# Fabrication of a Low-Cost $CuInS_2$ Solar Cell by Ink Processing

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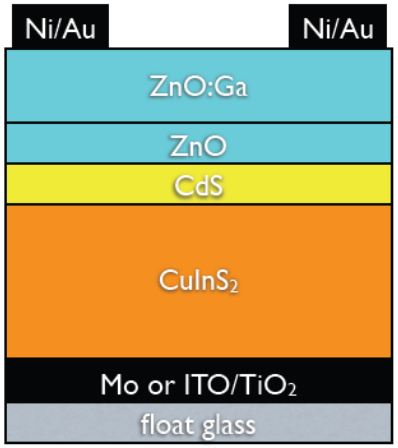
# Outline

- Objective

  Develop scalable fabrication steps to make $CuInS_2$ (CIS) photovoltaic cells using solution-processable inks.

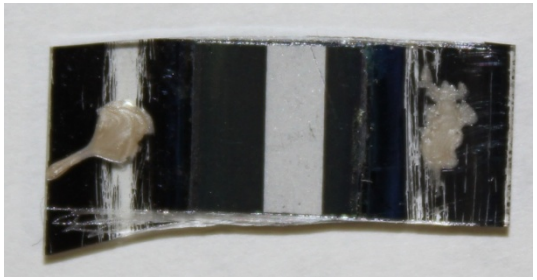



- Project Progress

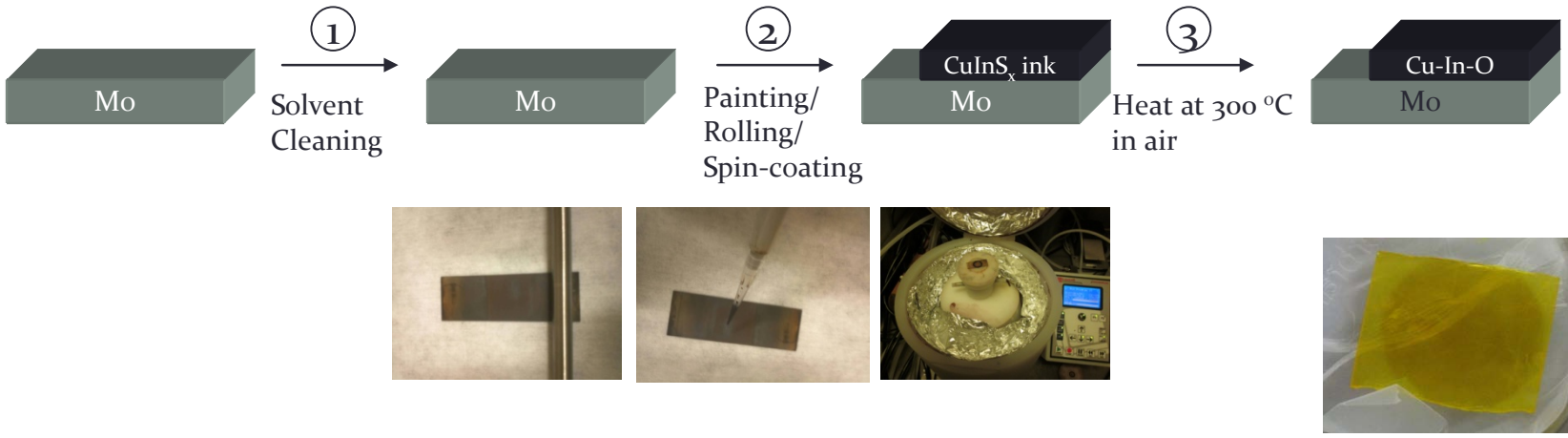
  1. Solution-based deposition and characterization of CIS, CdS, ZnO, Ga-doped ZnO
  2. Integration of layers into a working cell
  3. Control of fabrication steps

- Initial Results

  IV under 1.5 air mass yielded $V_{oc}$ = 0.07 V and $J_{sc}$ = 4.3 mA/cm$^2$, with a fill factor of 0.26 and efficiency of 0.1% (0.15 cm$^2$ area) .

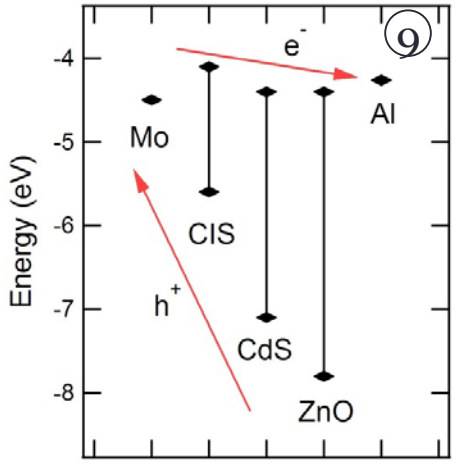


# Fabrication Process

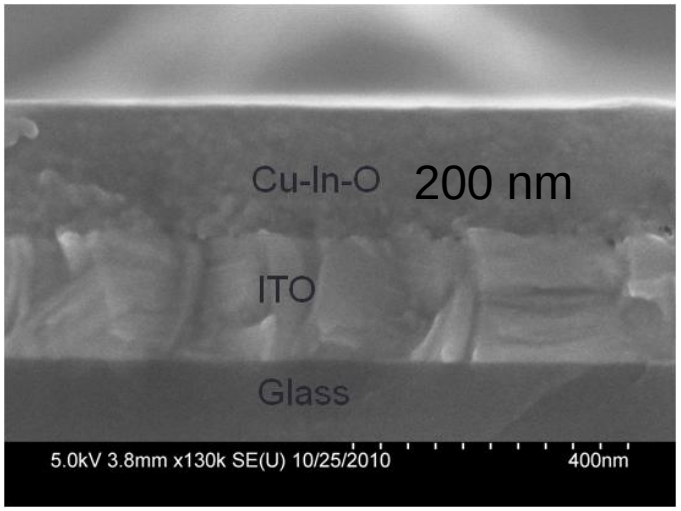




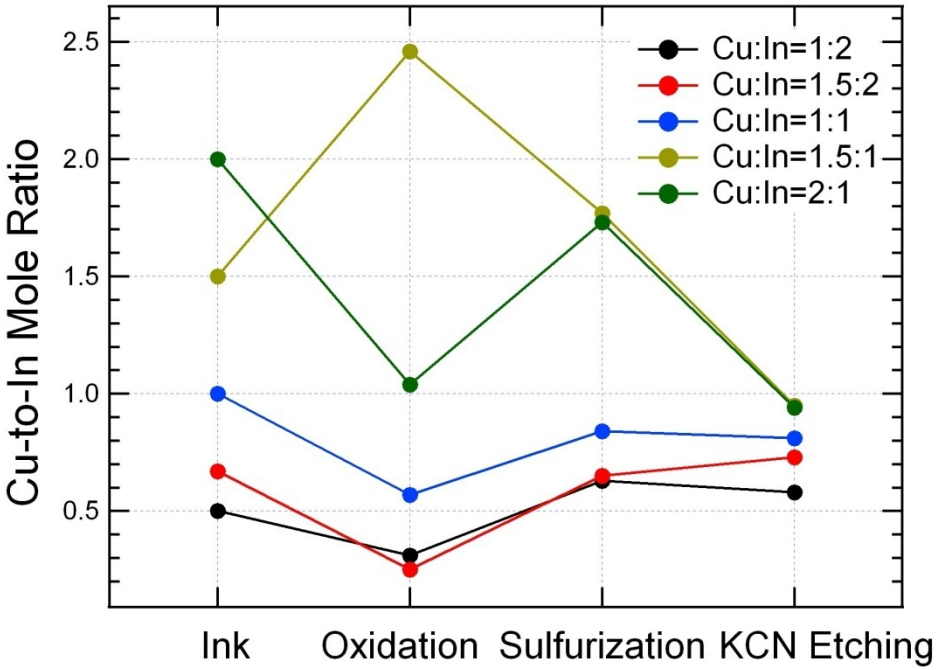


# Surface Composition of $CuInS_2$ Layer

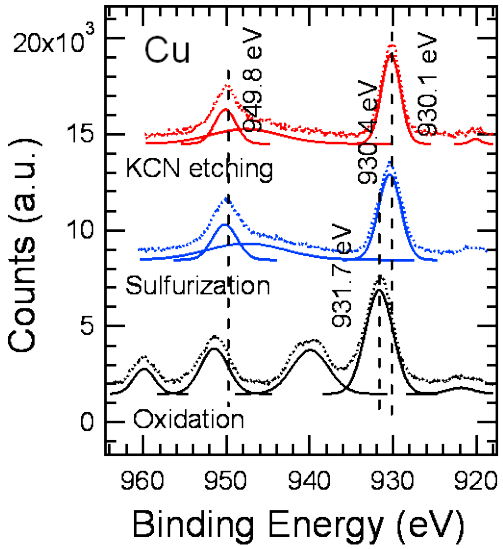



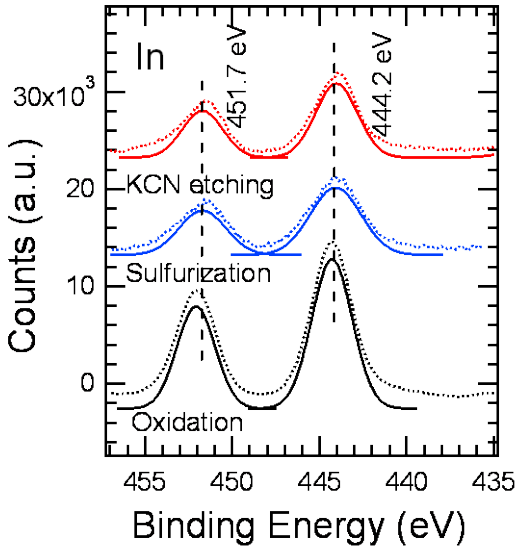

SEM image of Cu-In-O layer deposited by spin coating

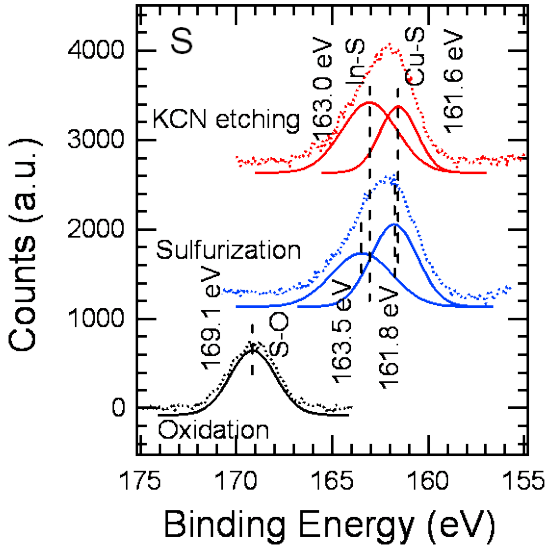


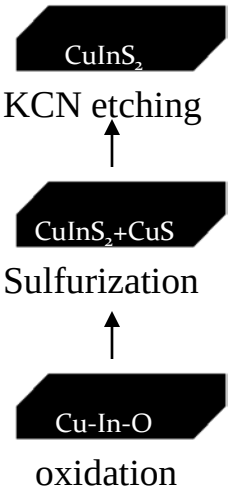

Cu/In mole ratio at different steps. Ratio in ink varied from 1:2 to 2:1. After oxidation, Cu/In ratio decreased comparing to the initial ratio in ink for all of the samples, except the 1.5:1 one, suggesting that surface is In rich. After sulfurization, Cu/In ratio increased again, showing that Cu merged to the surface. After KCN etching, excess CuS was removed and final stoichiometry was reached for the samples with initial Cu/In ratio larger than 1.

# Surface Composition of $CuInS_2$ Layer



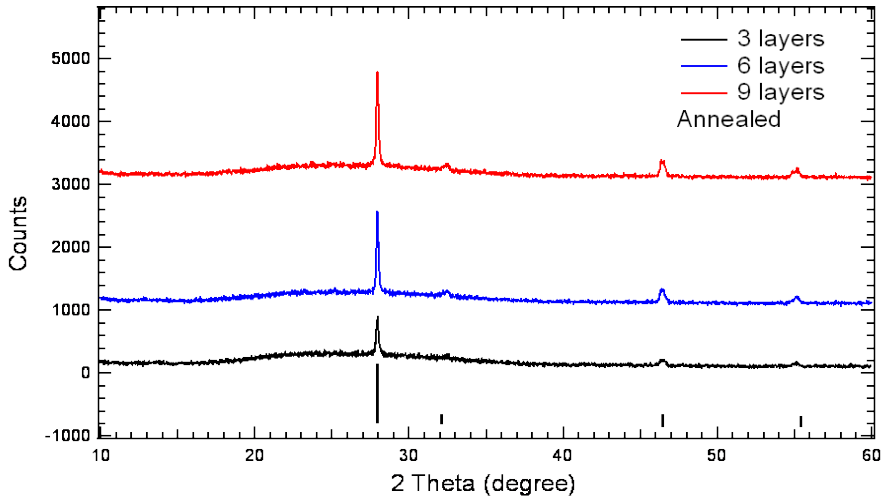




Cu $2p_{3/2}$ shifted from 931.7 eV after oxidation to 930.4 eV after sulfurization, and further shifted to 930.1 eV, indicting the transition from CuO to $CuInS_2$ with CuS to $CuInS_2$

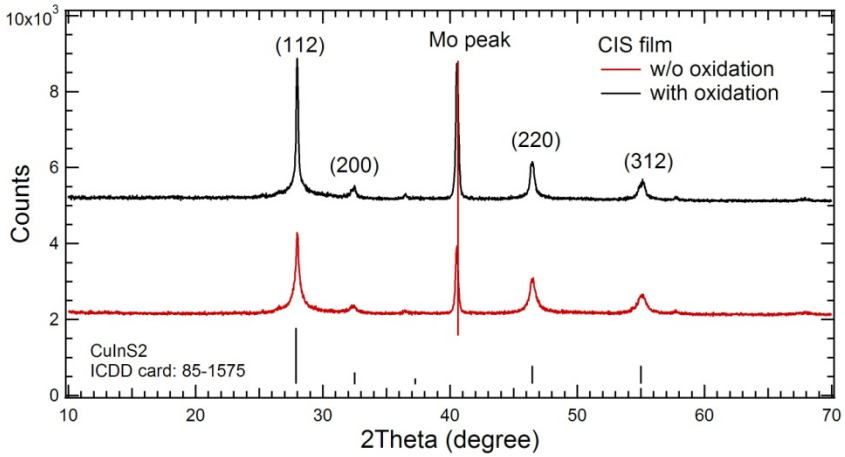
In $2p_{3/2}$ shifted 0.2 eV to the lower binding energy when changing from oxides to sulfides, then stayed at 444.2 eV, corresponding to In in $CuInS_2$.

After oxidation, a peak corresponding to sulfate was shown at 169.1 eV After sulfurization, a broad peak for metal sulfides appeared from161 to 164 eV. The de-convolution of this peak shows that KCN etching did remove extra CuS phase formed on the surface.

# Crystal Structure



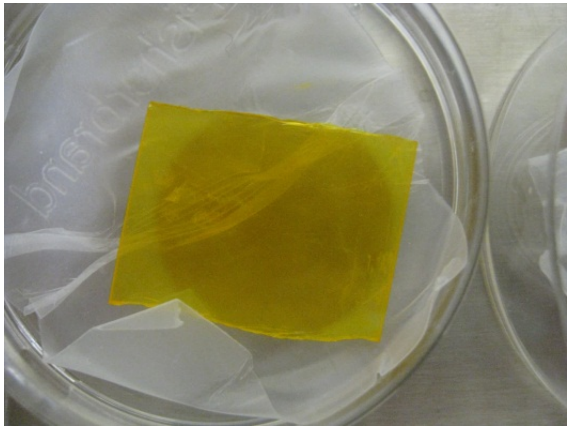

CIS layer made by spin-coating
Substrate=glass

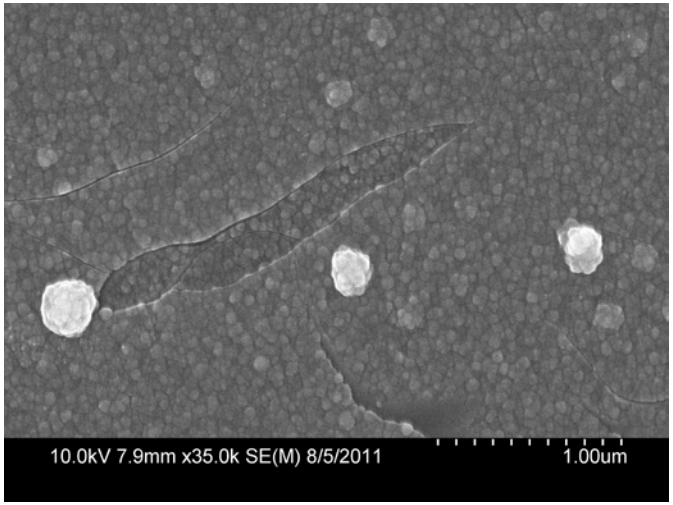



CIS layer made by painting
Substrate=Mo coated glass

# CdS Deposition Using CBD

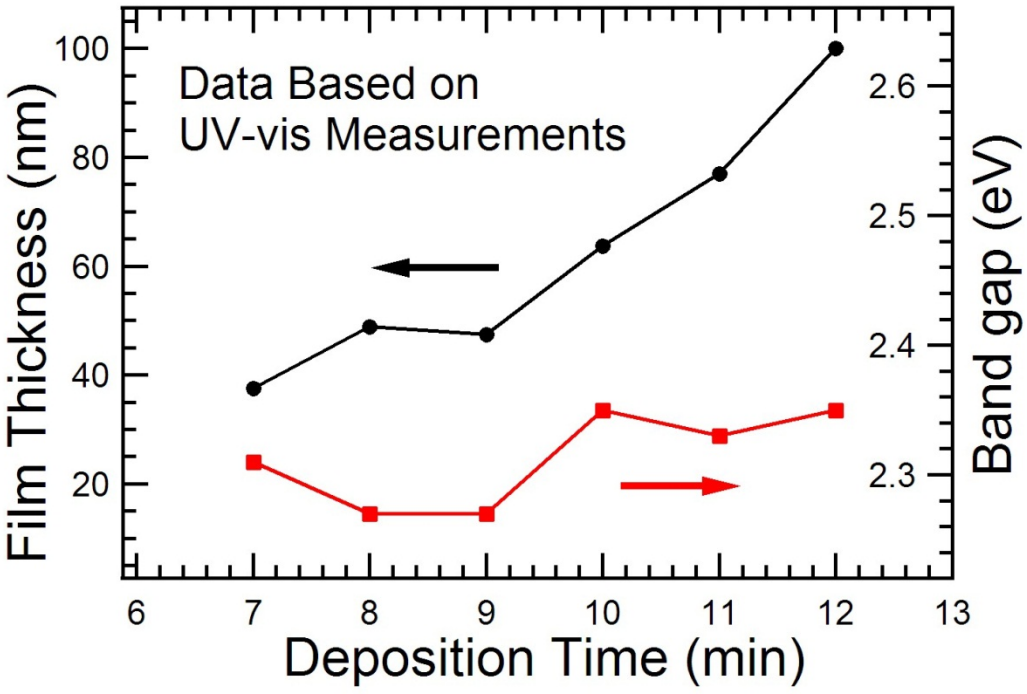

The Chemical Bath Deposition Setup

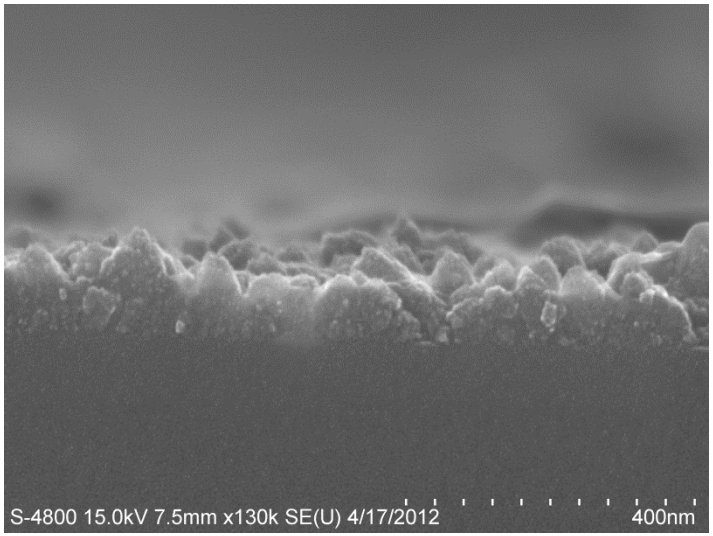




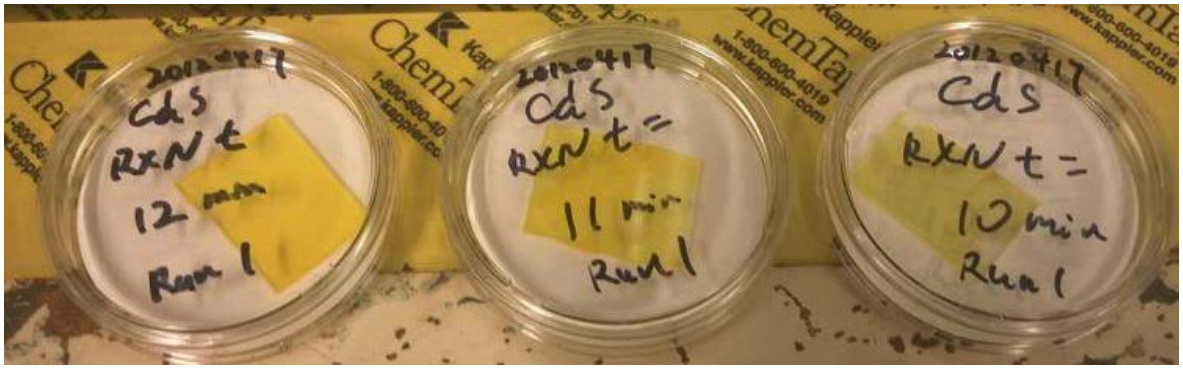

Small grains with an average size of 50 nm were obtained, as shown in the SEM image.

# Thickness/Band gap vs. Deposition Time

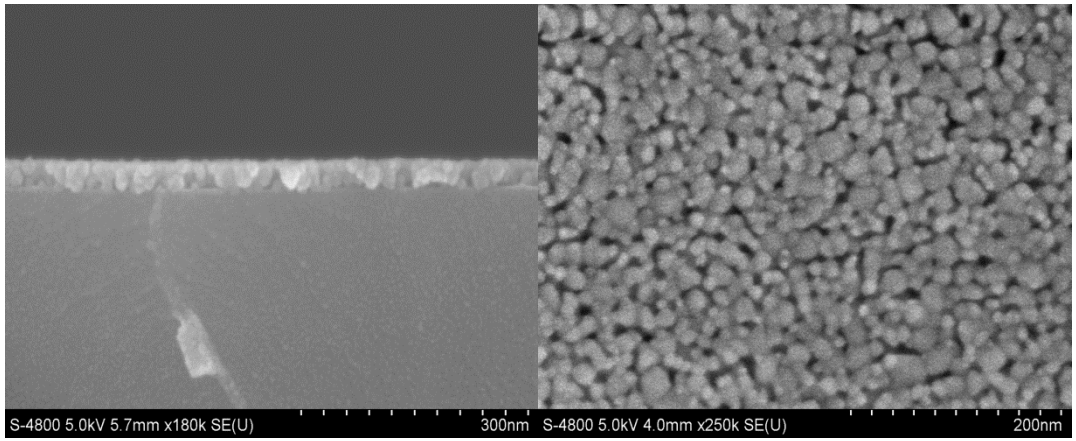


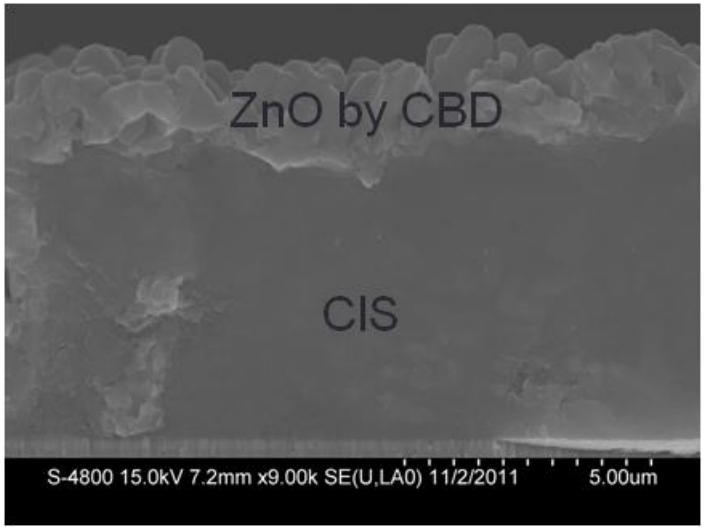

SEM image of CdS film with deposition time of 11 min. Film thickness is about 80 nm

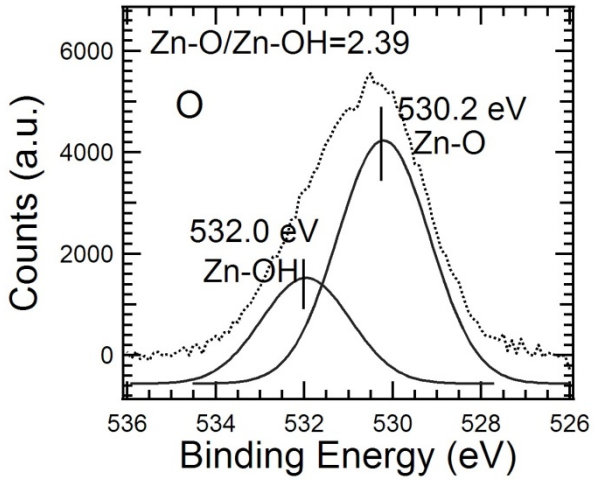


# ZnO by Sol-Gel and CBD

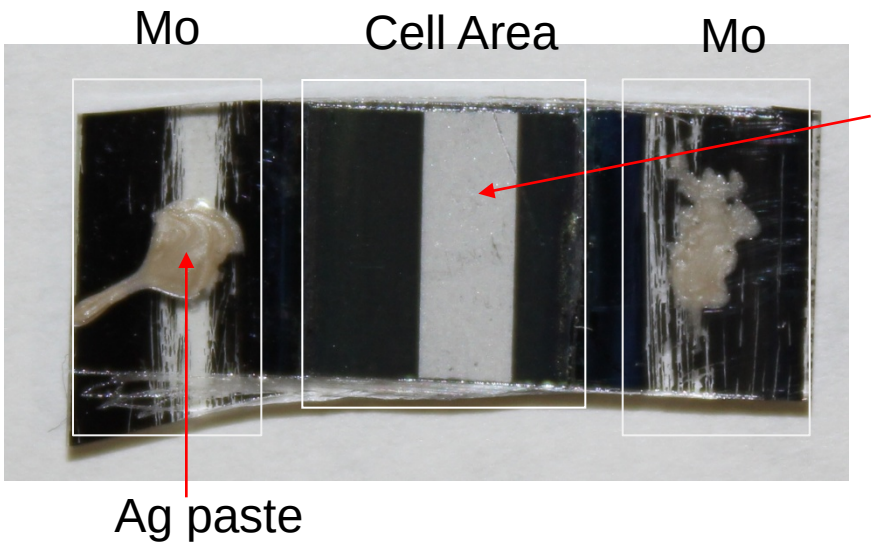



Cross-section Topography

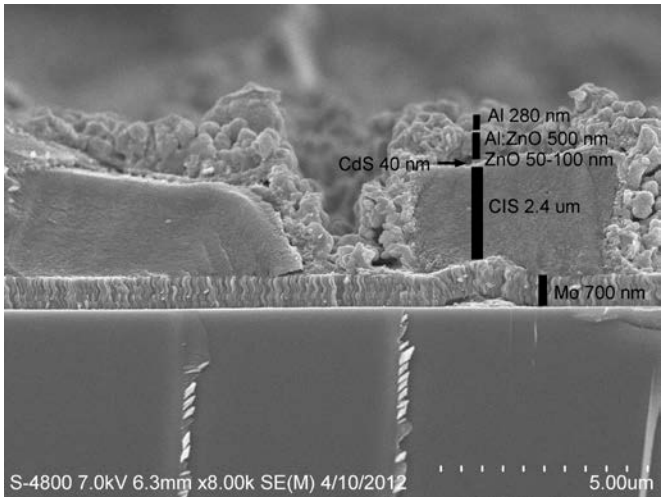


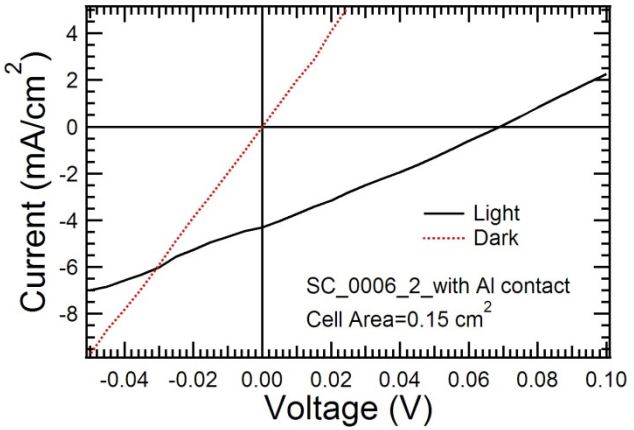



# The First Working Cell




Al: 280 nm
Al:ZnO: 500 nm
ZnO: 50 nm
CdS: 40 nm
CIS: 2400 nm
Mo: 700 nm




Sample dimension: 1.5 by 0.5 cm
Cell dimension: 0.5 by 0.5 cm
Al contact 0.2 by 0.5 cm
Cell Area: 0.25-0.10=0.15 cm$^2$

Sample #: FJ_20120321_SC_Sample0006

# Conclusion

- Demonstrated solution-based deposition of $CuInS_2$, CdS, and ZnO
- Process integration highlighted the need for good control of layer thickness
- First working cell with efficiency of 0.1% provides a path to improve the performance of future devices

# Acknowledgements


- We appreciate research help from Dr. Xerxes Steirer (Chemistry) and Deming Zhang (ECE) at the University of Arizona