Using Ferritin Quantum Dots to Harvest Solar Energy

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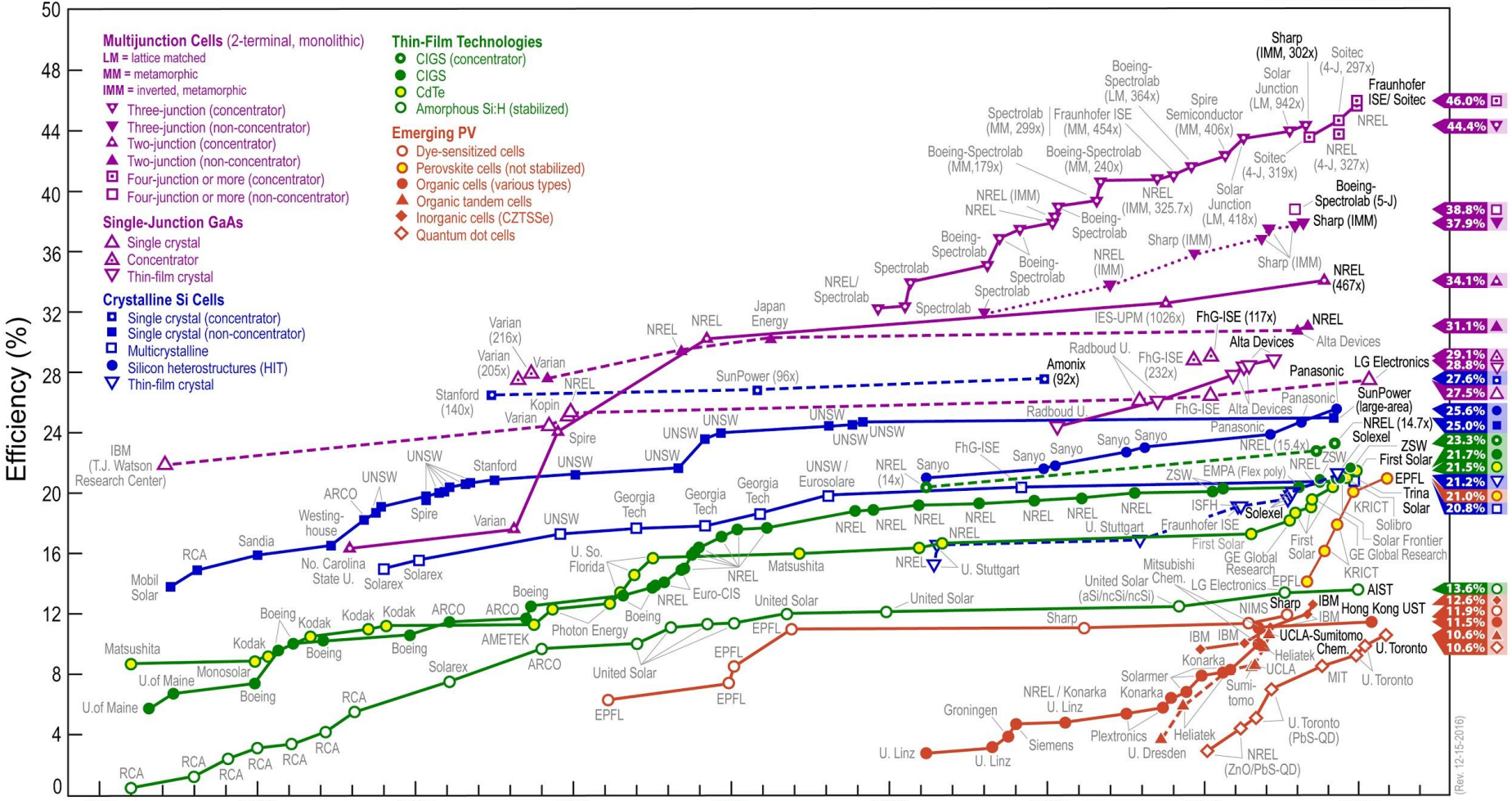
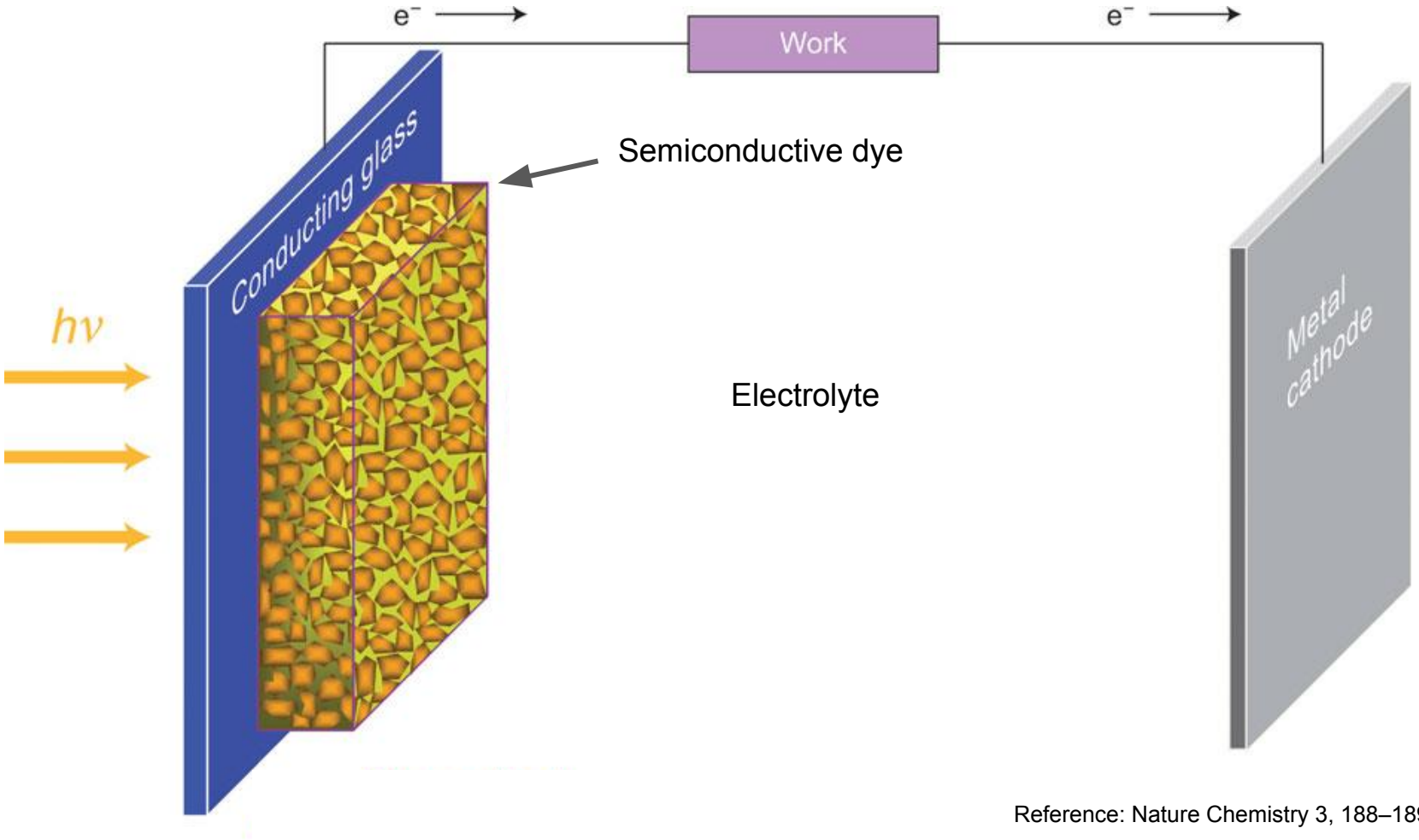
Best Research-Cell Efficiencies

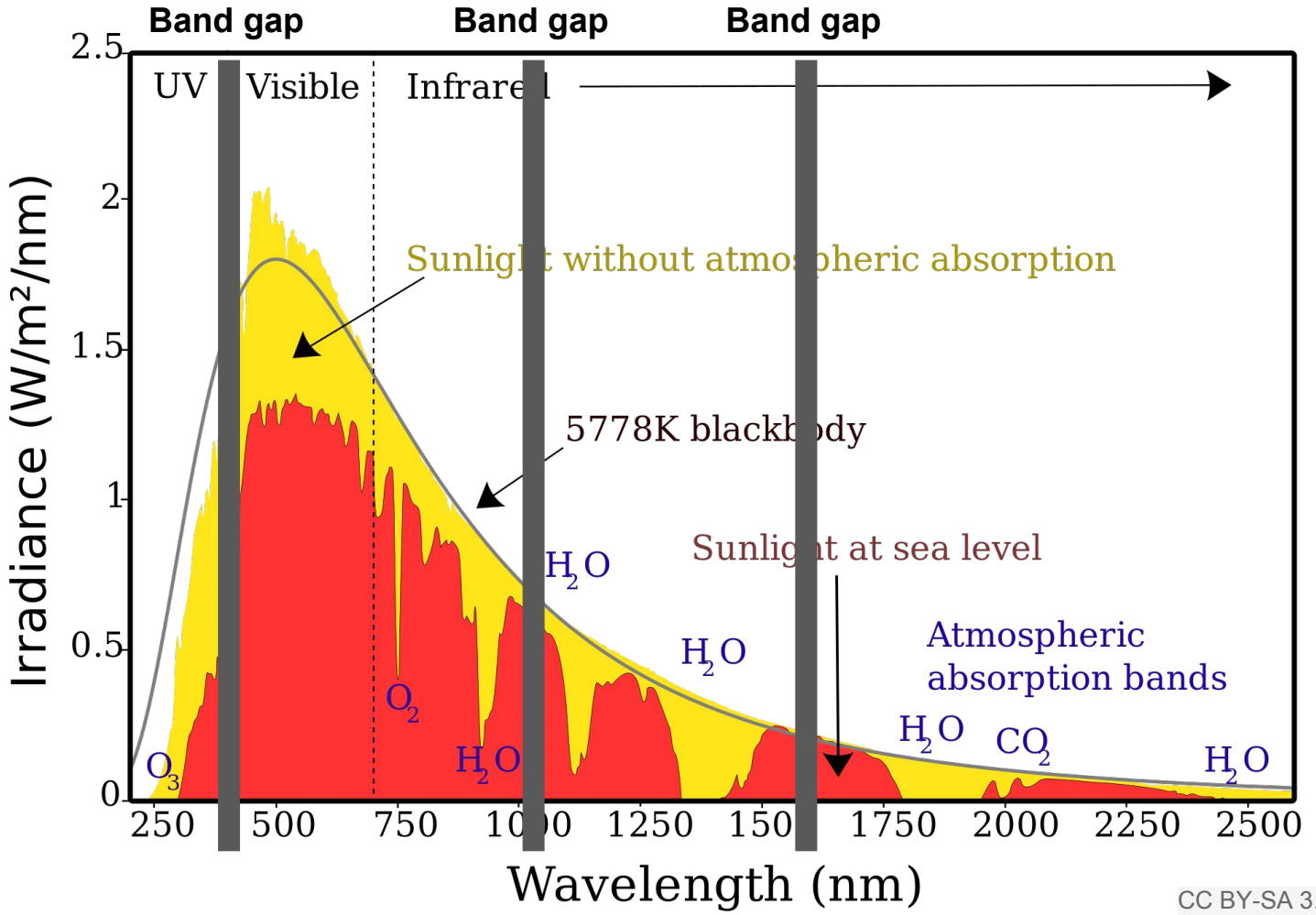
NREL
NATIONAL RENEWABLE ENERGY LABORATORY



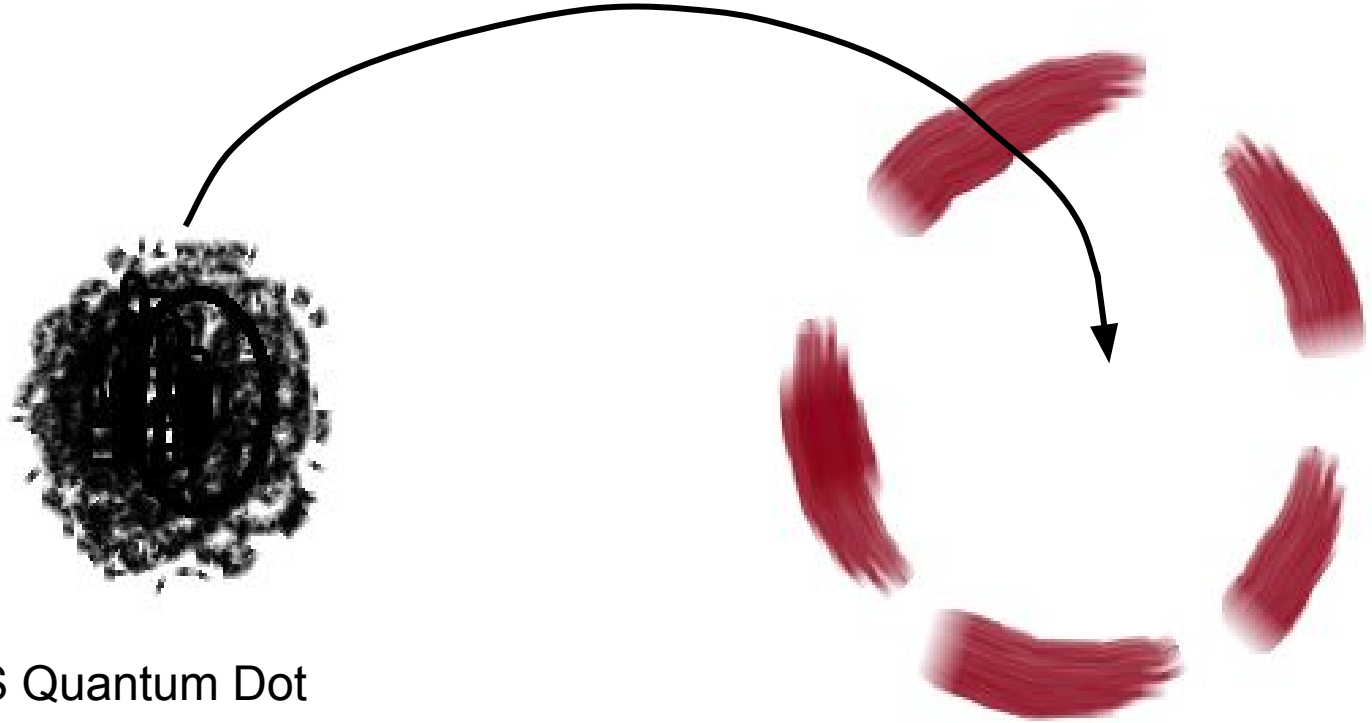
Dye-sensitized solar cells



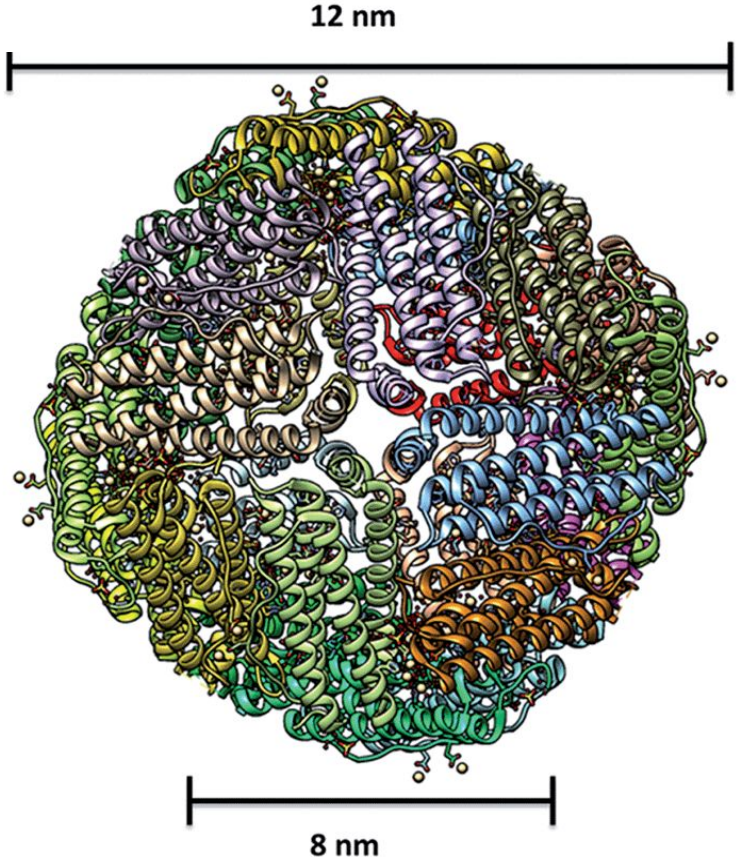
Reference: Nature Chemistry 3, 188–189 (2011)

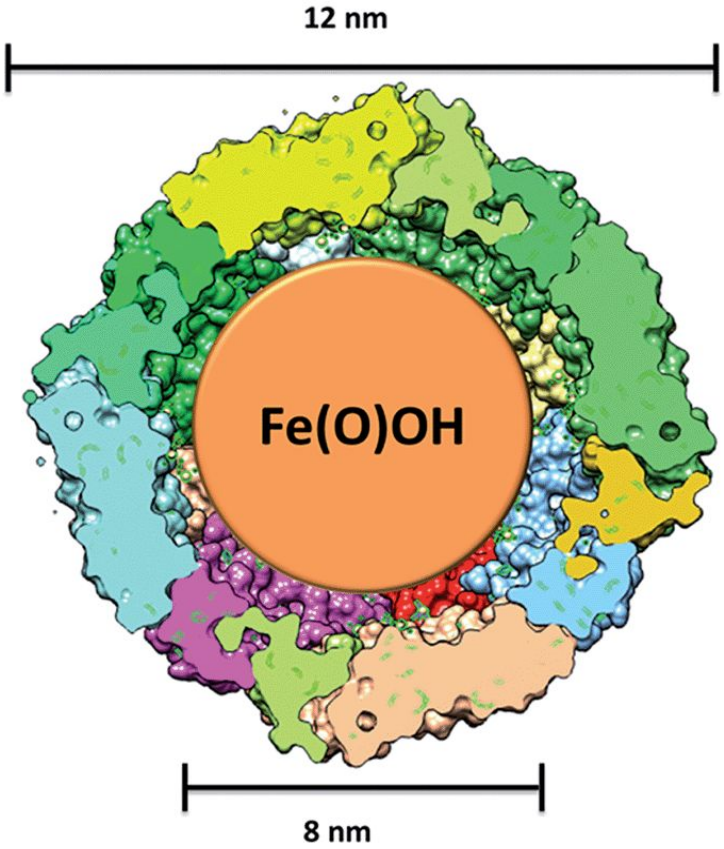


$$E_{QD} = E_{bulk} + \frac{C}{R^2}$$


PbS Quantum Dot
Ferritin

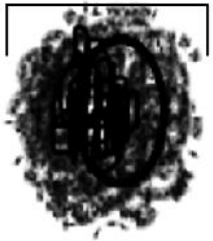
Ferritin





Lead sulfide quantum dots in ferritin

~ 2.25 nm

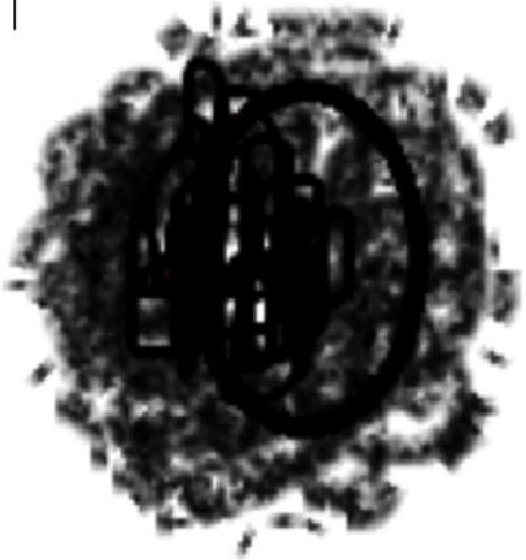


Conduction band

~ 1.33 eV

Valence band

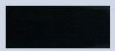
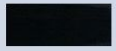
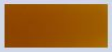
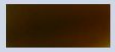
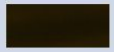
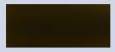
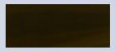
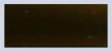
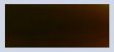
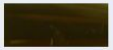
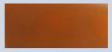
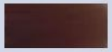
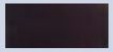
~ 6.10 nm

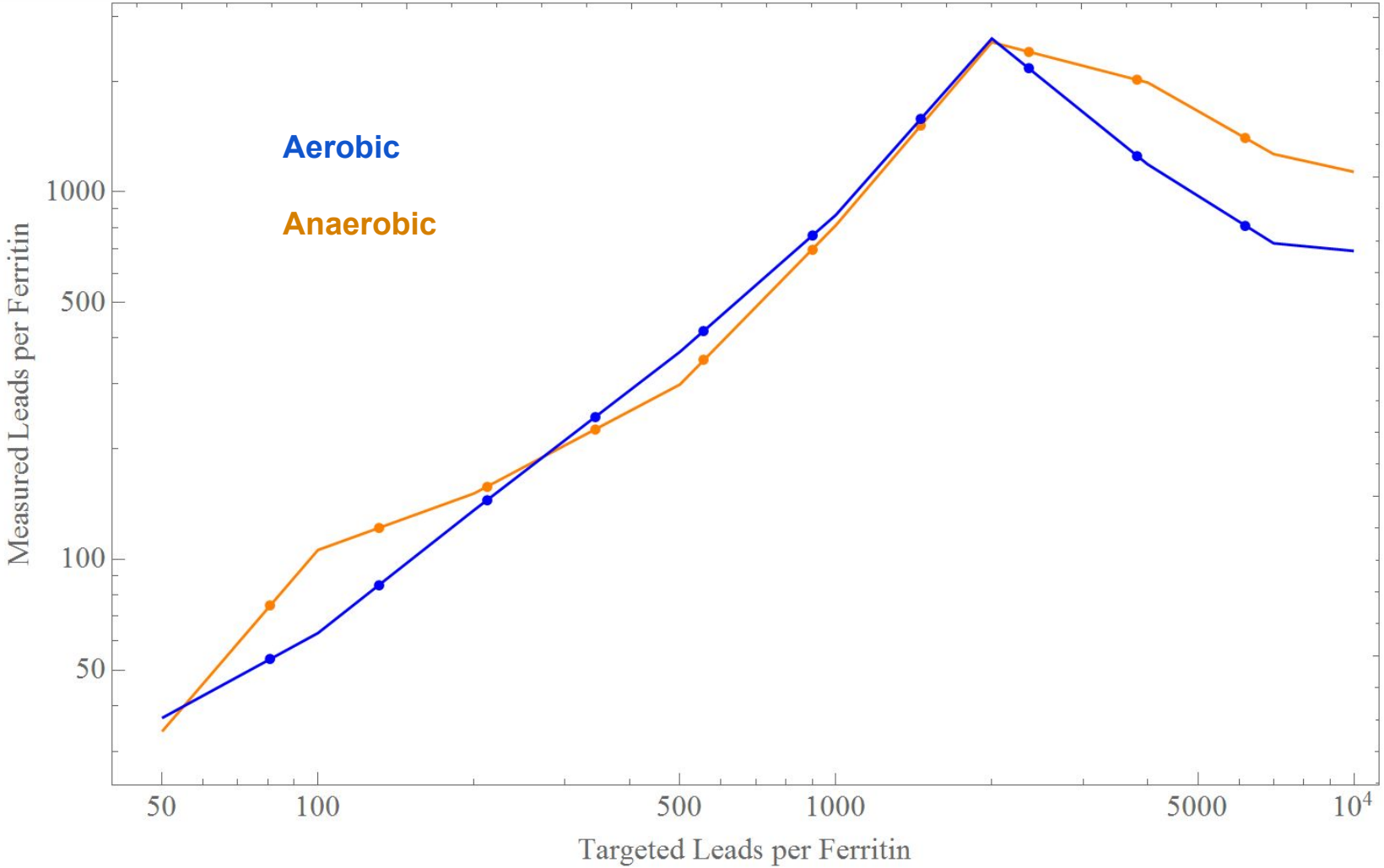


Conduction band

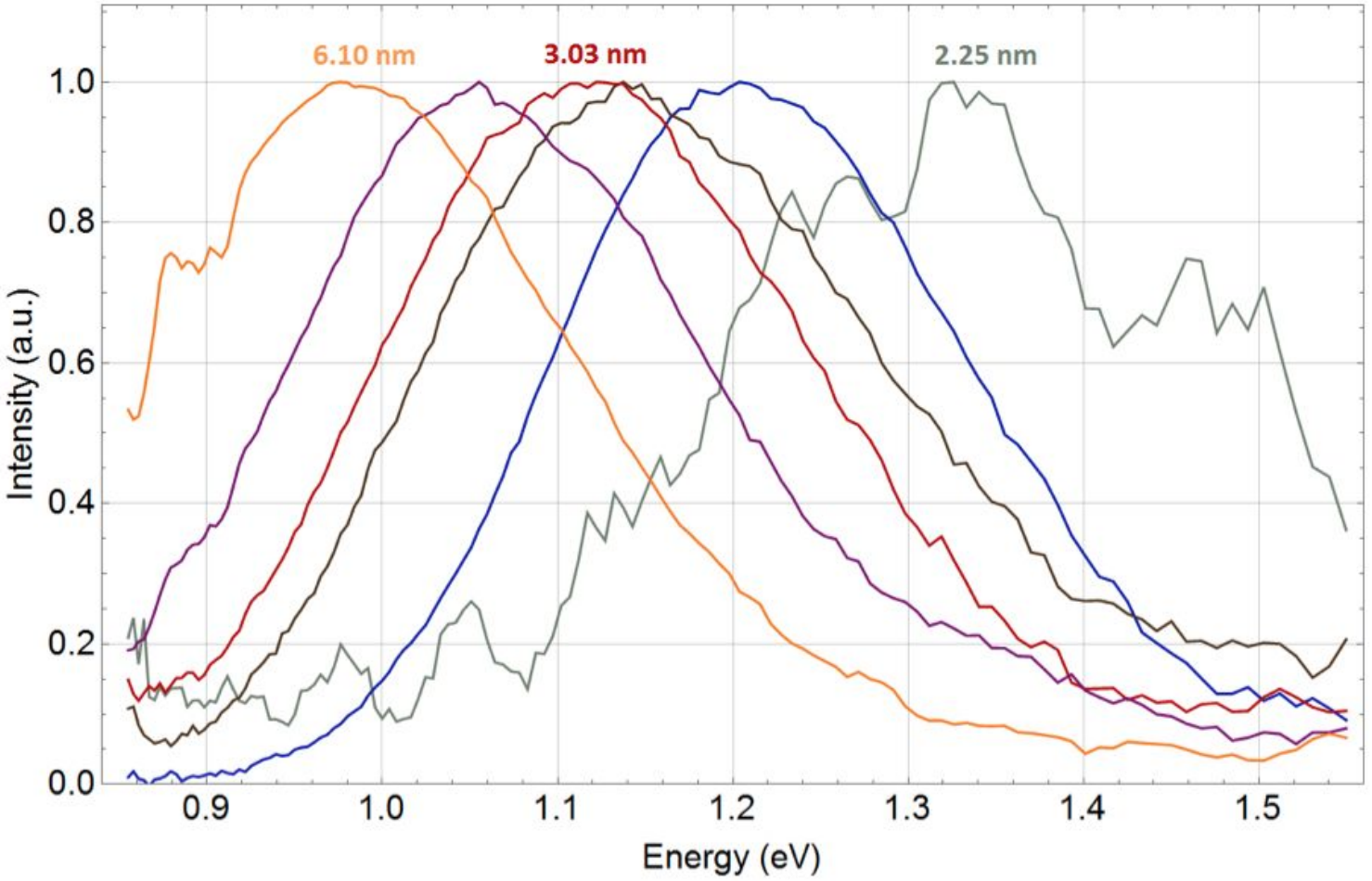
~ 0.93 eV

Valence band

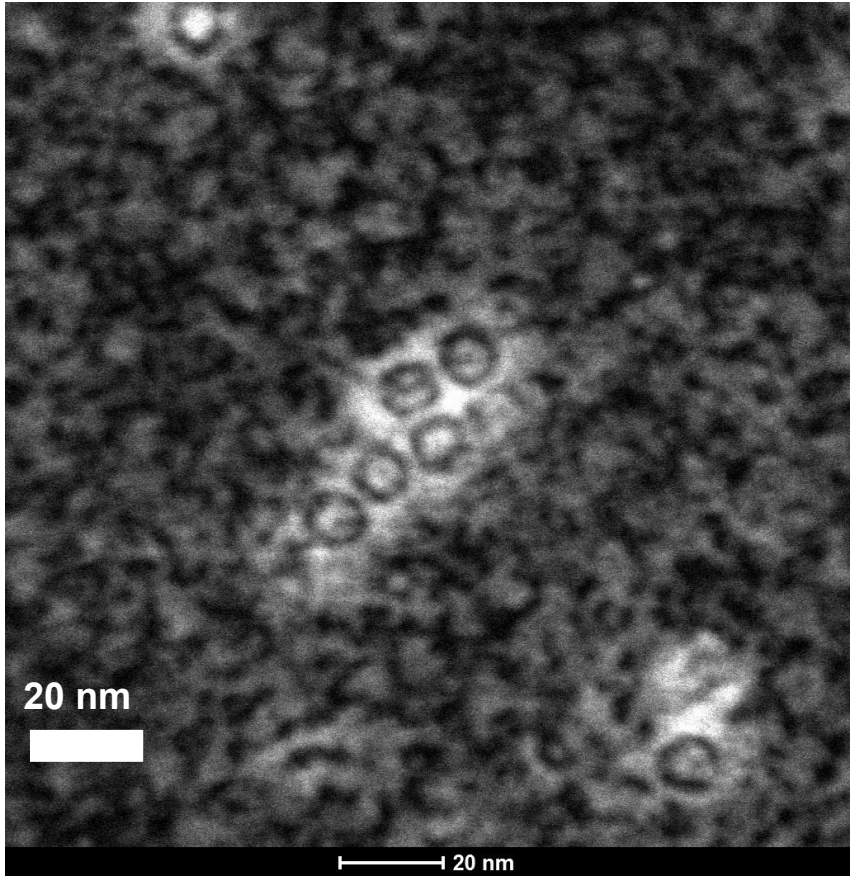
Sample	1	2	3	4	5	6	7	8	9
Targeted Lead/FTN	50	100	200	500	1000	2000	4000	7000	10000
Eq. 1 Core Size (nm)	1.71	2.1	2.71	3.68	4.64	5.85	7.37	8.88	9.99
Anaerobic									
Lead/FTN	34 ± 4	106 ± 17	151 ± 16	299 ± 56	811 ± 45	2552 ± 612	1982 ± 445	1266 ± 264	1133 ± 197
Band-gap Energy (eV)	1.33	1.25	1.23	1.14	1.03	1	1.11	1.22	1.30
Core Size (nm)	---	---	3.04 ± 0.54	---	---	5.70 ± 0.89	---	---	---
Color									
Diluted Color									
Aerobic									
Lead/FTN	37 ± 7	63 ± 11	136 ± 20	367 ± 63	865 ± 13	2611 ± 483	1187 ± 399	724 ± 121	690 ± 169
Band gap Energy (eV)	1.33	1.31	1.14	1.12	1.06	0.93	1.08	1.24	1.05
Core Size (nm)	2.25 ± 0.48	---	3.03 ± 0.39	---	---	6.10 ± 0.89	5.43 ± 0.75	---	---
Color									
Diluted Color									
3x Lead Anaerobic									
Lead/FTN	36 ± 7	74 ± 8	181 ± 10	---	---	---	---	---	---
Color				---	---	---	---	---	---

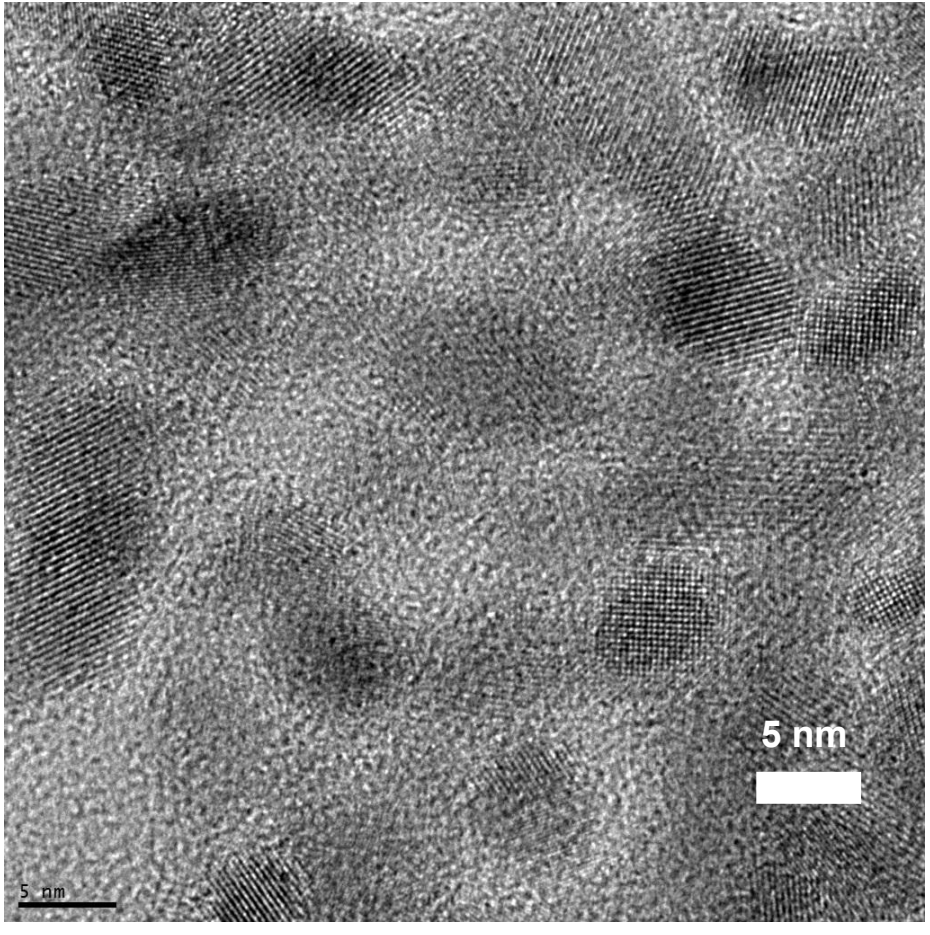

Aerobic
Anaerobic
Measured Leads per Ferritin
1000
500
100
50
50
100
500
1000
5000
10^4
Targeted Leads per Ferritin

Photoluminescence, 293 K

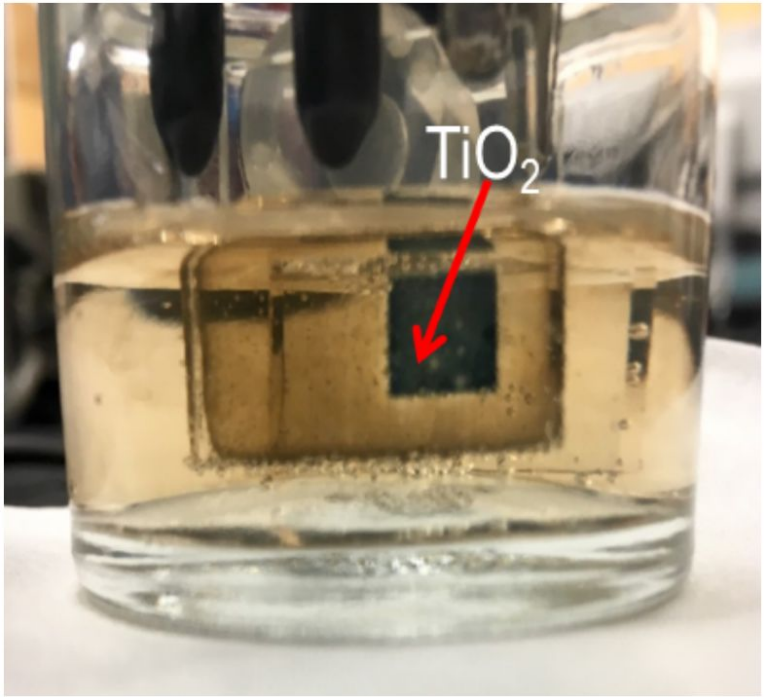


TEM core size measurements

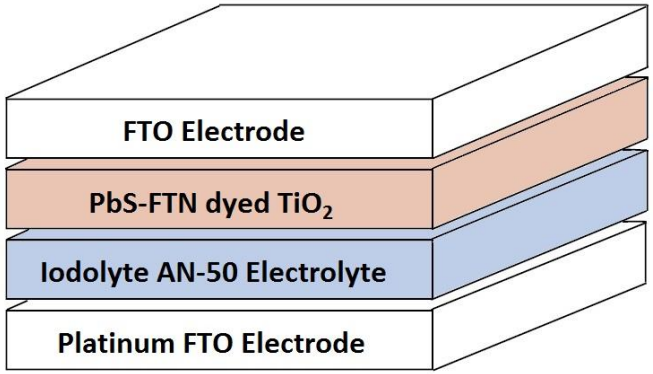




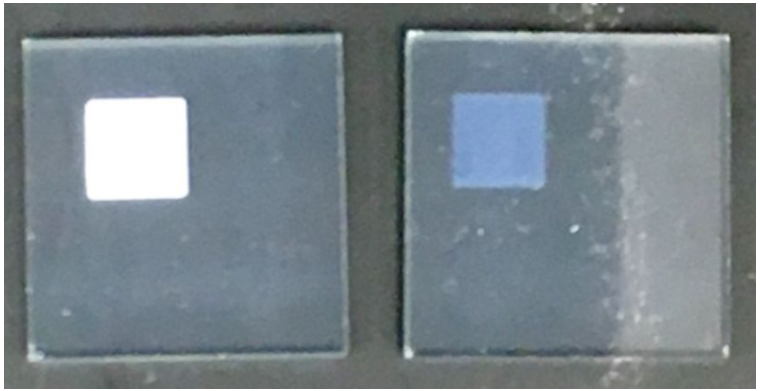
Solar Cell Fabrication



Electrophoretic Deposition



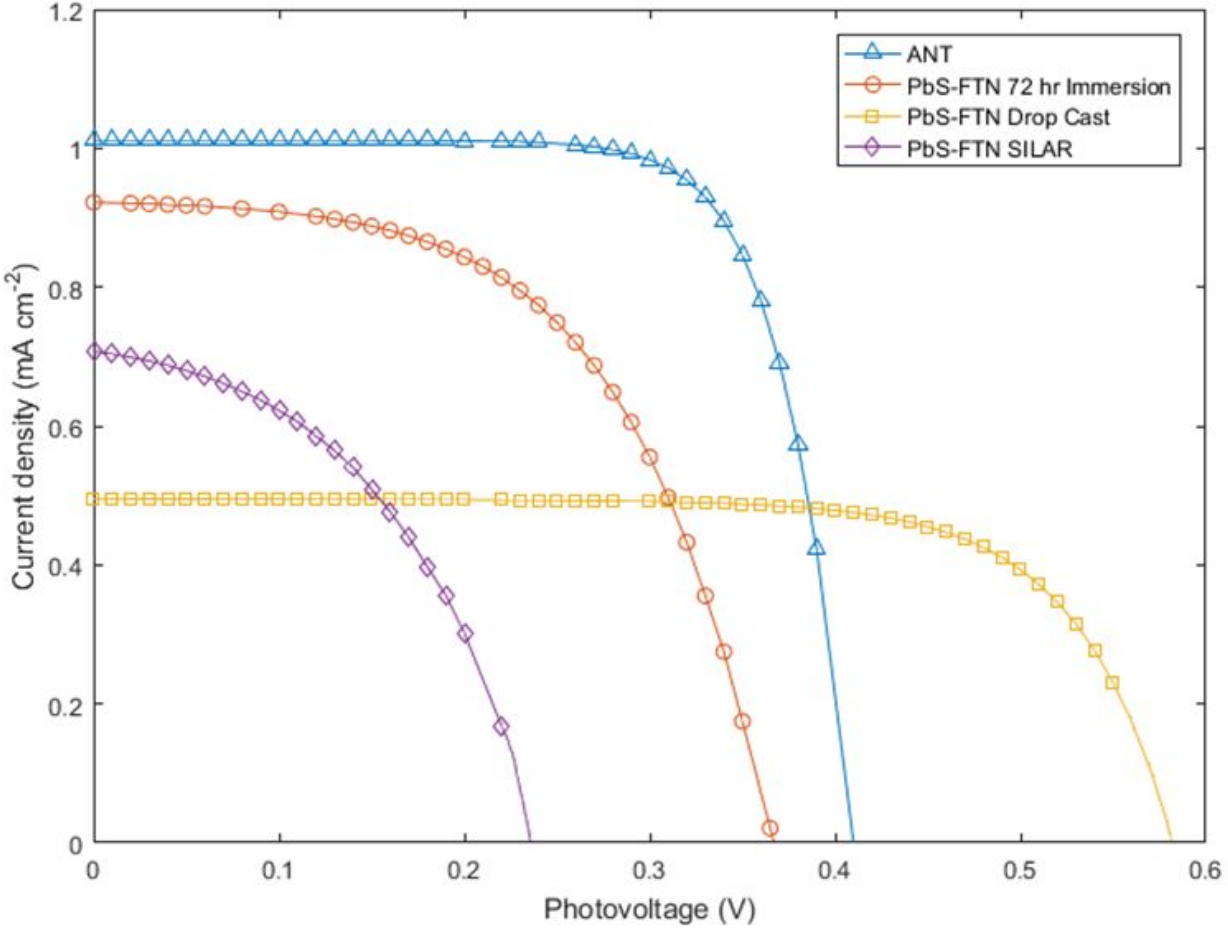
Dye sensitized solar cell



Titanium and Platinum Electrodes

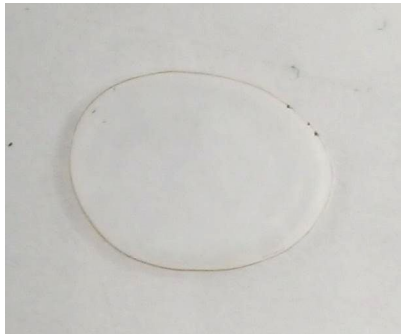
Solar Cell Performance

Device	η (%)
Anthocyanin	0.39
PbS-FTN Immersion	0.26
PbS-FTN SILAR	0.14
PbS-FTN Drop Cast	0.28



Photocorrosion comparison

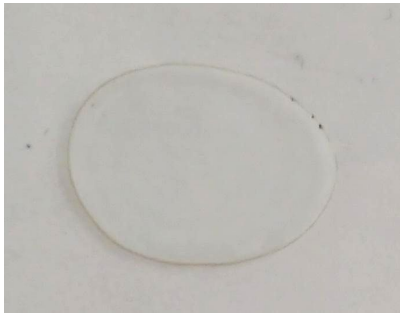
Non-ferritin PbS before



PbS-FTN before

4-hour
light exposure

Non-ferritin PbS after



PbS-FTN after

Summary

- Introduced one-step simplified synthesis of PbS-FTN
- Core sizes ranged from 2.25 - 6.10 nm, band gaps 0.93 - 1.33 eV
- PbS-FTN cell had efficiency of 0.28%
- Future work to improve solar cells:
    - Bacterial ferritin
    - Binding
    - Test spatial homogeneity and photocorrosion