Improved Efficiency of PCBM/P3HT Organic Solar Cell through the Addition of CuO Nanowires

Joann Hilman, Aaron Wang, Rabindra Dulal, and TeYu Chien

University of Wyoming

Department of Physics and Astronomy

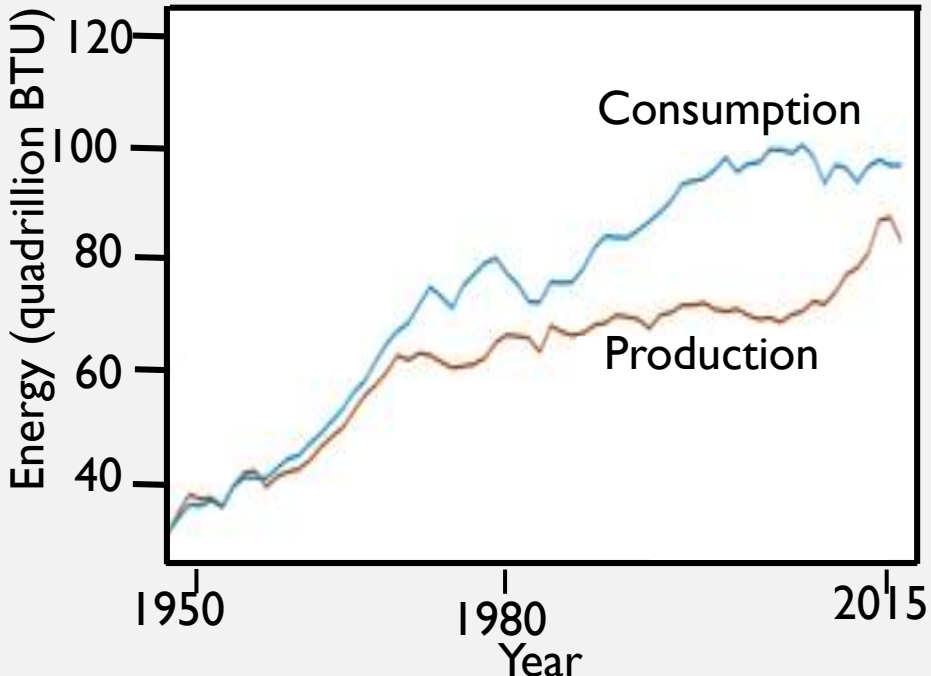
Background

US energy consumption continues to increase *[1]*

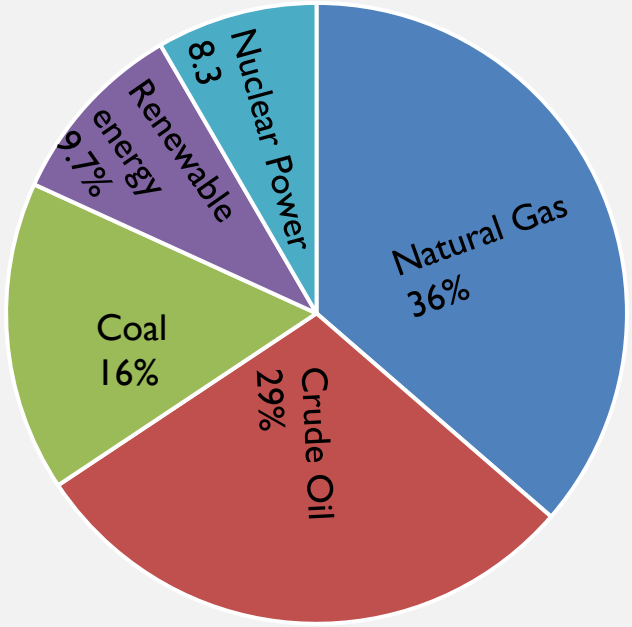
In 2015 only 9.7% of US energy production was renewable*[1]*

Solar energy only makes up 5.88% of renewable energy *[1]*

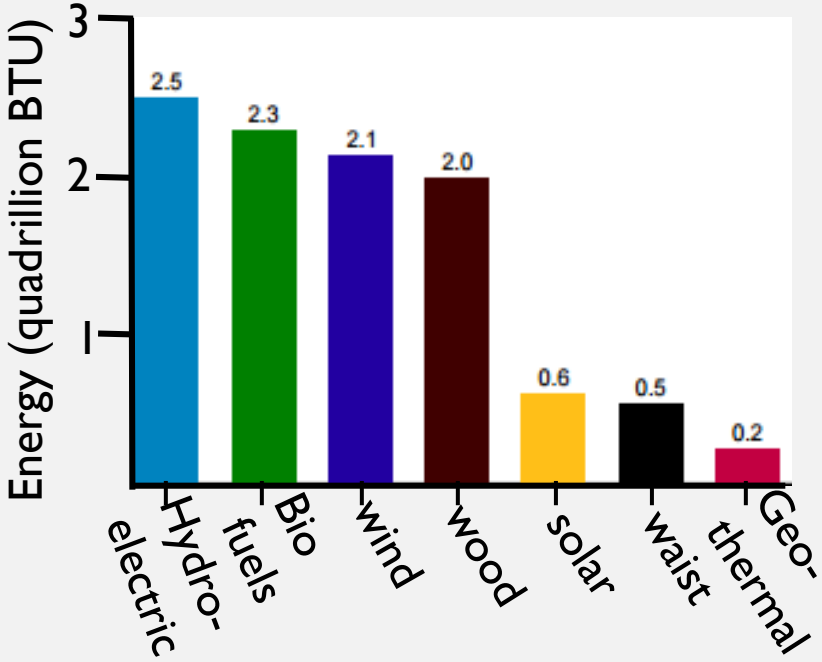
US Energy over view 1959-2016



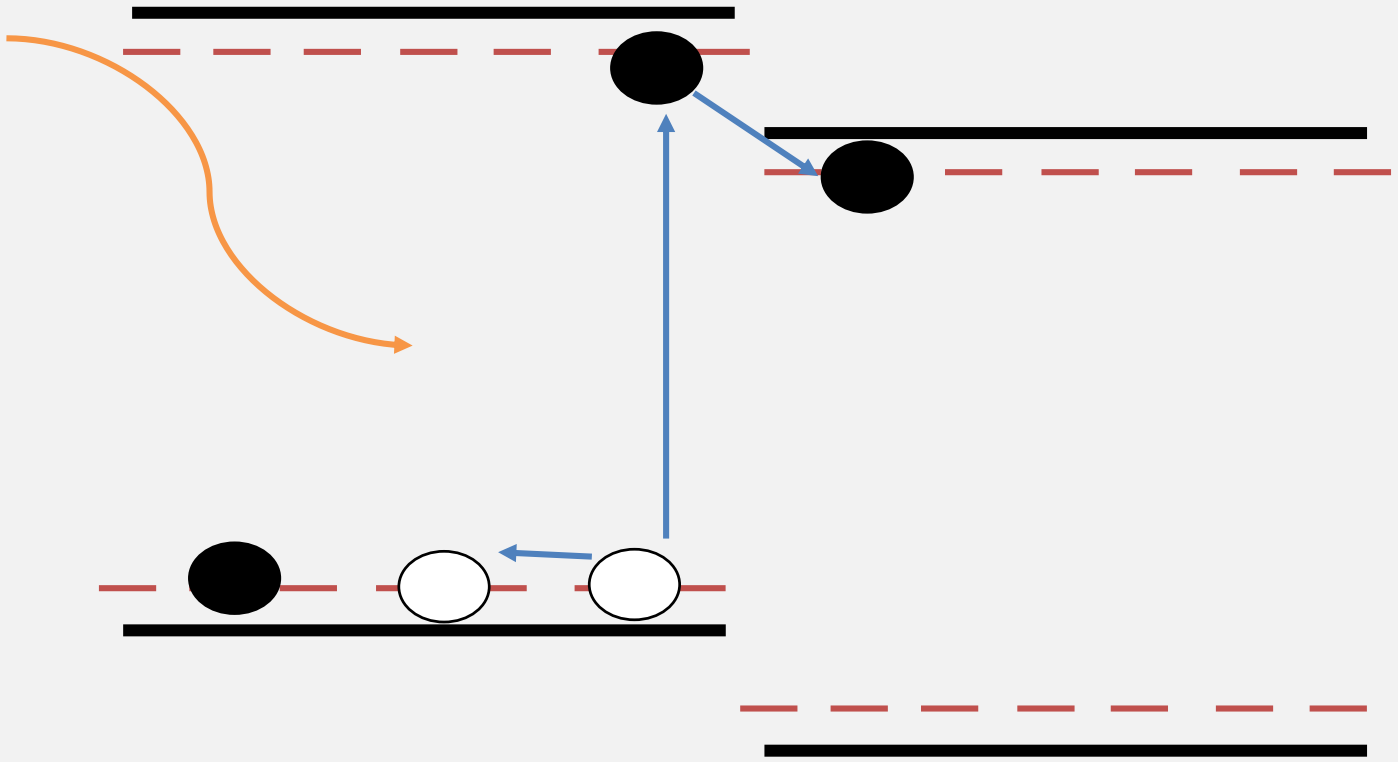
US Energy production by source 2015



US Renewable Energy production by source 2016



Photovoltaics



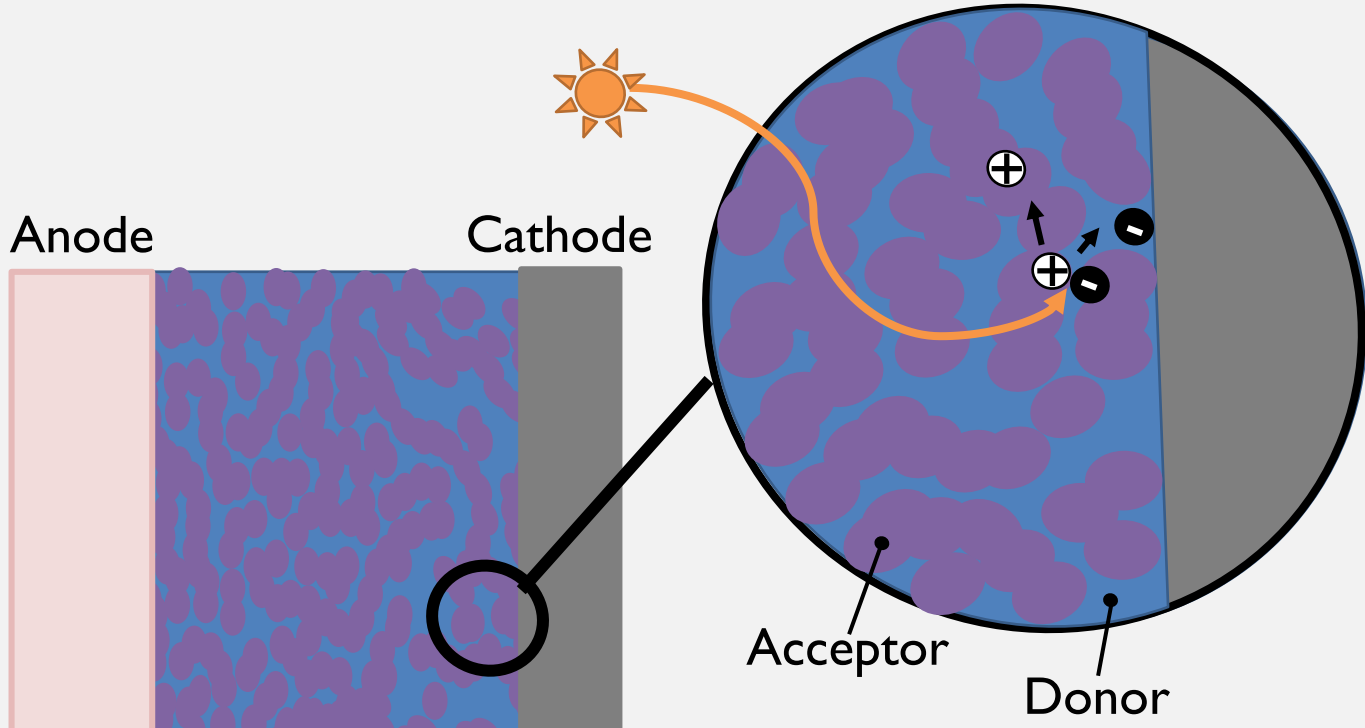
- Solar Cell converts light into electricity

1). Incoming light excites electron to a higher energy state

2). Electron moves towards lower energy creating current

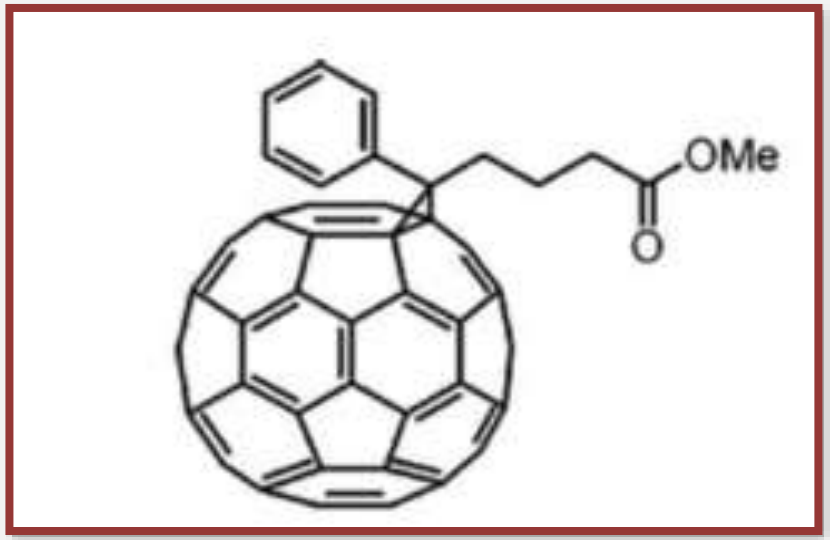
Bulk Hetero-Junction Organic Solar Cell

- Anode and cathode
- Active layer consists of two polymer semiconductors
- Incoming photon separates into exciton (electron hole pair)
- Charges will separate
- Electron and hole will travel collected at opposite electrodes
- Long travel path can cause recombination

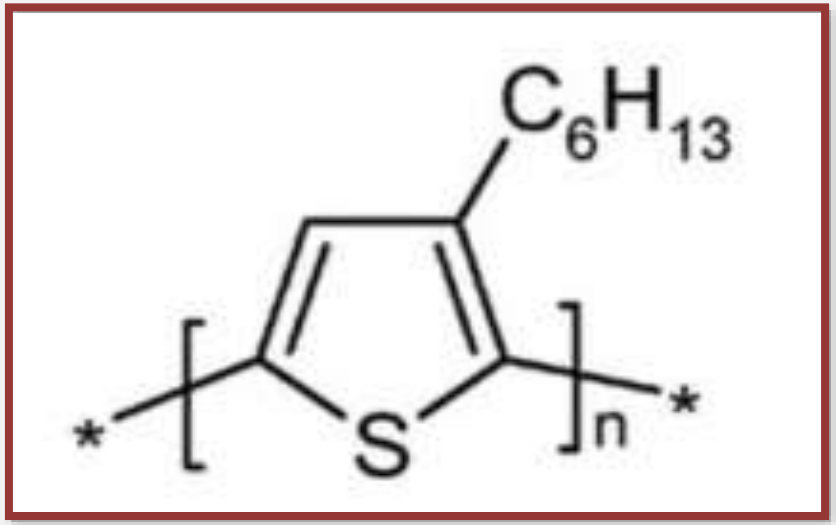


PCBM/P3HT

- PCBM – Phenyl-C61-Butyric Acid Methyl Ester *[2]*
- P3HT – Poly(3-Hexythiophene -2,5-diyl) *[2]*



- Electron Acceptor
  - Band gap ~3.7 eV *[Sigma Aldrich]*



- Electron Donor
- Band gap ~2.3 eV *[3]*
- Absorption coefficient of approx. $10^4 cm^{-1}$ *[3]*

P3HT Absorption Coefficient

Absorption coefficient determines how far light can penetrate into a certain material

Intensity is related to adsorption coefficient by

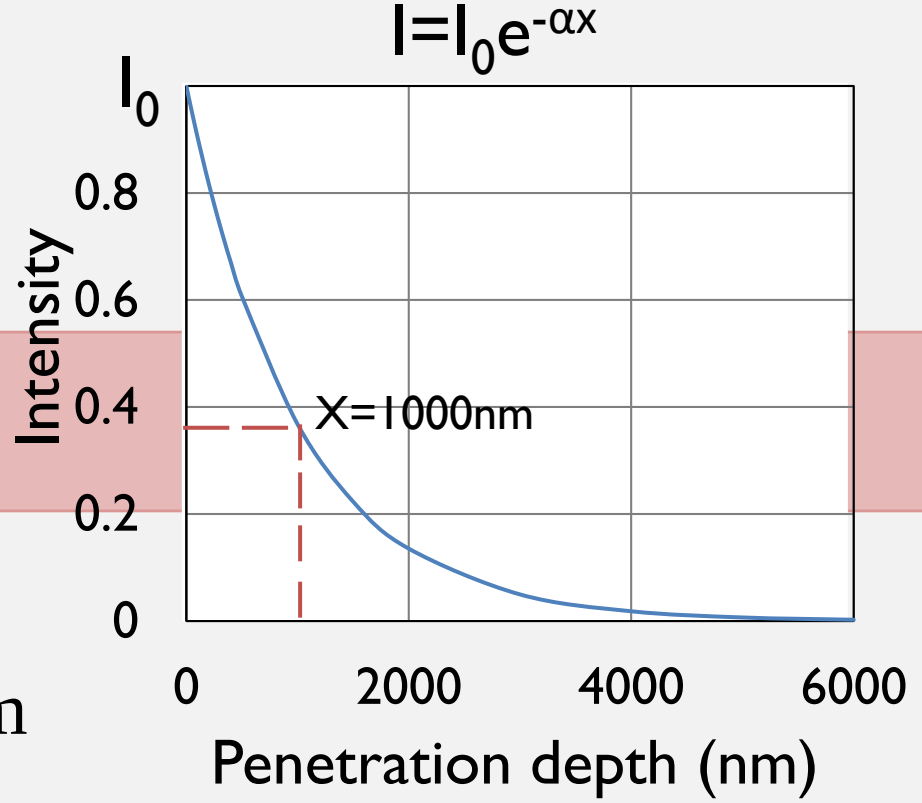
$$I(x) = I_0 e^{-\alpha x}$$

I(x)=intensity at depth x
α=absorption coefficient

Equation shows exponential decay

Where $\alpha = 10^4 cm^{-1}$

Light is mostly absorbed at e^{-1} (~.3678) or 1000 nm



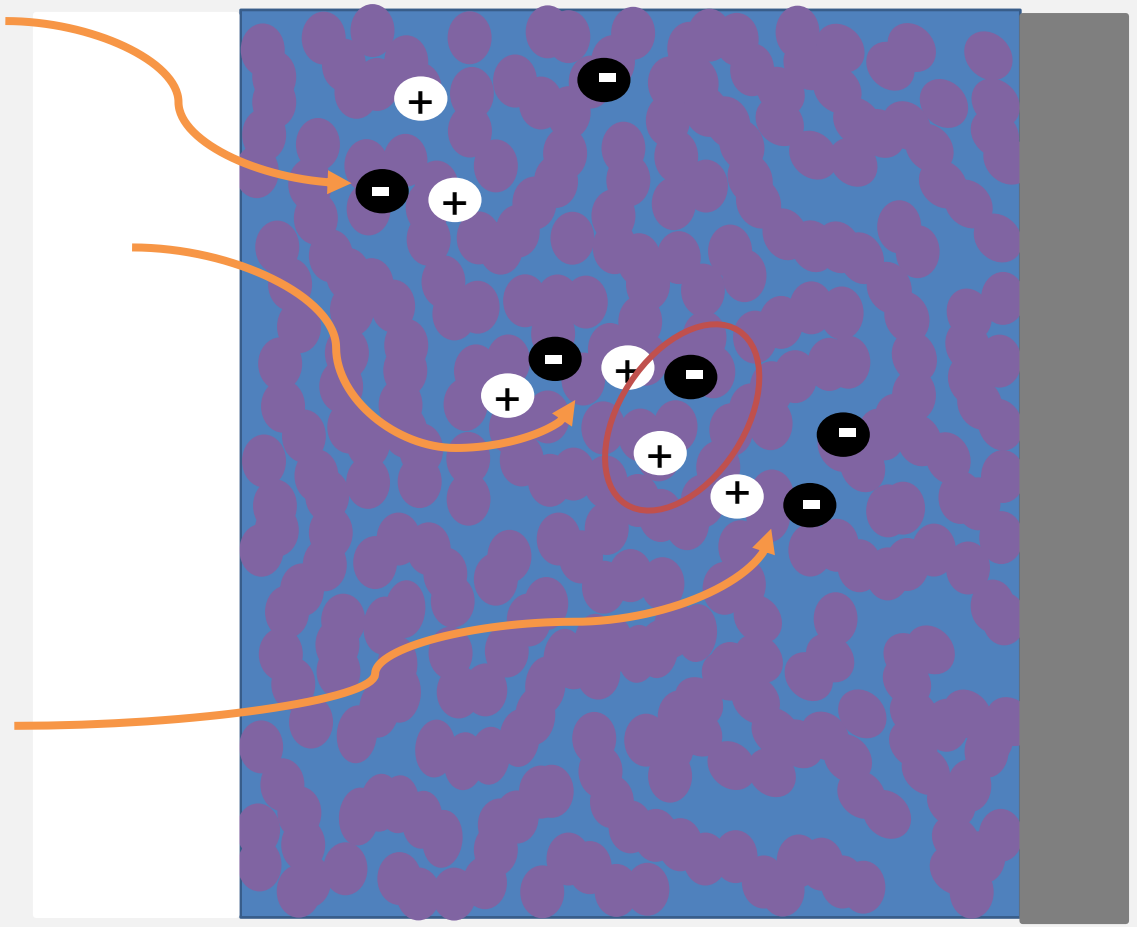
Efficiency

Theoretical highest efficiency at1000nm

Highest actual power conversion efficiency found at ~100nm *[4-8]*

Caused by long path length between electrodes

- Many excitons created at once
- Long travel distance means that some electrons will recombine with holes from other excitons



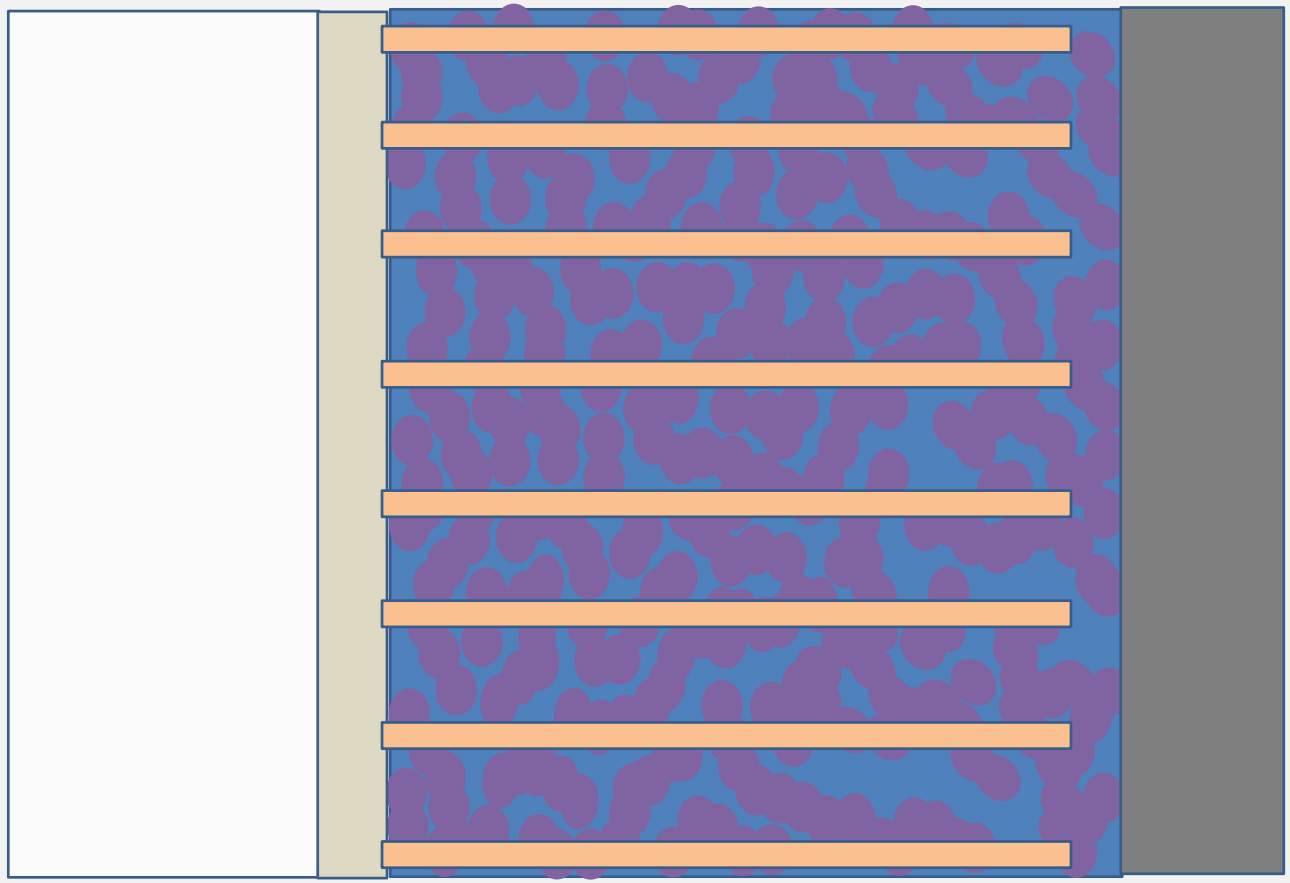
Nano-wire Enhanced Solar Cell

Extending electrodes into active layer will reduce path length

Normal cell consists of

- Clear electrode – FTO on glass
- 1000 nm thick active layer – PCBM/P3HT
- Top electrode - Nickle

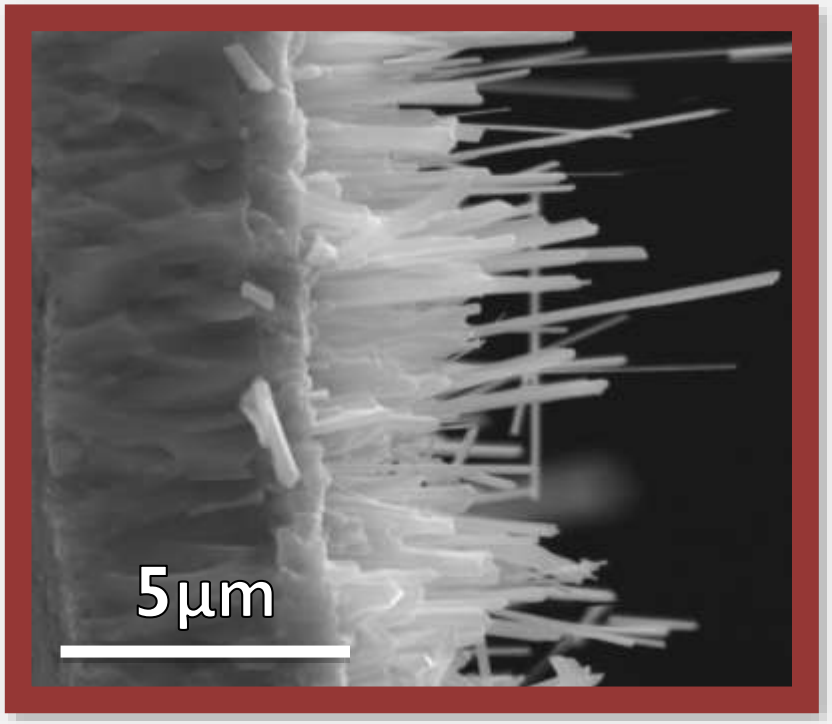
Add NWs to reduce path length for charge collection without reducing active layer thickness



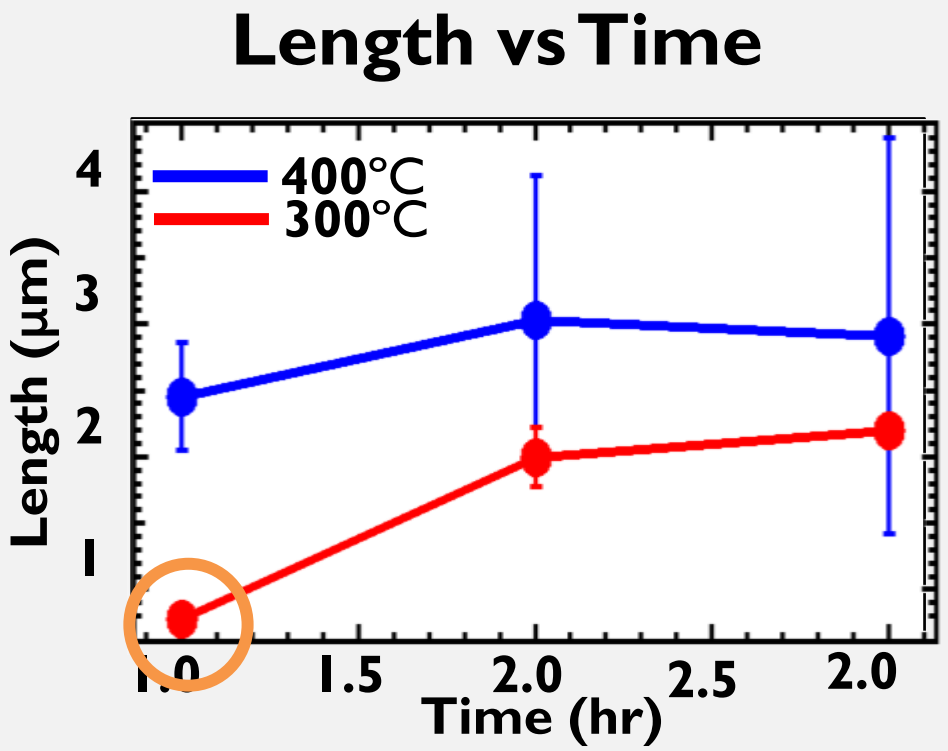
CuO Nano-wires

NWs grown through direct oxidation of Cu Foil

Active layer thickness 1 µm
NW length must be < 1 µm



SEM image of 400°C 2 hr oxidized Cu Foil

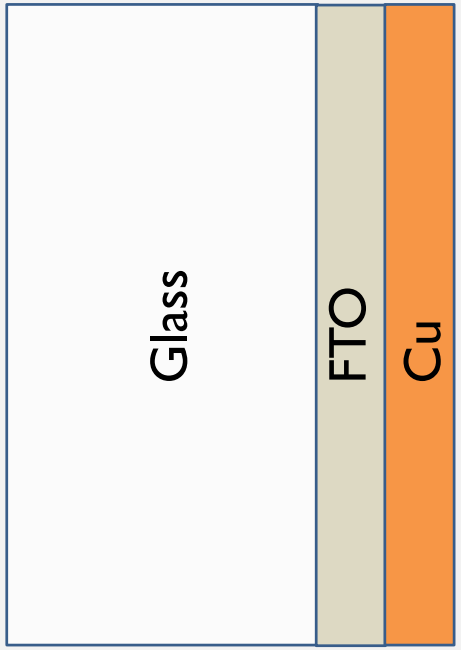


Lengths ranged from .776 µm to 2.91 µm with time and temperature

NWs oxidized for 1hr at 300°C have length of ~.776 µm

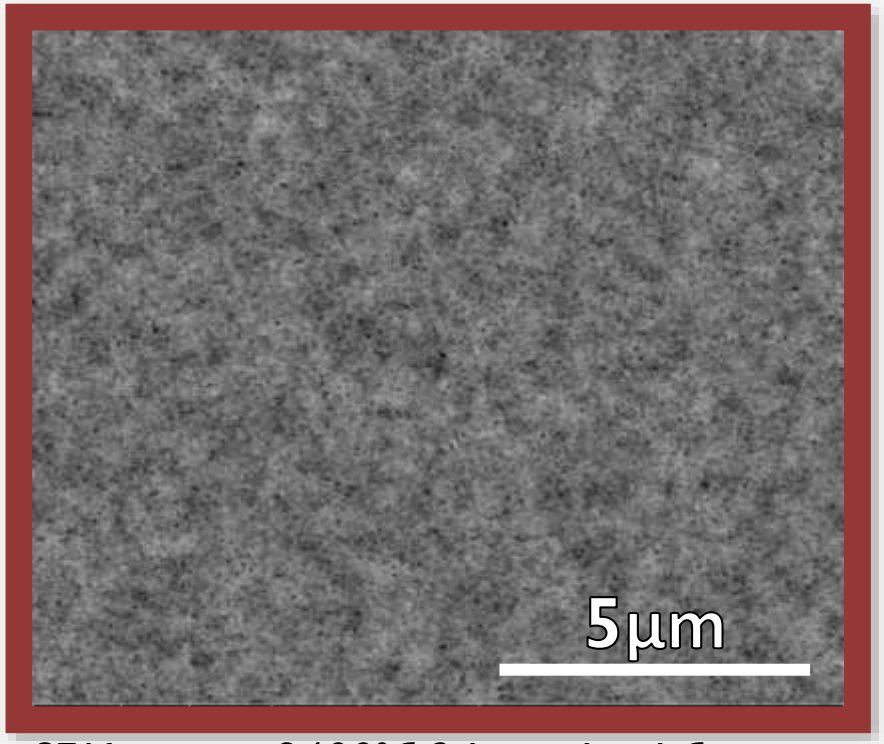
CuO Nano-wires

NWs must be grown on clear electrode



Thermal vapor deposition of Cu

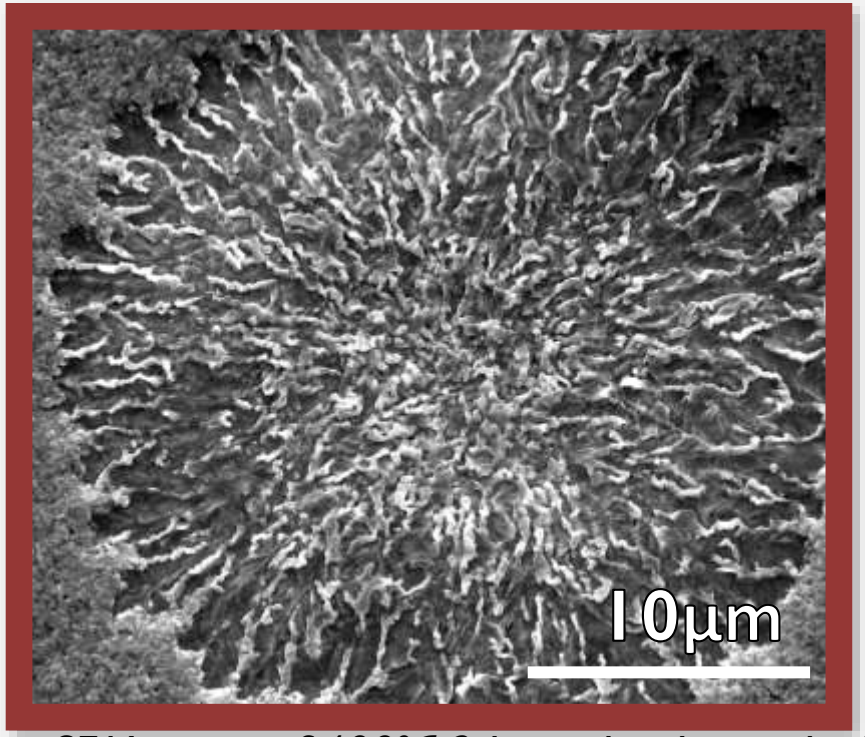
Oxidized sample



SEM image of 400°C 2 hr oxidized Cu on FTO glass

No NWs found after oxidation

Scratched sample to create rough surface

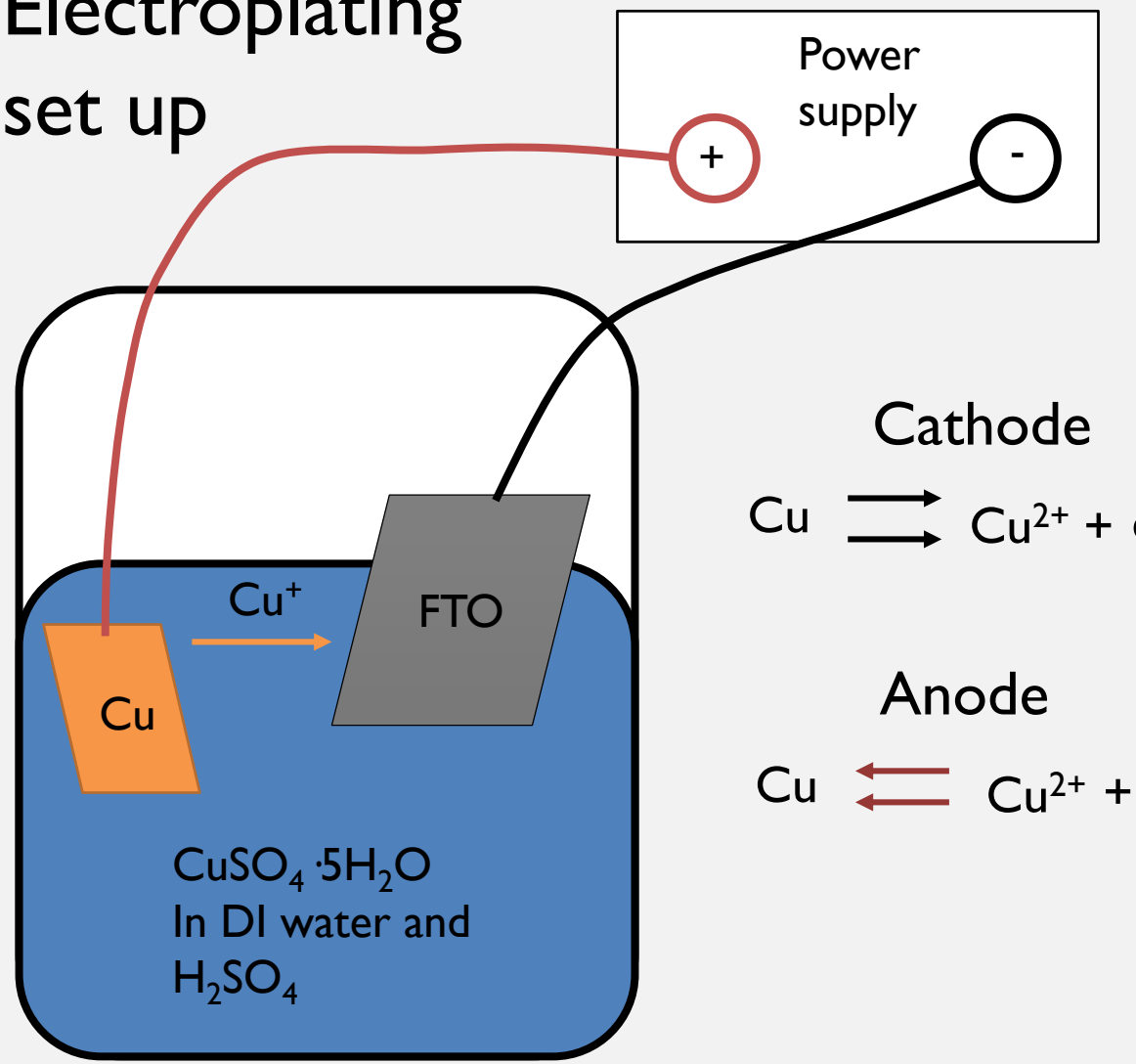


SEM image of 400°C 2 hr oxidized scratched Cu on FTO glass

No NWs found after oxidation

Electroplating

Electroplating set up



Cathode

$Cu \rightleftharpoons Cu^{2+} + e^{2-}$

Anode

$Cu \rightleftharpoons Cu^{2+} + e^{2-}$

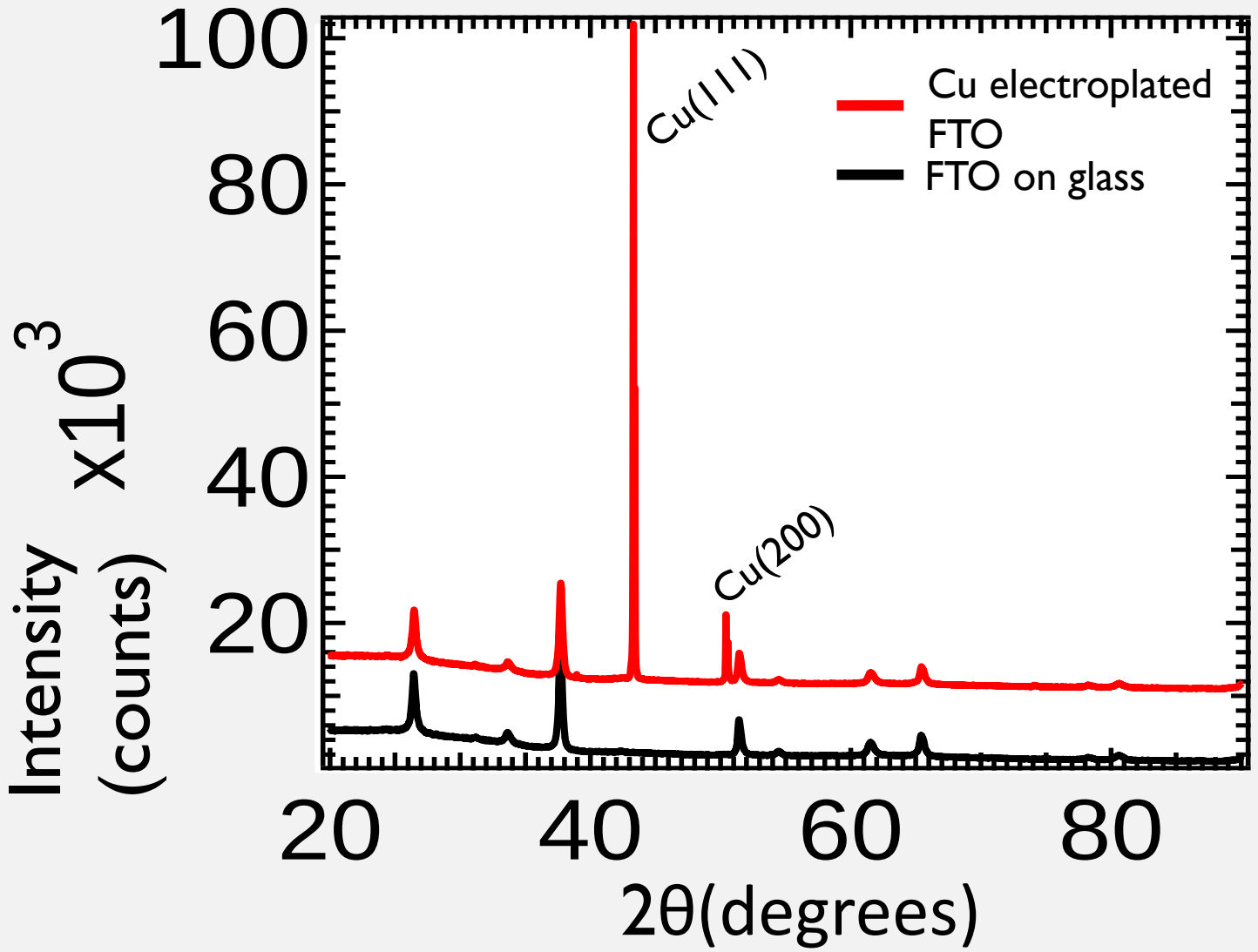
$$d = \frac{\frac{\mu}{N_A} It}{2eA\rho}$$

μ=Molecular weight
N_A=Avagadro's #
I=current
t=time
e=charge of electron
A=area
ρ= Density of copper
d=thickness

Time	10sec	300 sec	900 sec
Expected thickness	1μm	36 μm	110μm

XRD of Electroplated Cu on FTO Glass

- FTO glass electroplated with Cu for 300 sec
- Two copper peaks corresponding to Cu(111) at 43.3° 2θ and Cu(200) at 50.42° 2θ planes in spectra



Summary

- PCBM/P3HT has best theoretical power conversion efficiency at 1000nm
- Long path length for charge collection may be causing a decrease in efficiency
- We will attempt to use CuO NWs to shorten path length and increase efficiency
- Unable to grow NWs on thermal vapor deposited copper
- Succesfully deposited copper through electroplating

Future Work

- Oxidize copper electroplated FTO glass
- Fabricate 1000nm PCBM/P3HT Solar cell without NWs
- Fabricate solar cell with NWs
- Compare efficiency

Acknowledgment

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Special thanks to my advisor Dr. TeYu Chien

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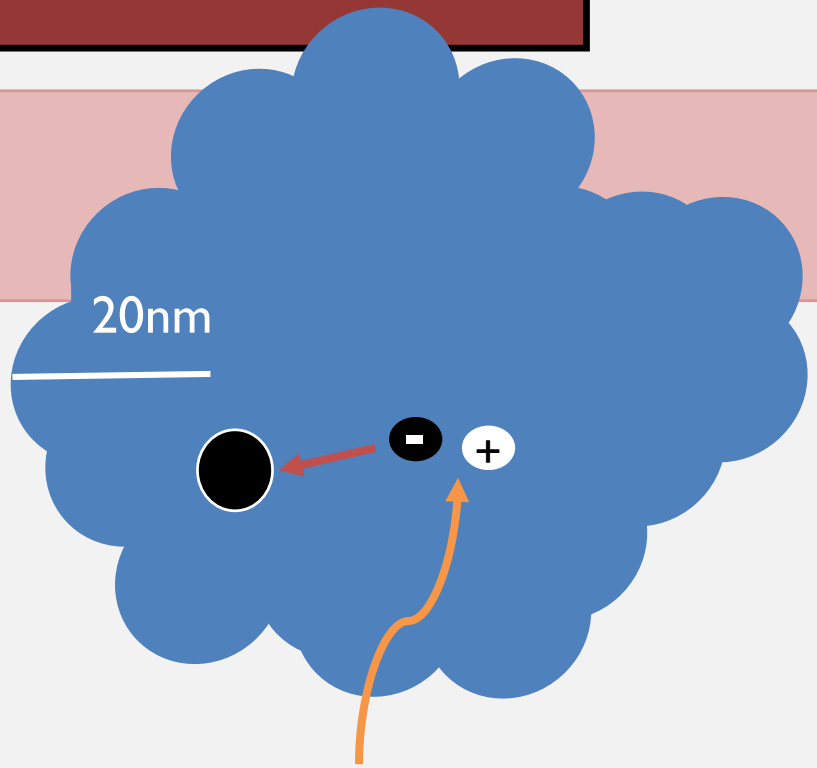
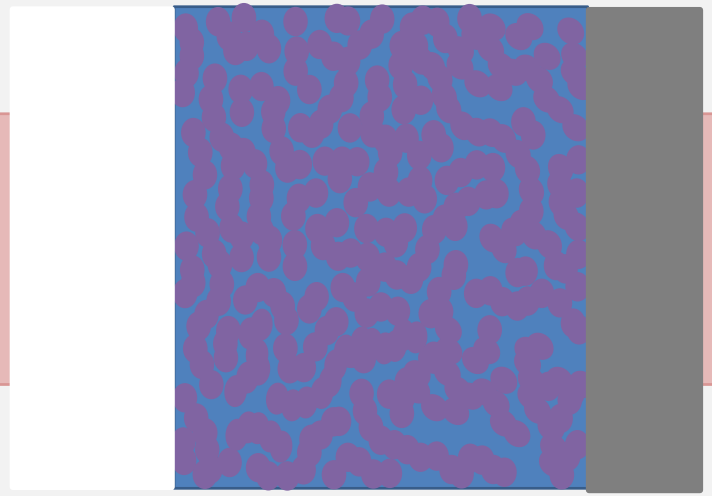
Exciton Recombination

Exciton has short mean free path



- Exciton path length is 10nm to 20nm
- Exciton formed in domain larger than 20nm may recombine before charge diffusion



Many small domains in a bulk hetero-junction organic solar cell