

Solar Hydrogen Production on Porphyrin-Based Organic Photovoltaics

Michael G. Walter
University of North Carolina at Charlotte



Carl Wamser Symposium
September 28th, 2012

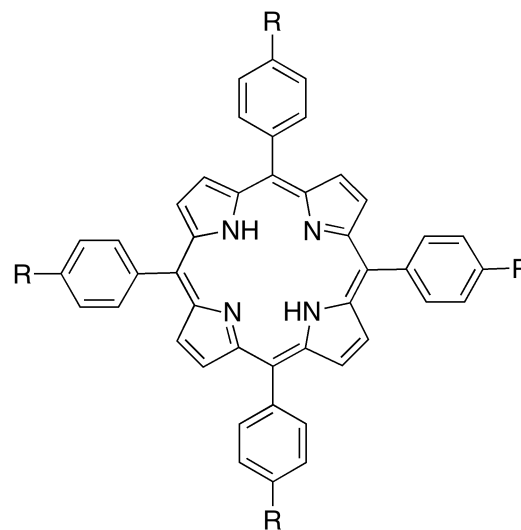
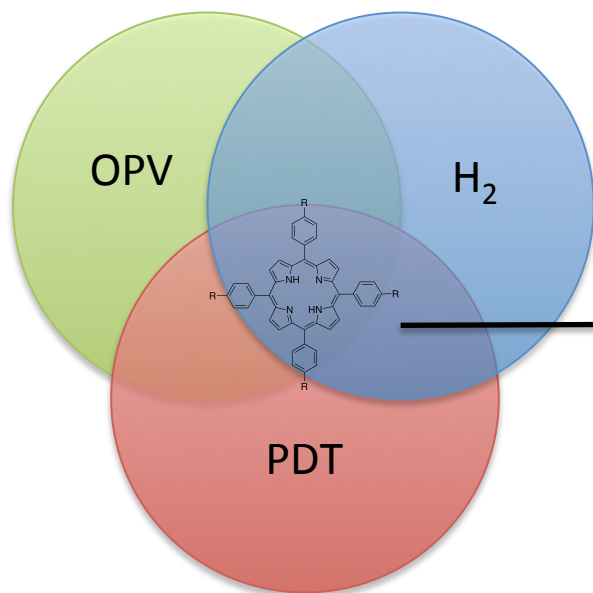
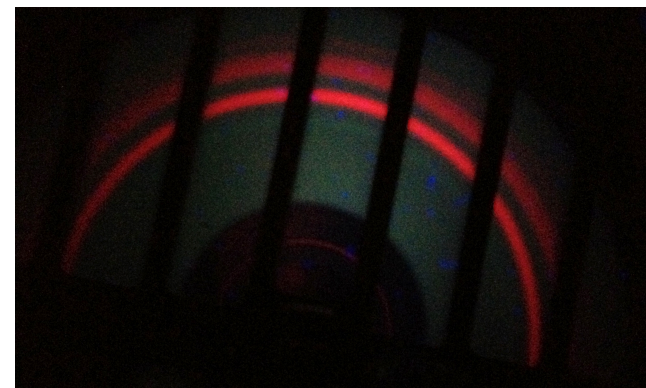




Walter Research Group



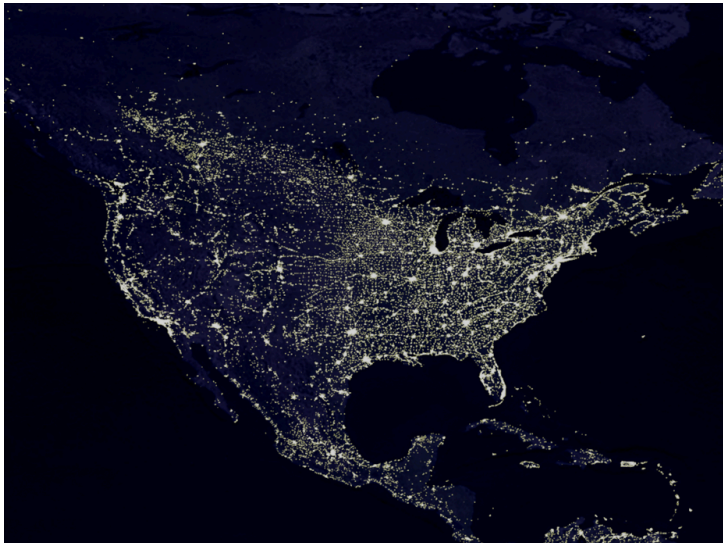
- Organic Solar Cells (OPV)
- Solar Fuels (H_2)
- Photodynamic Therapy (PDT)



5,10,15,20-tetrakis(p-R-phenyl)porphyrin

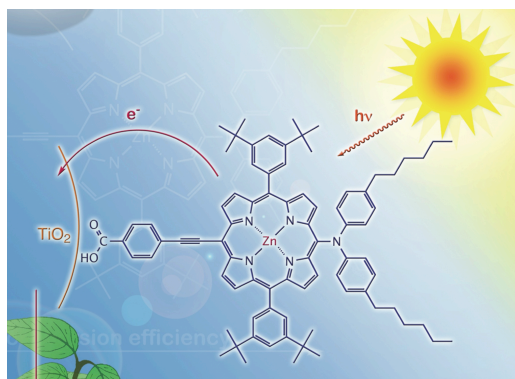
Motivation?

- Society needs: Clean energy with minimal environmental impact
- Solar: can help address the 15 TW needed
- Economics: cheap solar energy conversion!

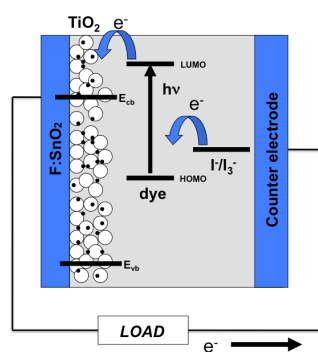
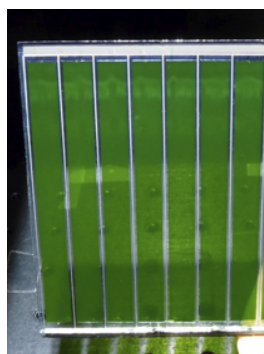


Porphyrins in DSSCs / OSCs

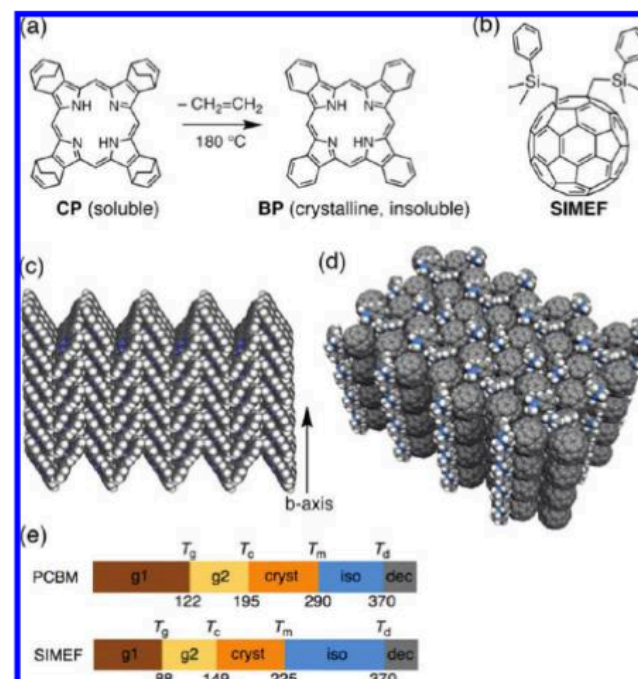
- Dye-sensitized TiO₂ Solar Cells (12%)



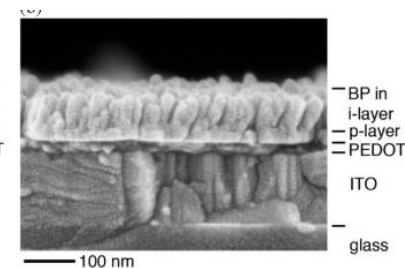
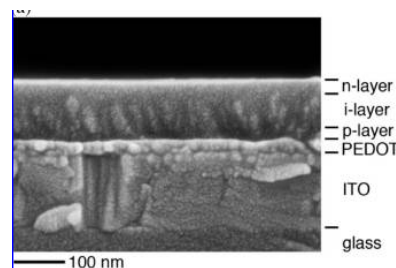
Walter, M. G.; Rudine, A. B.; Wamser, C. C.; "Porphyrins and Phthalocyanines in Solar Photovoltaic Cells," *J. Porphyrins Phthalocyanines* (2010), 14 759-792.



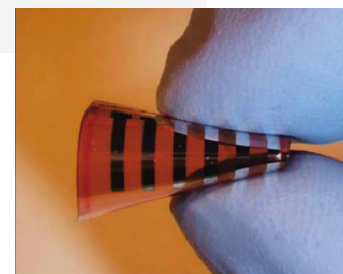
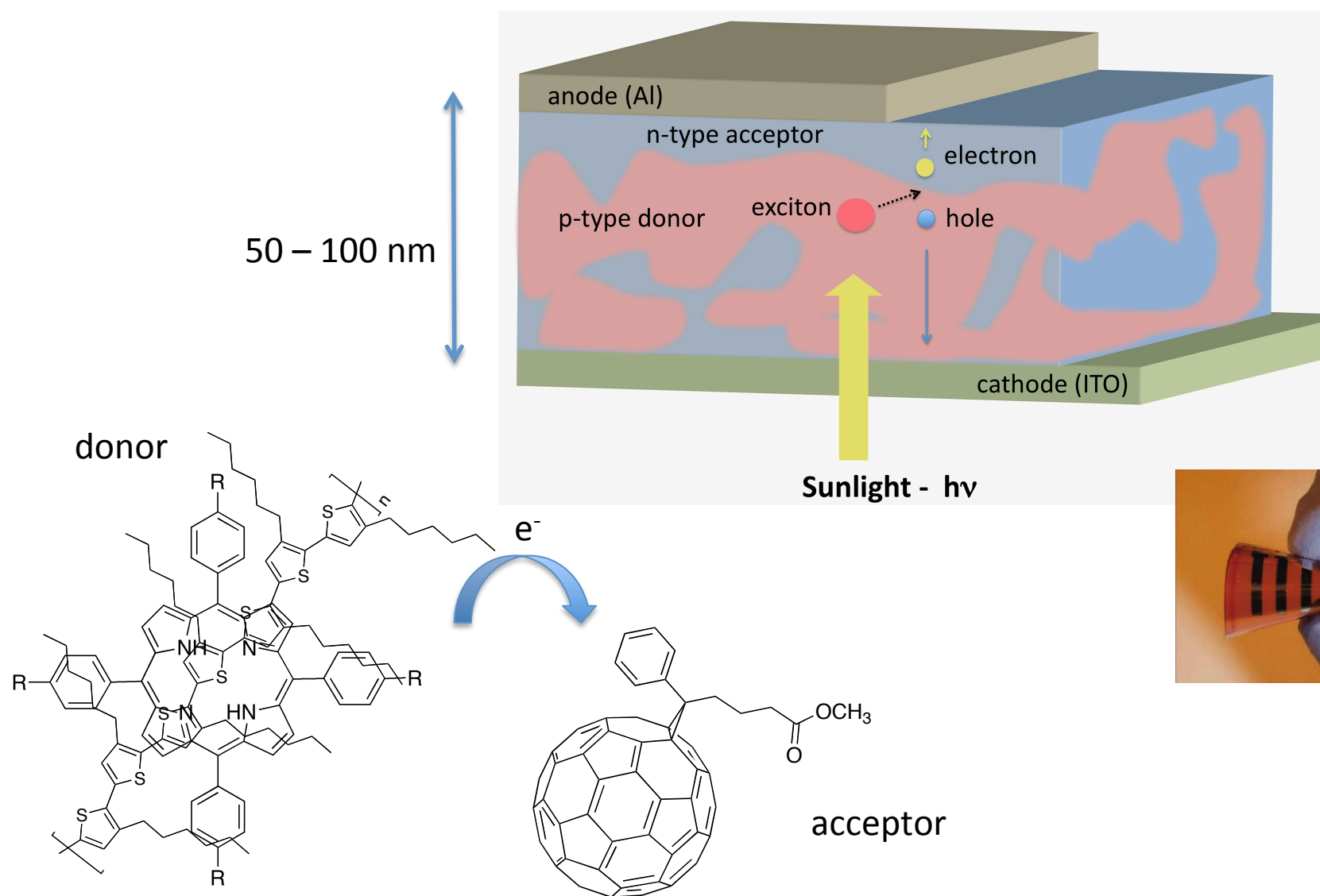
Yella; et al. "Porphyrin-Sensitized Solar Cells with Cobalt (II/III)-Based Electrolyte Exceed 12 % Efficiency." *Science* (2011), 334 629-634.



- Organic Solar Cell (10%)

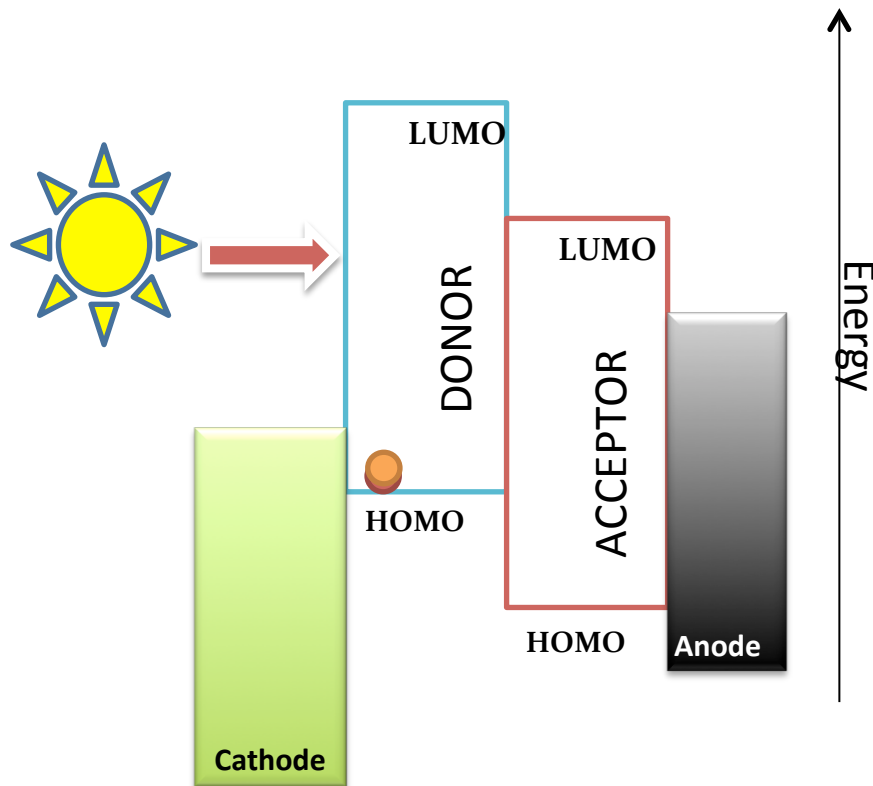


Organic Photovoltaics



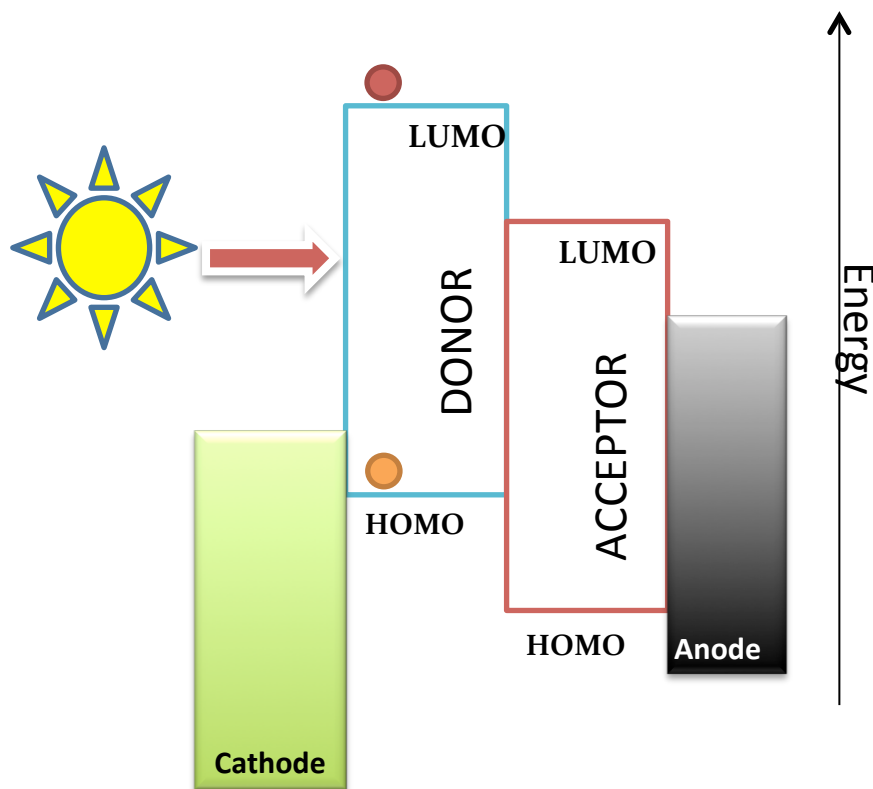
Bulk Heterojunction Energy Level Diagram

1. Exciton formation
 $\text{HOMO} \rightarrow \text{LUMO}$

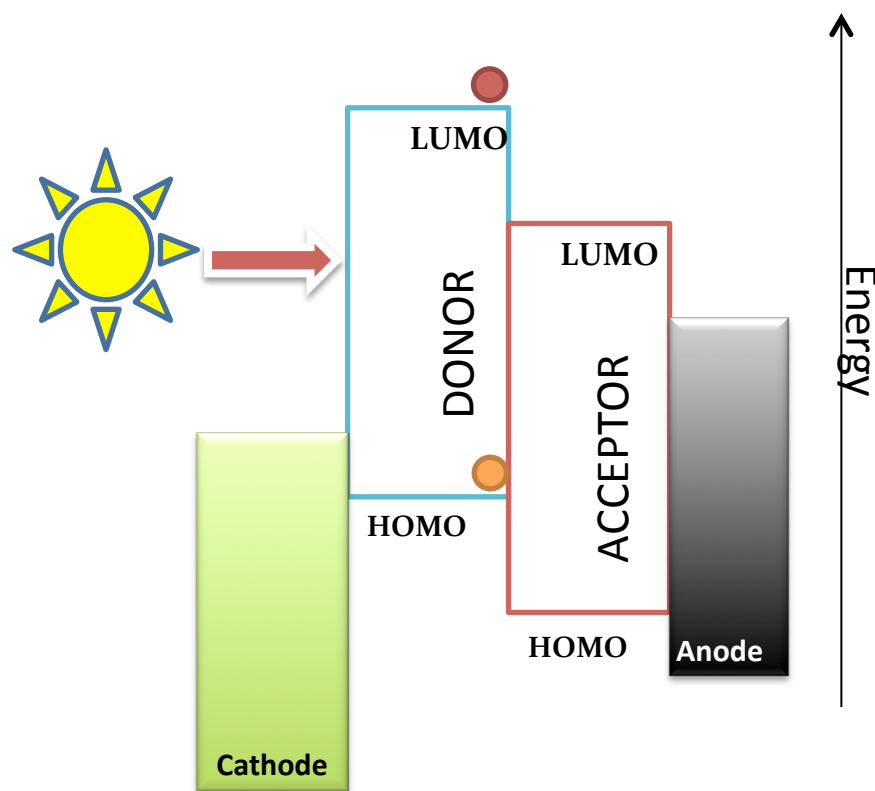


Bulk Heterojunction Energy Level Diagram

1. Exciton formation
 $\text{HOMO} \rightarrow \text{LUMO}$
2. Exciton diffusion



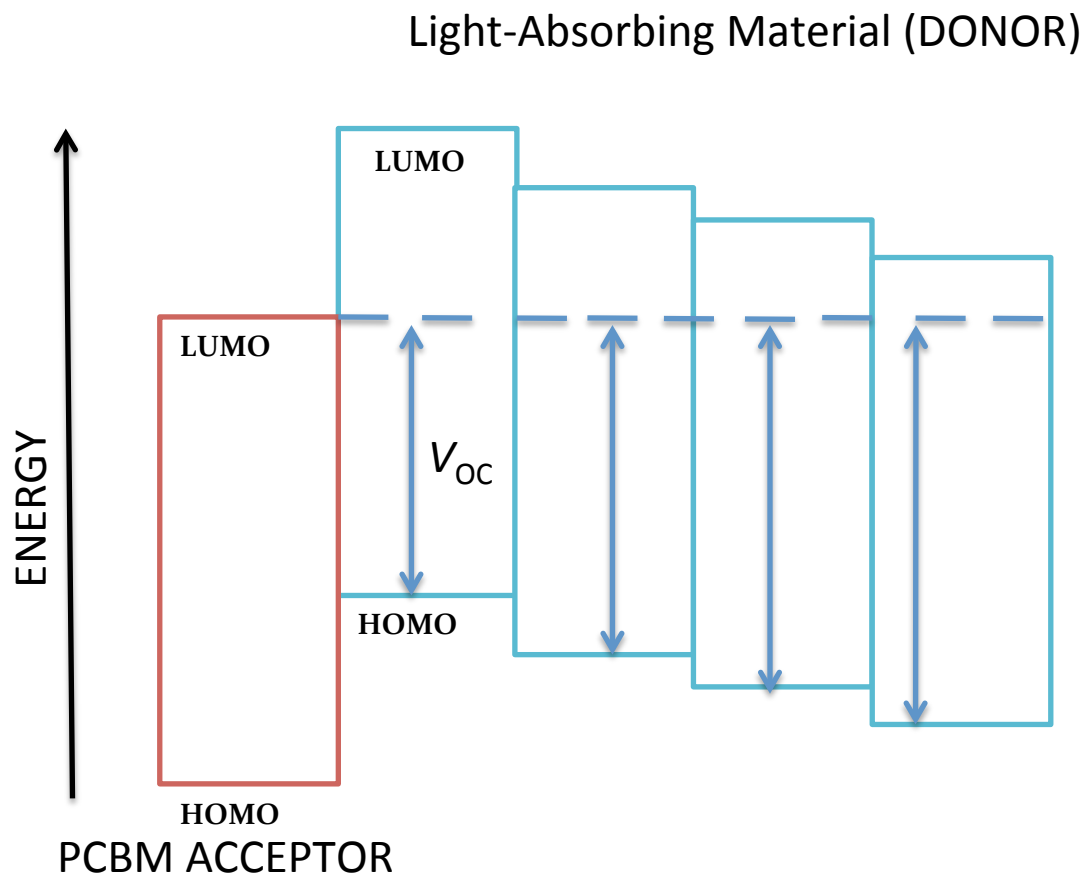
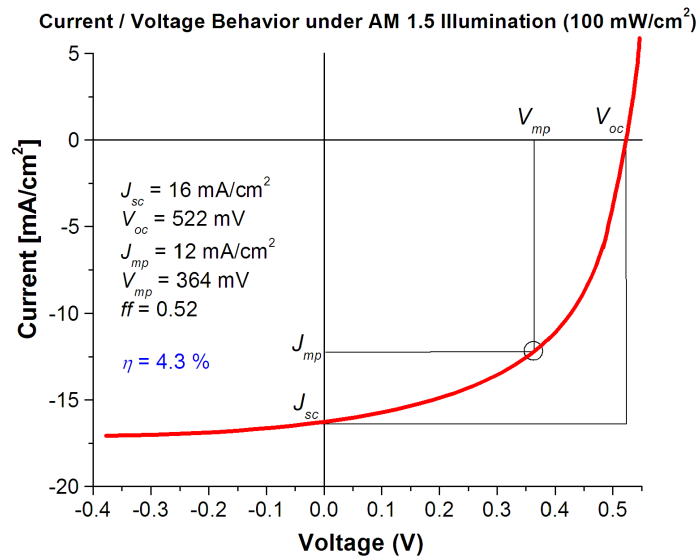
Bulk Heterojunction Energy Level Diagram



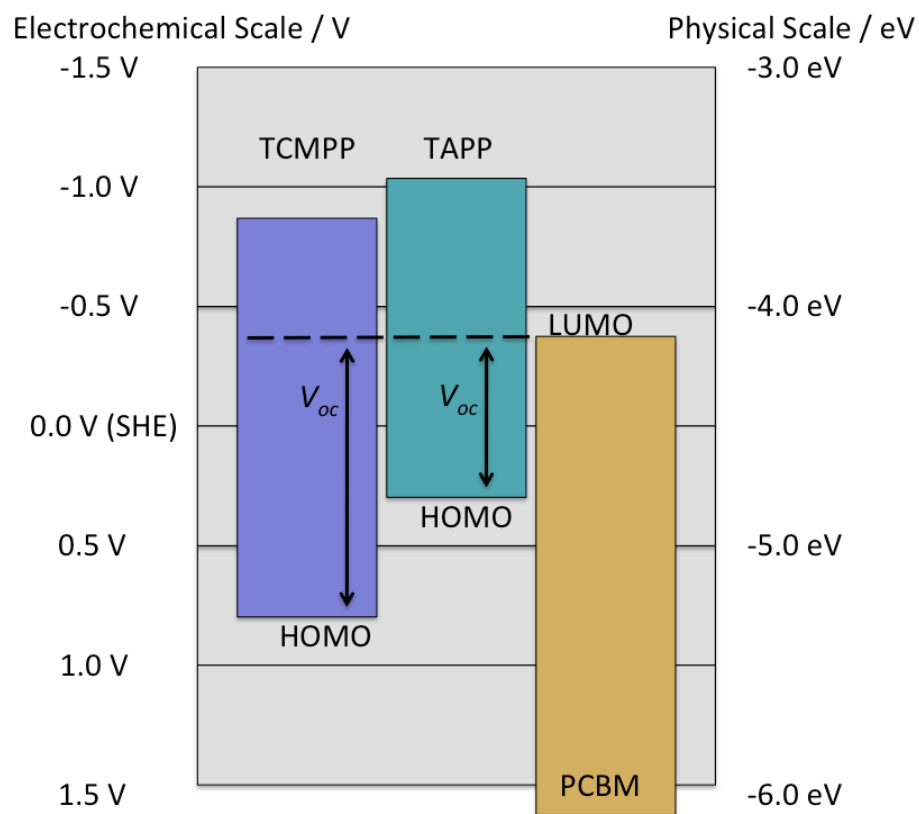
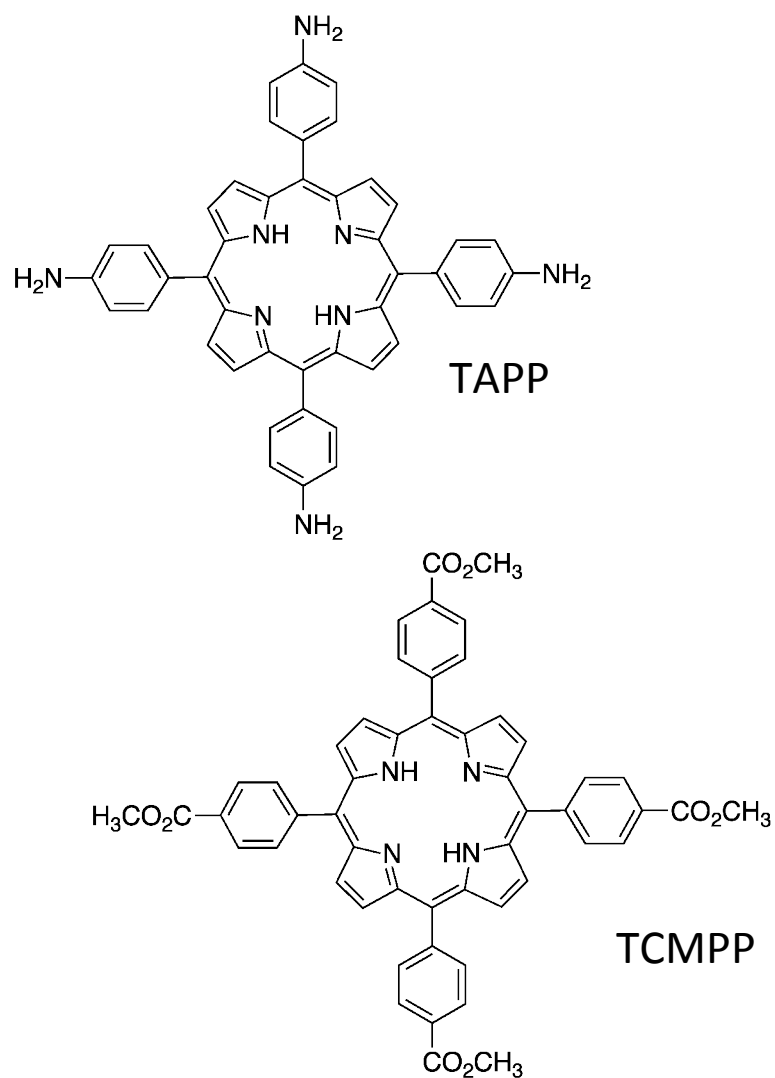
1. Exciton formation
 $\text{HOMO} \rightarrow \text{LUMO}$
2. Exciton dissociation
3. Charge transfer from
DONOR to ACCEPTOR
material
4. Holes migrate toward
cathode and electrons
migrate to anode

Increasing V_{oc} to Increase Efficiency

$$\eta = \frac{J_{sc} \cdot V_{oc} \cdot ff}{P_{in}}$$

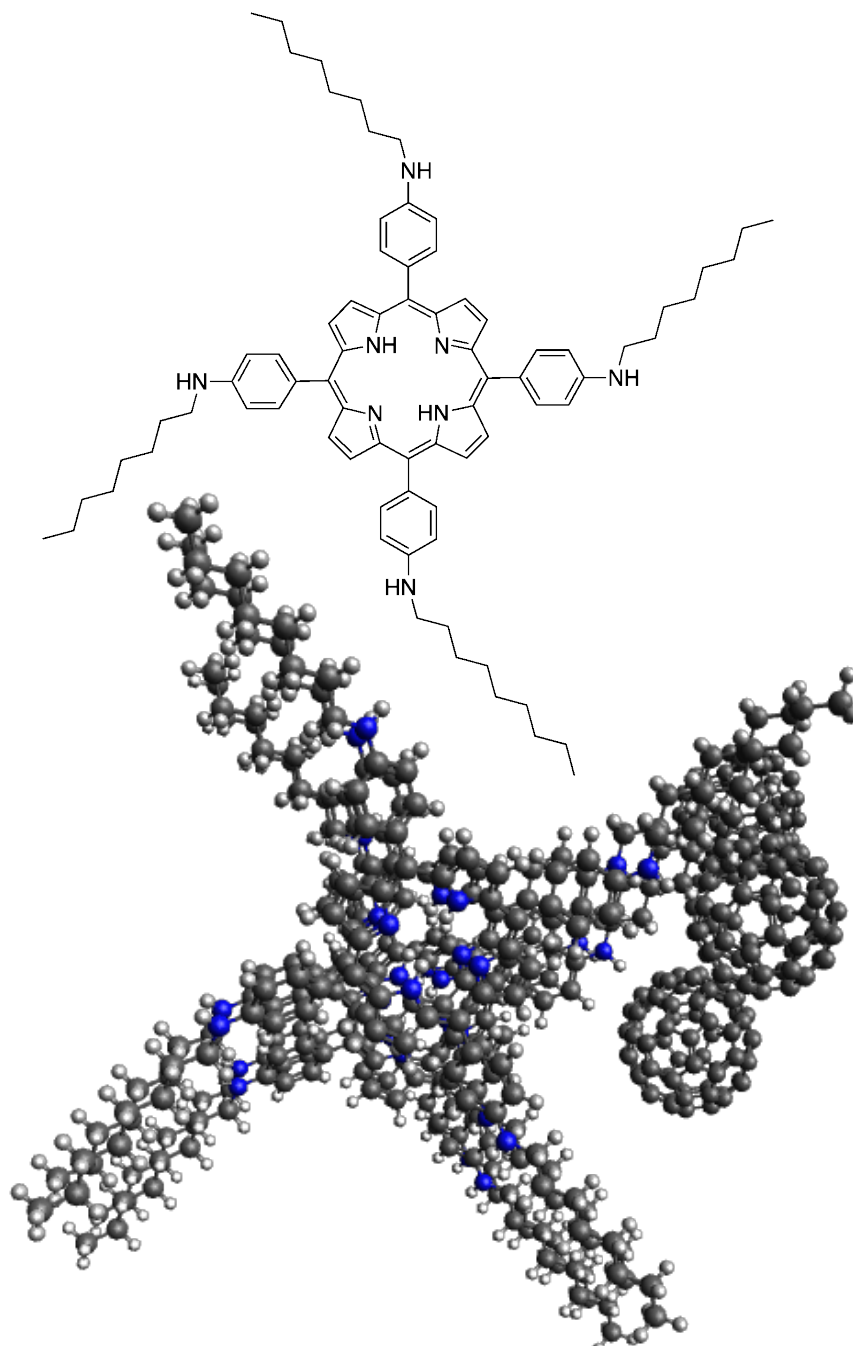
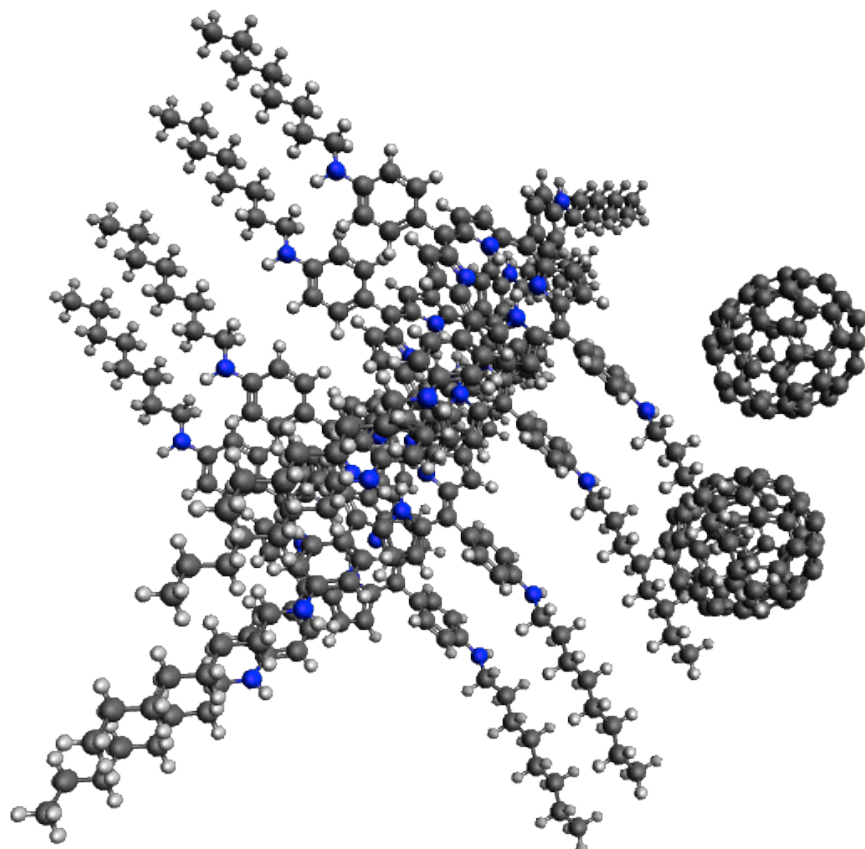
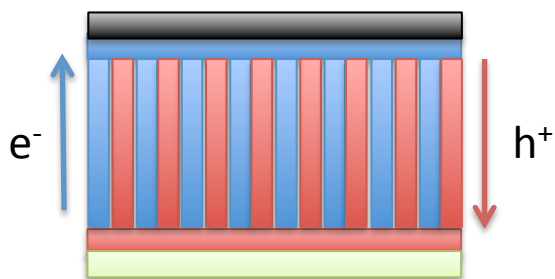


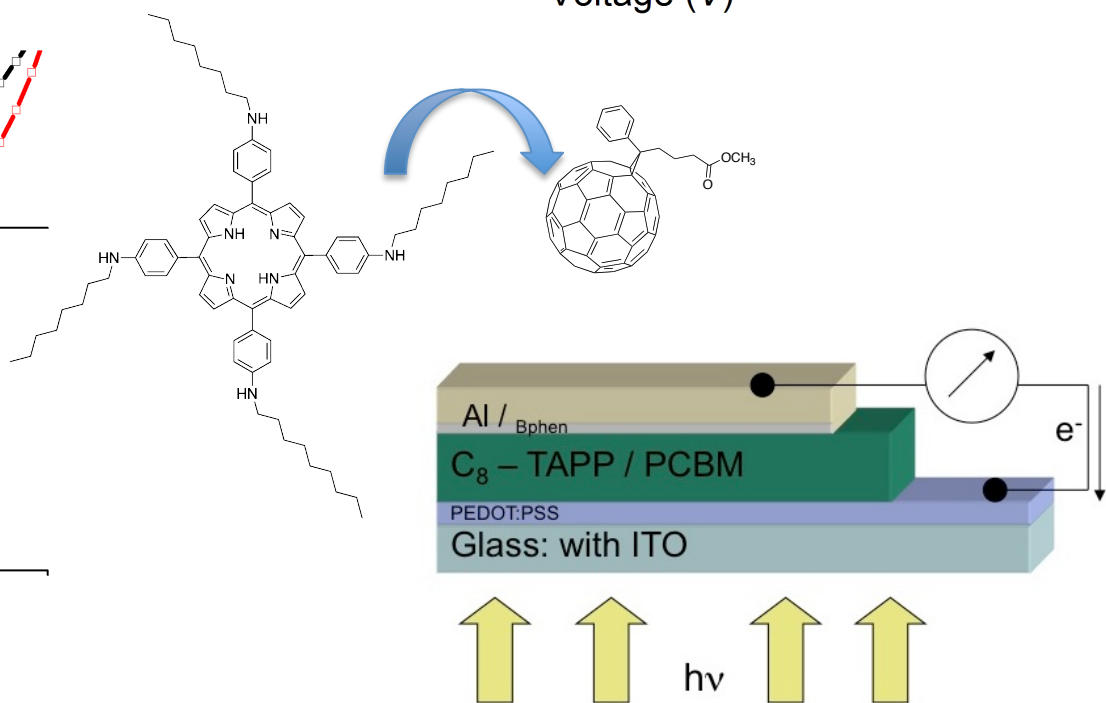
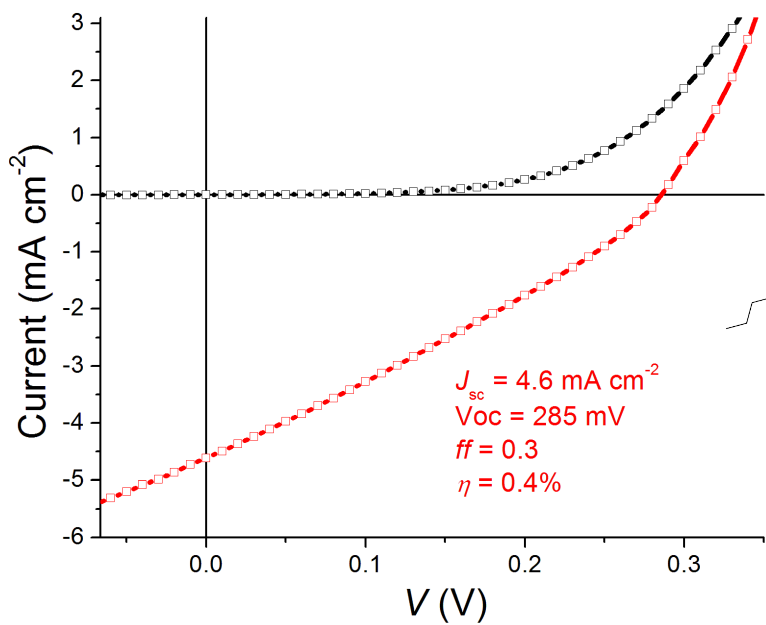
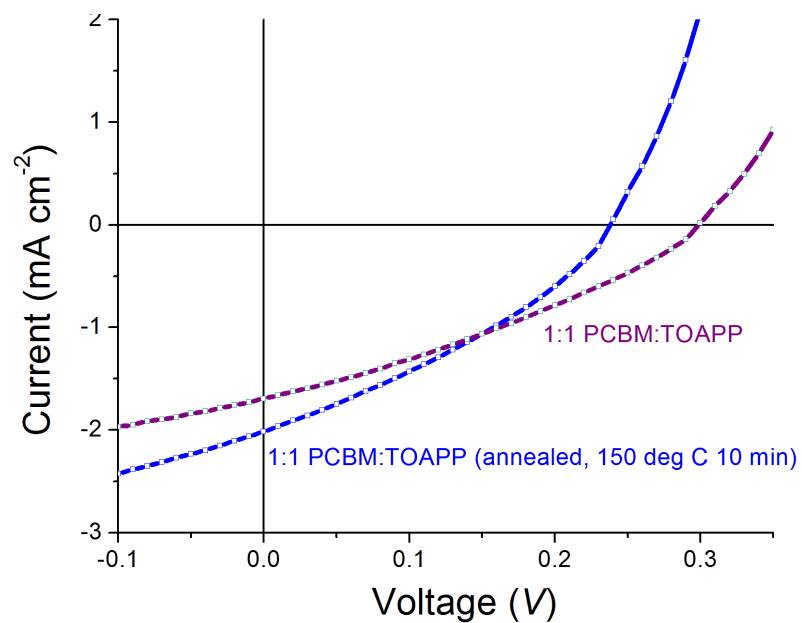
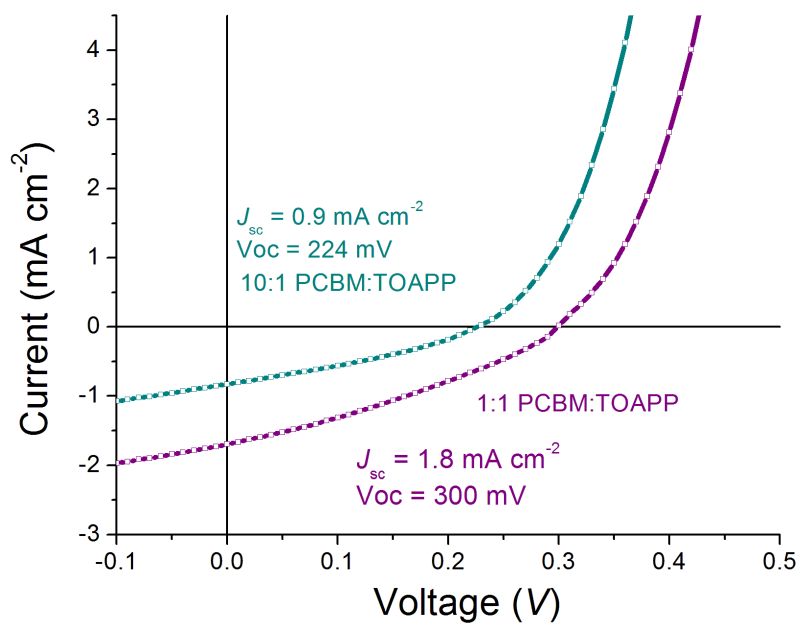
Porphyrins in Solar Cells



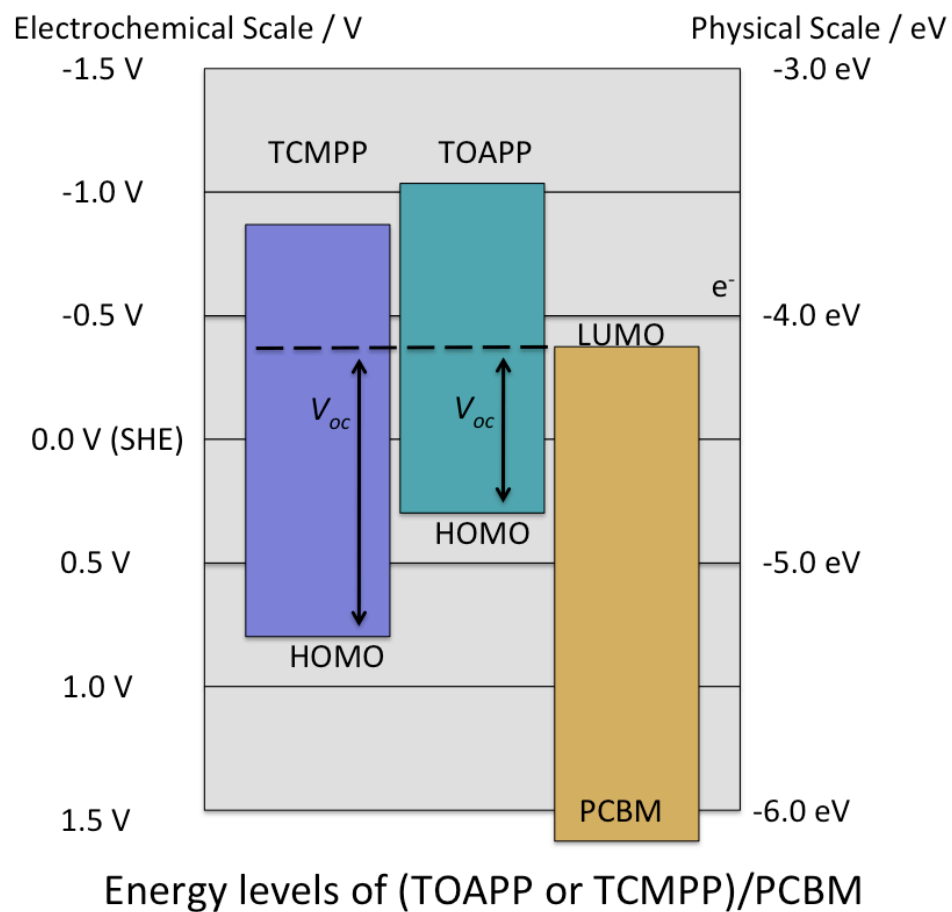
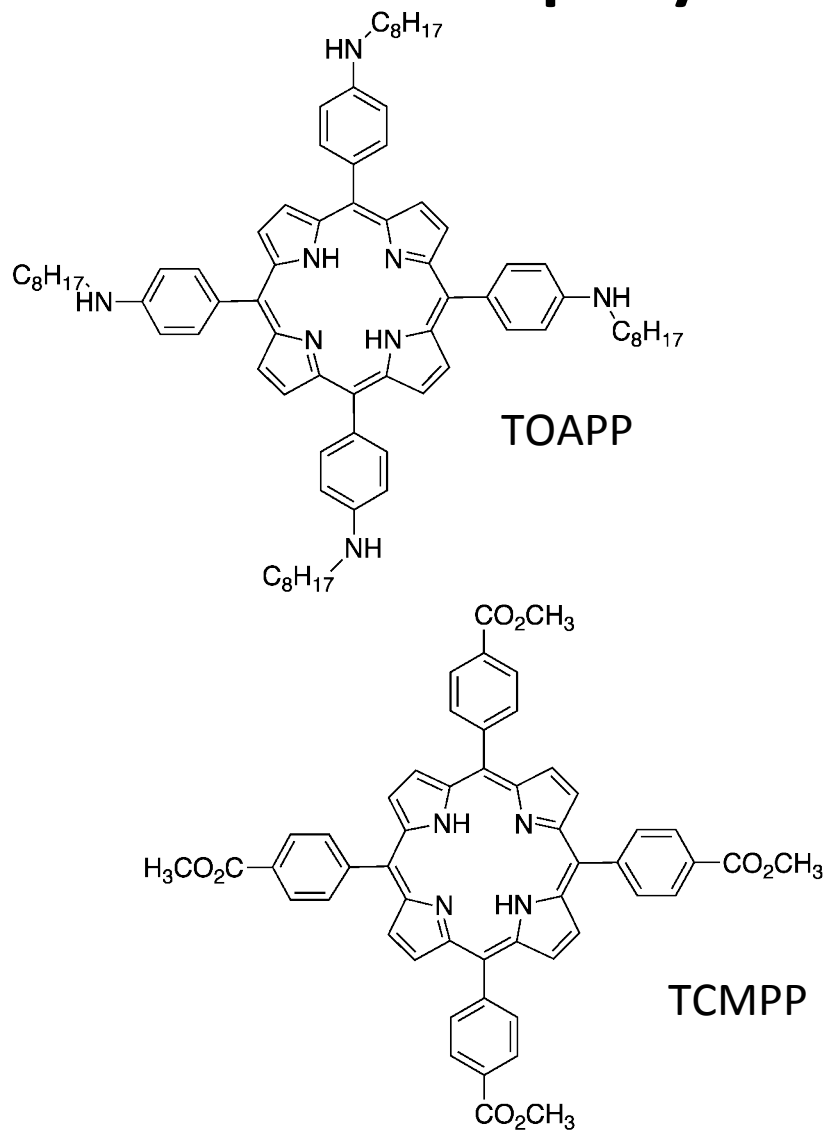
5,10,15,20-tetrakis(N-octyl-4-aminophenyl)porphyrin

“Ideal” junction, width < 10 nm
exciton diffusion length, ~10 nm



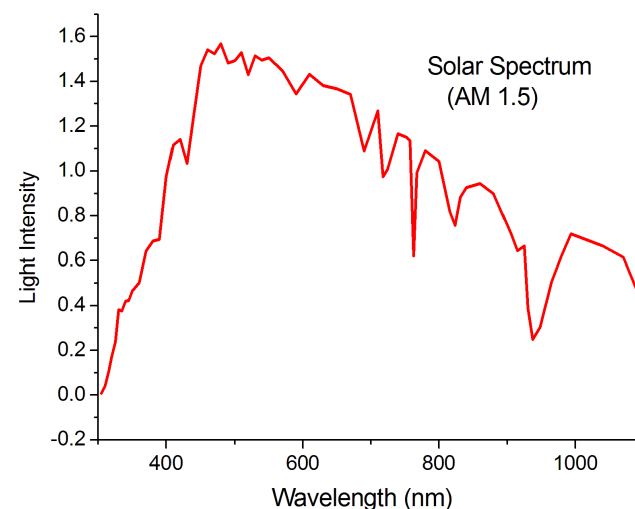
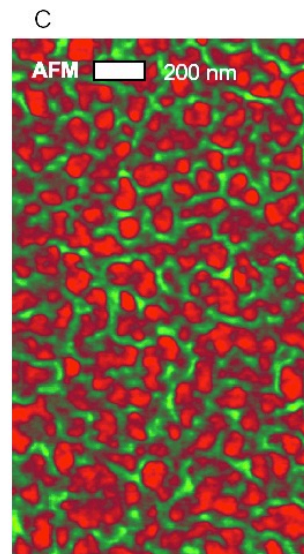


Porphyrins in Solar Cells



Questions:

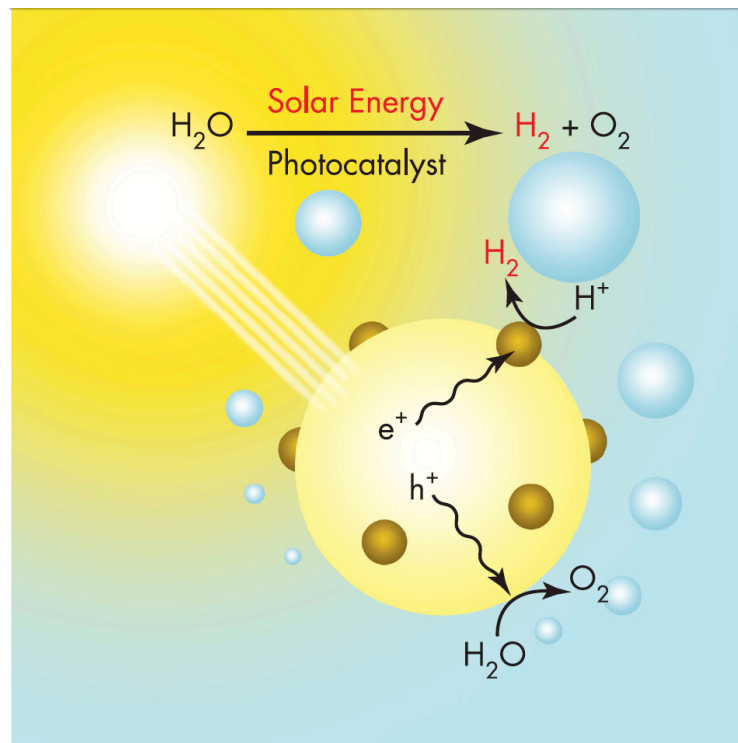
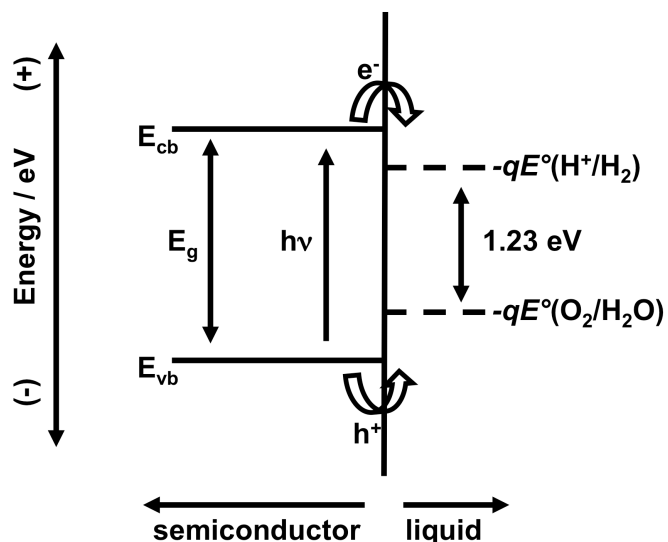
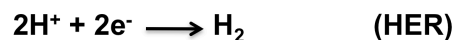
- What molecular shape helps direct phase ordering of the porphyrin donor material?
- What is the optimal nanomorphology for charge extraction? Increase domain size?
- How can donor-acceptor porphyrins help to increase rate of free charge carrier generation? Visible light responsiveness?



Solar Fuels

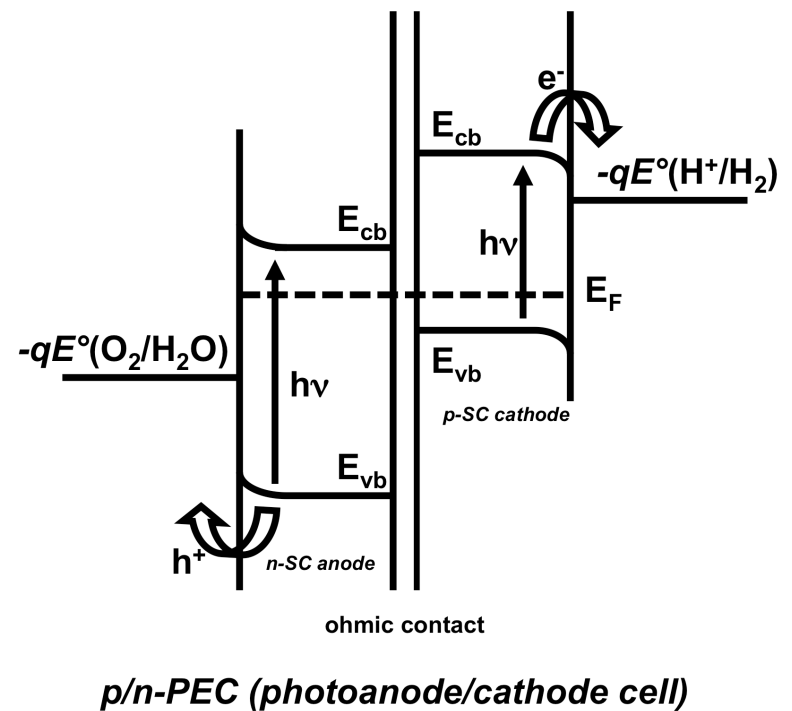
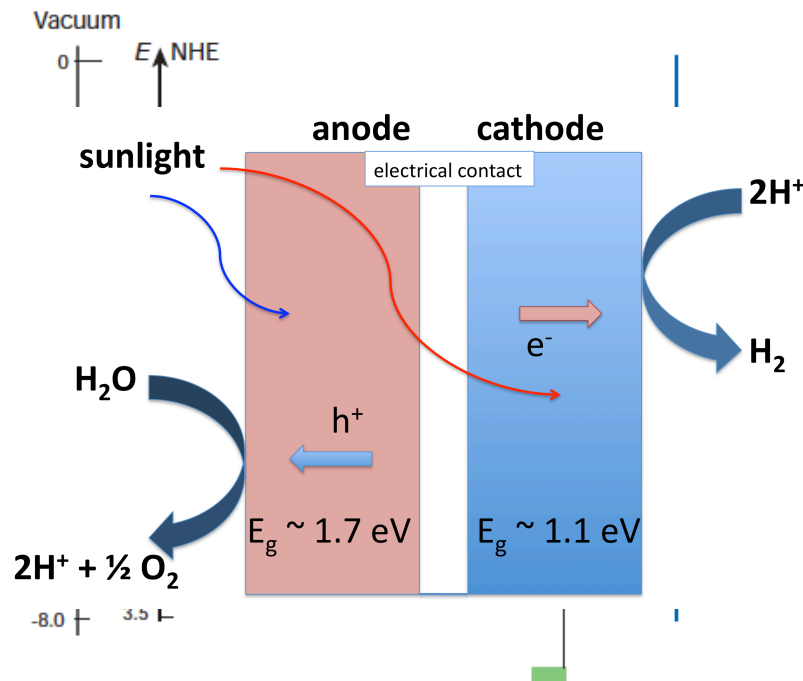


- Splitting H_2O into H_2 and O_2 with **light-driven** photocatalysts = store solar energy in chemical bonds

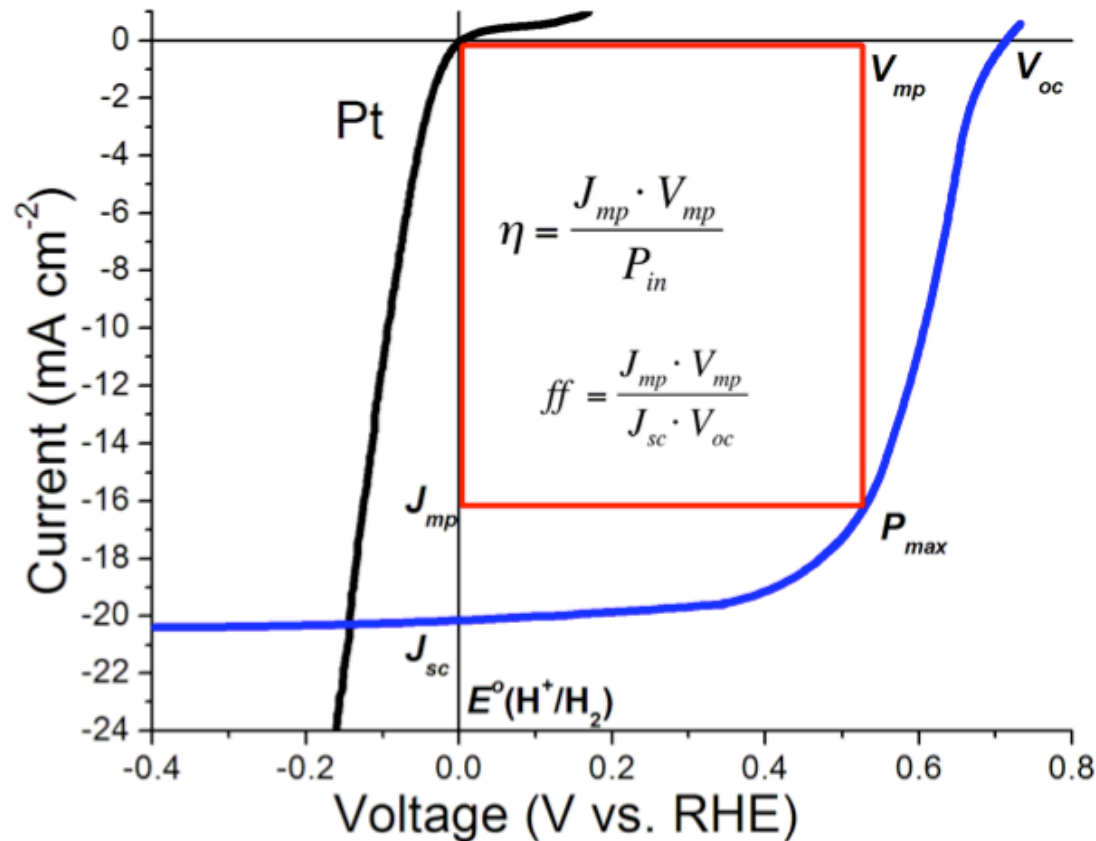


Solar Fuels

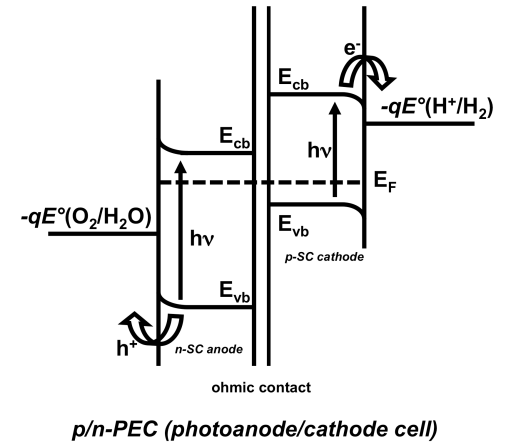
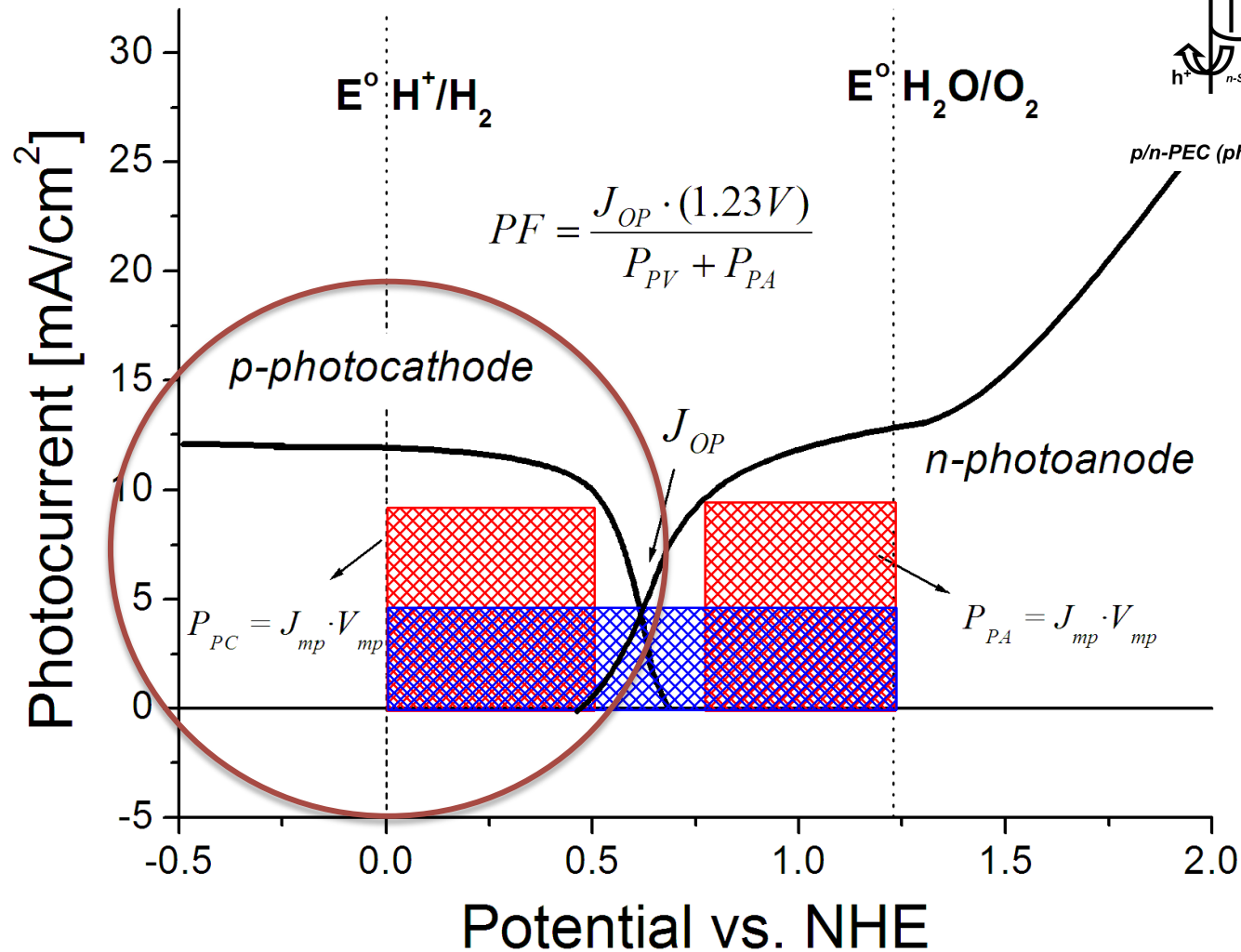
- Splitting H_2O with light-driven semiconductor photoelectrodes



Measuring H₂ Semiconductor PEC

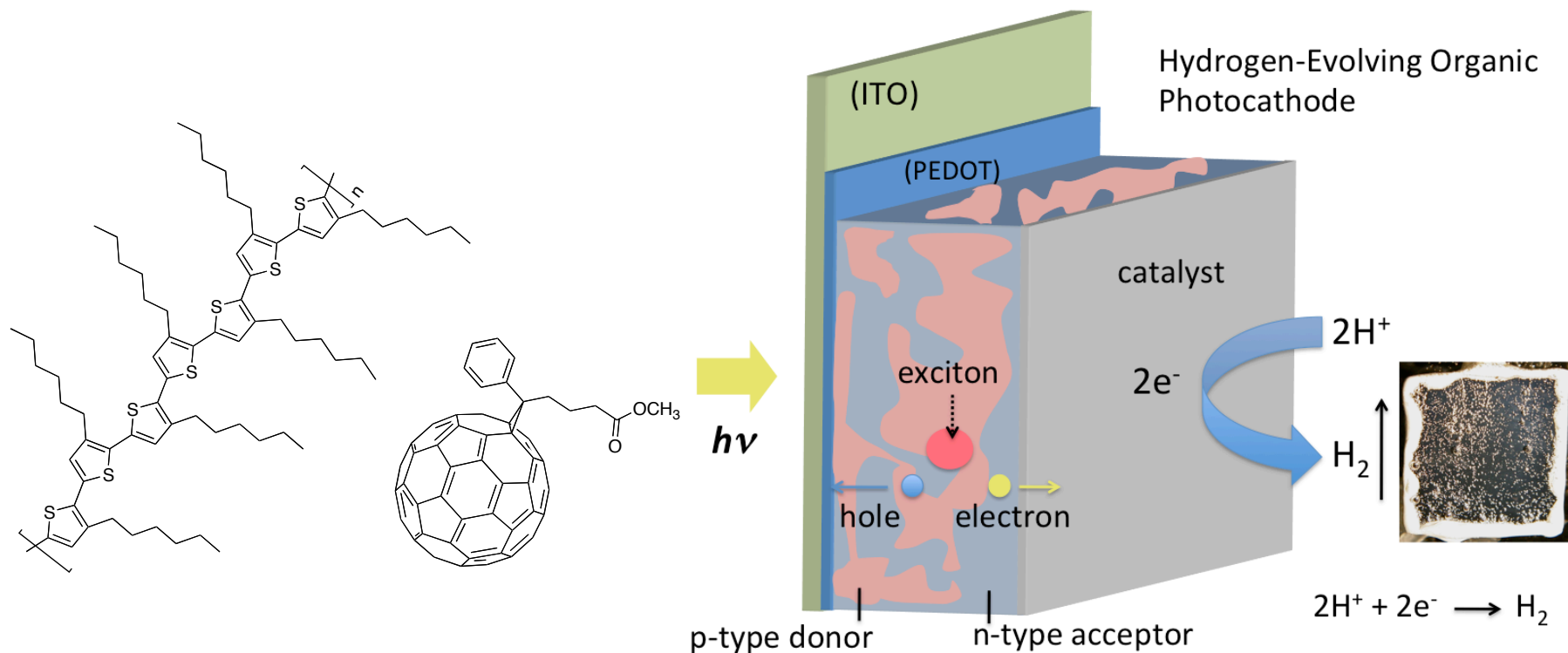


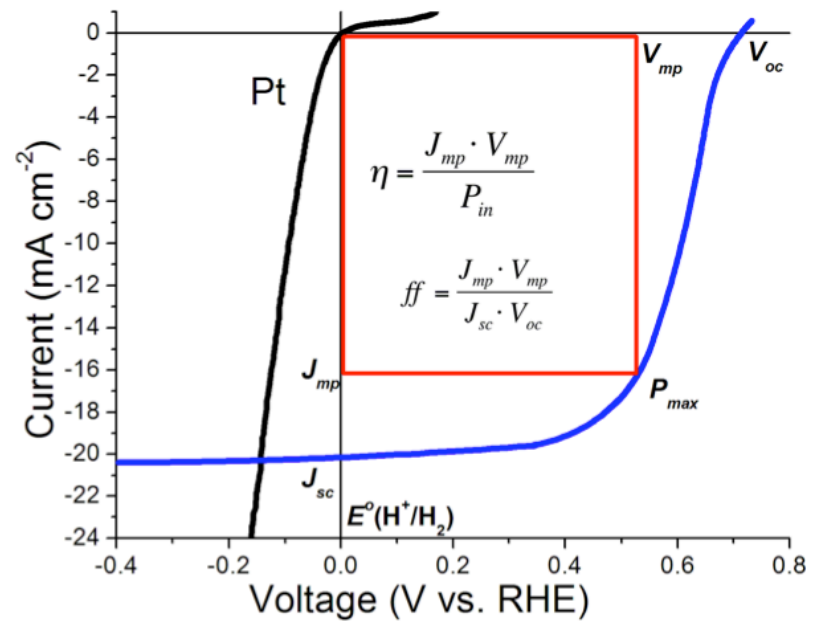
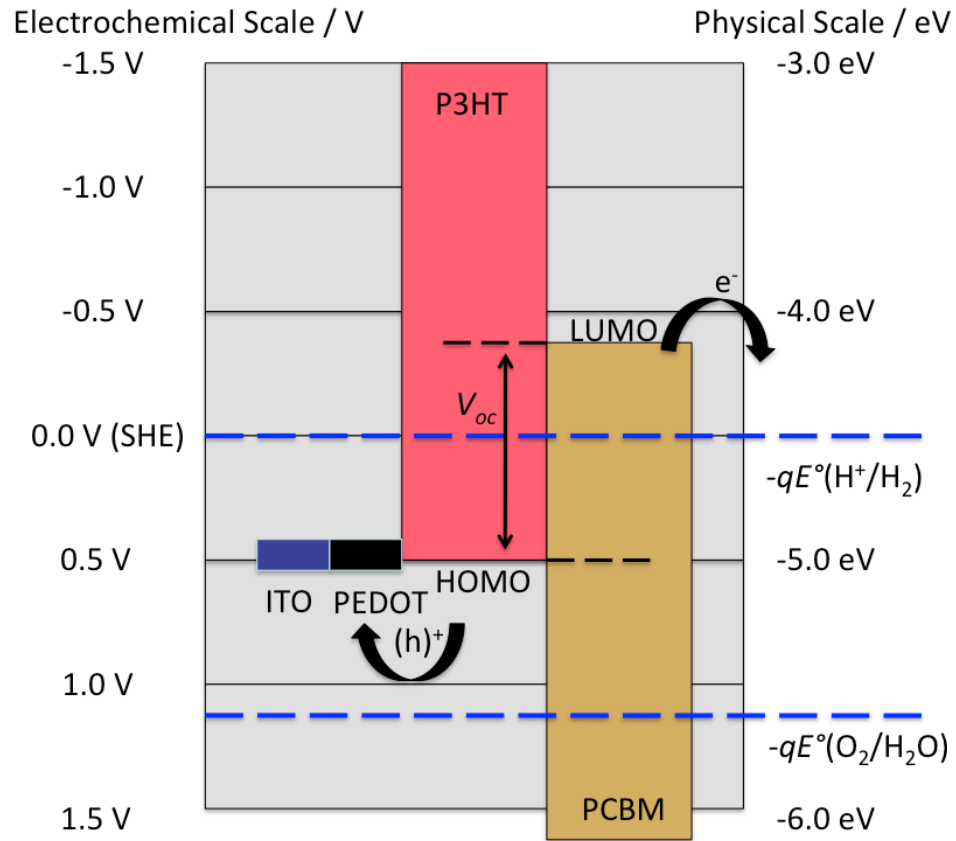
(PEC) Power Factor



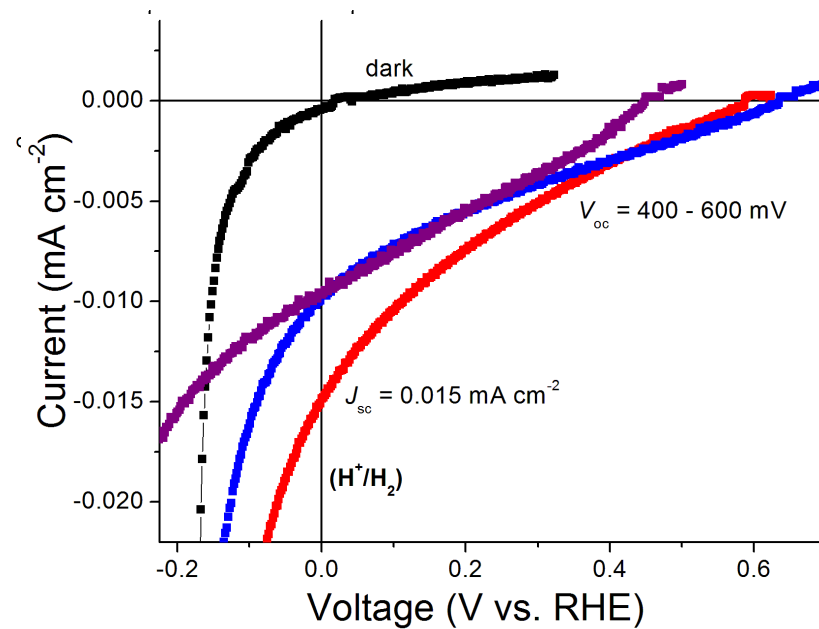
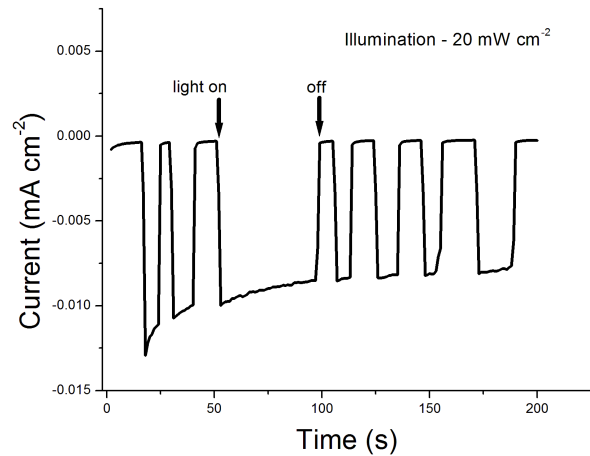
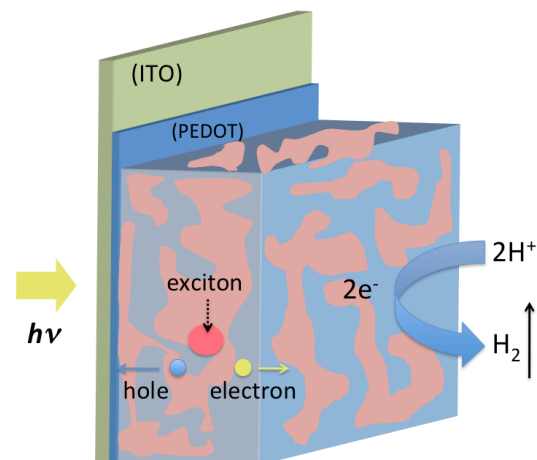
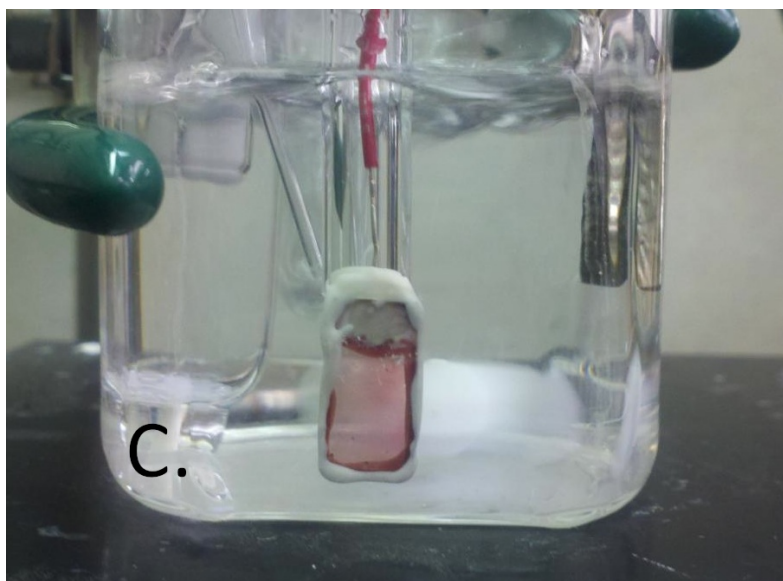
Organic PV for H₂ PEC

- Polymer solar cell with the incorporation of a hydrogen evolving catalyst
 - Easily processed, lightweight photocathodes for hydrogen evolution



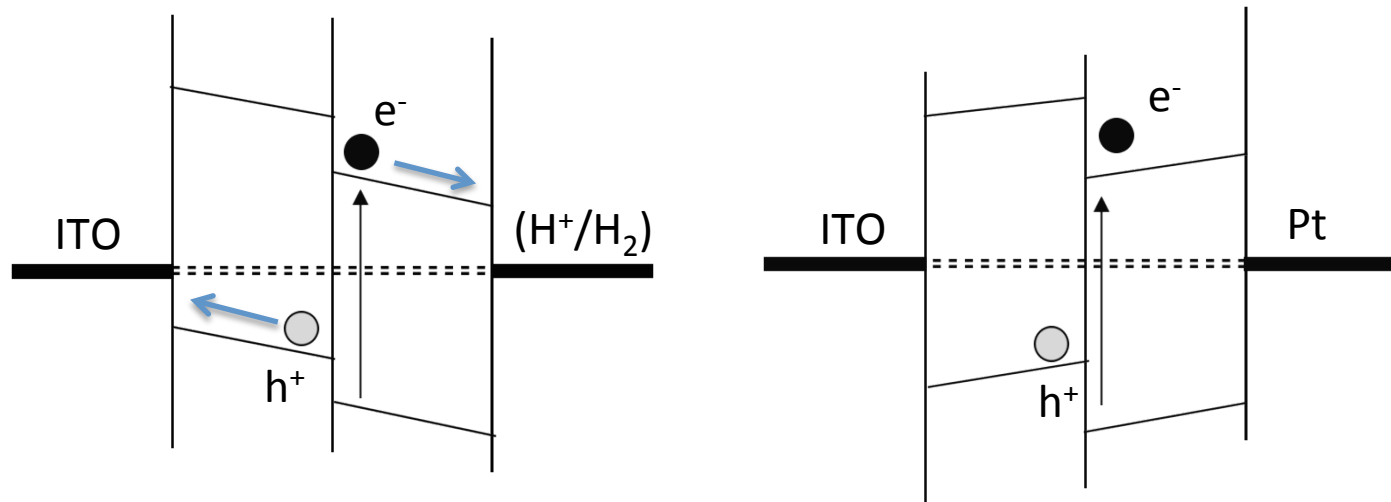


OPV H₂ Photoelectrode



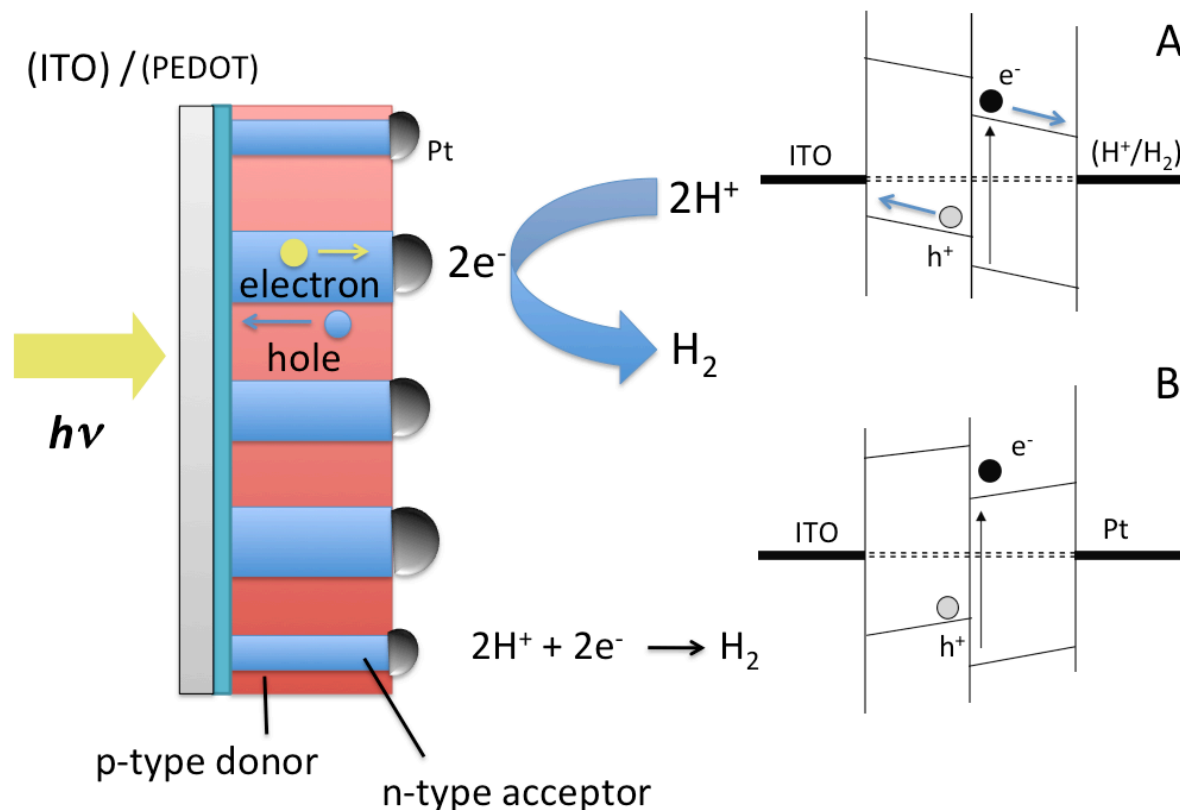
Metal catalyst contact

- Both OPV and PEC have little/no observable photocurrent with Pt contact



Ideal OPV H₂ PEC

- BHJ photoelectrode needs to contact redox couple
- Catalyst particles to increase photocurrent

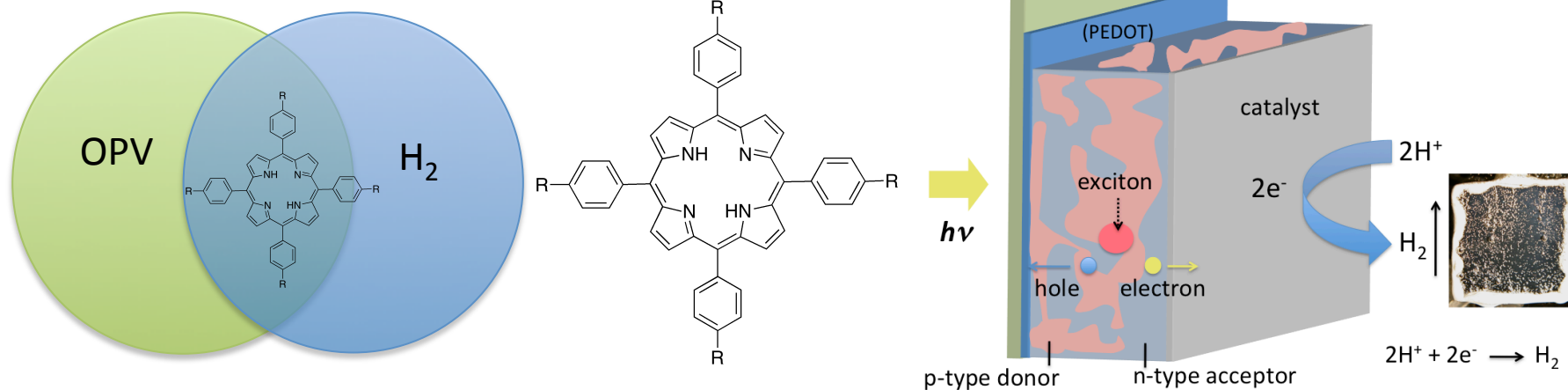


Questions:

- What is the pH dependence of a BHJ in contact with aqueous redox potential?
- Do catalyst nanoparticles (or islands) need to cover both phases (or just one)?
- How well do porphyrin photoelectrodes perform in this configuration?

Future....

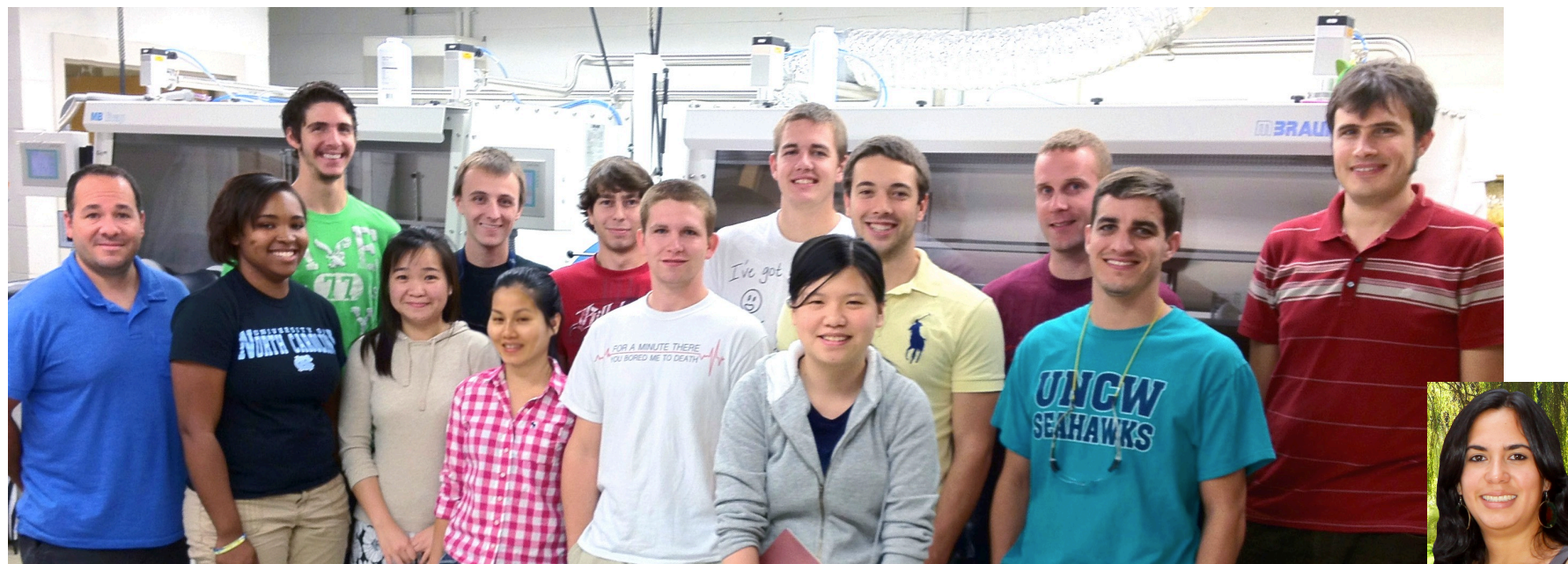
- Printable, water splitting membranes?
 - Porphyrin OPV PECs
 - Molecular catalysts



Walter Lab Research

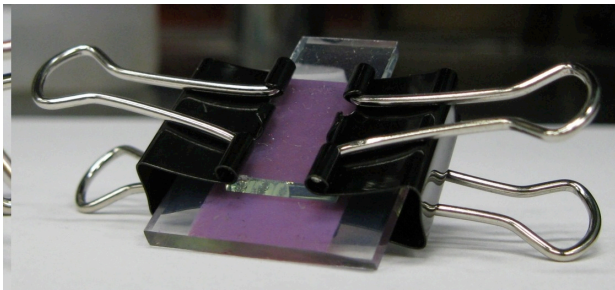


Acknowledgements:



Outreach – “Juice from Juice”

www.blackberrysolarcells.org, www.juicefromjuice.org



Thank you - Carl Wamser!

- Mentoring
 - MS
 - PhD
 - Postdoc
 - Assist. Prof.

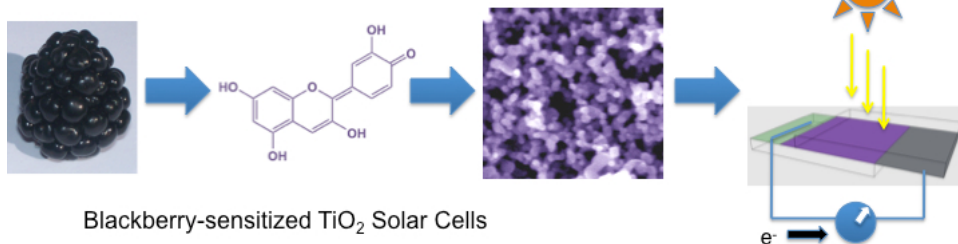
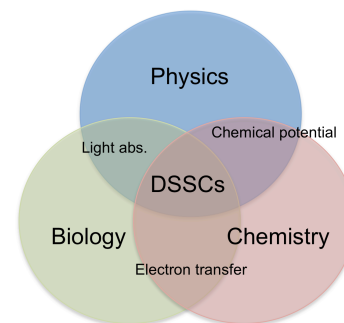


Thank You! Questions?



Blackberry DSSCs (Solar Cells)

Chemistry Students of all ages, (High School, Undergrads, Graduate)



www.arborsci.com/dye-sensitized-solar-cell-kit
www.blackberrysolarcell.org
www.juicefromjuice.org