Recent Advances in Solar Cell Technology

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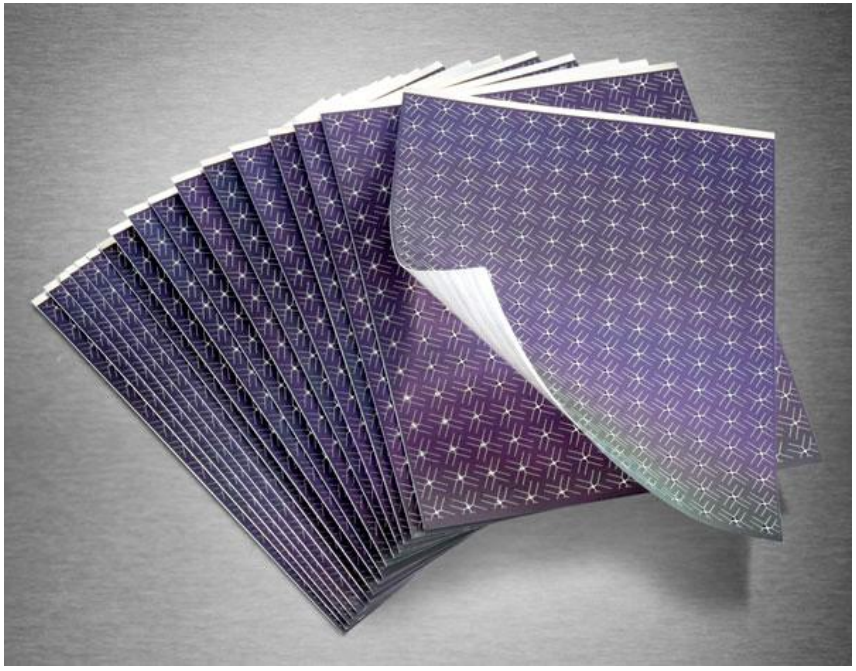
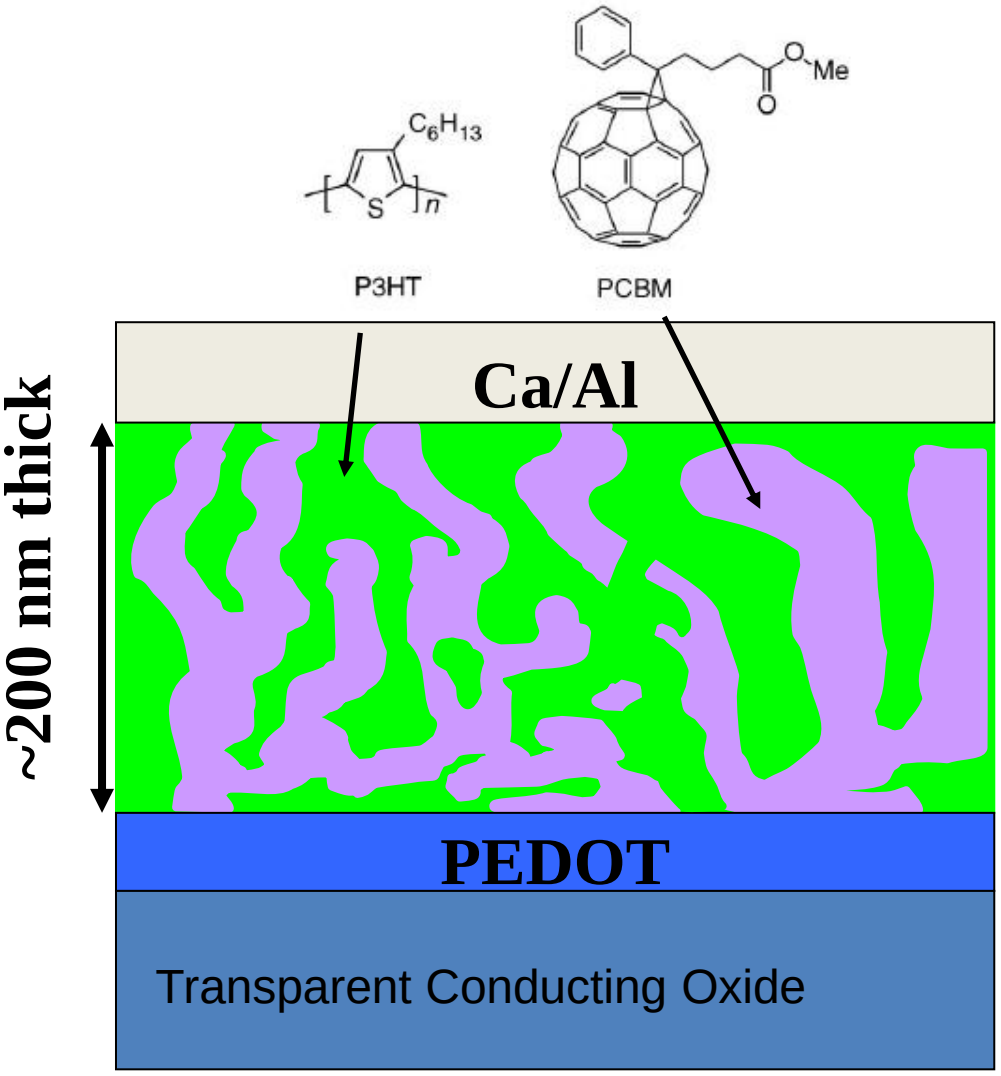


Nanosolar

Konarka

Why did I decide to make nanostructured solar cells?

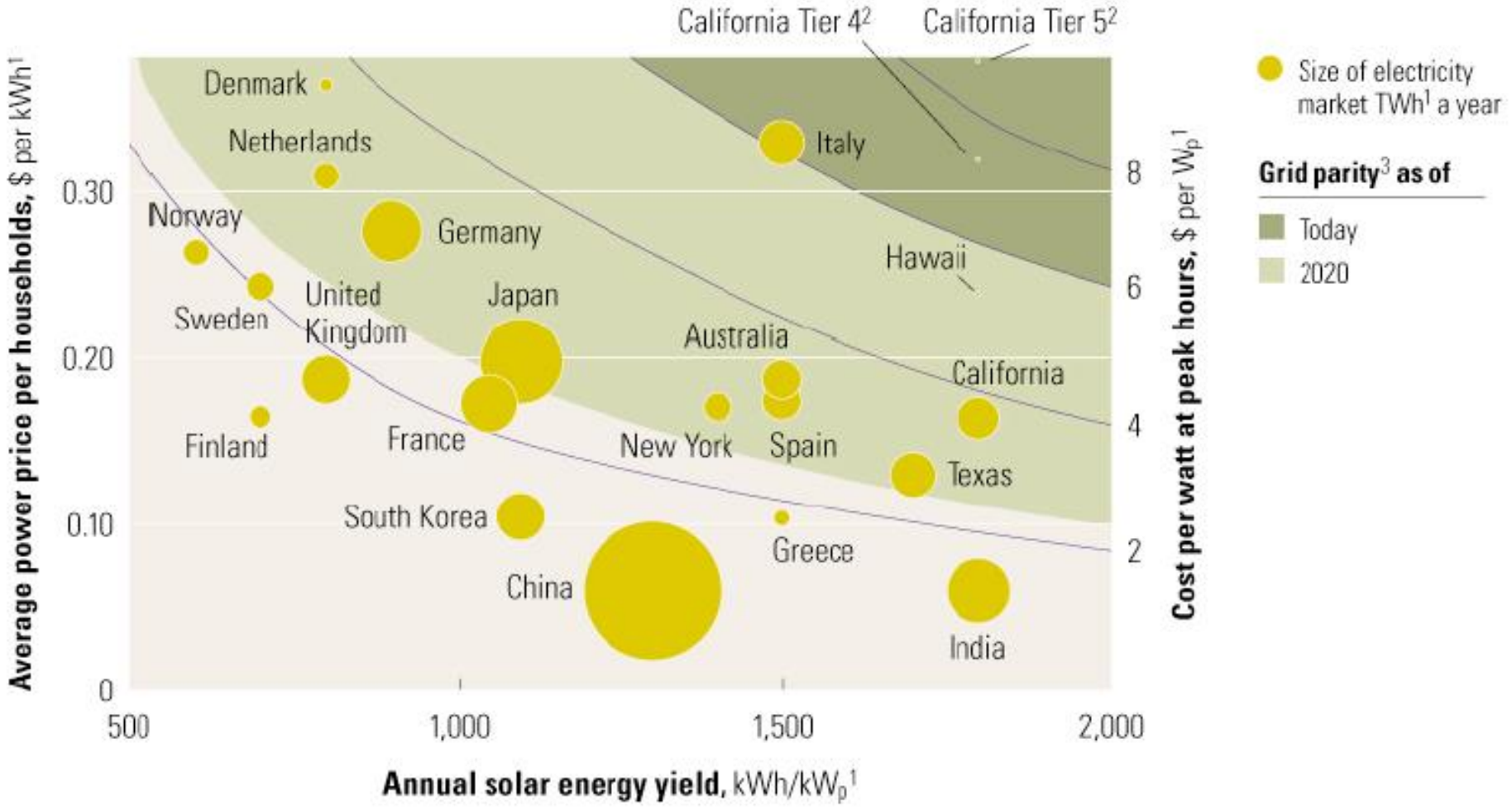



88.12.7

To provide the world with 10 TW of solar electricity by 2030

- We need to grow the industry by ~ 35 %/year.
- Not run out of essential materials.
- Make enough money in 2 years to double the factory size.
- Get energy payback within two years so that we generate more power than we use.

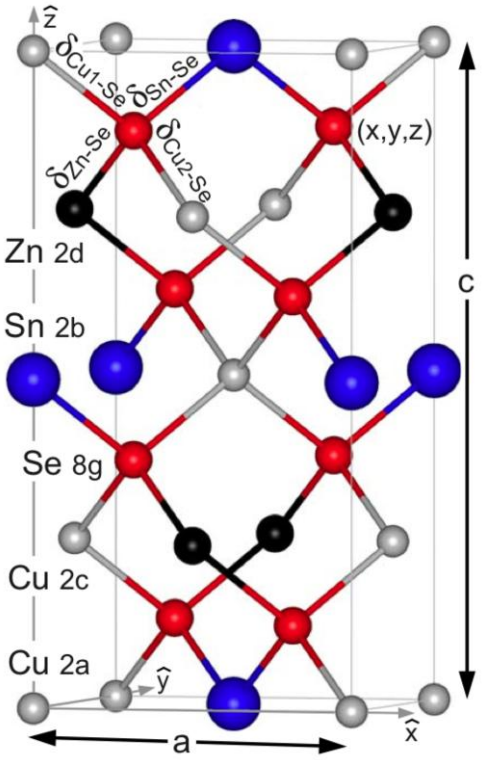
The grid parity cost depends on location



Source: CIA country files; European Photovoltaic Policy Group; Eurostat; Pacific Gas & Electric (PG&E); Public Policy Institute of New York State; McKinsey Global Institute analysis

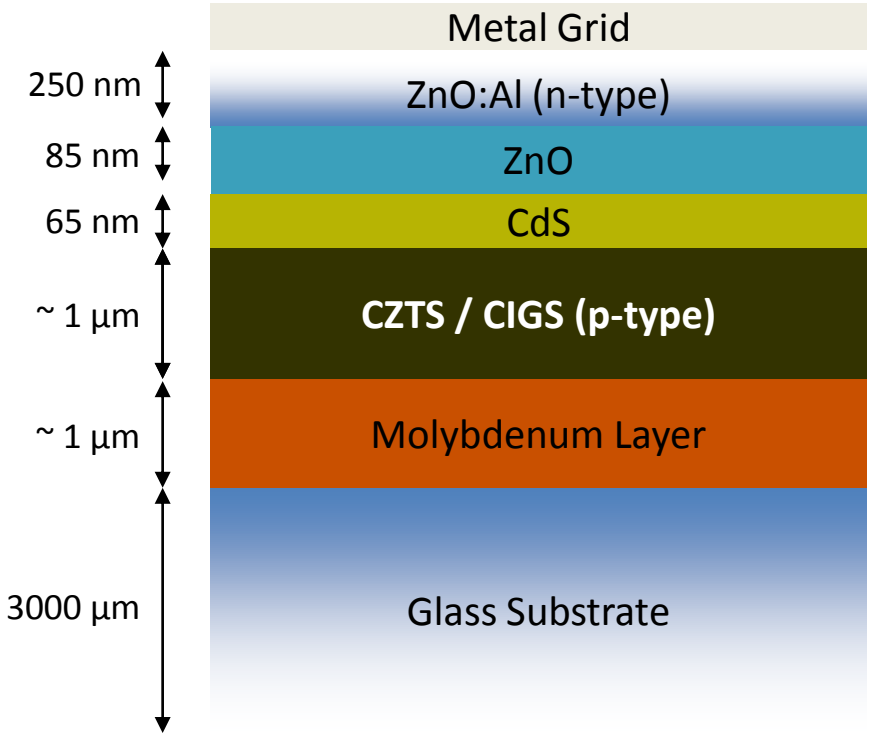
Efficiency Potential

Unit Cell



	Grey	Black	Blue	Red
CZTS	Cu	Zn	Sn	S,Se
CIGS	Cu	In,Ga	In,Ga	Se

Device Stack

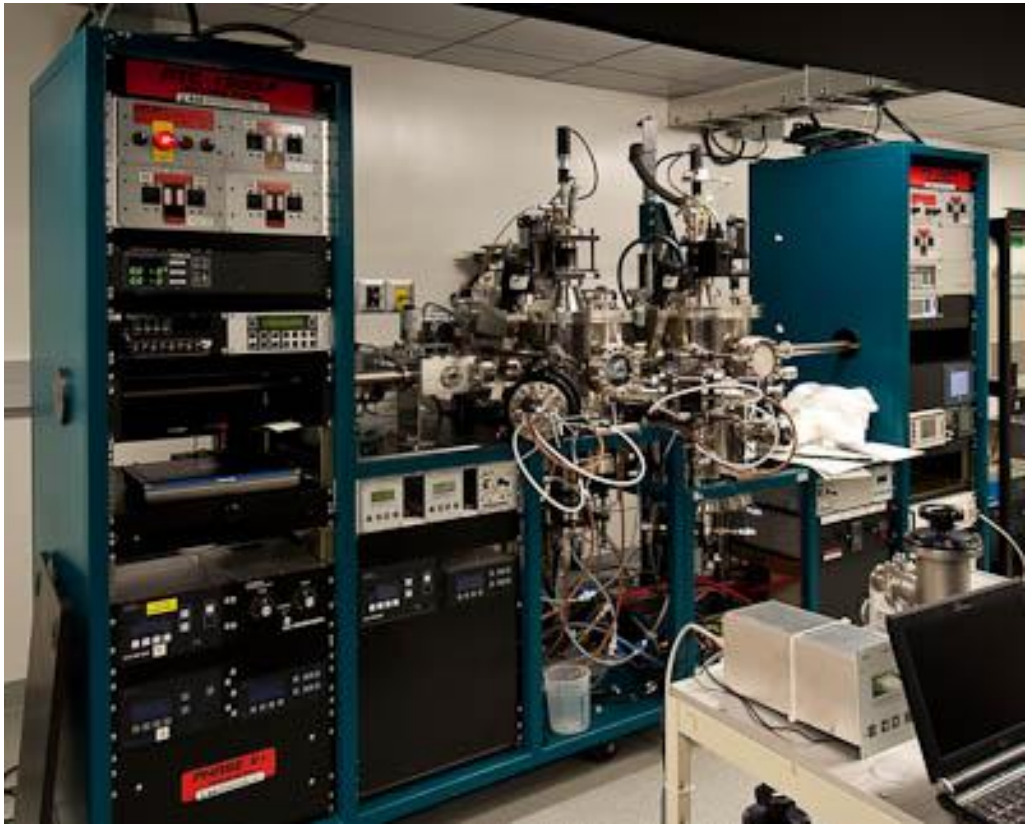


CIGS record efficiency

20.3%

Persson, C. (2010). Electronic and optical properties of Cu2ZnSnS4 and Cu2ZnSnSe4. Journal of Applied Physics, 107(5), 053710-053710-8. AIP.

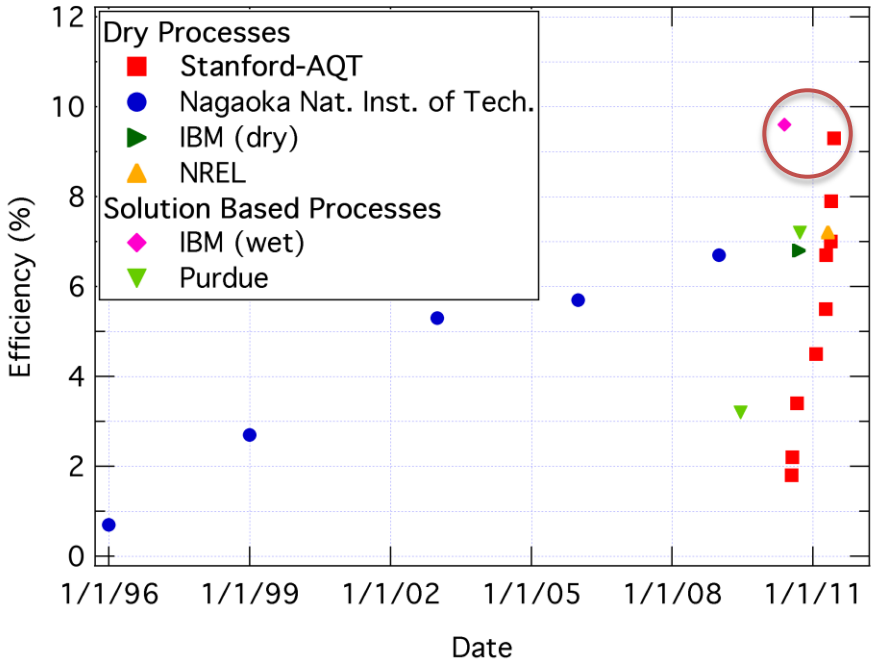
AQT Sputter Chamber



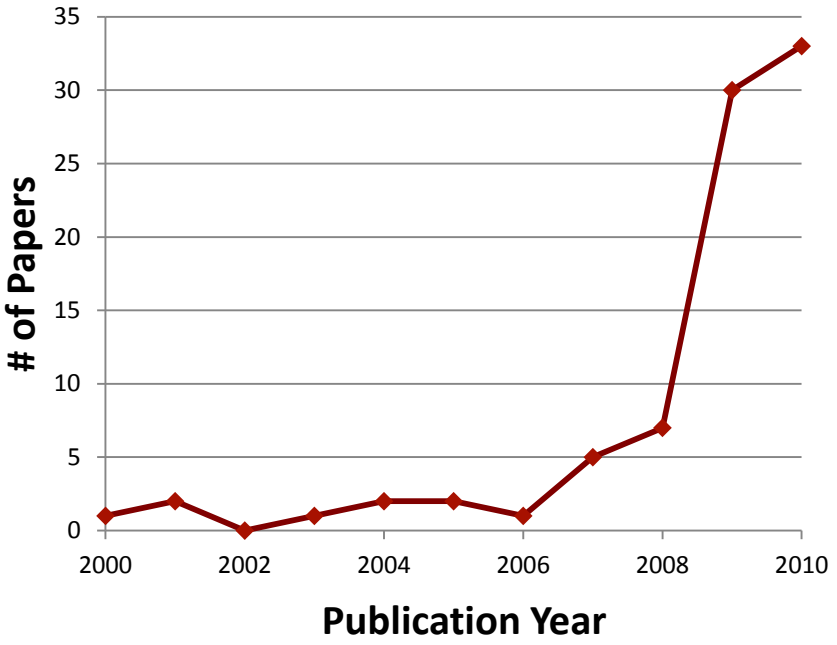
- Compound targets
- Sputtering at room temperature + Anneal

CZTS History

CZT(S,Se) Efficiency vs. Time

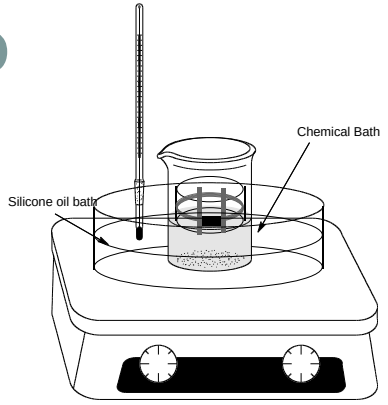


# of CZTS Papers vs. Time

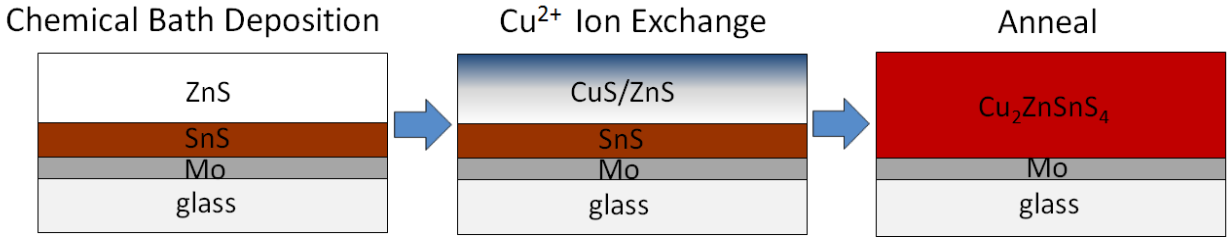


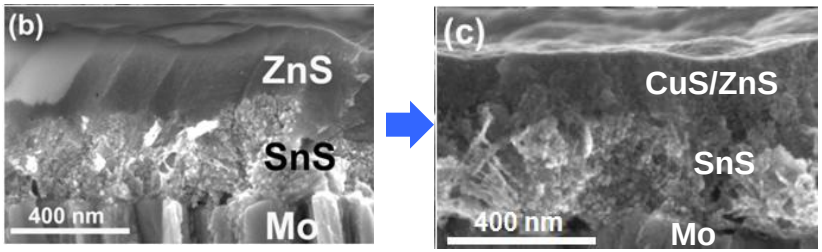
- **IBM World Record – 9.6%**
- **AQT-Clemens Record – 9.3%**
- CZTS research base growing fast

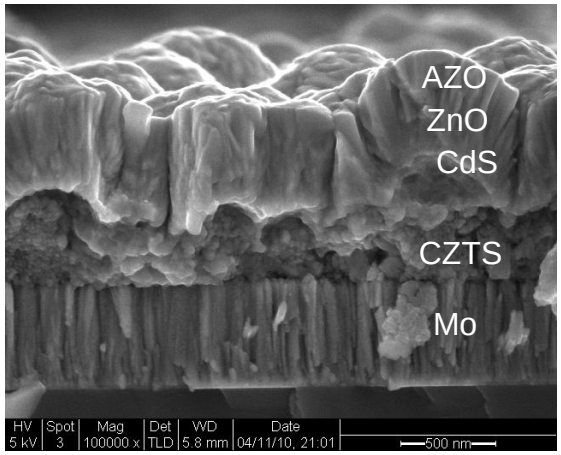
Solution Processed PV Absorbers
Bent Research Group



- Chemical Bath Deposition
  - In conjunction with:
    - Metal Ion Exchange
    - Sulfidization
  - Solution-based deposition technique used for rapid, economical growth of thin films on a variety of substrates.
  - Applicable to a wide range of materials (CdS, ZnS, SnS, Cu_2ZnSnS_4)



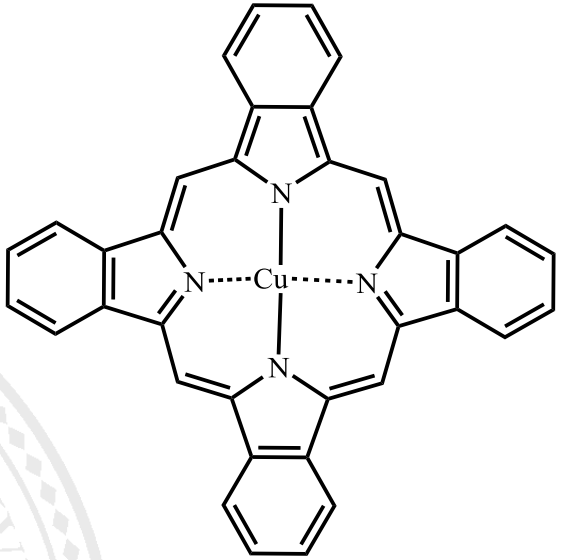




CBD CZTS in PV Device

A. Wangperawong et al., Thin Solid Films 519 (2011) 2488–2492

Organic Semiconductors



CuPc
Copper Phthalocyanine

Attractive properties:

- Abundant: ~100,000 tons/year
- Mature industry/markets
- Low materials cost: ~1$/g → 17¢/$m^2$
- Low-cost manufacturing
- Non-toxic

Large Scale Printing of Semiconductors!

Konarka

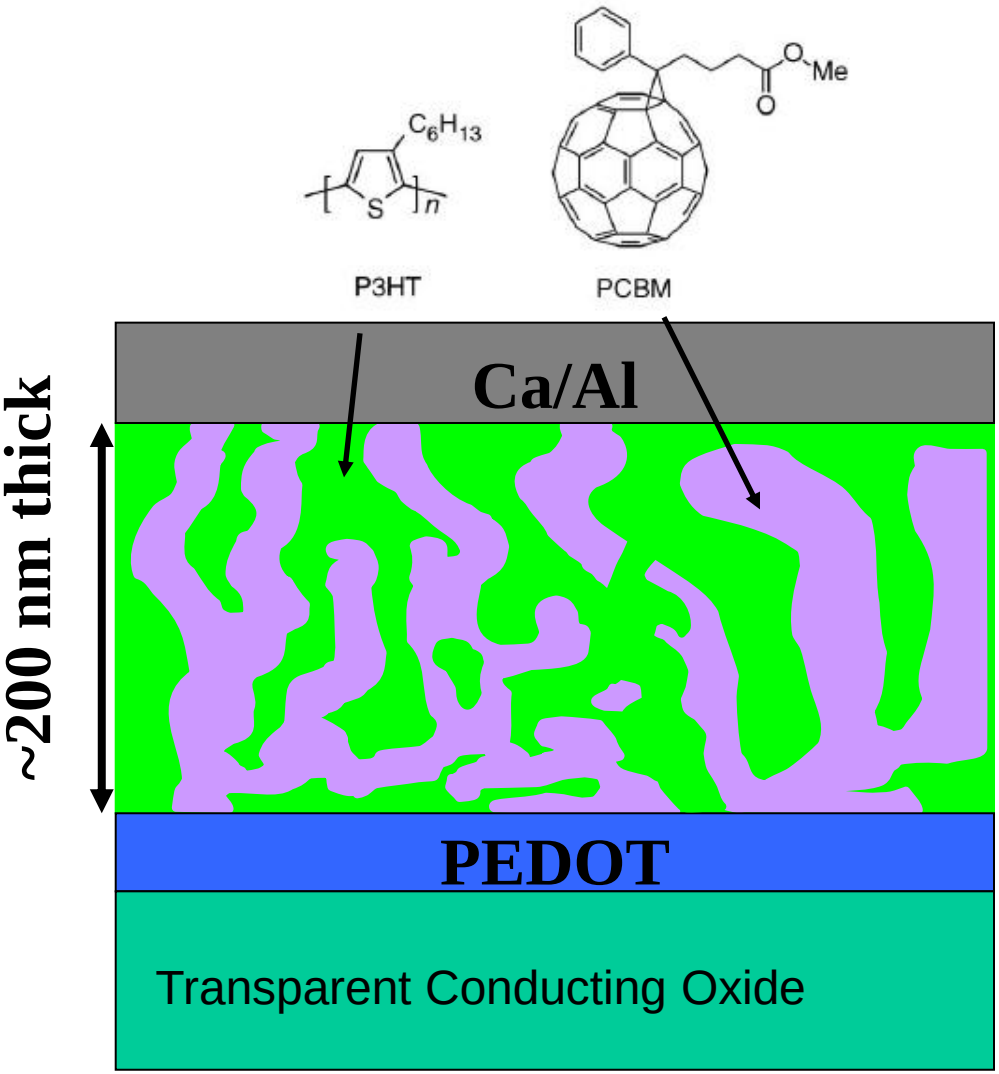
Polymer-Fullerene Bulk Heterojunction Cells

- Donor polymer (i.e. P3HT) absorbs light generating an exciton (i.e. bound electron hole pair).

- Exciton must diffuse to the Donor/Acceptor (e.g. PCBM) interface to split.

- Electrons travel to the back electrode.

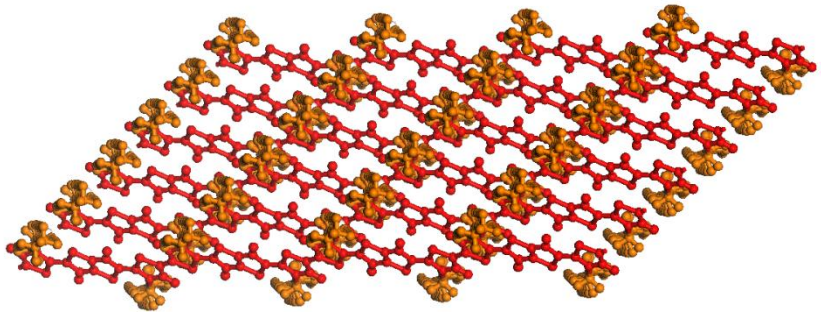
- Holes travel to the front electrode.

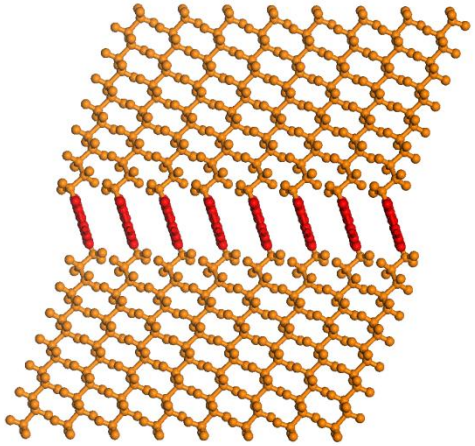


Record efficiency = 8.3 %

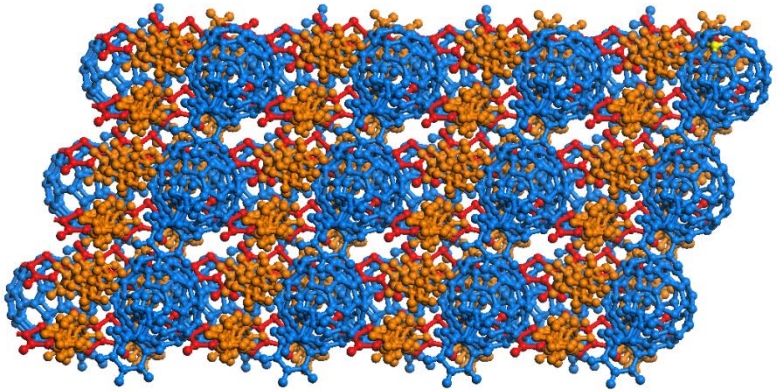
Comparison of pBTTT and the co-crystal

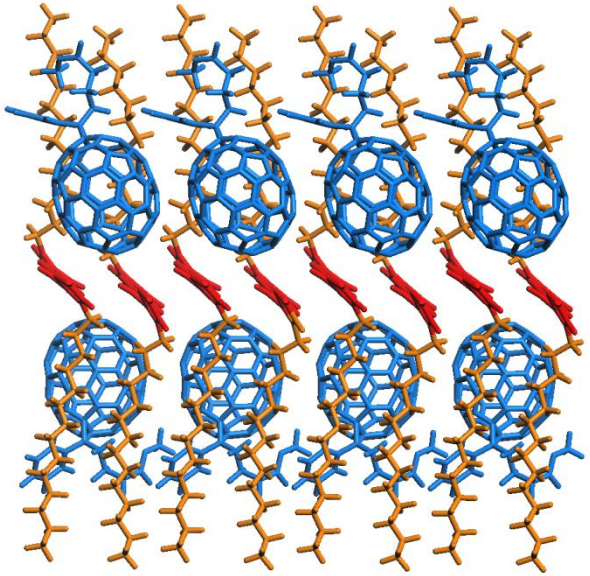
pBTTT





Co-crystal





Upcoming Energy Seminar Talks

September 26, Eli Yablonovitch, University of California at Berkeley,
"Solar Energy Mini-Series, The Opto-Electronic Physics Which Broke the Efficiency Record in Solar Cells"

October 10, Alan Goodrich, National Renewable Energy Laboratory
"Solar Energy Mini-Series: Cost Modeling of Solar Cells"

October 17, 12:30-1:30ish, Zhengrong Shi, Chief Executive Officer, Suntech Power Holdings Co., Ltd.
"Solar Energy Mini-Series: The Suntech Story" (Location TBD)

November 14, Consulting Professor Richard Swanson, SunPower
"Solar Energy Mini-Series: Future Opportunities in the Solar Industry“

Time: 4:15 PM Location: NVIDIA Auditorium, Jen-Hsun Huang Engineering Center

Solar Cell Classes at Stanford

MATSCI 156/256: Solar Cells, Fuel Cells and Batteries: Materials for the Energy Solution (Clemens)

MATSCI 302: Solar Cells (McGehee)

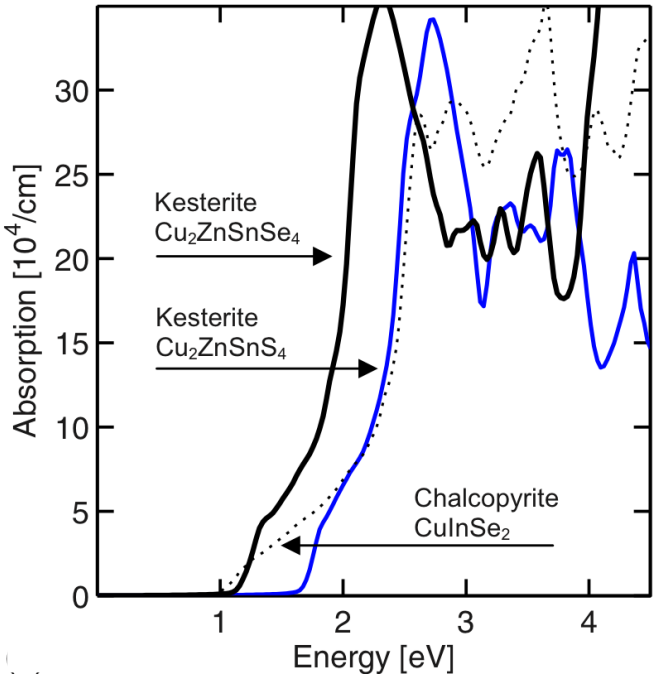
Professors at Stanford who Work on Solar

There is a list of names and topics on my website

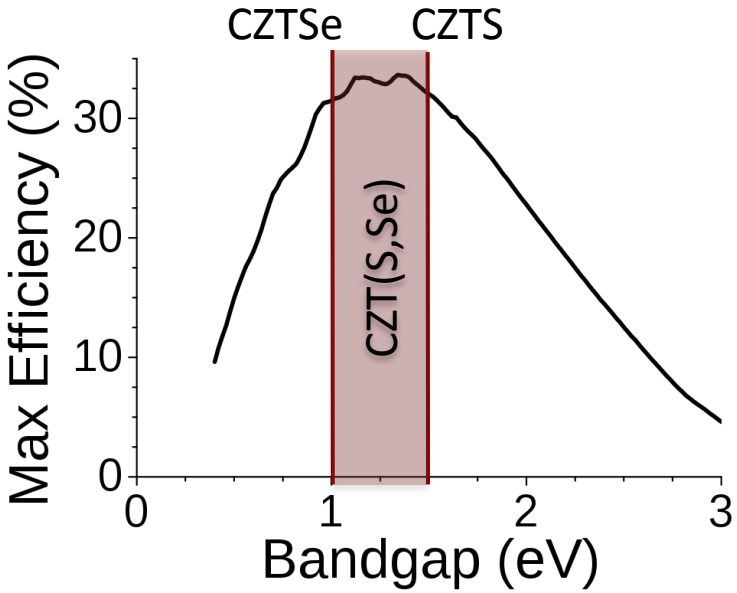
Material Properties

- Absorption Coefficient
  - > 10^4/cm
  - Direct transition
- Bandgap
  - Ideal range
  - Direct transition

Absorption Coefficient vs. Energy



Maximum Efficiency Limit



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