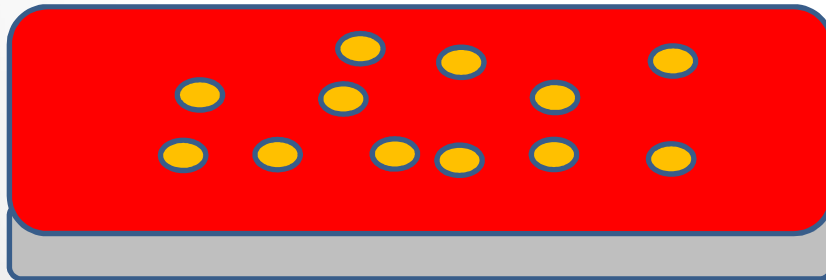
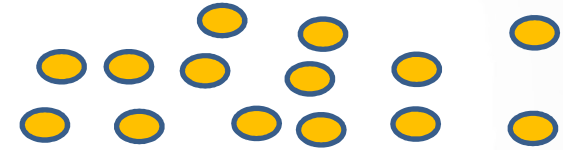


Molecular mobility in organic solar cells a mixed blessing

Gitti L. Frey

The Organic & Hybrid Materials and Devices (OHMD) Group



- Morphology stability (all organic electronics)
- Doping (all organic electronics)



- Stability (all organic electronics)
- Sensing (OFETs)



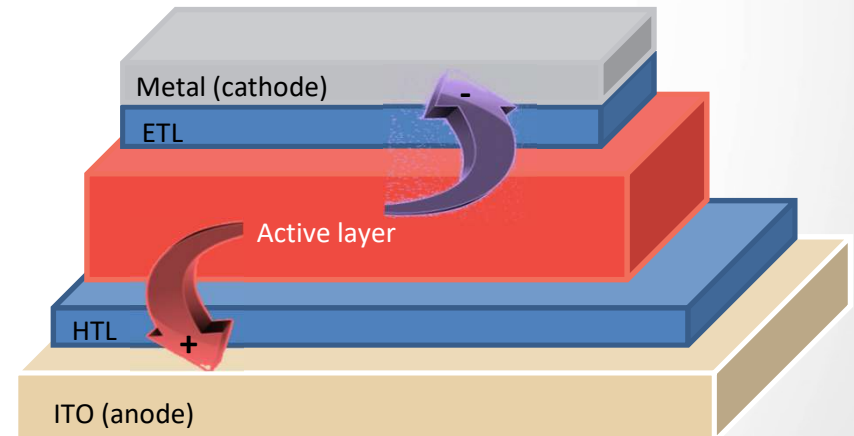
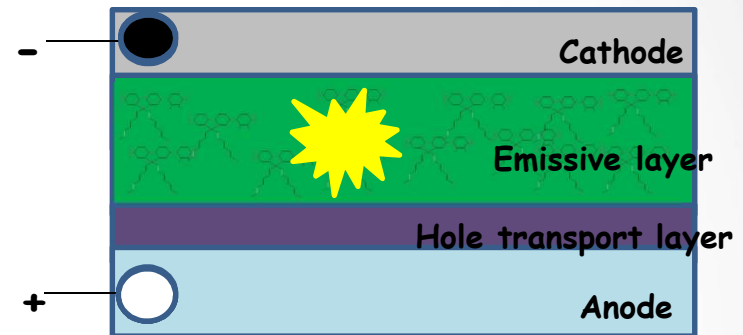
Department of Materials Science and Engineering

Technion - Israel Institute of Technology

Sede Boker Symposium March 2018

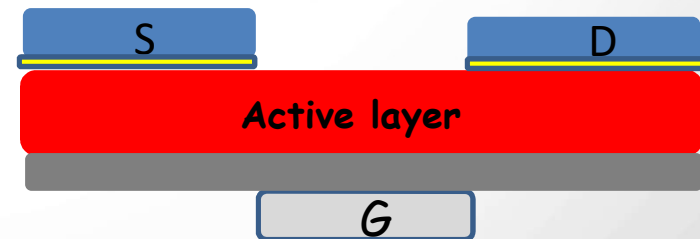
Interlayers in organic electronic devices

- **Interfacial energetics**
carrier injection/extraction,
carrier selectivity, contact
resistance

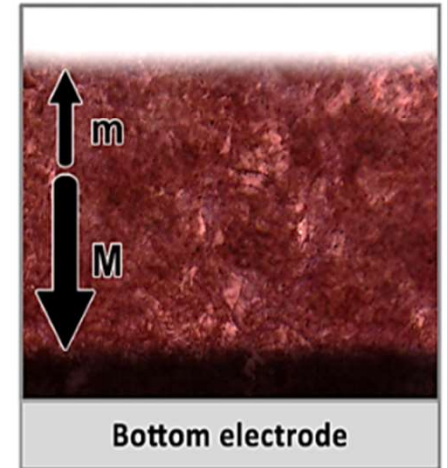


*Processing top interlayer
necessary*

*But technically challenging and
should also consider printing*



Mechanism for spontaneous formation of interlayers



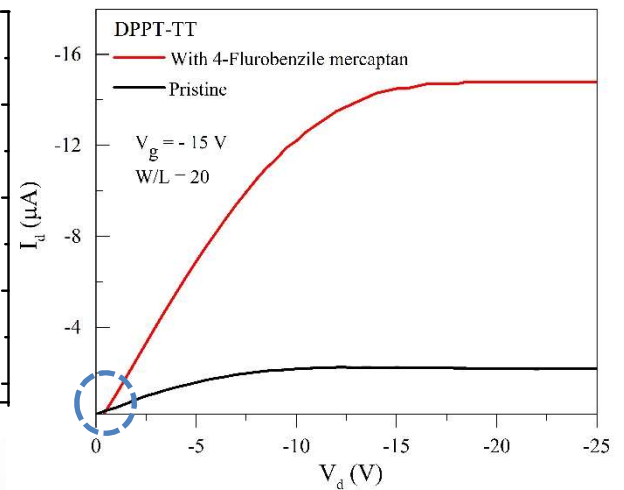
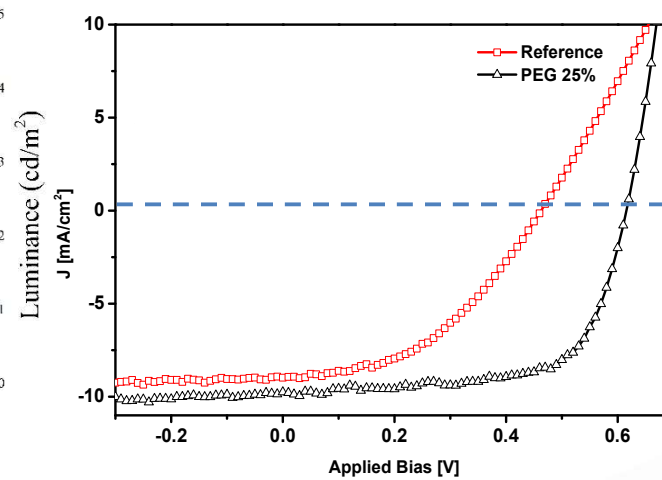
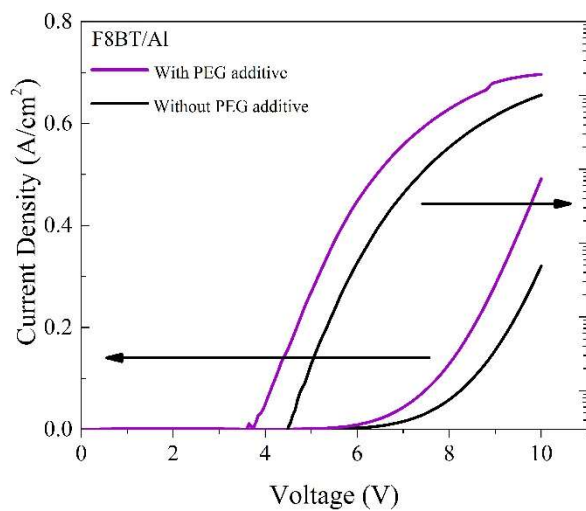
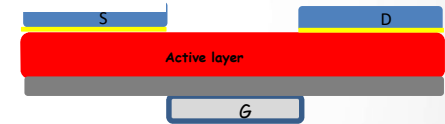
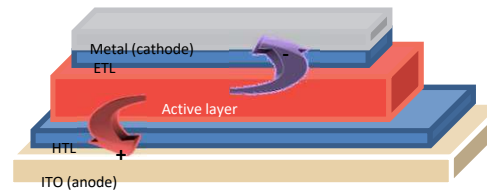
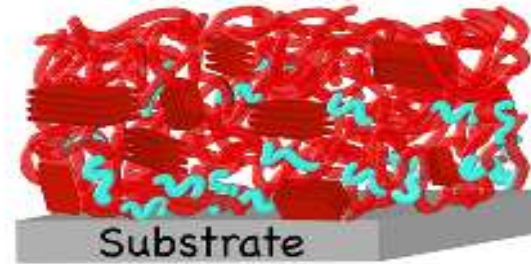
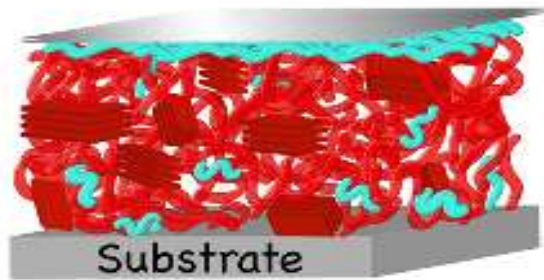
Surface energy
low \uparrow (F, Si)
High \downarrow (polar)

Solubility (\downarrow)

Density (\downarrow)

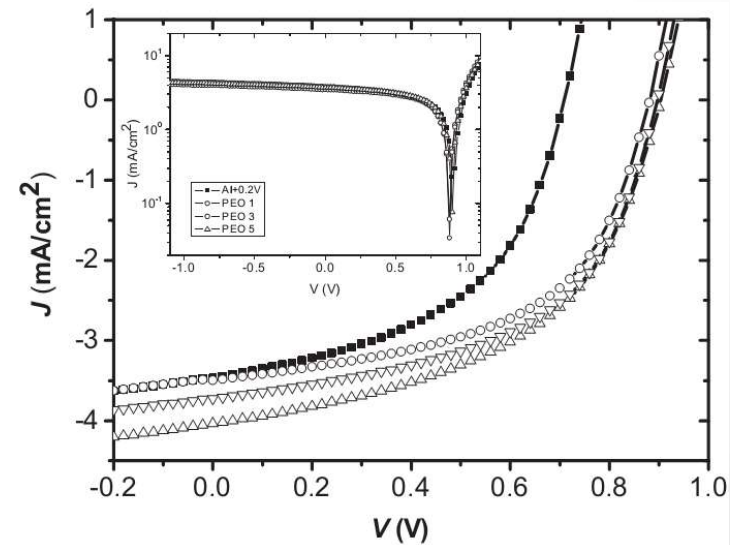
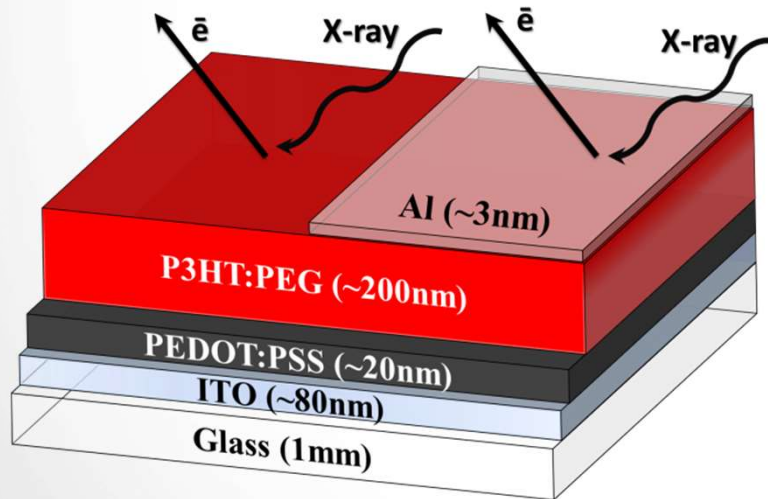
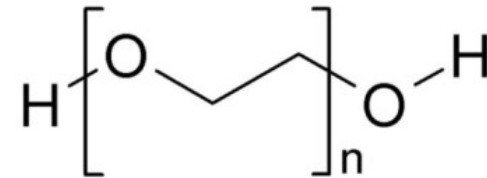
**Can metal/additive
interaction induce additive
migration to metal/organic
interface?**

Interlayer induced by additive/metal interactions



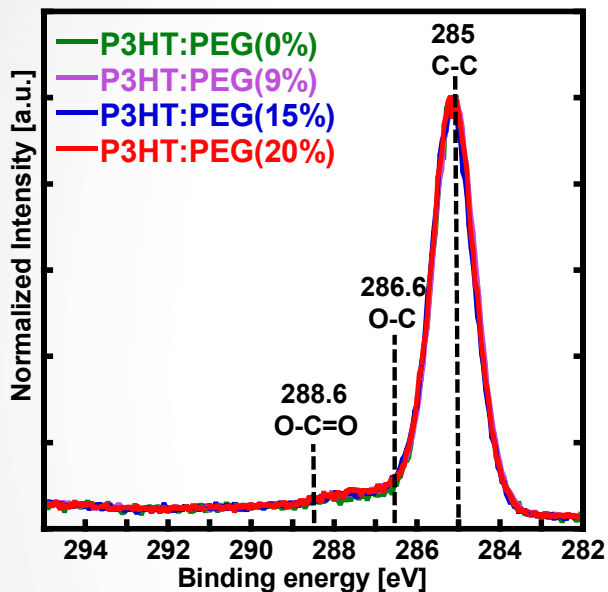
Additive for cathodic interlayer in OPV

- PEG shown to increase of Voc and FF
- High surface energy ↓
- XPS fingerprint

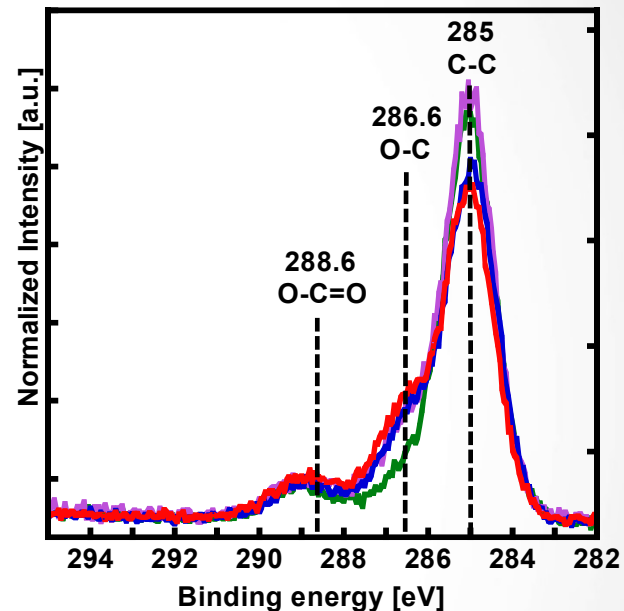
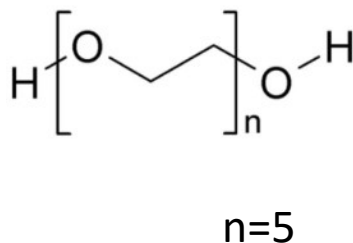


Material	Surface Energy [mJ/m ²]
P3HT	27
PCBM	38
PEG	43

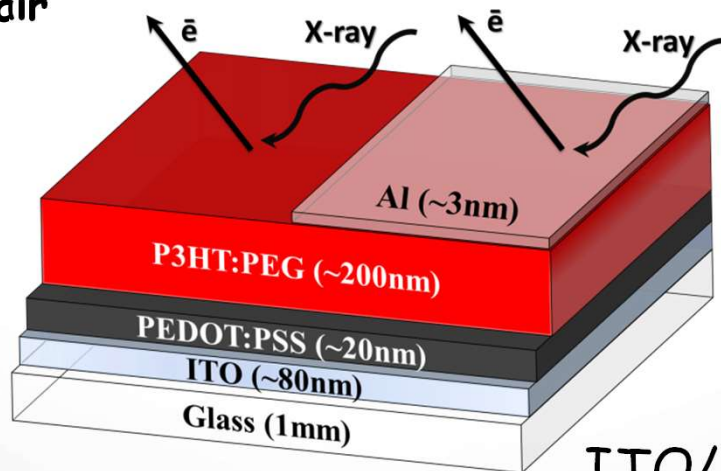
Surface (air/blend) vs. Interface (Al/blend)



PEG **absent** at blend/air interface



PEG **present** at blend/Al interface

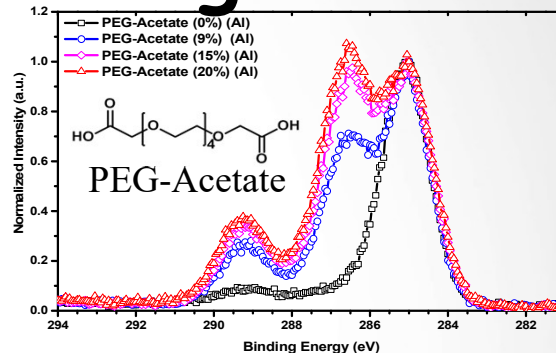
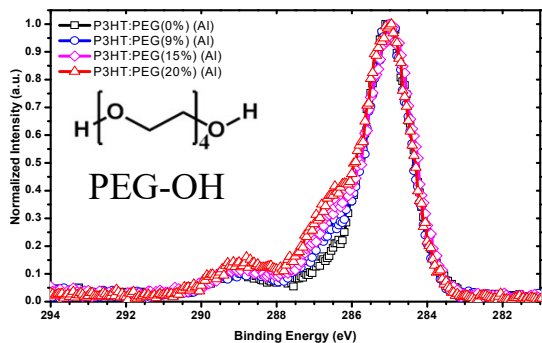
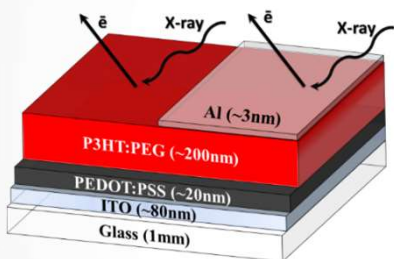


➤ **PEG migration induced by the metal evaporation!**

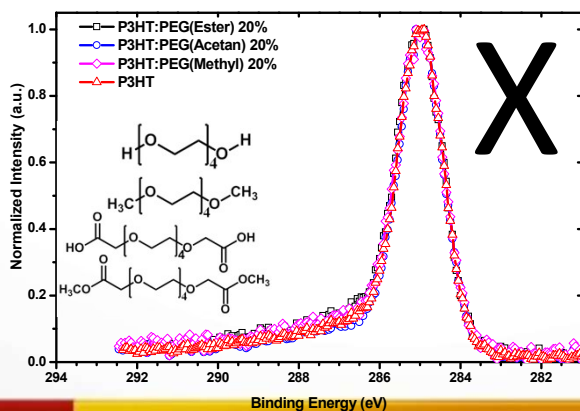
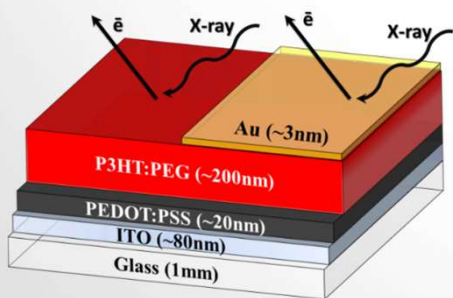
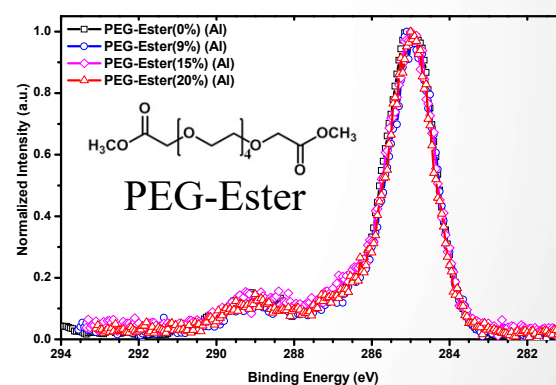
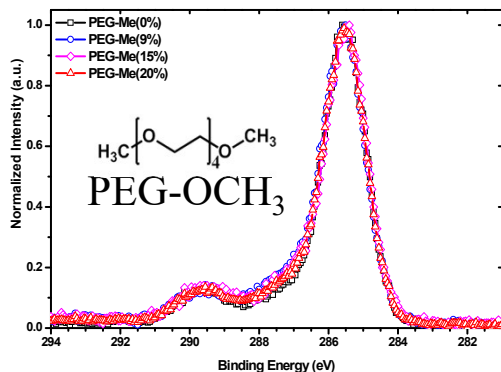
ITO/PEDOT:PSS/P3HT:PEG/Al

End group/metal interaction induces migration

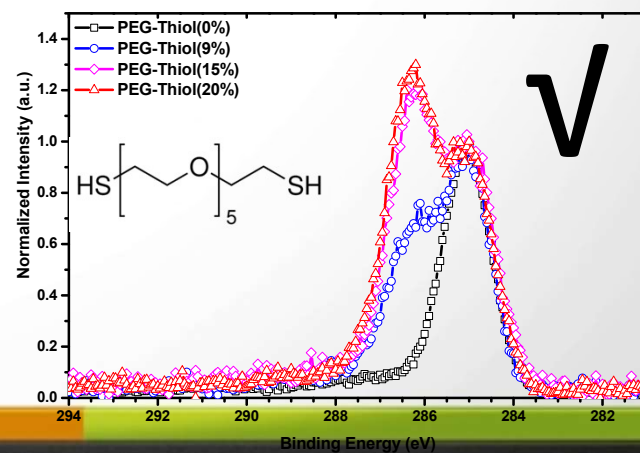
✓



X



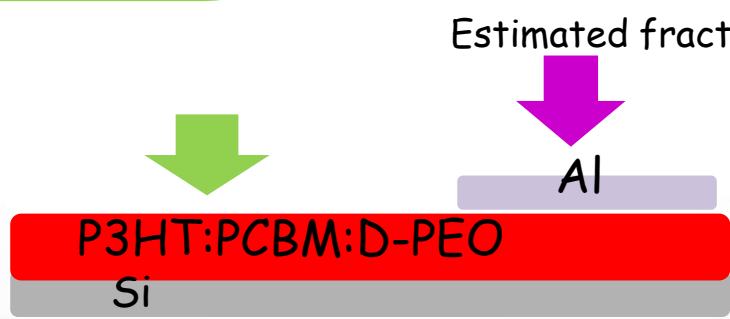
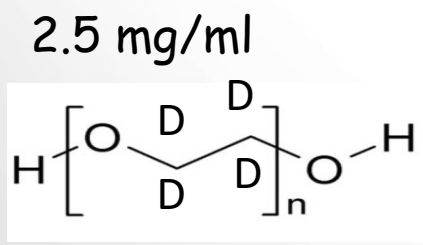
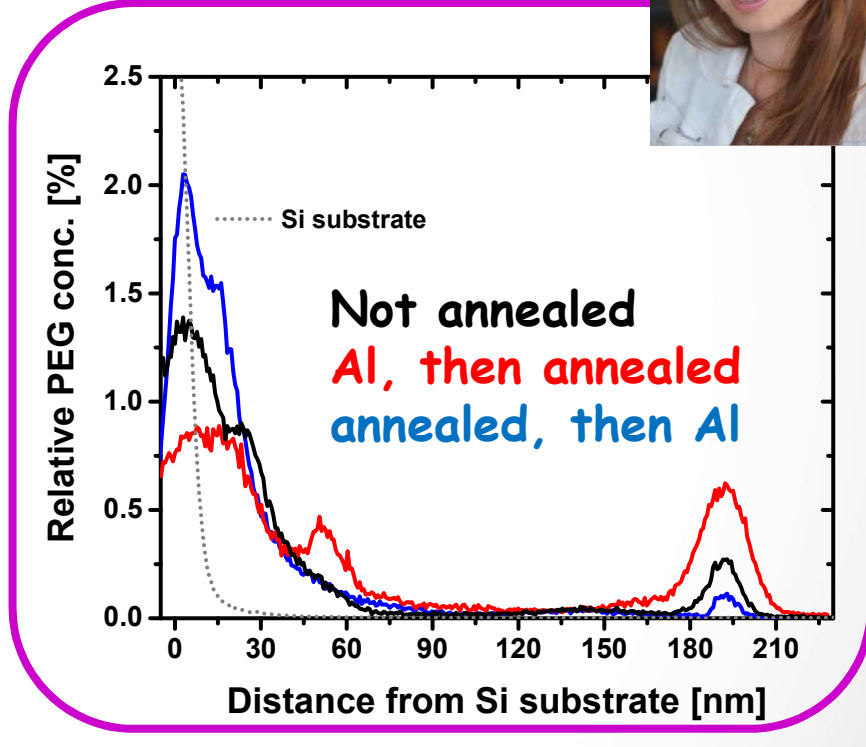
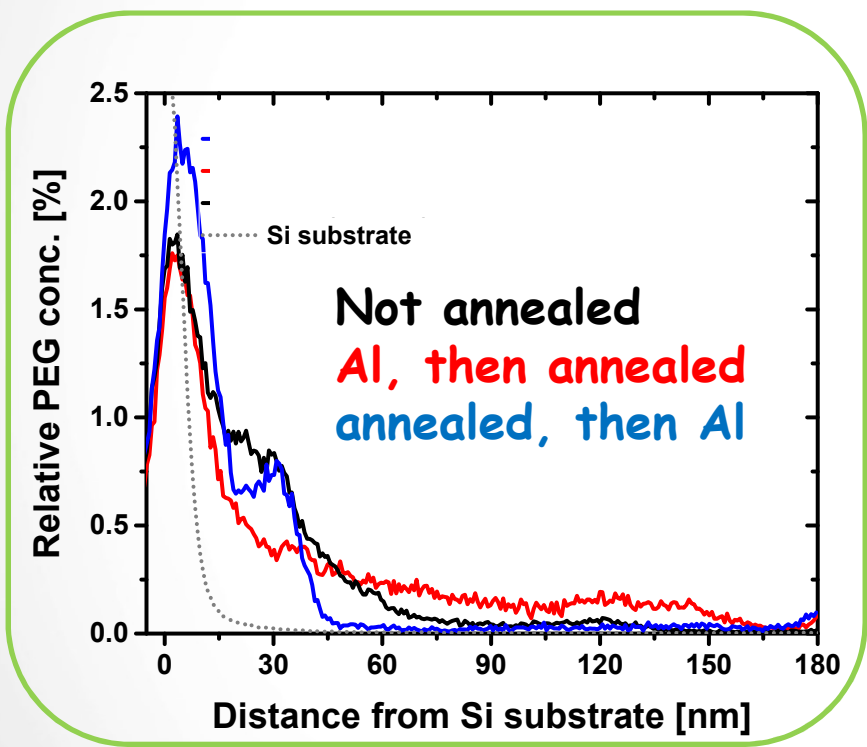
X



✓

Dynamics of segregation

DSIMS - with Prof Michael Chabynyc, UCSB

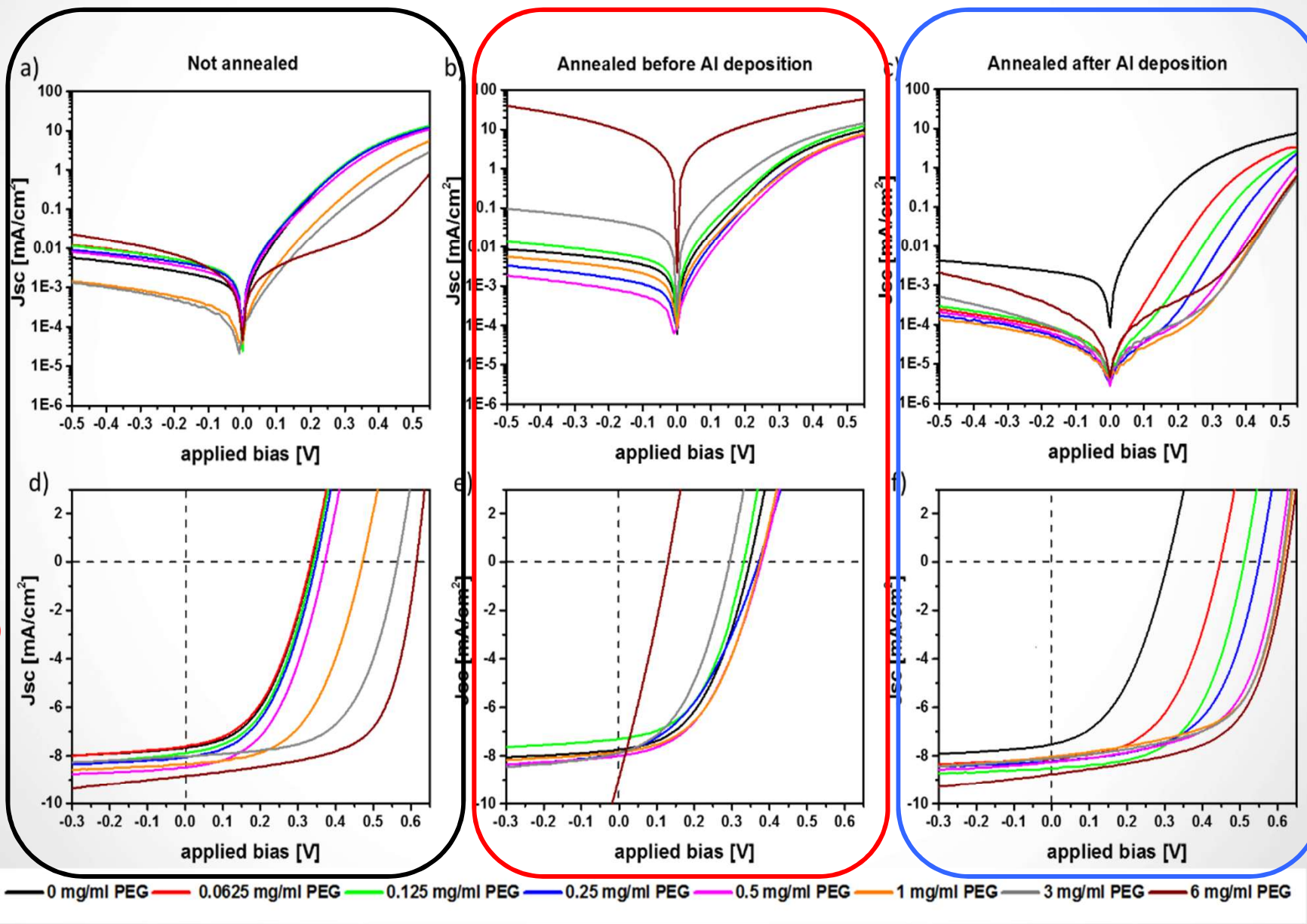


Estimated fraction of D-PEG at the interface:

- not annealed: 7 %
- annealed before Al: 2 %
- annealed after Al: 22 %

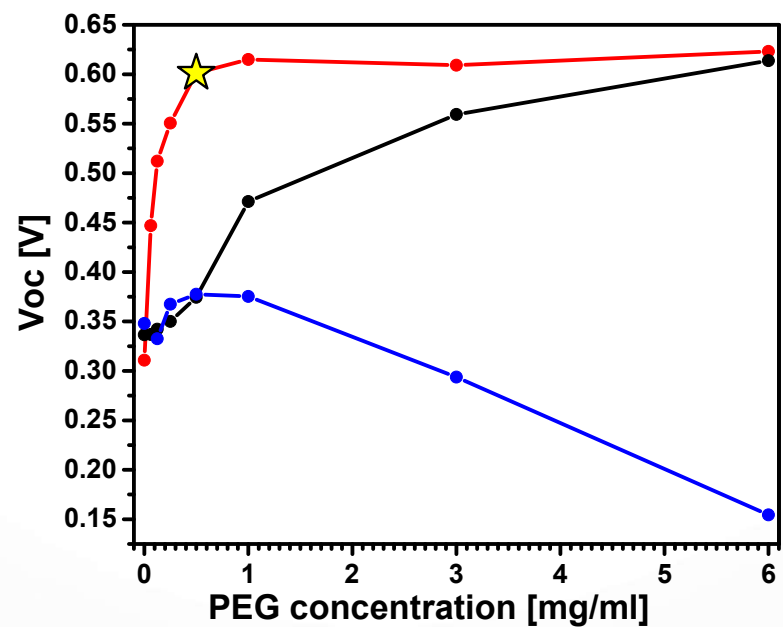
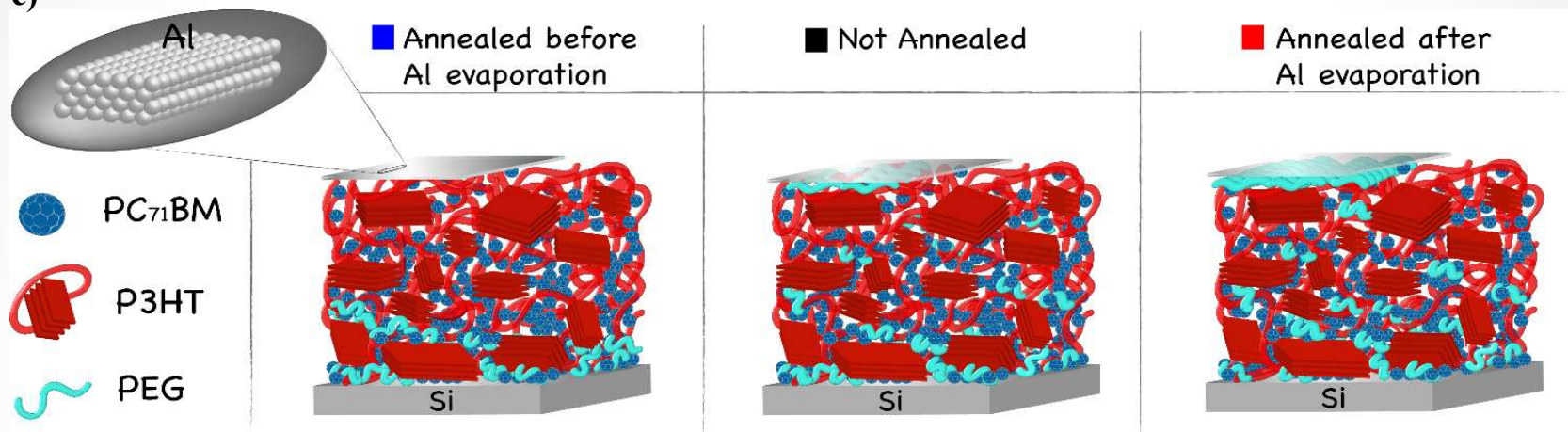
DARK

Light



Dynamics of segregation

c)

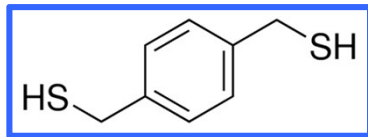




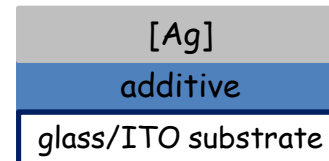
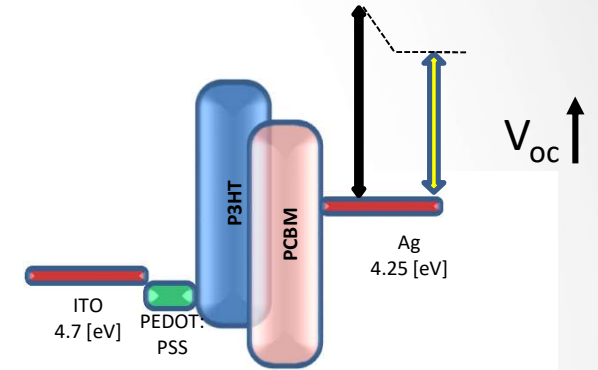
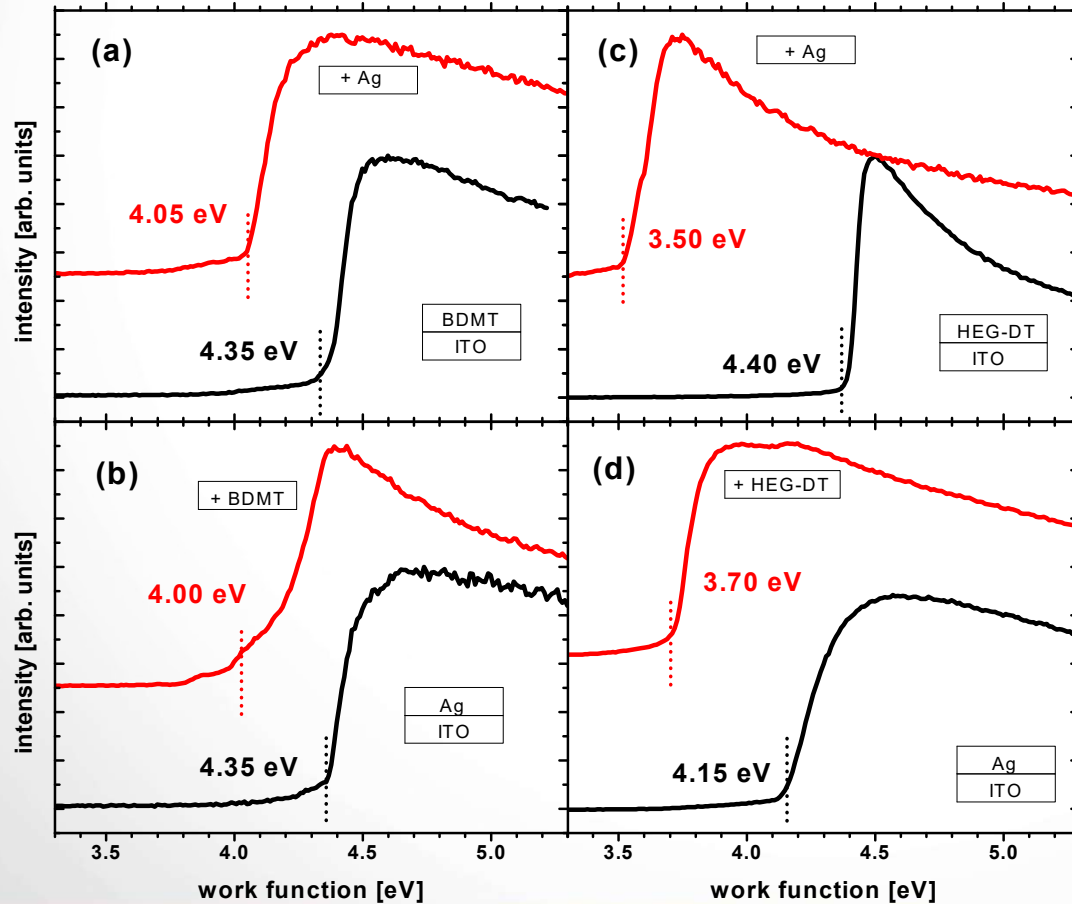
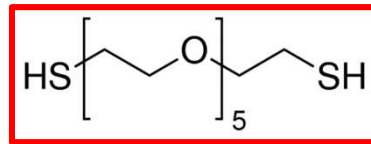
Electronic structure interlayer/cathode

With Norbert Prof Koch Humboldt-Universität zu Berlin

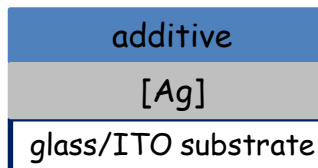
BDMT



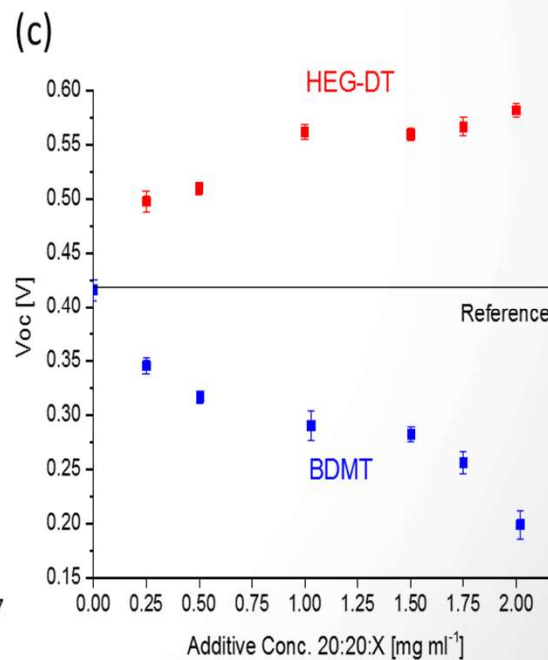
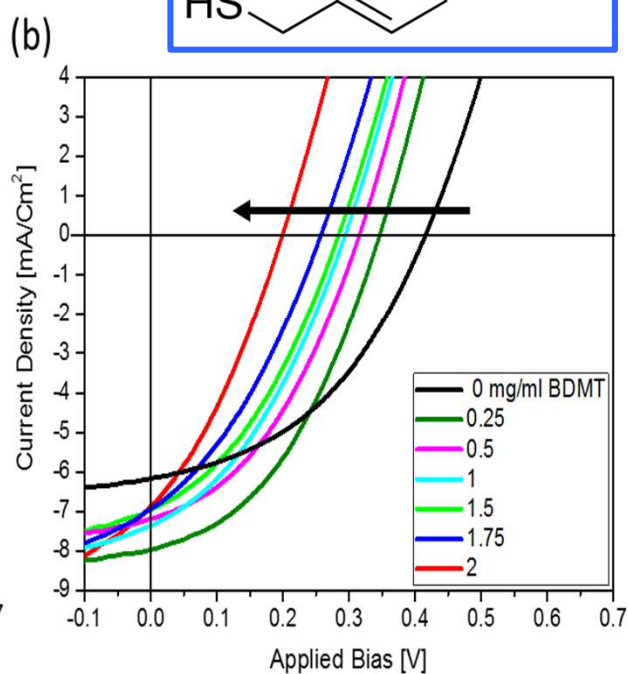
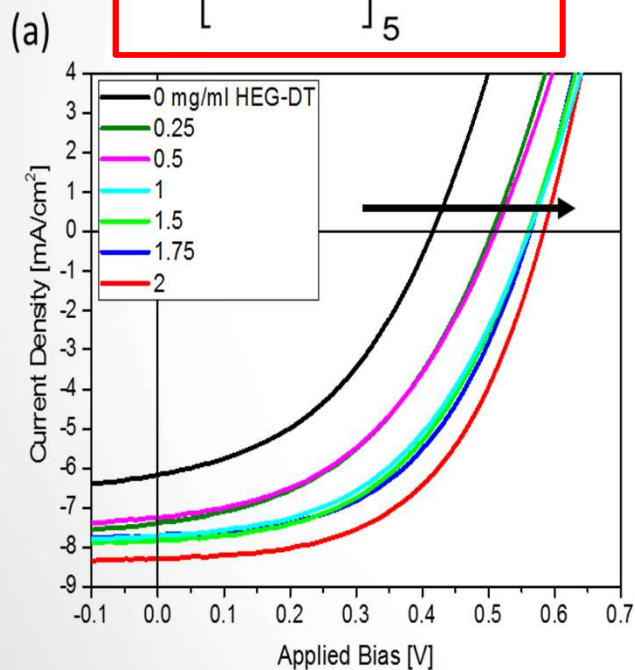
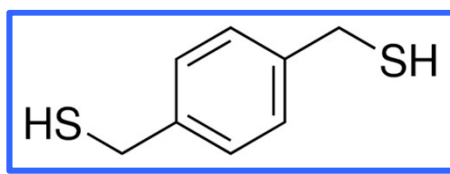
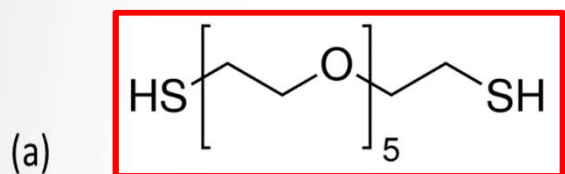
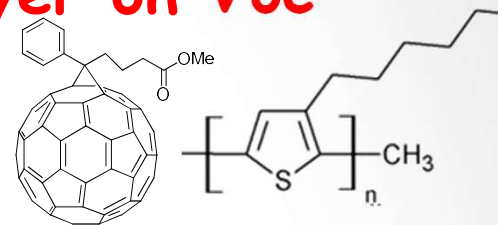
HEG-DT



WF
 HEG-DT/Ag ~ 3.5 eV
 BDMT/Ag ~ 4 eV
 Ag ~ 4.25 eV

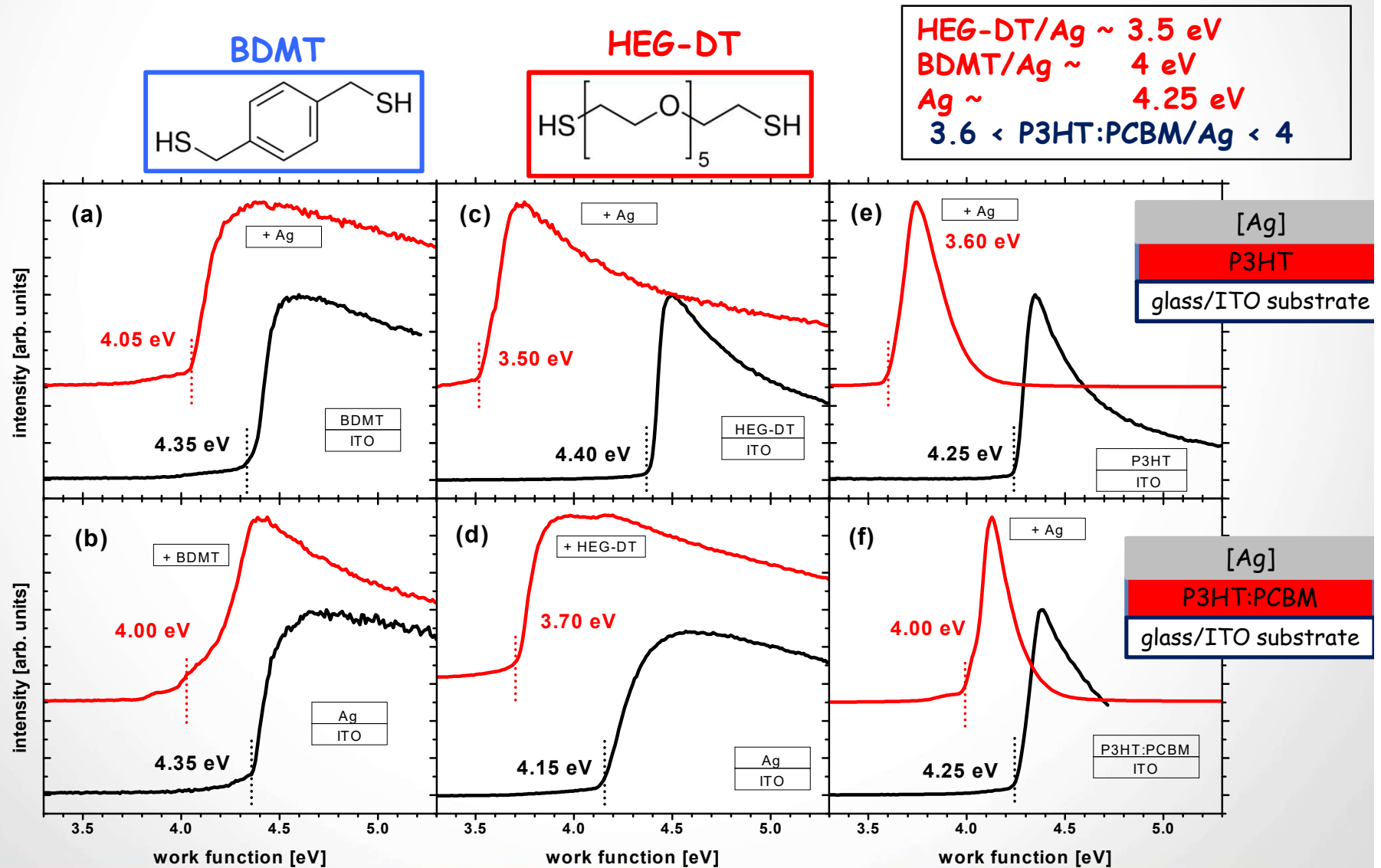


Effect of HEG-DT or BDMT interlayer on Voc

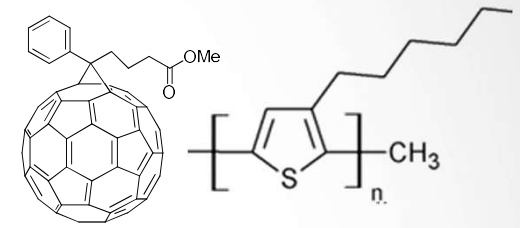
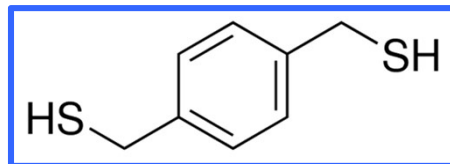
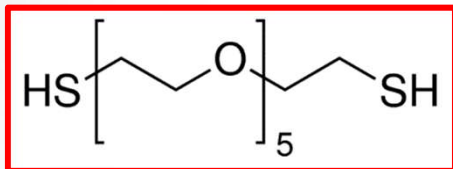


Electronic structure interlayer/cathode

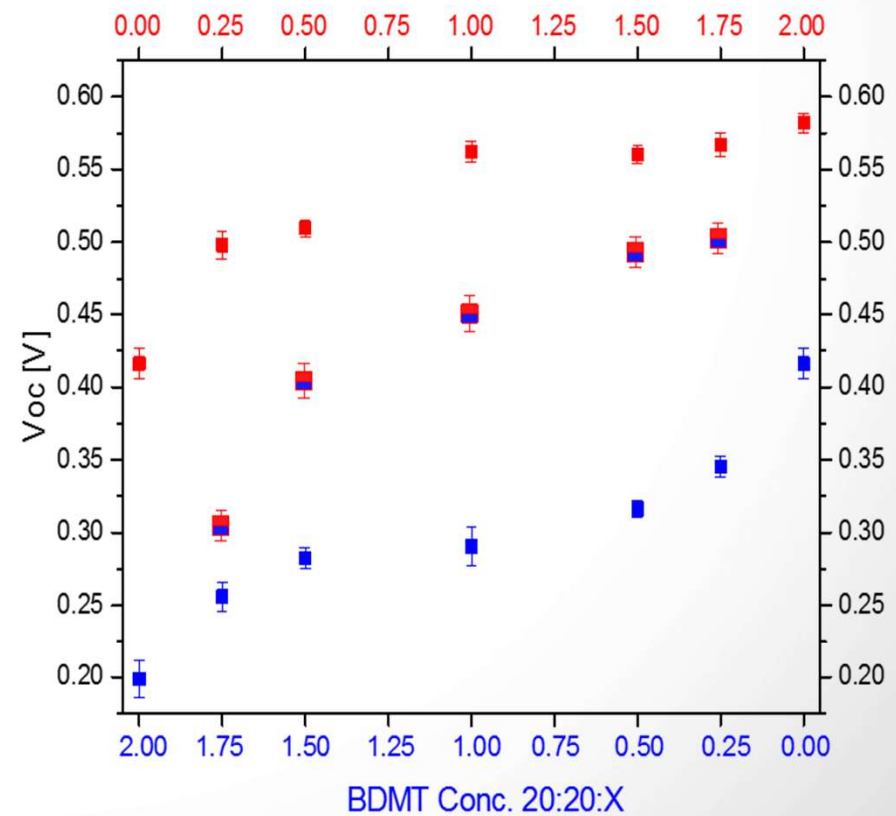
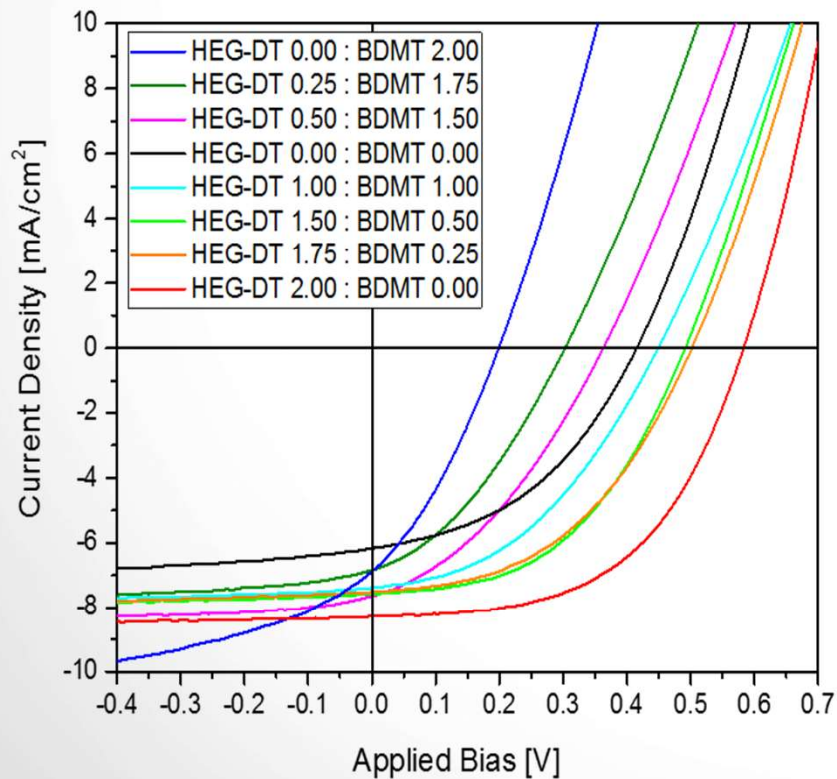
With Norbert Prof Koch Humboldt-Universität zu Berlin



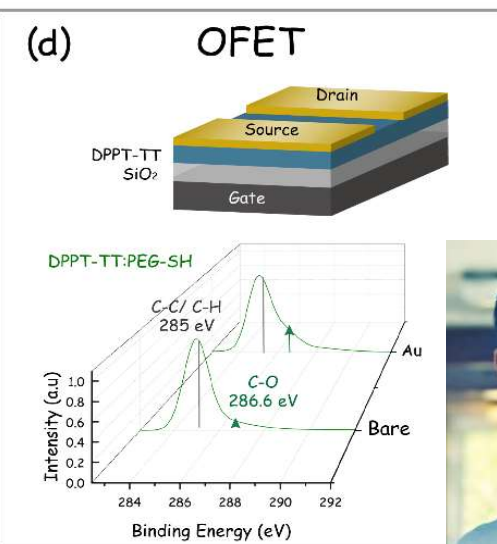
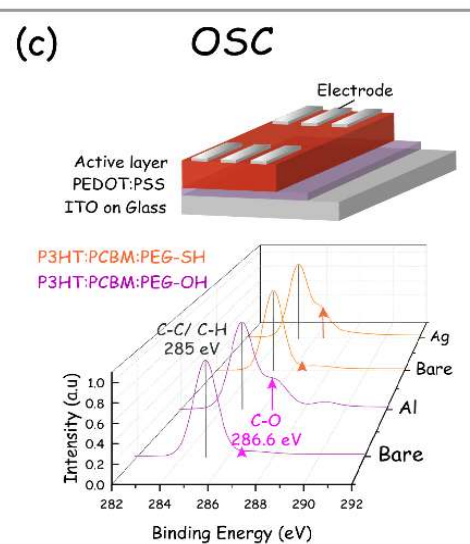
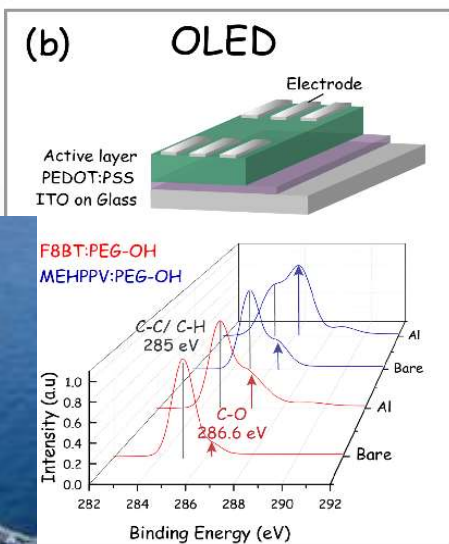
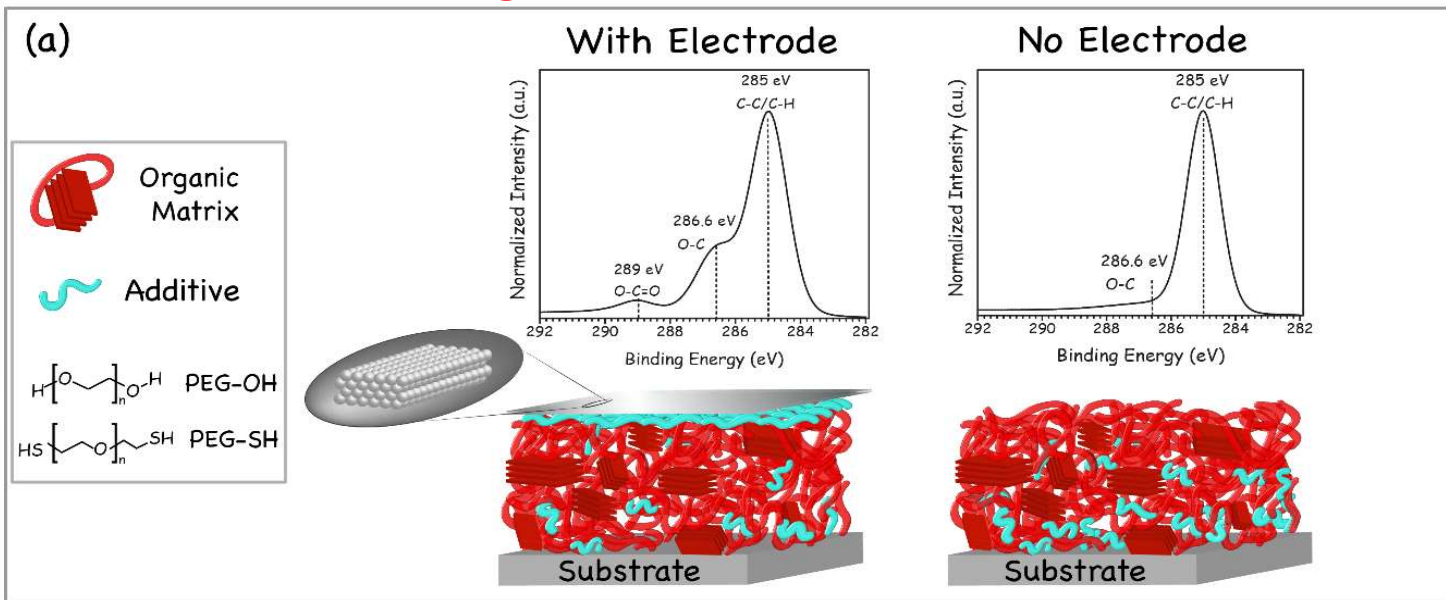
Tuning interfacial electrochemical potential



HEG Conc. 20:20:X



Interlayers Self-Generated by Additive-Metal Interactions in Organic Electronic Devices

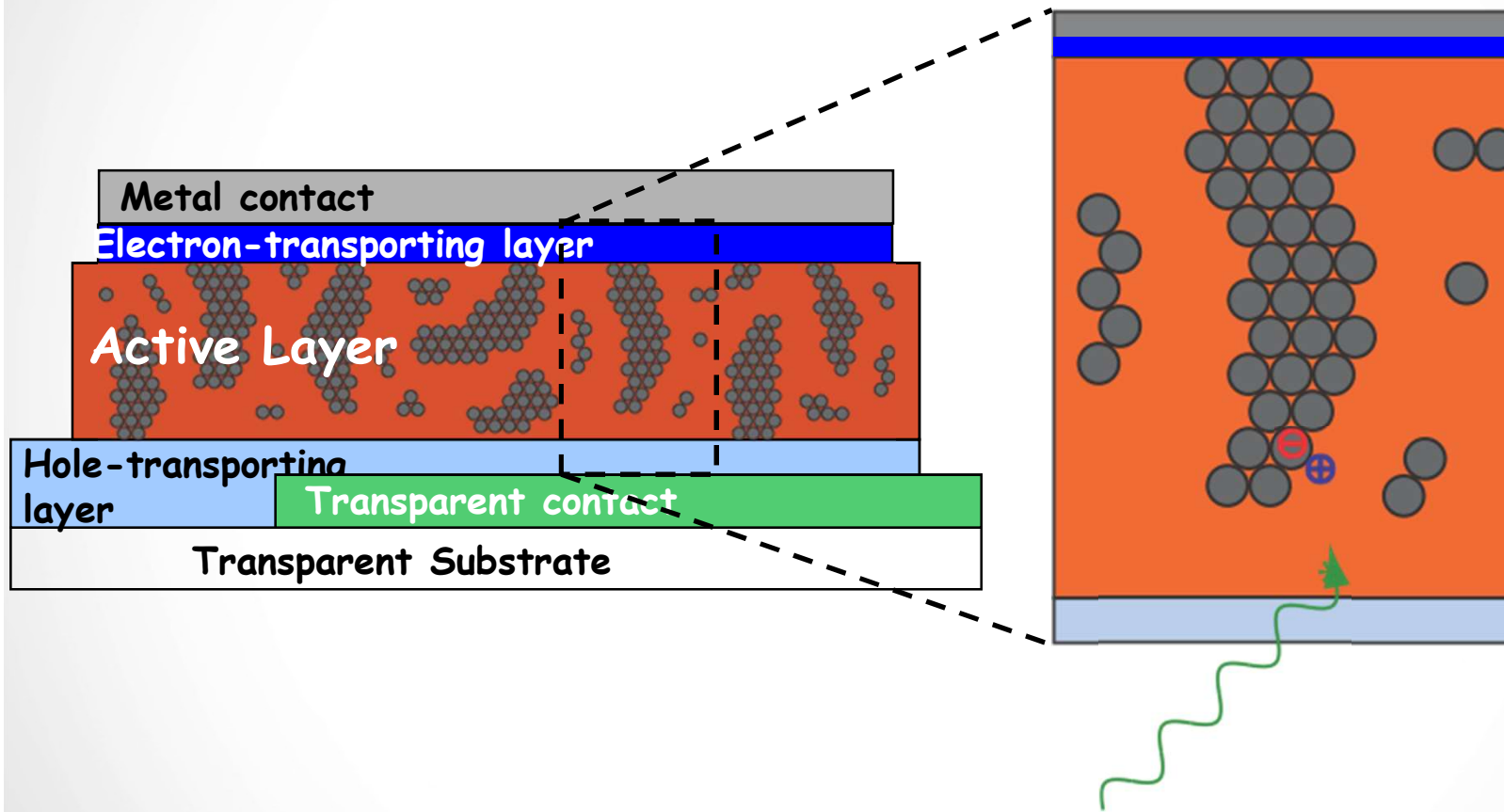


Nuzman et.al. *J. Mater Chem C*, 5, 12744 -12751 (2017)

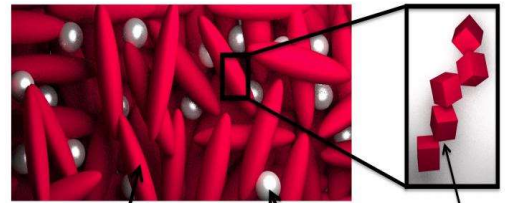
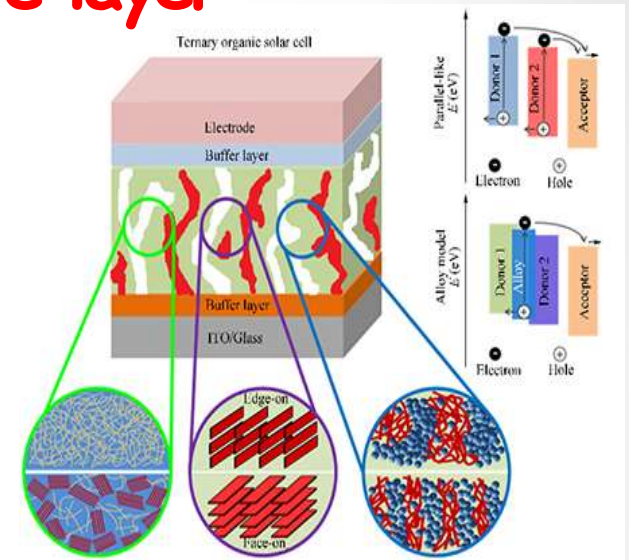
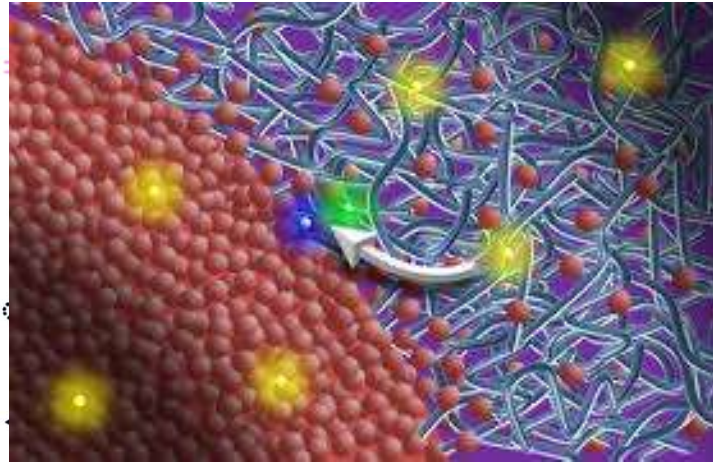
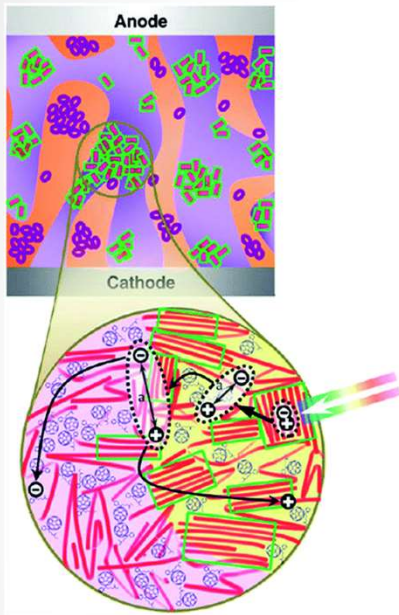
Adv Mater, in revisions (2018)

Sarkar et al, in prep. POSTER

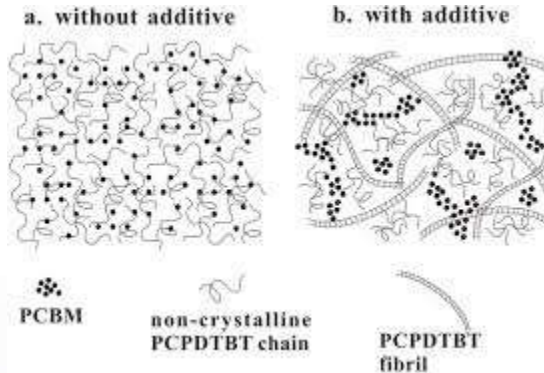
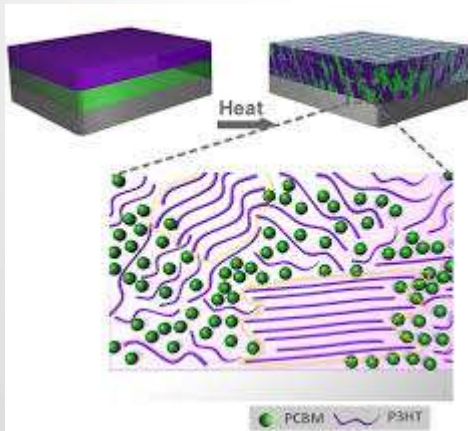
The structure of organic solar cells



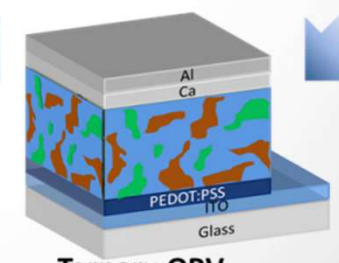
The morphology of the active layer



Wire-shaped p -DTS(FBTTh₂)₂ domains at the surface of the film
PC₇₁BM
Crystallites

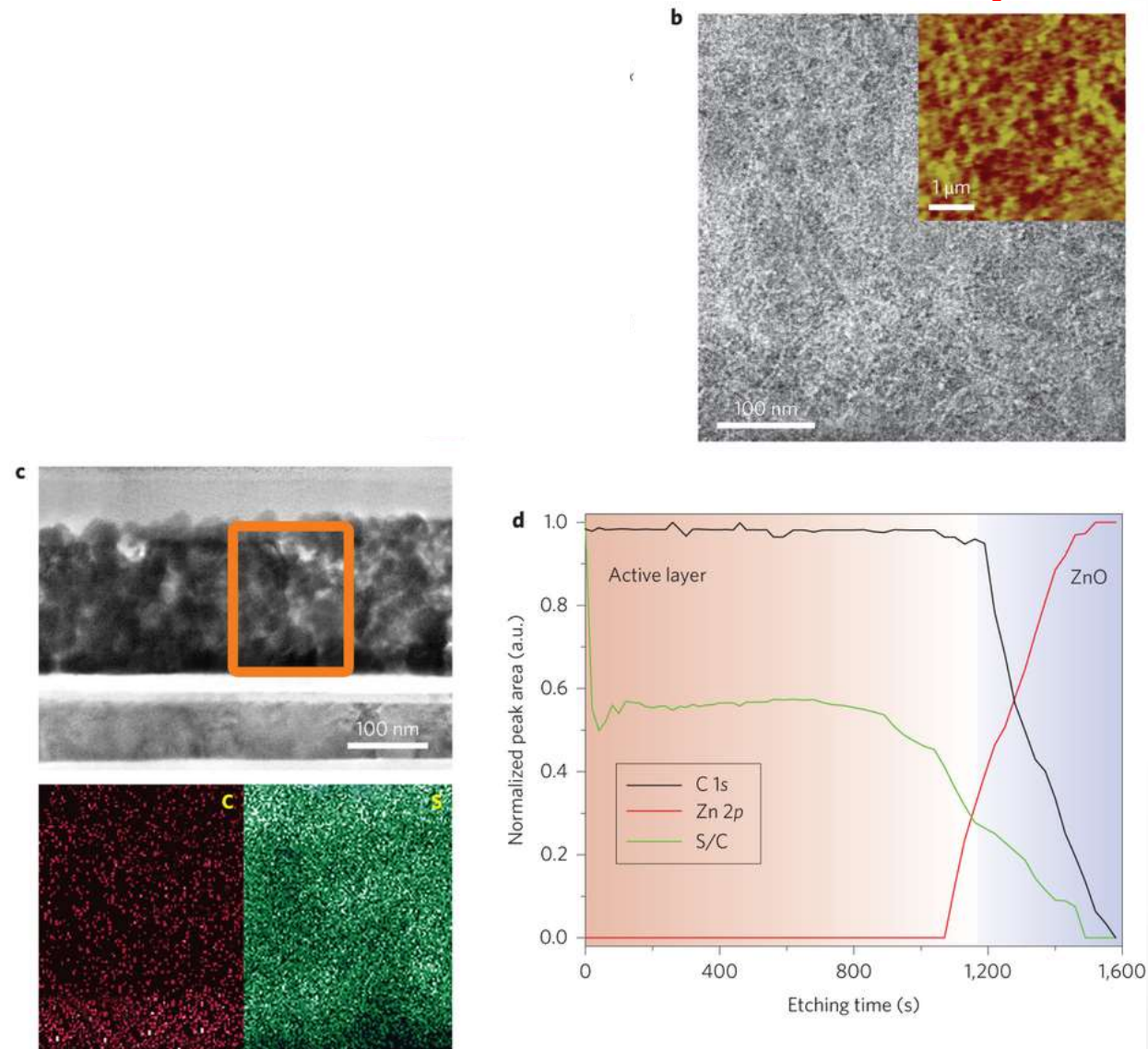


Compatible?

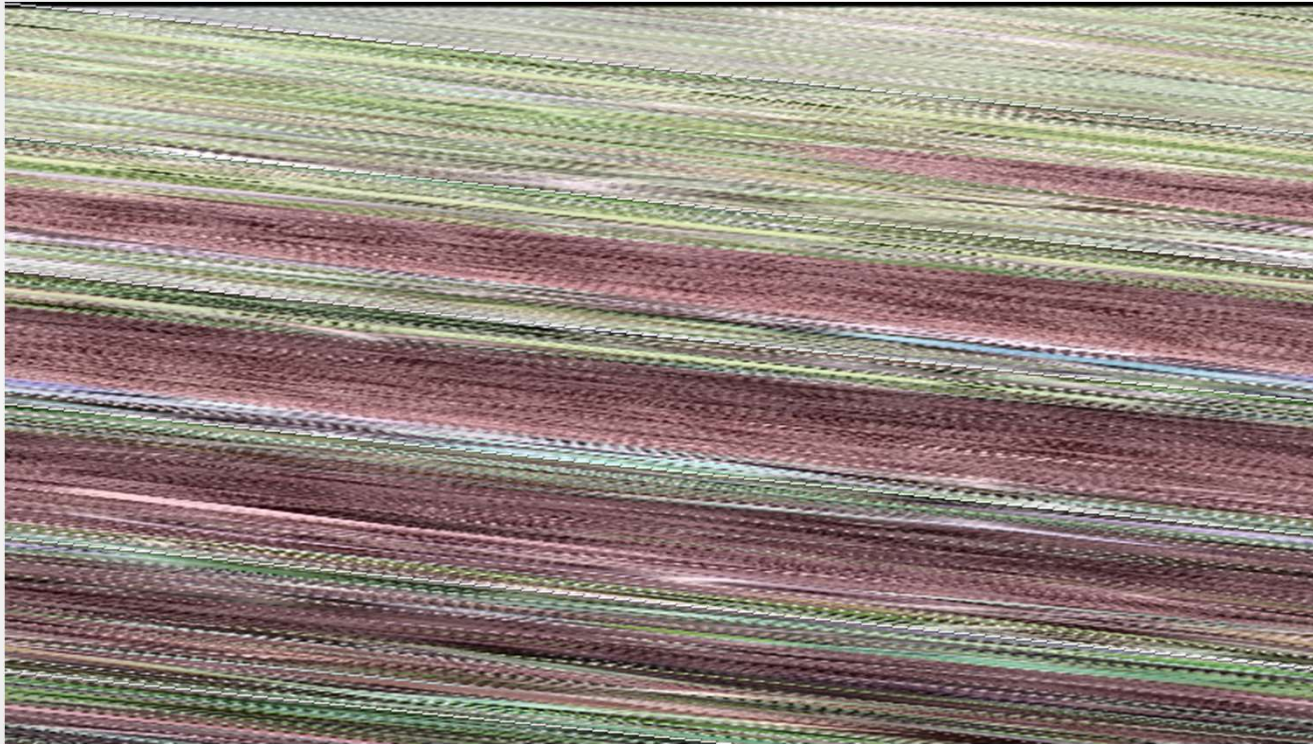


Ternary OPV

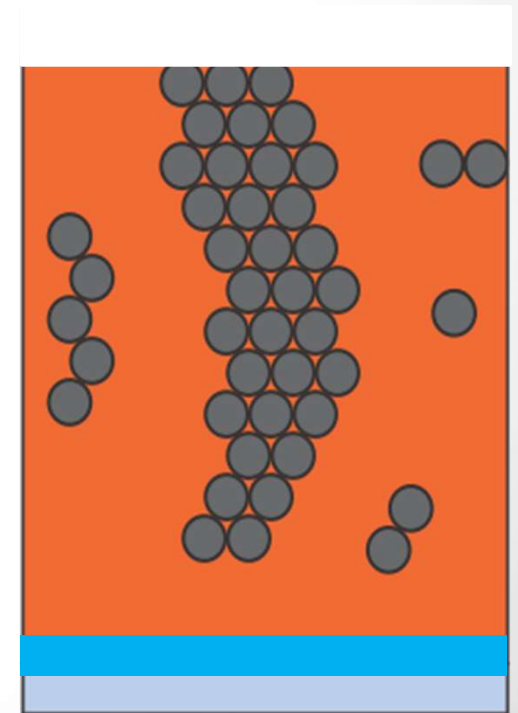
The morphology of the active layer



Selective molecular diffusion through BHJs ???

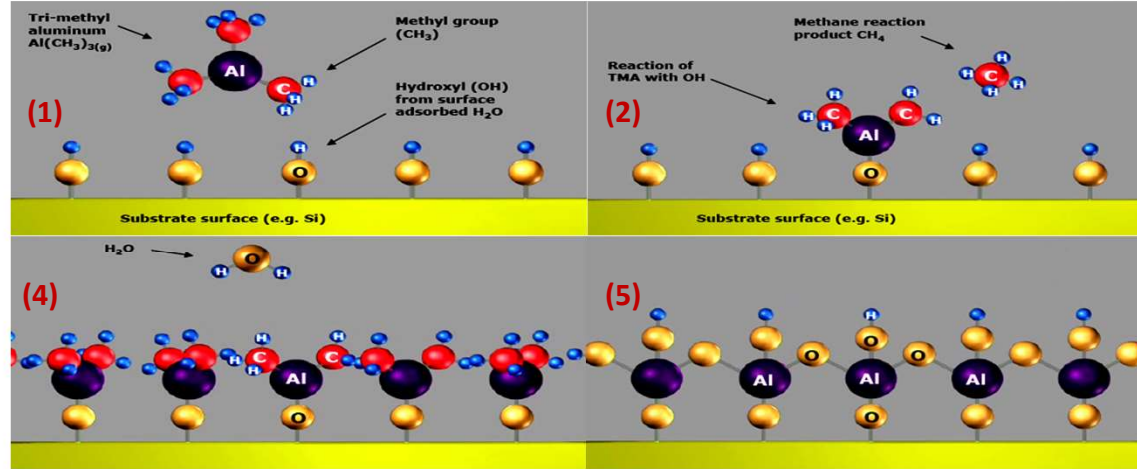


Gas phase

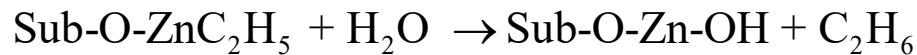
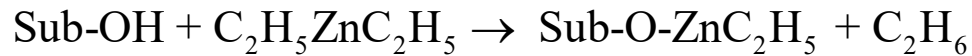
A diagram showing several yellow oval shapes representing gas phase molecules, scattered in the upper right area of the image.

Atomic Layer Deposition - ALD

ALD: gas phase
Conformal growth
of metal oxide
layer on surfaces

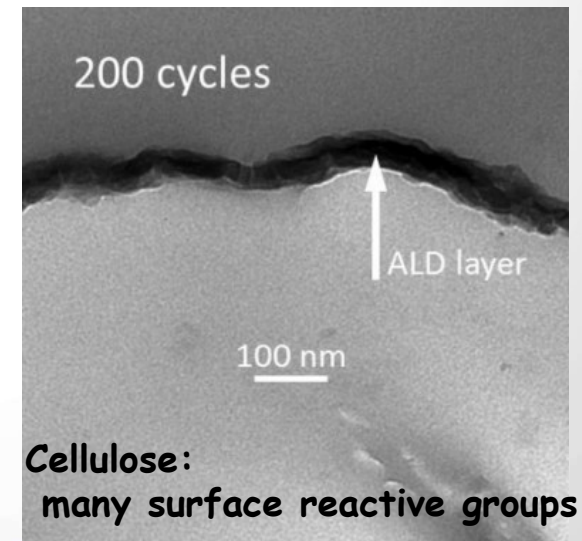
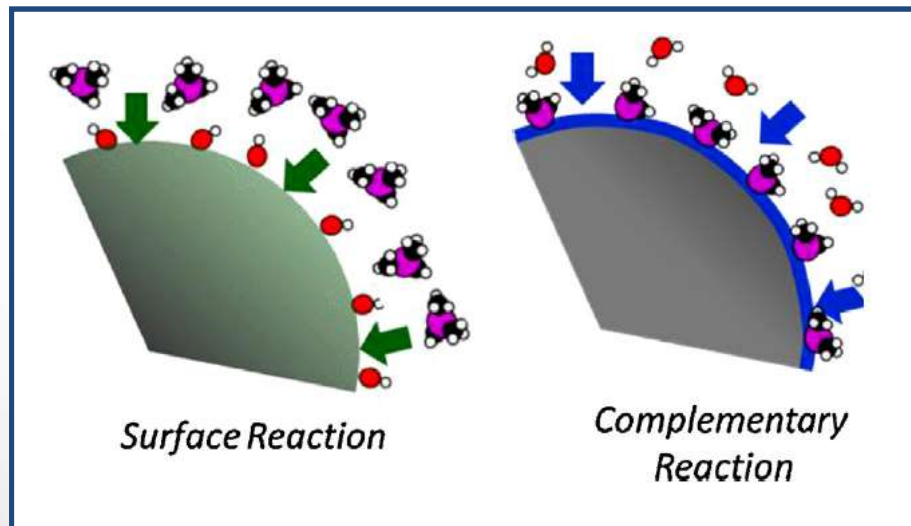


ZnO:

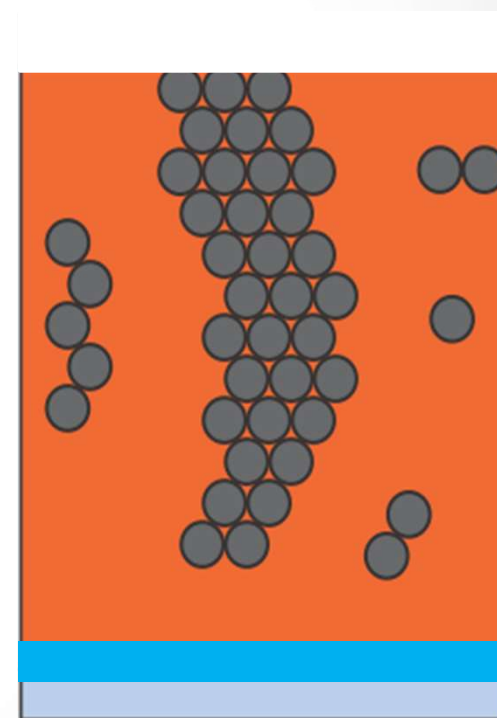
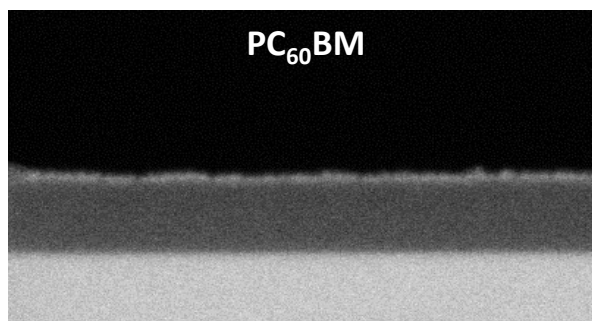
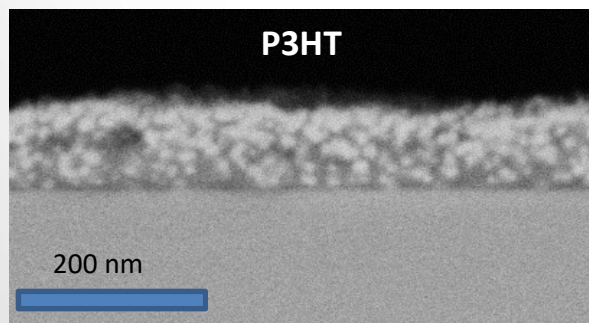
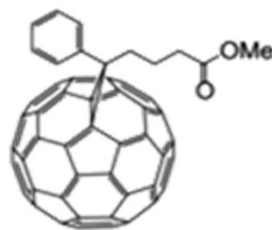
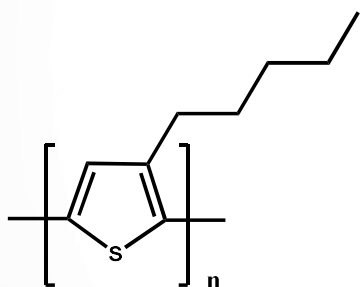


**ALD on
polymers**

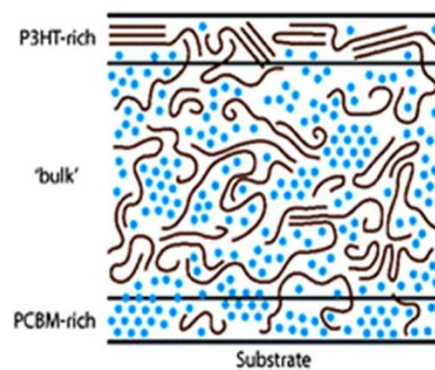
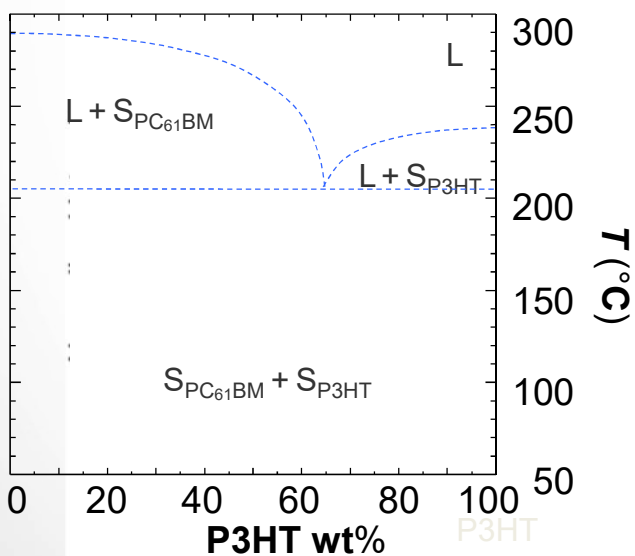
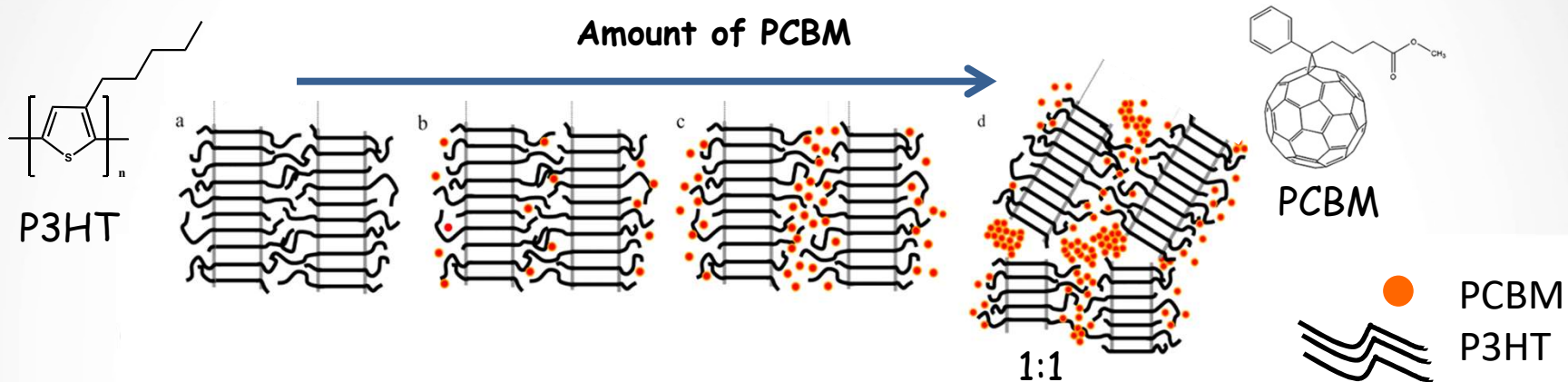
Parsons et al.
Coordination
Chemistry
Reviews, 257,
(2013)



VIP - expose BHJs to Gas Phase organometallic Metal oxide precursors (an ALD system...)



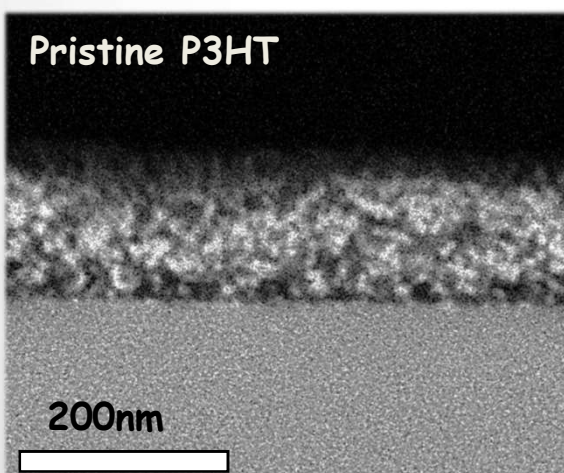
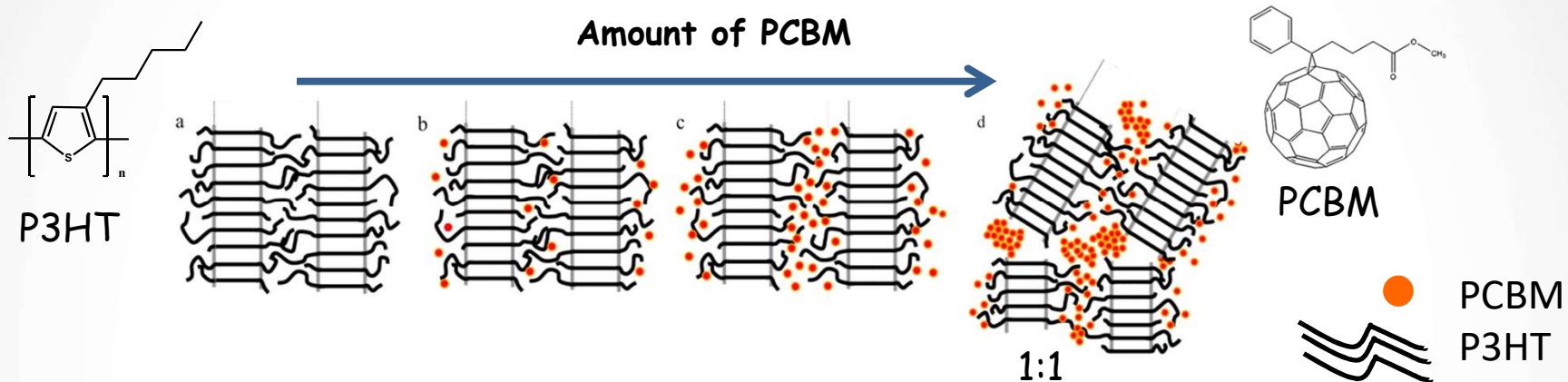
Can we map the Morphology of the BHJ?



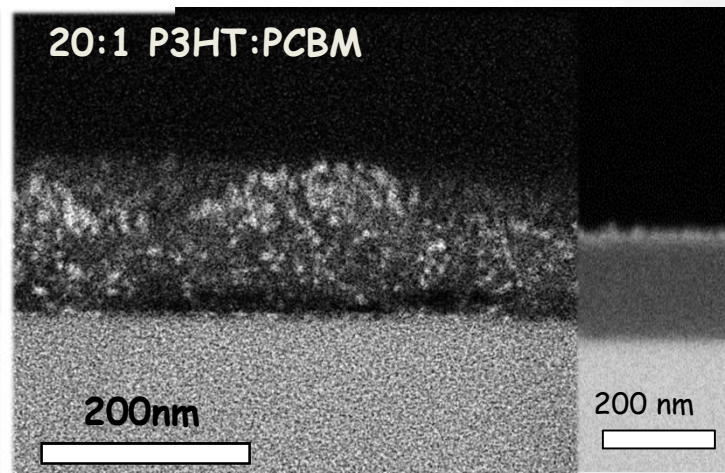
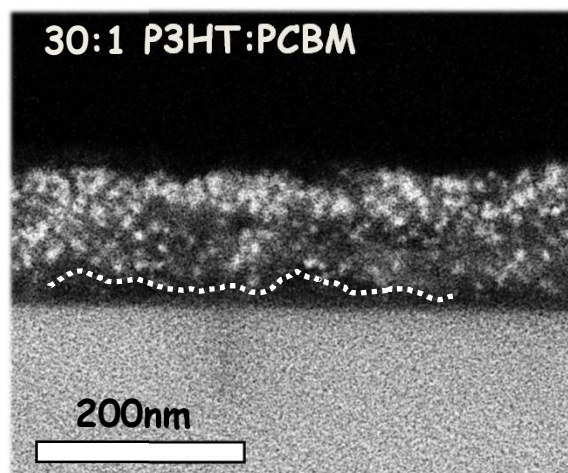
J S Kim et al, JMCC 2013, 1, 6235-6243

C. Muller et al., Adv. Mater., 2008, 20, 3510

Can we map the Morphology of the BHJ?

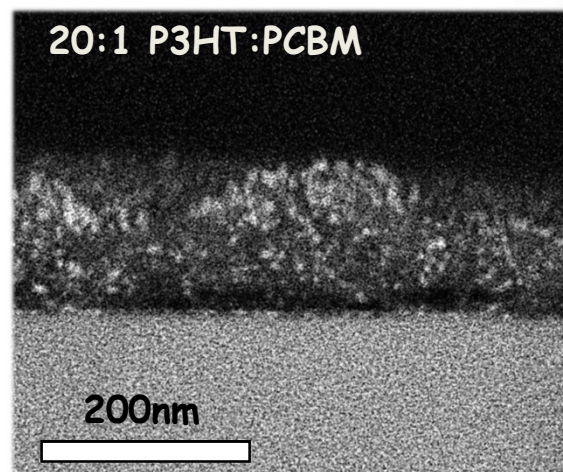
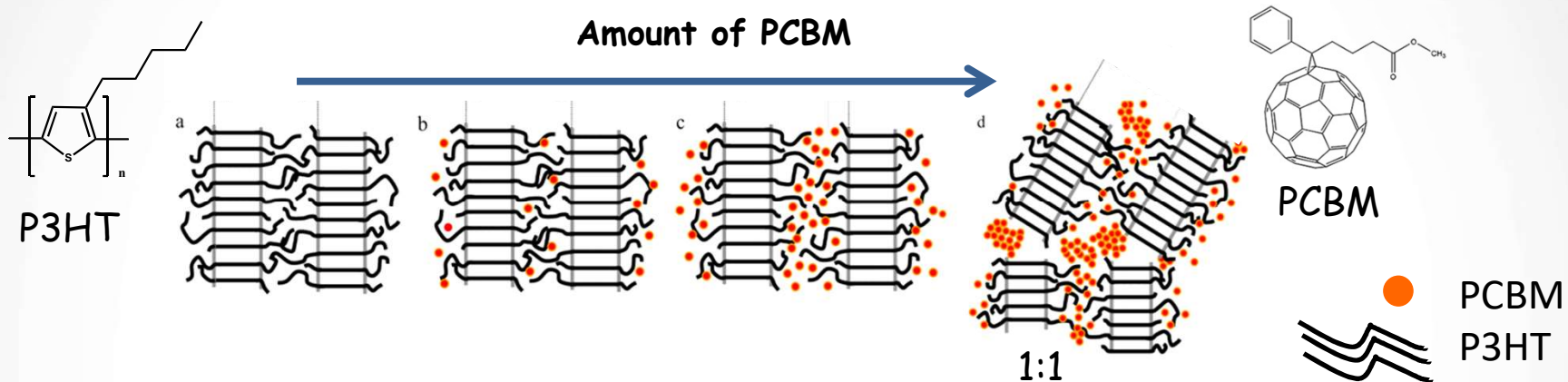


VIP - sub-surface ZnO deposition
(white domains)

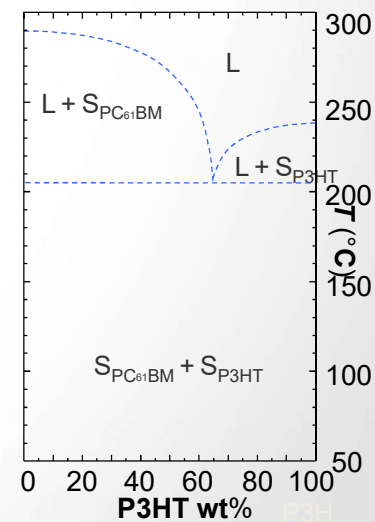
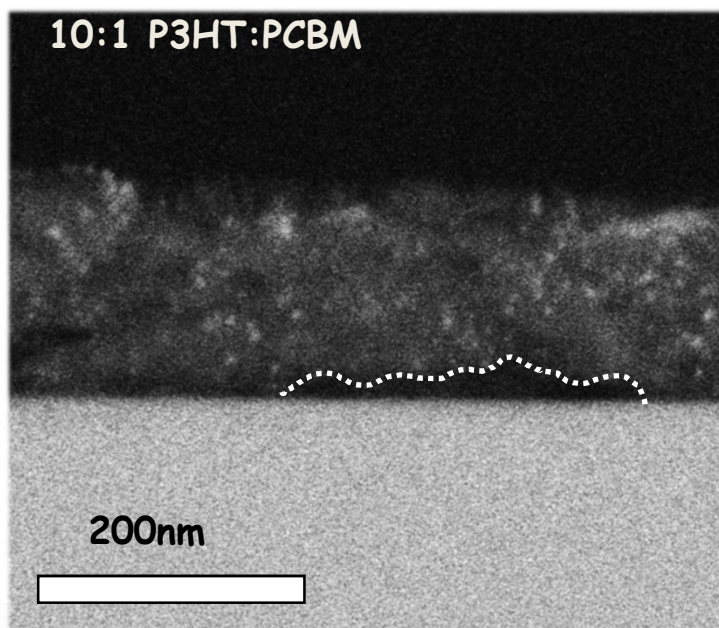
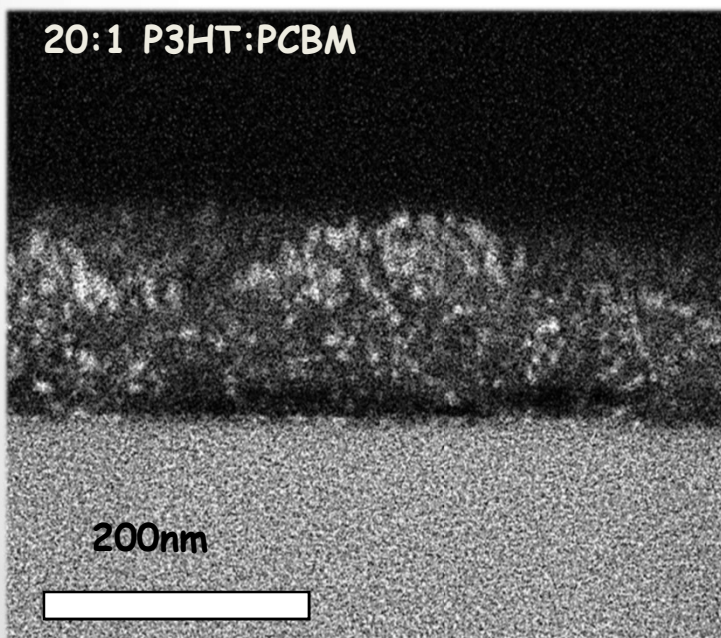
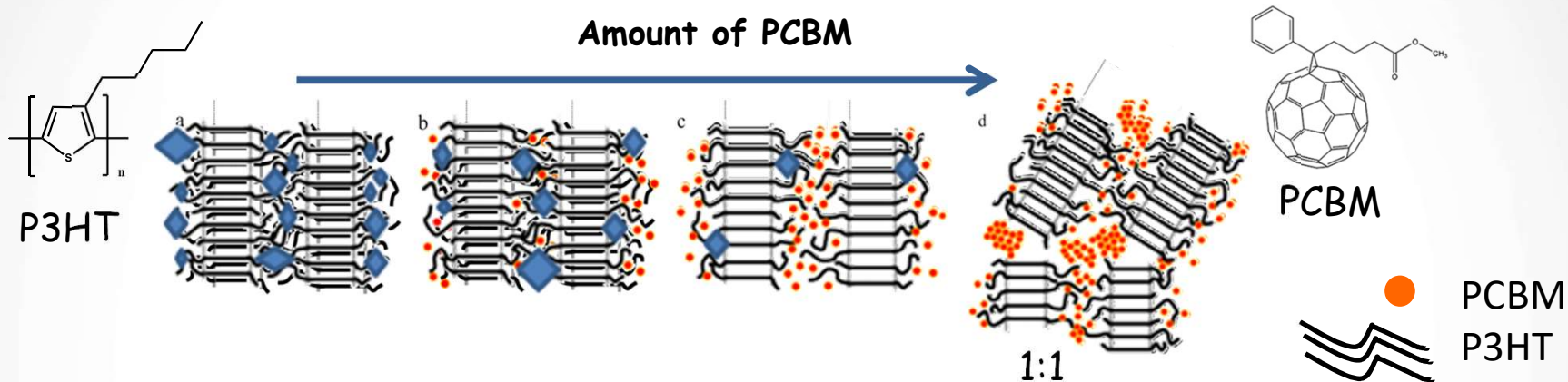


NO VIP - surface ZnO deposition
(white top layer)

Can we map the Morphology of the BHJ?

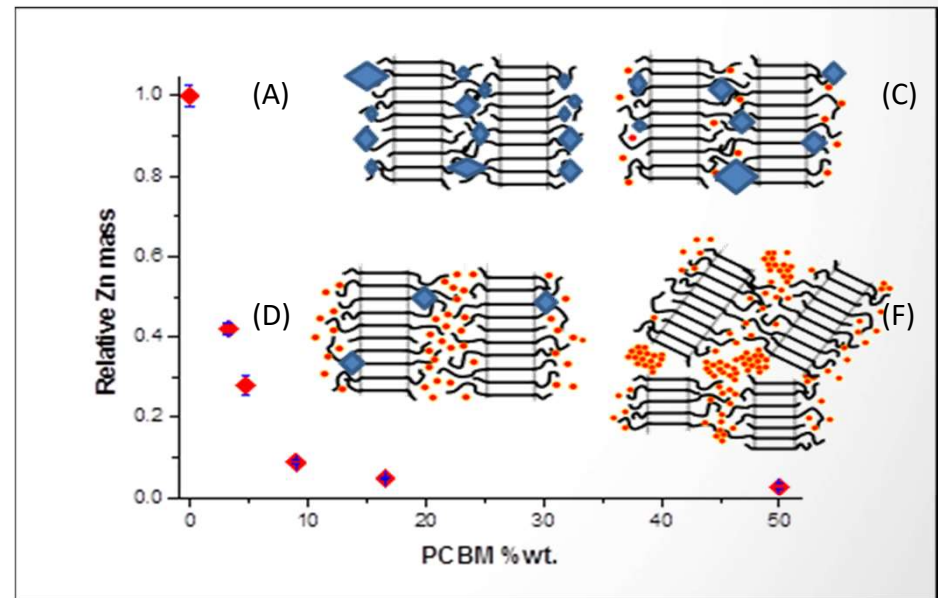
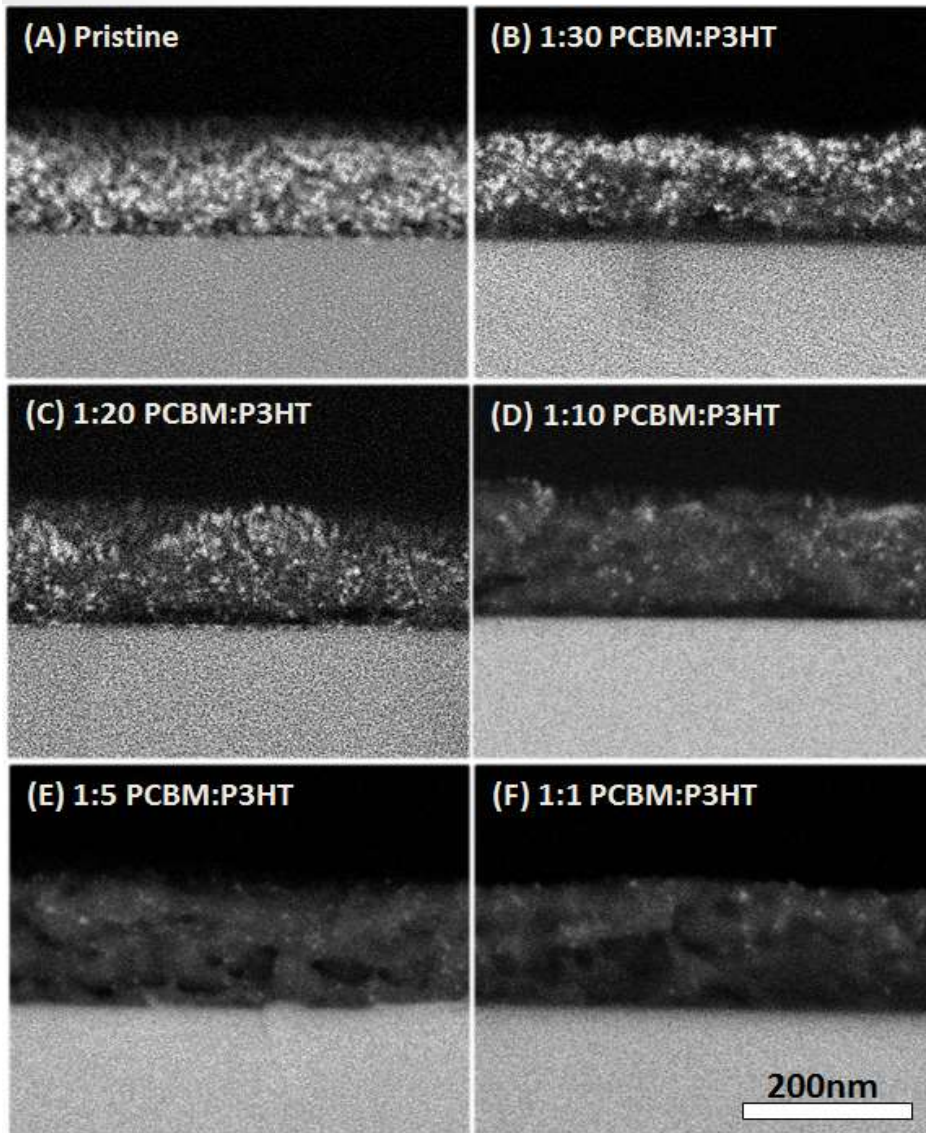


Can we map the Morphology of the BHJ?

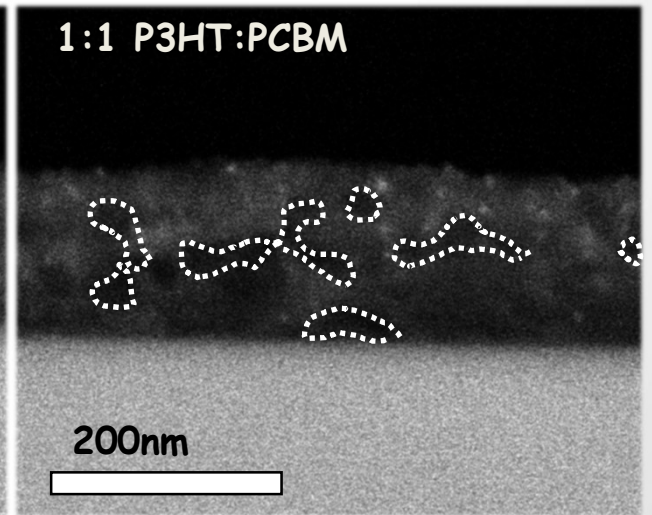
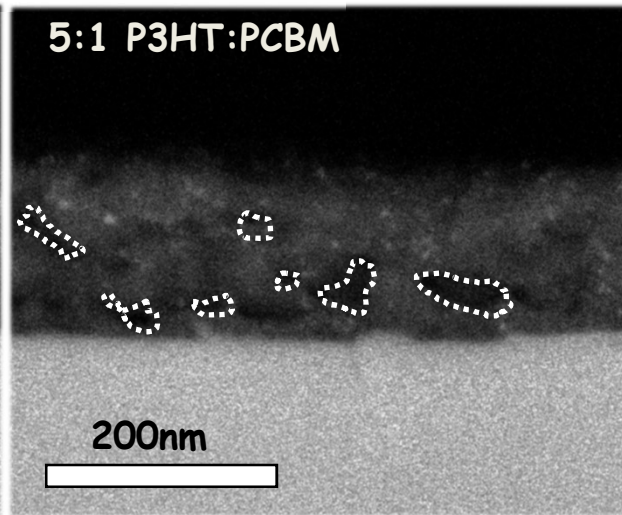
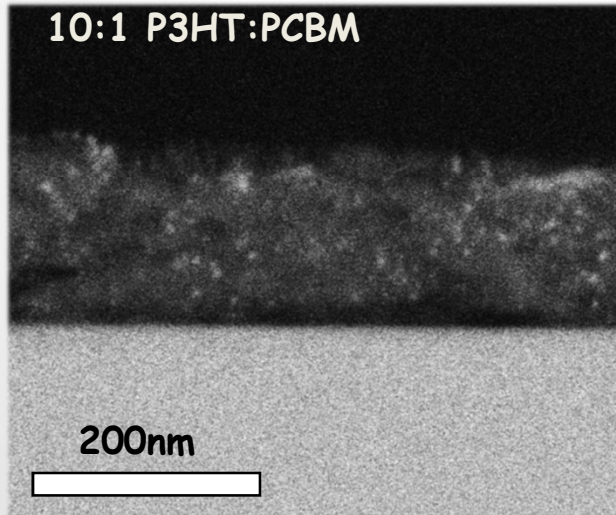
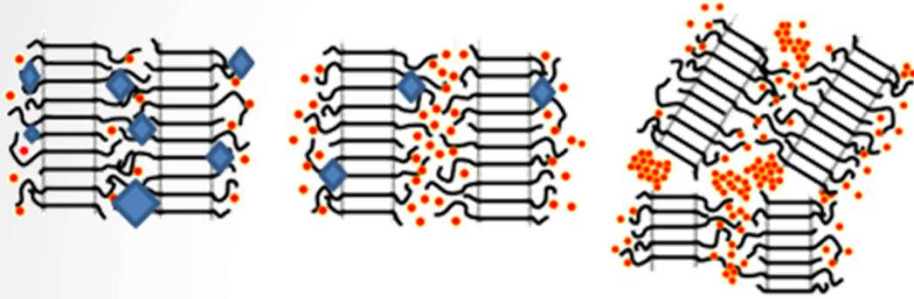


Mapping P3HT:PCBM morphology

- We can map the distribution of amorphous regions in a P3HT film
- We can map the distribution of PCBM in a P3HT:PCBM film
- We can determine the solubility limit of PCBM in the film



Mapping P3HT:PCBM morphology

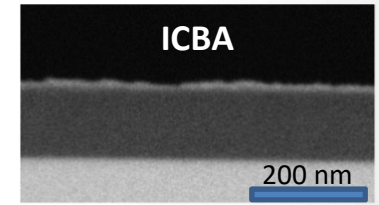
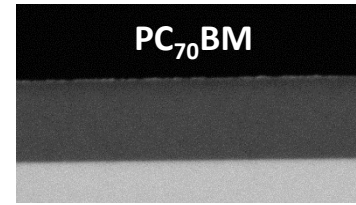
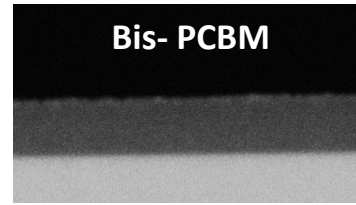
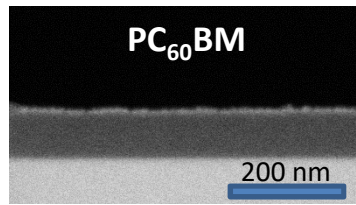
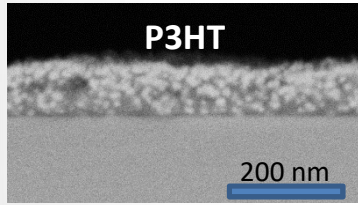
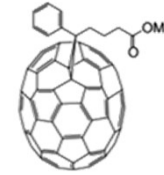
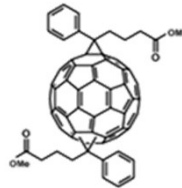
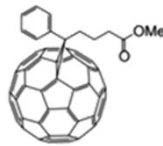
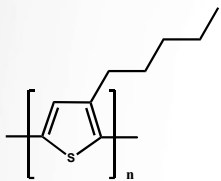


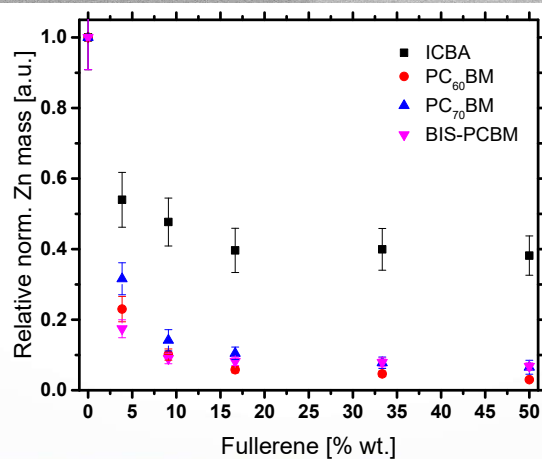
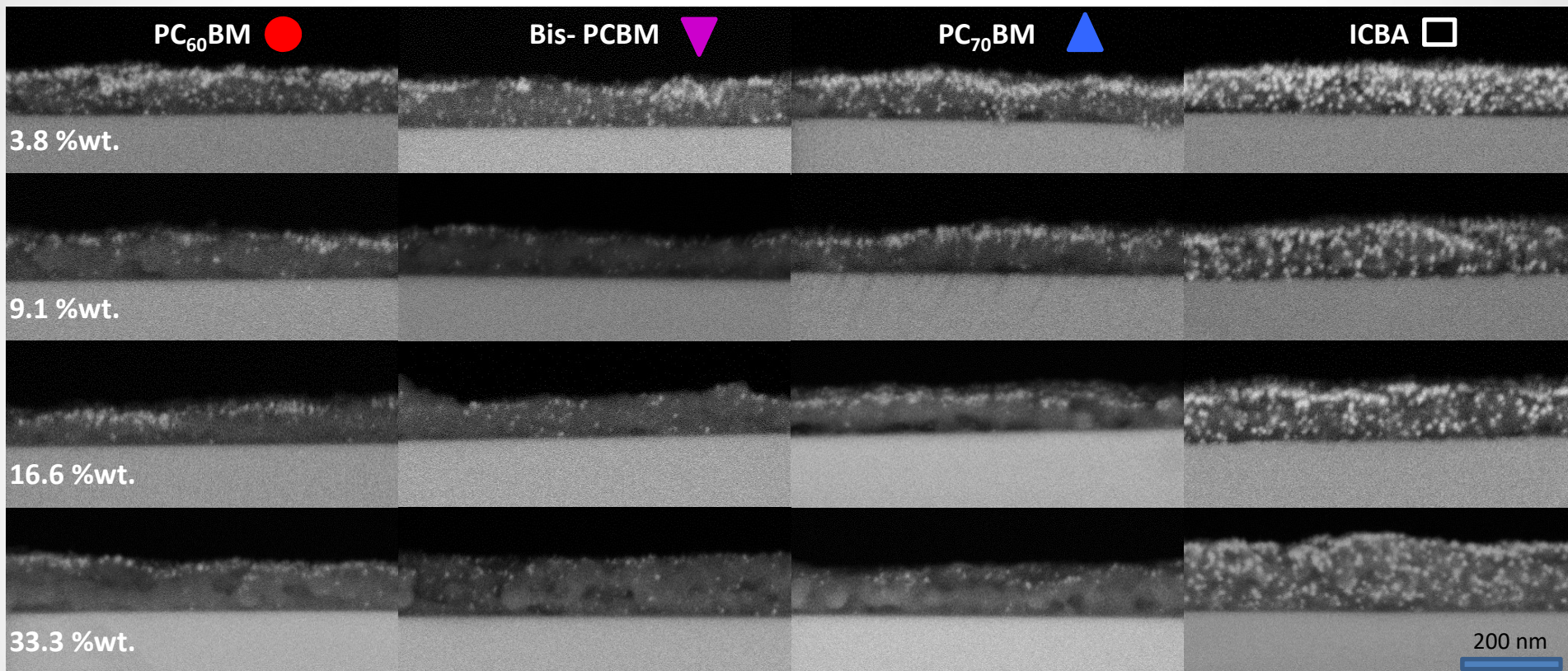
What about other systems? (less known... High efficiency)

Effect of fullerene acceptor on blend Morphology

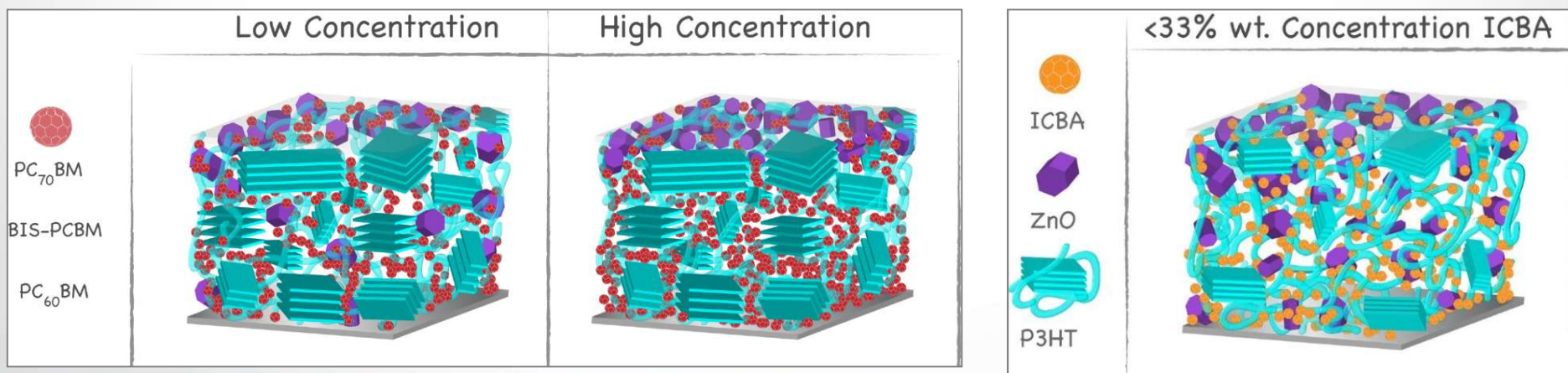
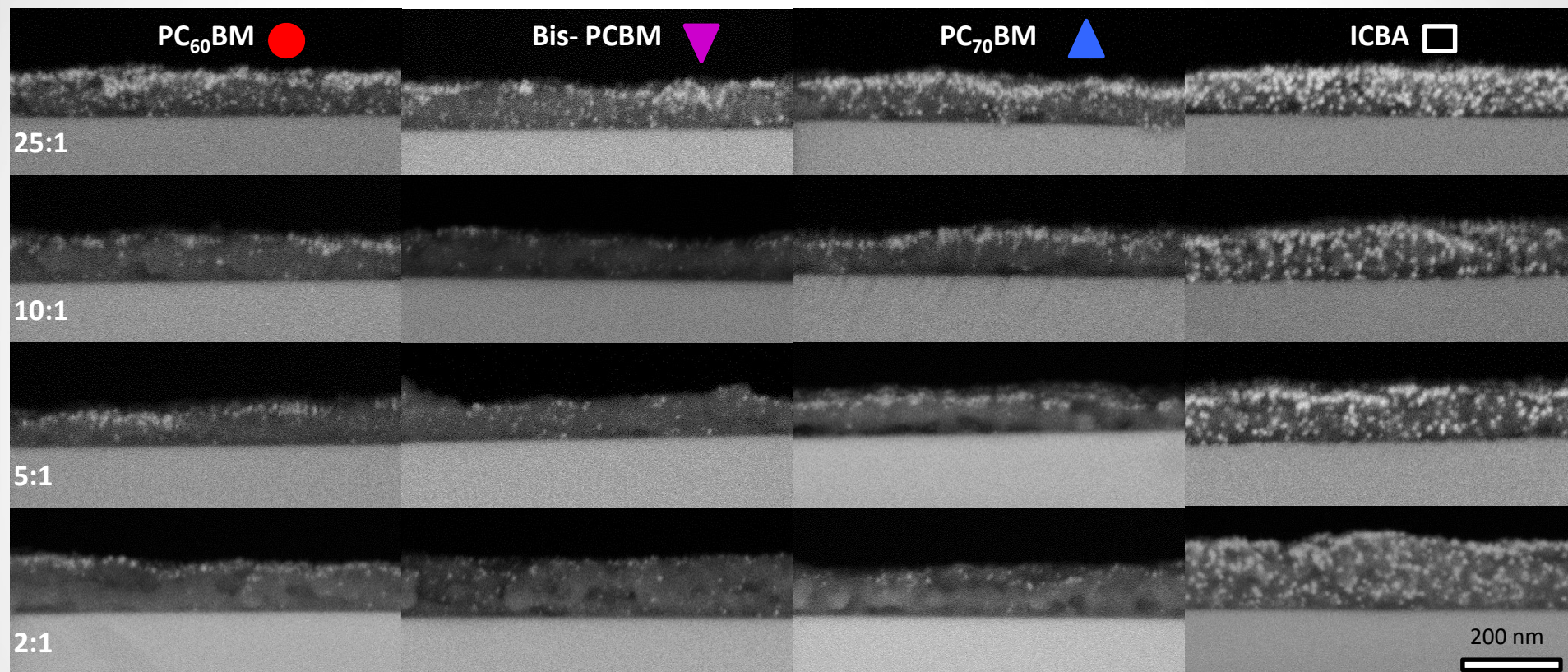
"Donor"

"Acceptors"



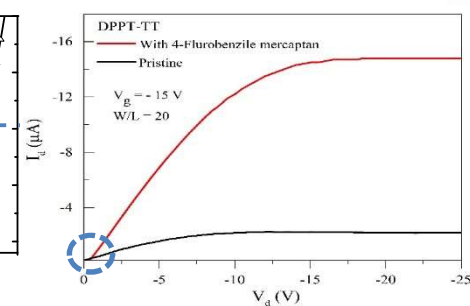
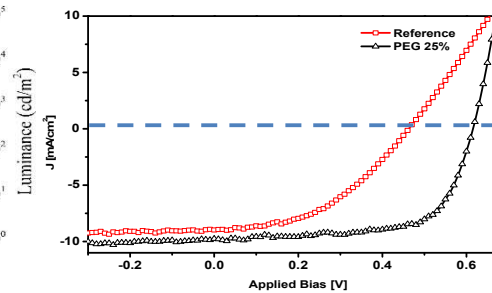
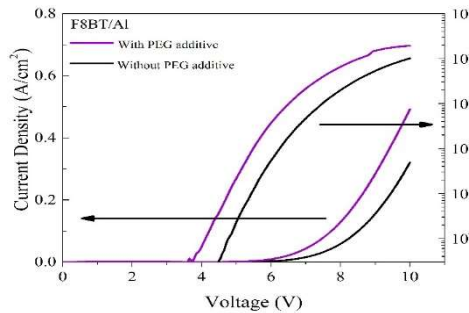
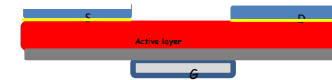
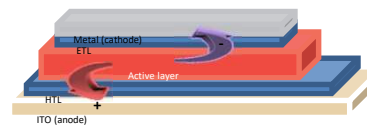
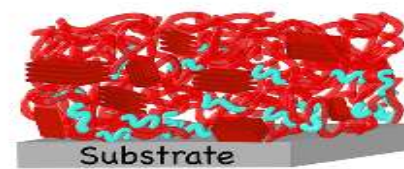
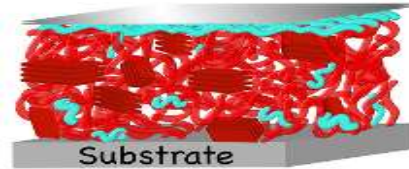


ICBA vitrifies P3HT → more amorphous → higher free volume
 Stingelin et al. J. Mater. Chem. A, 5, (2017).

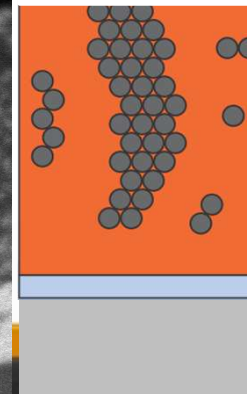
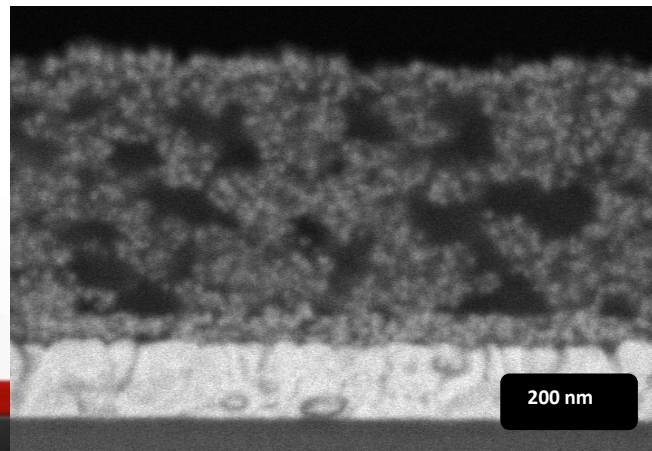


Summary and Conclusions:

Interlayer induced by additive/metal interactions

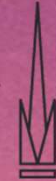


VIP composition - processing - structure- performance correlation





Georgia
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ITN INFORM



Technion centers and facilities:

MIKA - Electron Microscopy Center - Dr Kaufman & Dr Brenner & M Kalina

Surface Analysis Lab - Dr. Brenner & Dr. Kamira Cohen Weinfeld

RBNI - Technion Nanotechnology and Nanoscience center

GTEP - Technion Energy Innovation

50 nm
