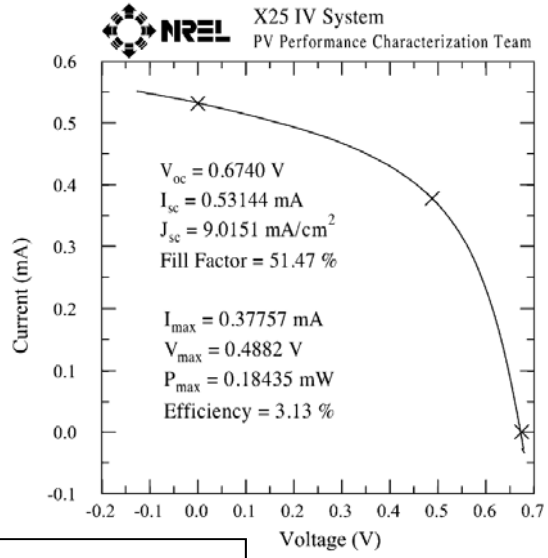
CdSe tetrapod







Absorption of CdSe

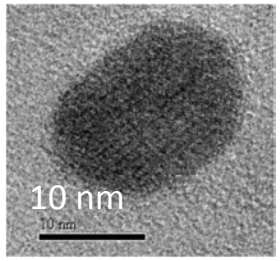


PCE : 3.13 %

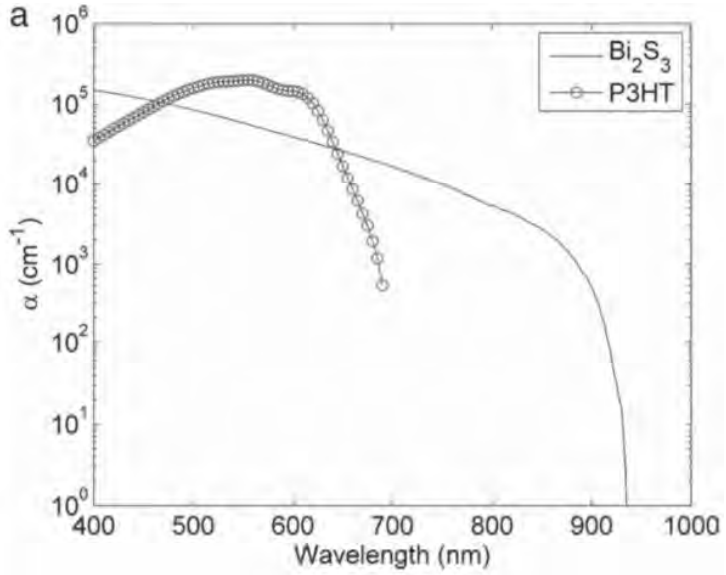
Highest PCE in polymer/nano particle hybrid solar cells

Dayal, *et al., Nano Letters* **2010** *10* (1), 239-242

Bismuth Sulfide (Bi_2S_3)

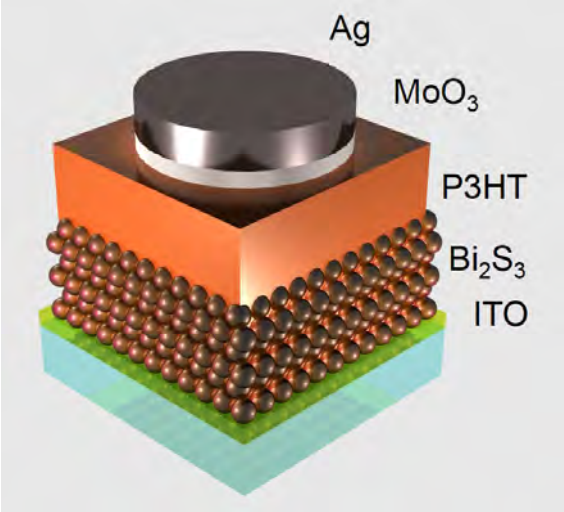


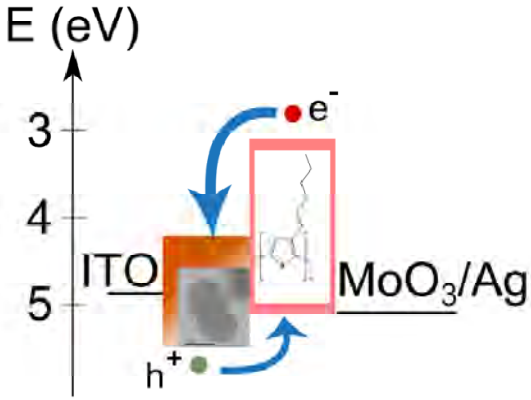
- Non-toxic (Cd, Pb have toxicity)
- Band gap: 1.3 eV (CB: -4.3 eV, VB:-5.6 eV)
  -Strong absorption in near IR region
  → Contribution to light harvesting

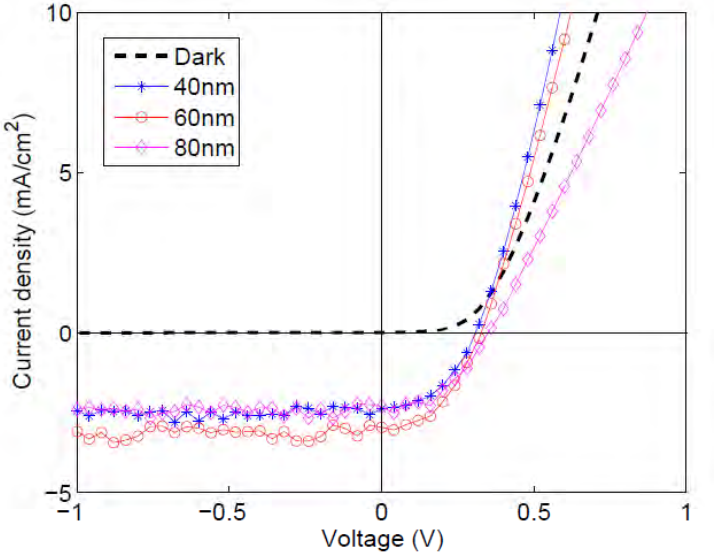


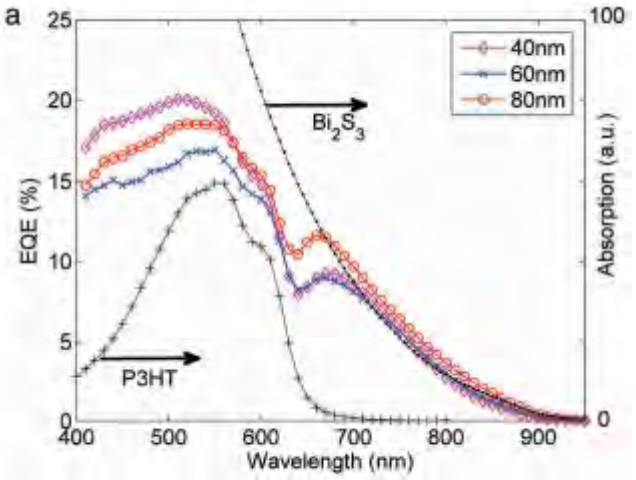
Good n-type Material
for Environmental Friendly
Hybrid Solar Cells

Polymer : Bi_2S_3 device (Bilayer) (From ICFO group)









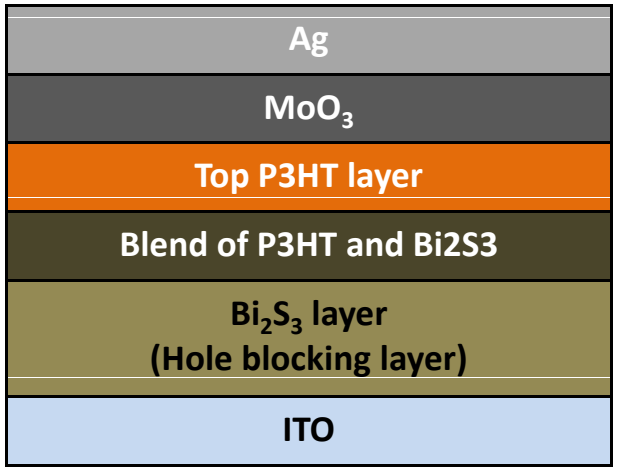
V_{oc} = 0.32 V
J_{sc} = 3 mAcm^{-2}
FF = 49%
PCE = 0.46%

Martinez, L.; Konstantatos, G., *Adv. Ener. Mater.*, **2011,** *1*, 1029.

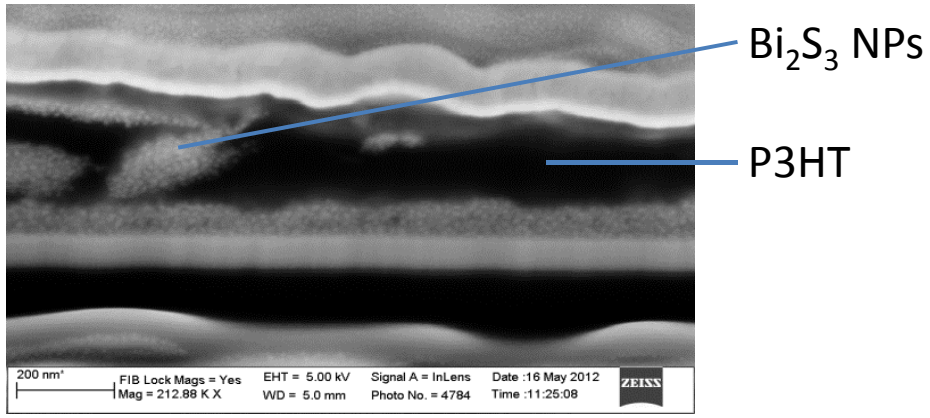
Bulk heterojunction device

Problem of Bulk Heterojunction Device

Device structure



Cross sectional SEM image of BHJ device



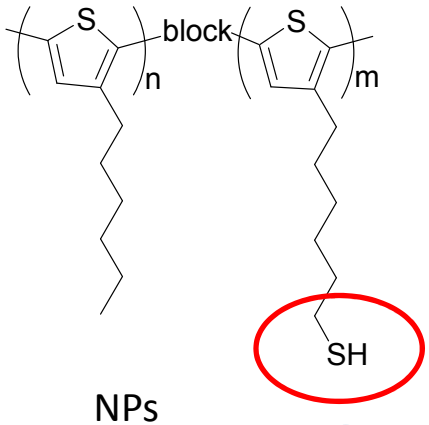
Very Poor Mixing between Bi_2S_3 NPs and P3HT

Small D/A interface area limits its efficiency

→ **PCE : ~0.7%**

Need to control morphology in BHJ device
By interactions between functional polymers and NPs

Thiol Containing Block Copolymer

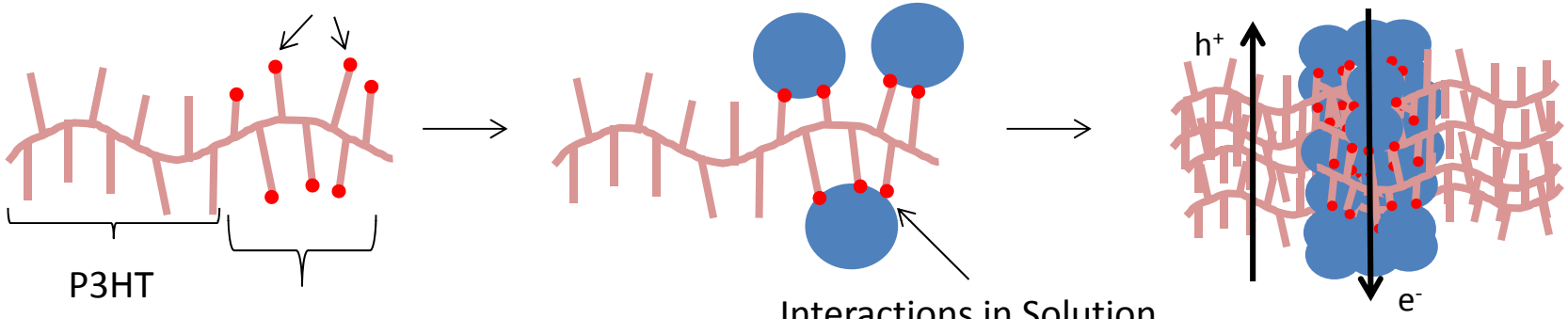


SH-P3HT

Expectation

Thiol groups

NPs

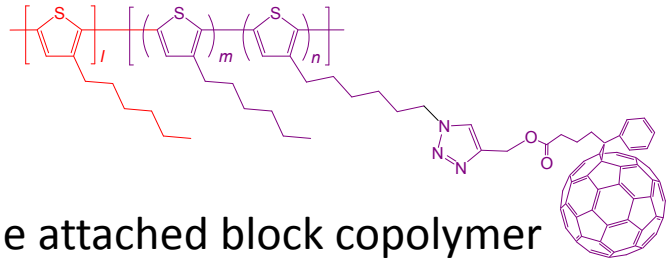


P3HT

Functional P3HT

Interactions in Solution

Self-assembled
Small D/A Domains

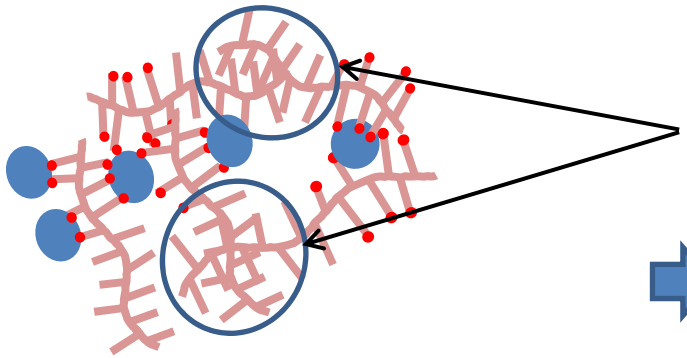


Fullerene attached block copolymer

This Idea Stems from Our Previous Work

Miyanishi et al. *Macromolecules*, **2012**, *45*, 6424

Discussions

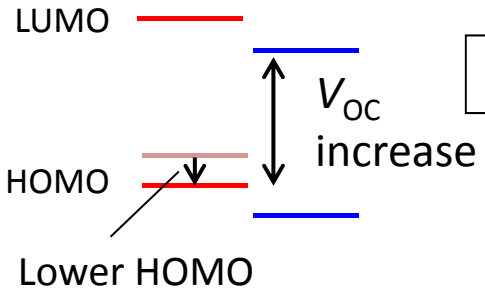


By attaching NPs through thiol group, packing of P3HT might be disturbed

SH-P3HT domain has poor crystallinity

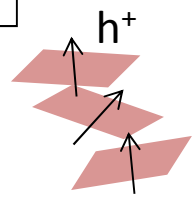
Reasons of V_{OC} increase and J_{SC} decrease

- Worse packing of polymer
- Isolation of NPs



Lower HOMO → V_{OC} ↑

Bad charge transport pathway → J_{SC} ↓



Worse packed P3HT

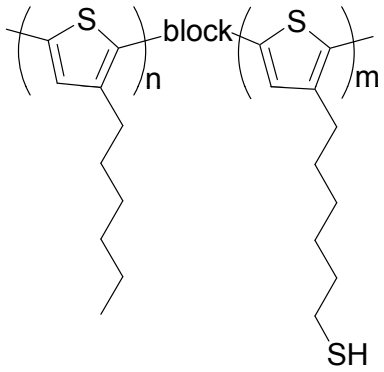
Amount of thiol groups seem too much

Use blend of normal P3HT and SH-P3HT or less thiol containing SH-P3HT

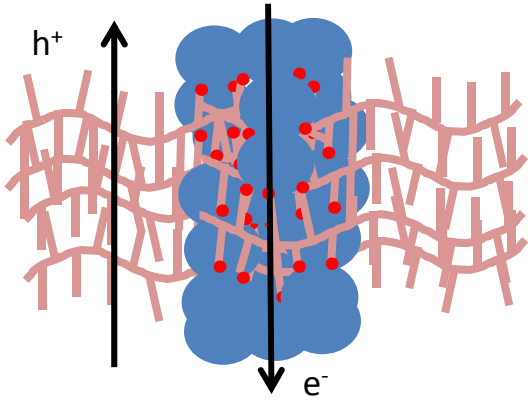
Summary

- Thiol Functionality Significantly Improved Morophology in NPs/Polymer Blend Films.

- Controlling Degree of Aggregation by Mixing P3HT and SH-P3HT Enhanced PCE to Close to 1 %.



SH-P3HT



Use of Functional Block Copolymer Is A Promising Approach
To Control Morophology of Hybrid Solar Cells