Optimizing TiO_2 Layers for Flexible Perovskite Solar Cells using Intense Pulsed Light

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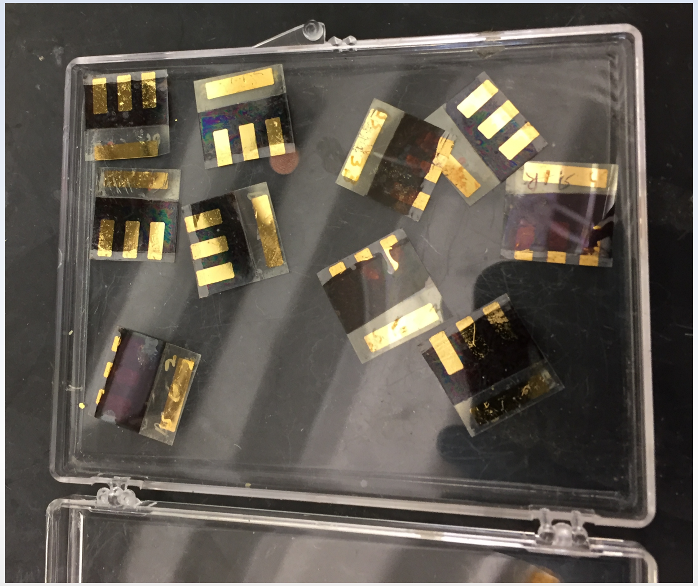

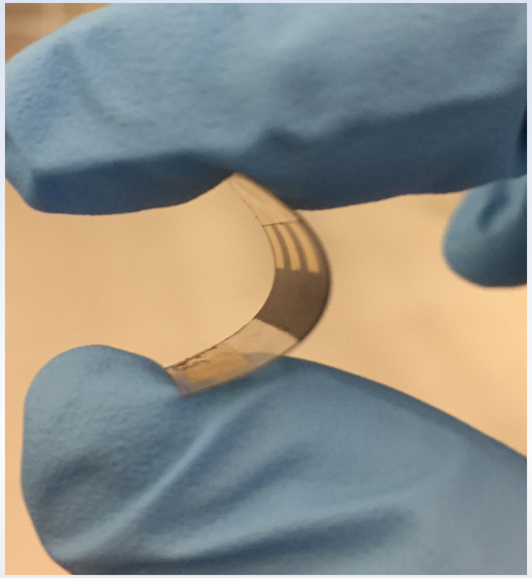

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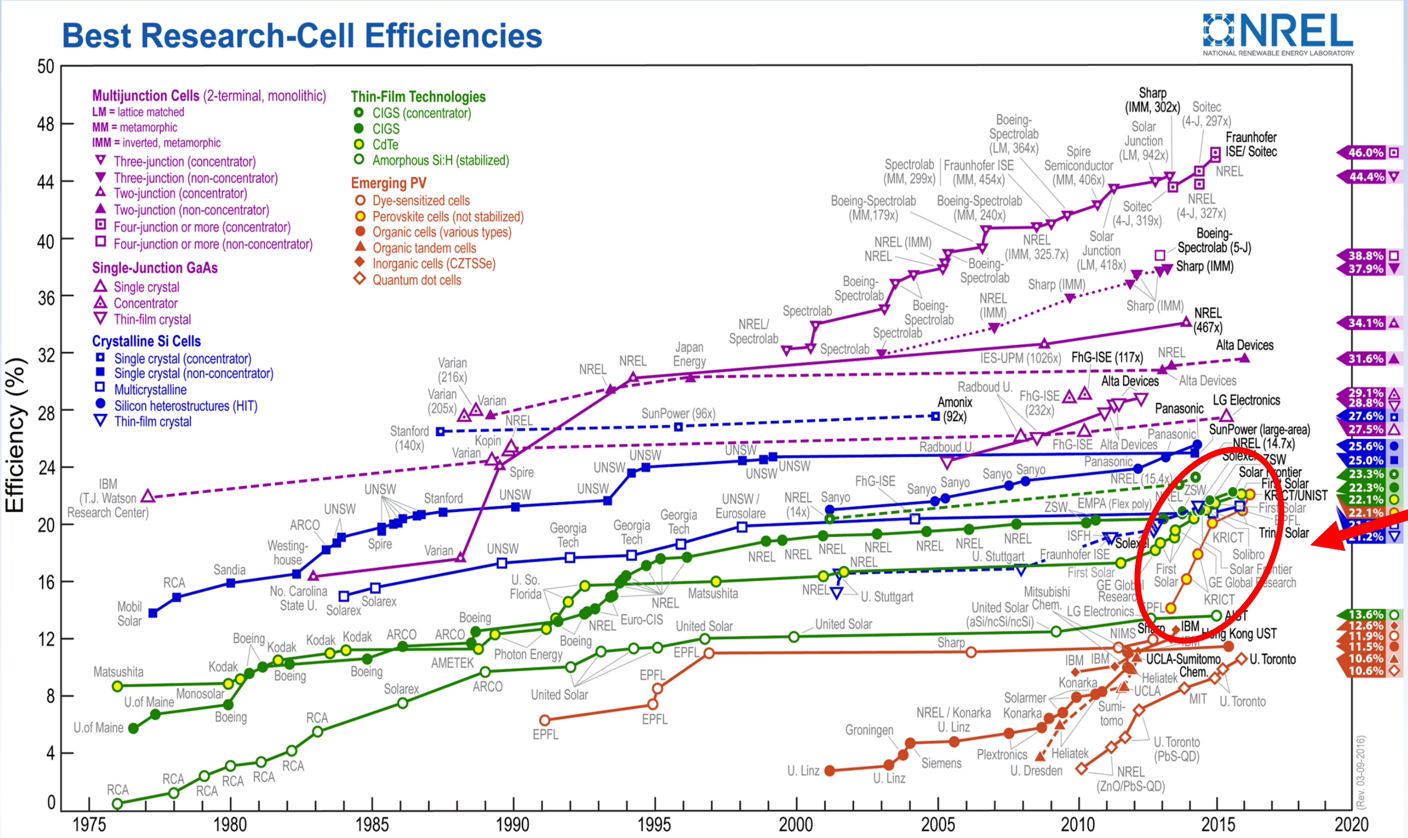
Motivation and Background



Perovskite solar cells

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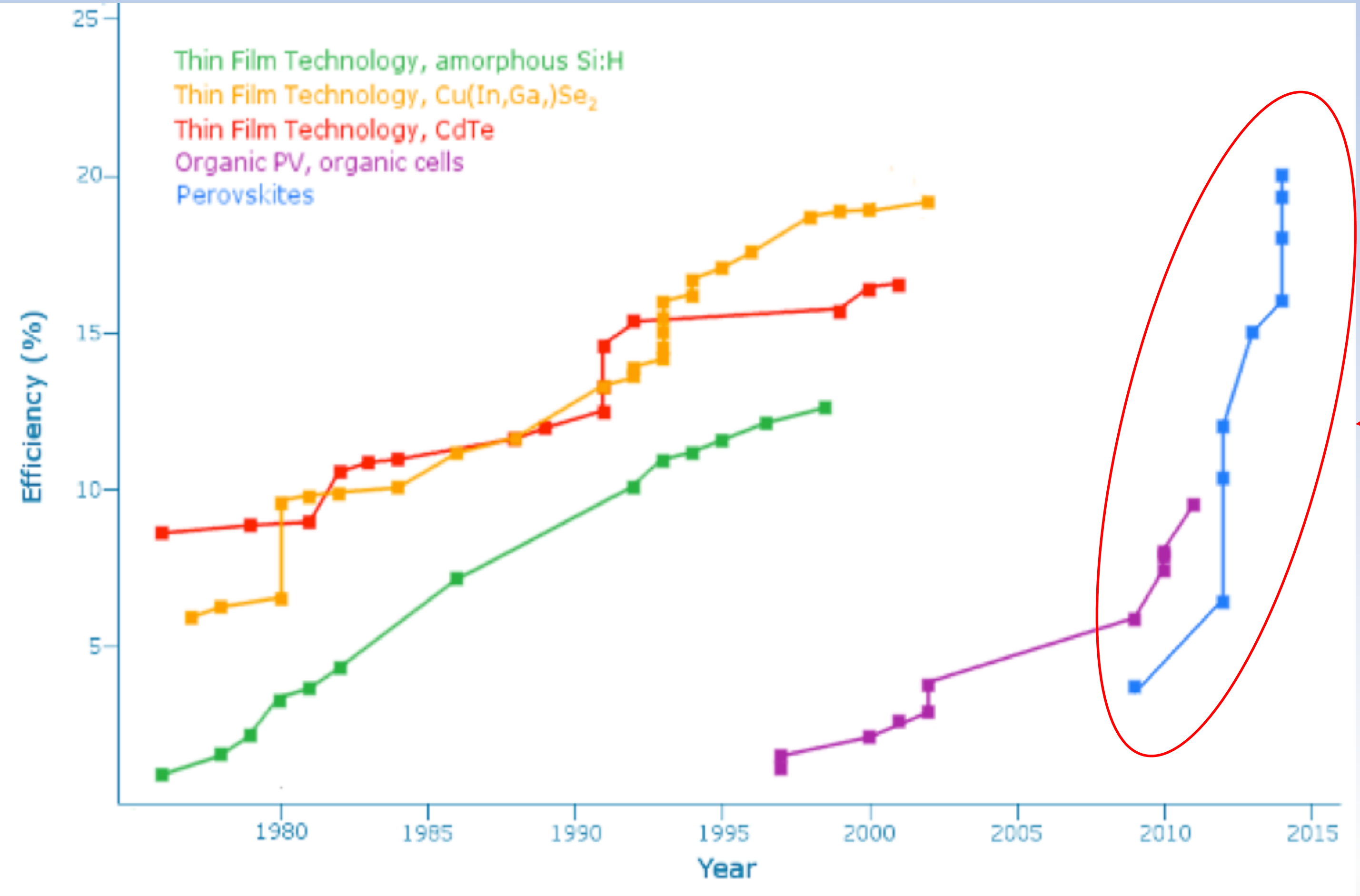
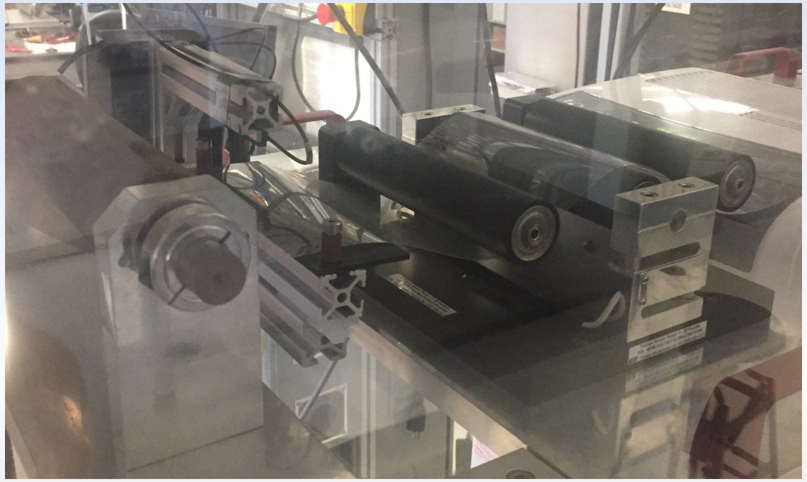
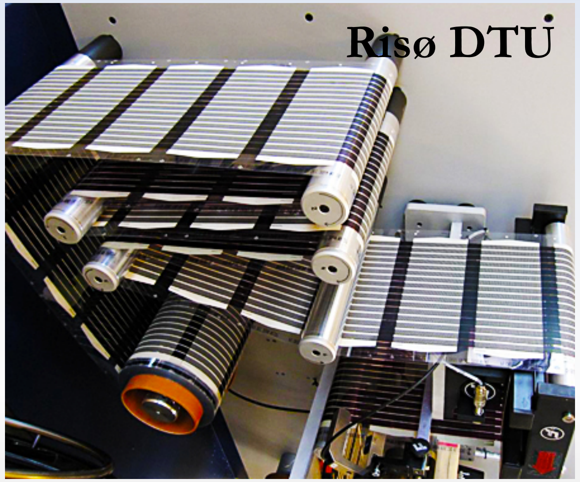


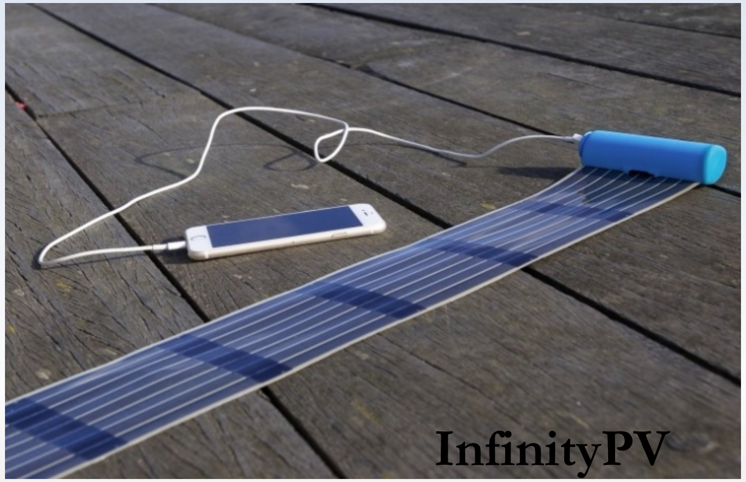
Perovskite solar cells

Goal:

- To fabricate working cells using low temperatures (<150 °C)
  - Allows us to work on flexible polymer substrates, enabling roll to roll technology and vastly lowering the cost of production
  - Flexible solar cells can also do things that cannot be done by their rigid counterparts

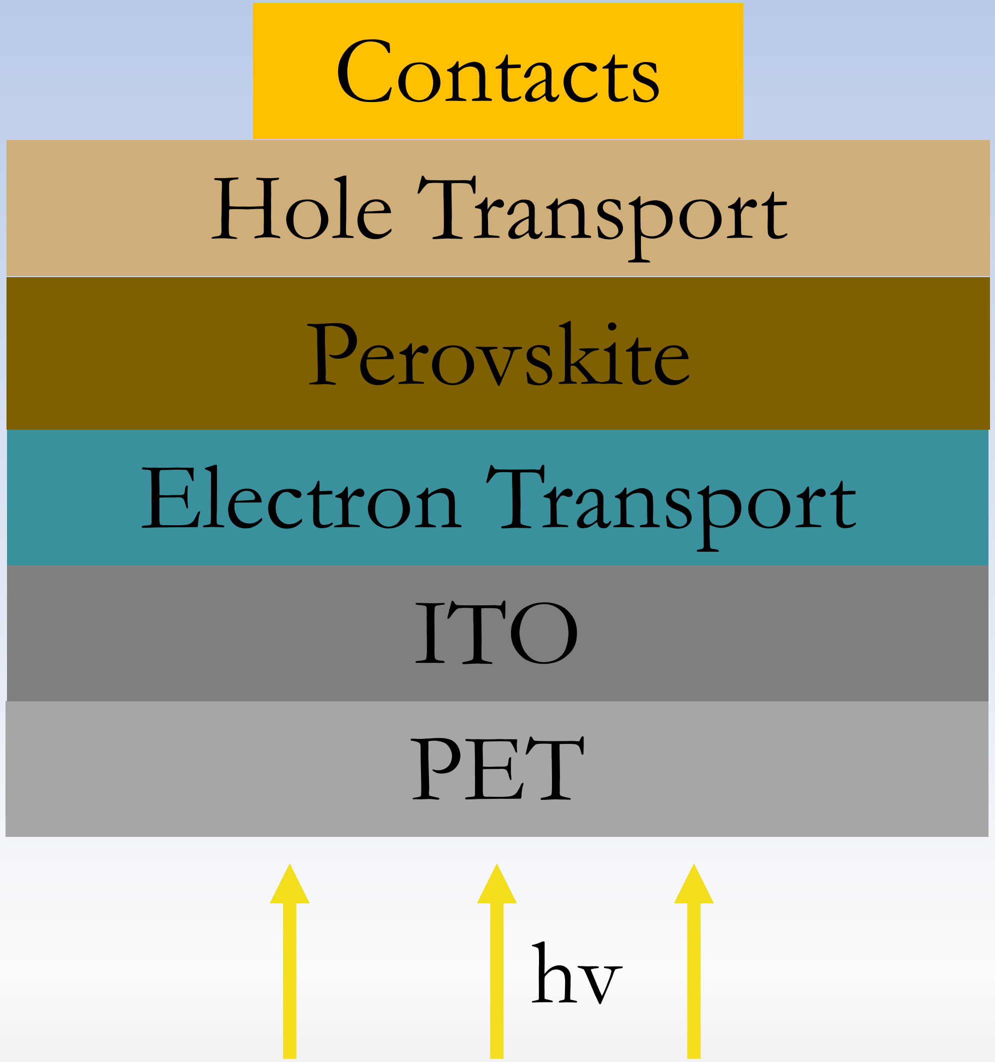






Typical Device Structure

- Operates on a p-i-n junction: light separates electron-hole pairs in the perovskite
- Main focus is on the electron transport layer and fabricating at low temperatures



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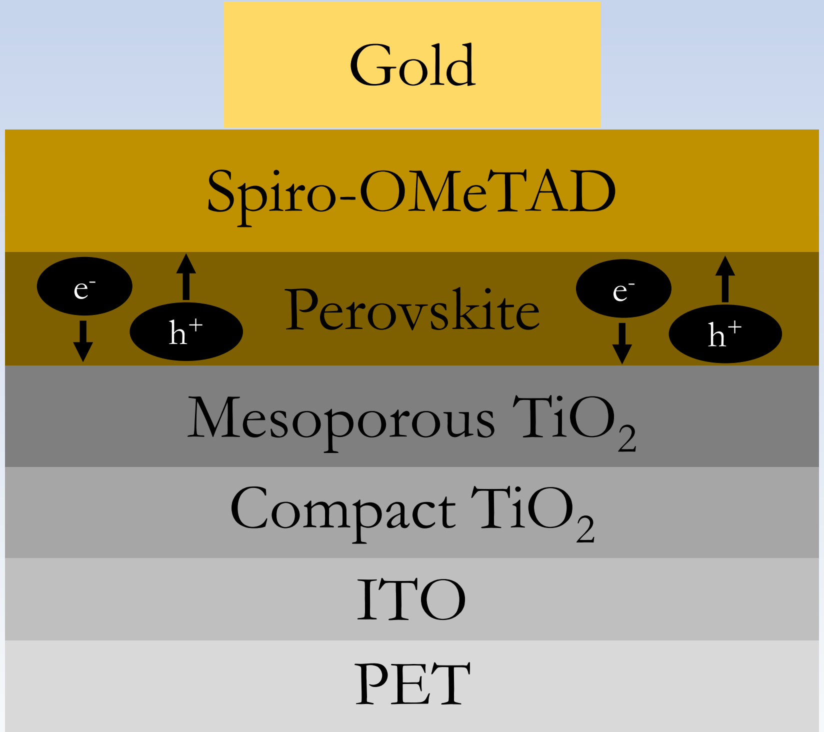
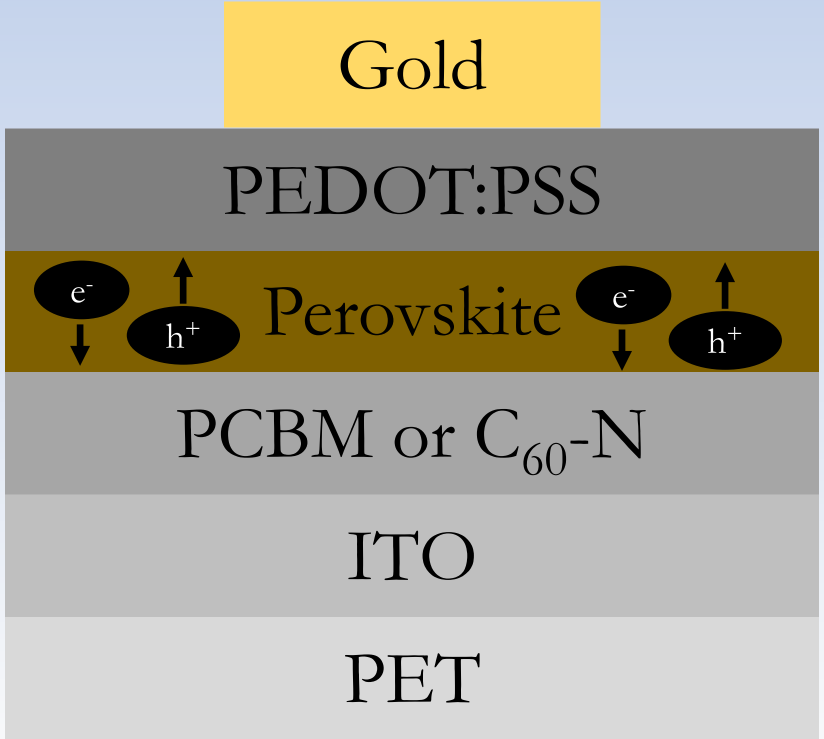
Perovskite Solar Cell Architectures:



- Involves a high temperature sintering step at 500 °C



- Expensive materials cost

Materials Cost:

	TiO_2 cells (glass substrate)	Polymer Cells (PET substrate)
Electron Transport Layer	TTIP: $61/500ml TAA: $90/500ml TALH: $78/500ml	PCBM: $600/500mg ICMA: $540/500mg
Hole Transport Layer	Spiro MeOTAD: $304/g	PEDOT:PSS: $2000/g
Efficiencies	~15-20%	PCBM: 12% Other fullerine-based polymers: up to 16%

Prices from Sigma Aldrich

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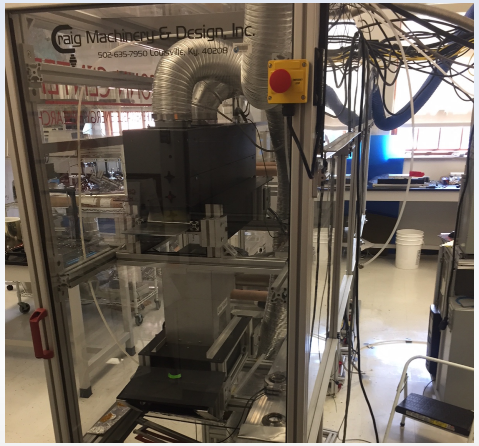
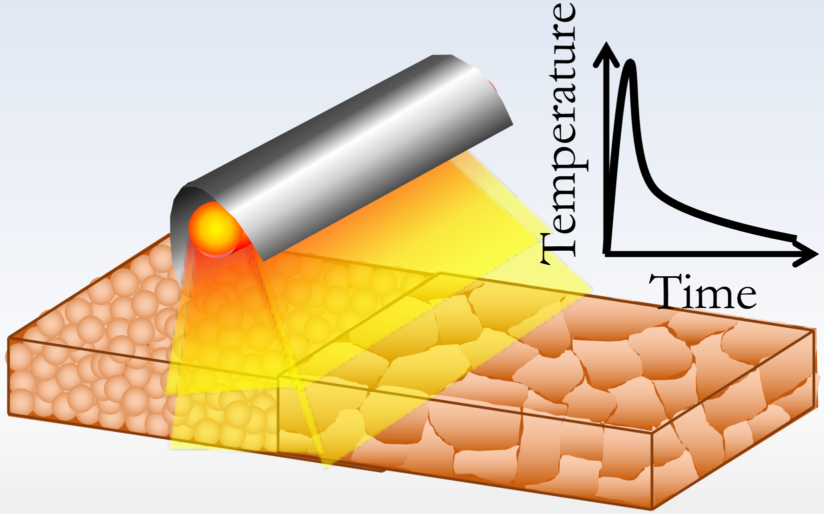
Intense Pulsed Light Sintering:

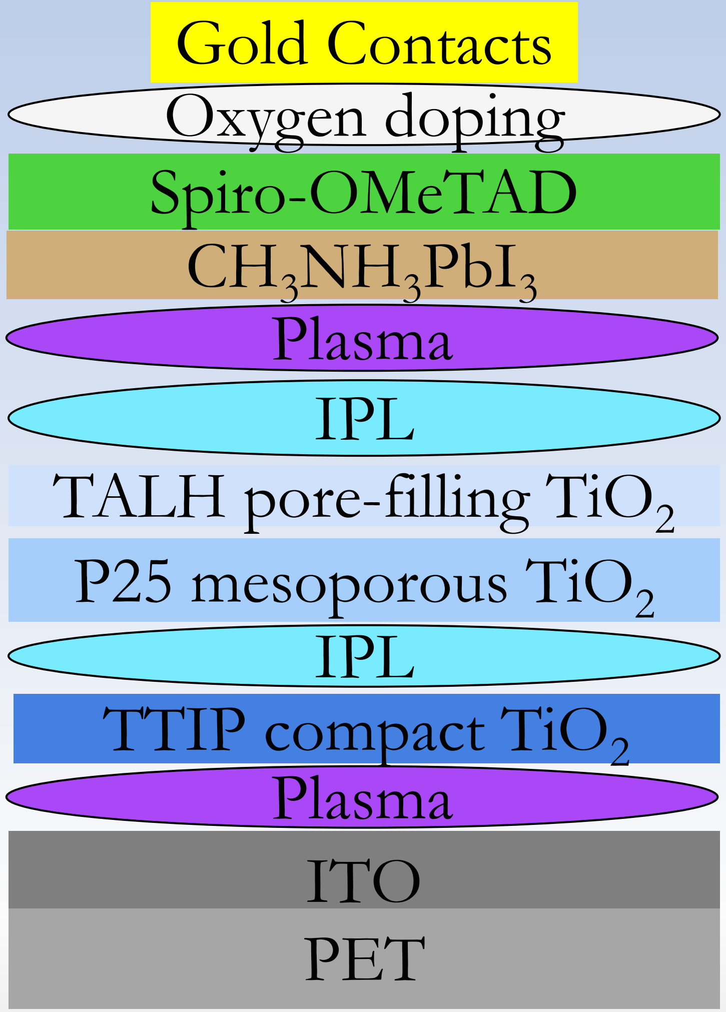
- Uses high voltage to deliver high amounts of energy (~60 J/cm^2) in the form of 2ms pulses of light
- Can deliver the energy required to sinter the TiO_2 without damaging the PET substrate





Device Structure:

- Titanium isopropoxide (TTIP) for the compact layer (35nm) - spin-coating followed by IPL
- Dyesol P25 particles for the mesoporous (200-300nm) – spin-coating followed by IPL
- Titanium(IV) bis(ammonium lactato)dihydroxide (TALH) for the pore-filling TiO_2 (~20nm)
- Triple cation perovskite solution (FAI, MAI, CsI $+PbI_2$)



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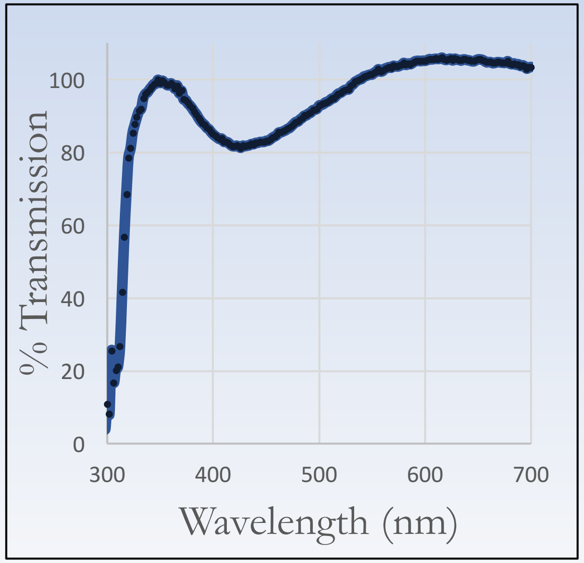
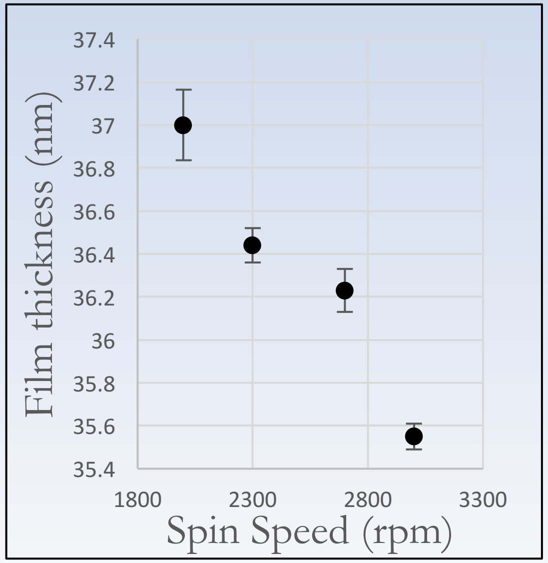
TTIP Film Characterization:

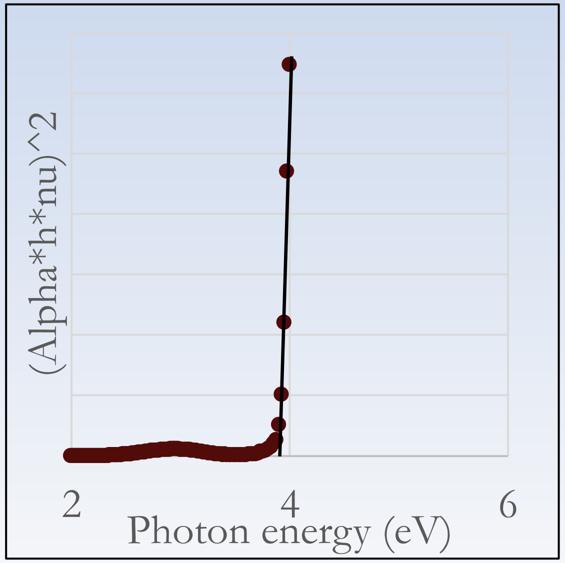
UV-Vis spectroscopy:



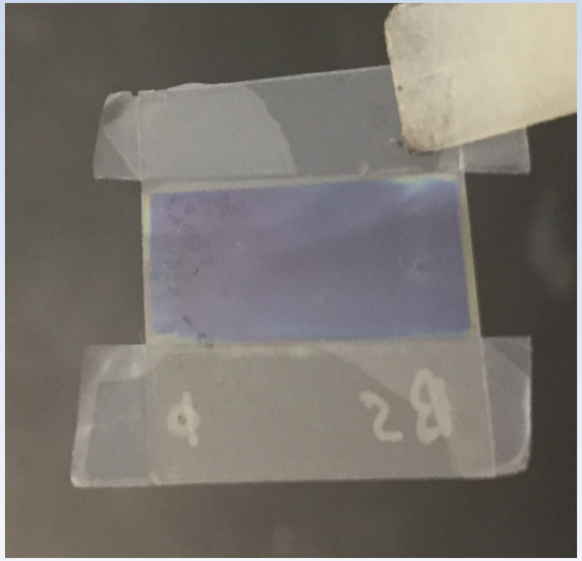
Film thicknesses:



Tauc plot:



Surface coverage:



- Film thicknesses of 35-37nm with band gap energy of 3.85eV

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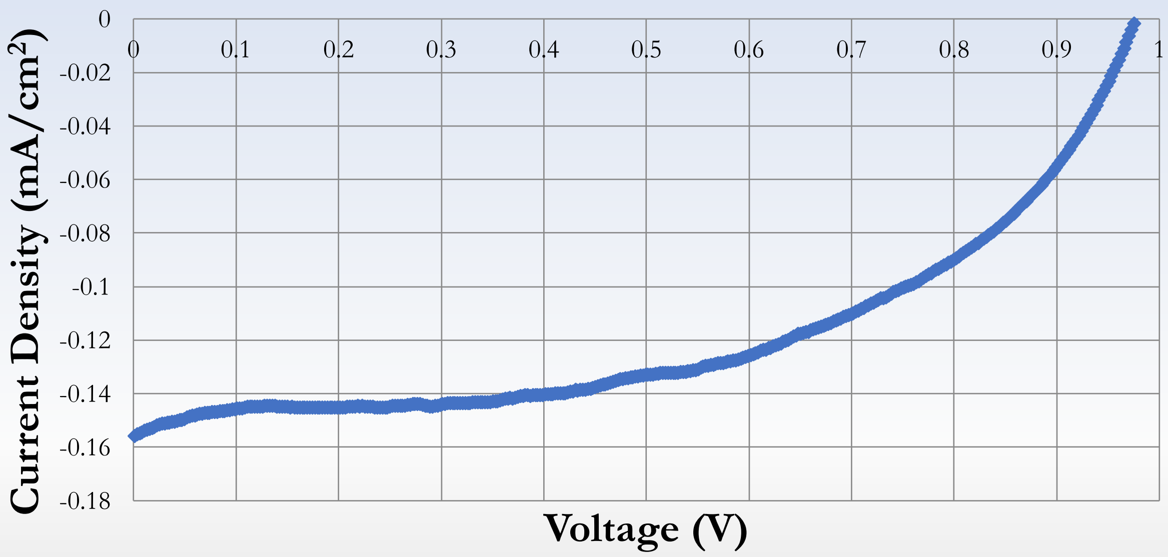
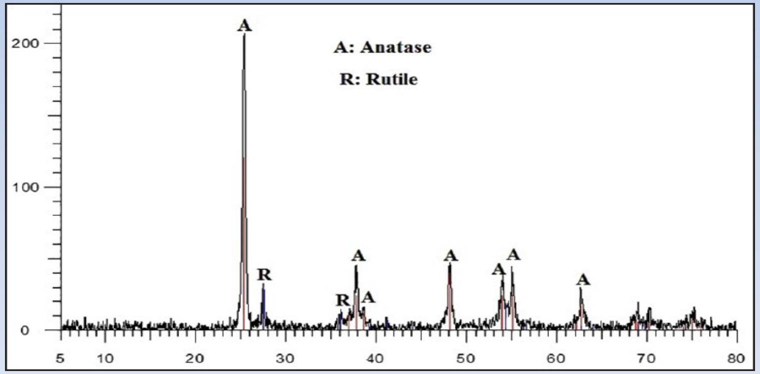
TTIP X-Ray Diffraction:

- Did not see TiO_2 peaks, meaning there could be residual amorphous TiO_x or organic material on the samples, leading to low performance

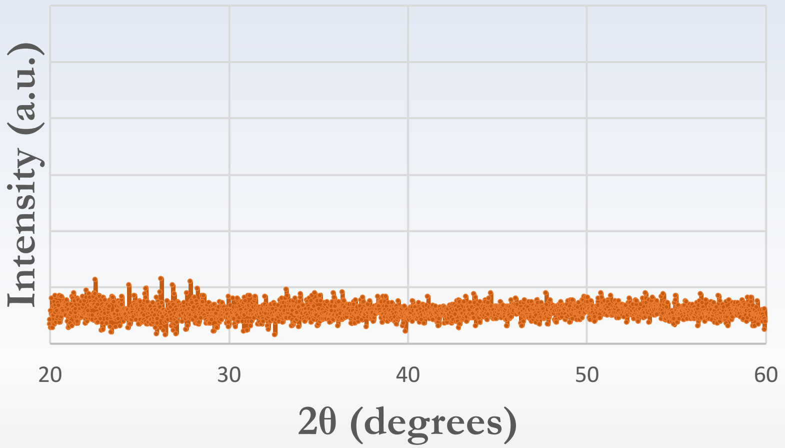
J-V Characterization for TTIP only ETL



Expected TiO_2 XRD



TTIP Film:



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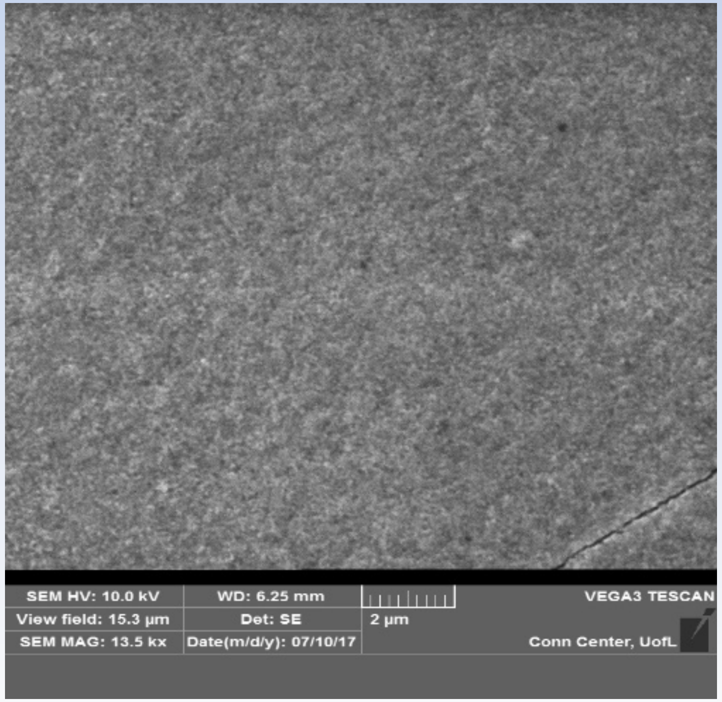
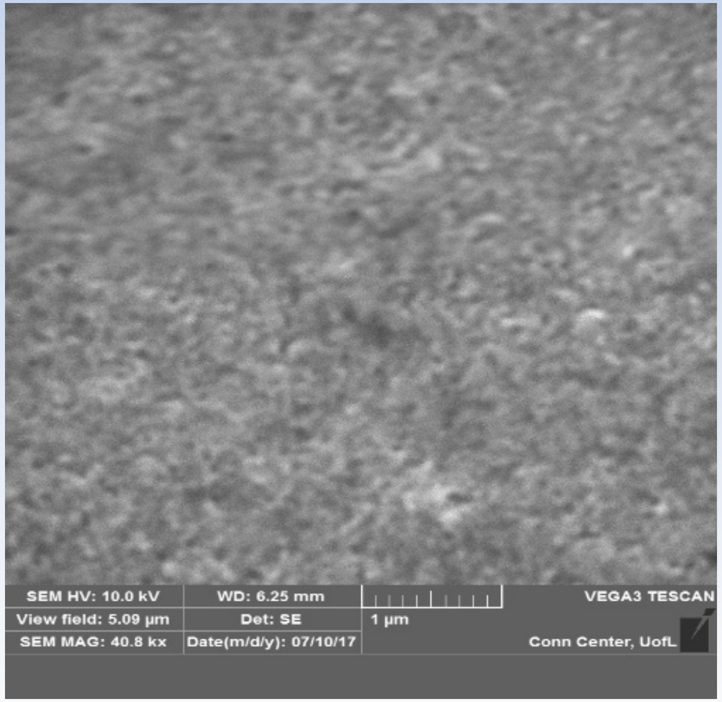
Dyesol Mesoporous Layer – SEM Images:





- SEM images show excellent surface coverage

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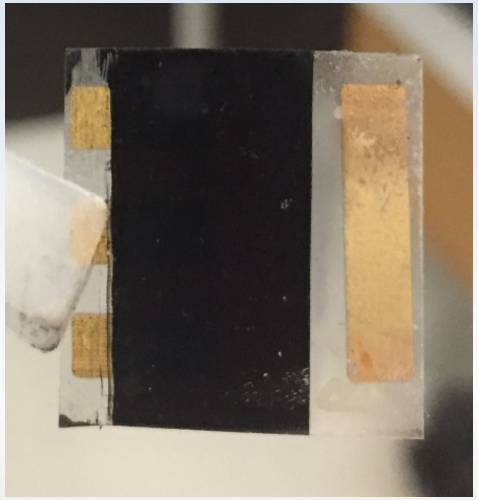
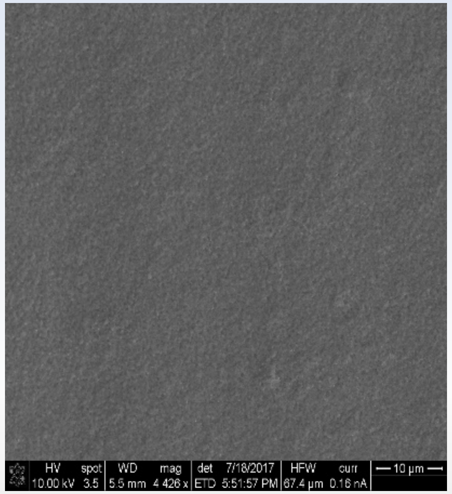
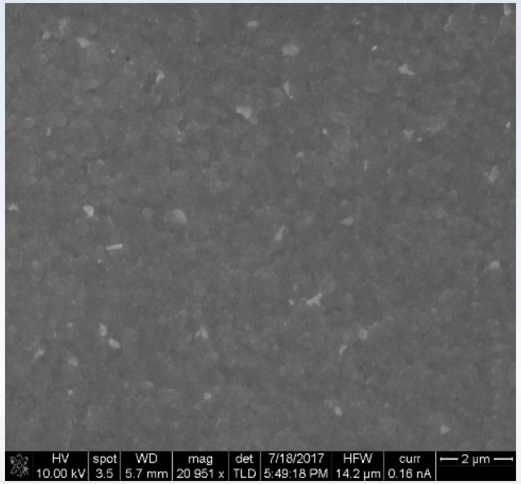
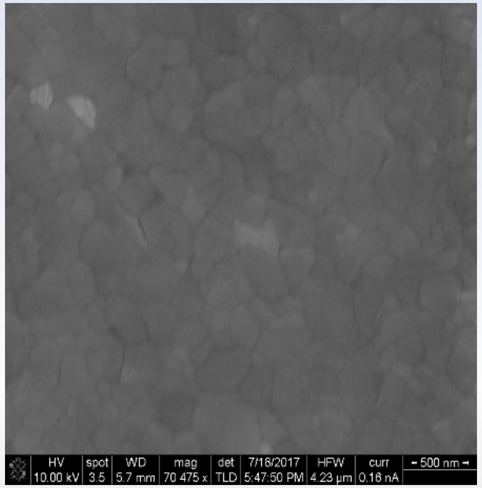
Triple Cation Perovskite Film:

- Used a solvent-solvent extraction method with a triple cation solution consisting of MAI, FAI, CsI, and PbI_2
- Decent surface coverage, grain sizes of 100-200nm









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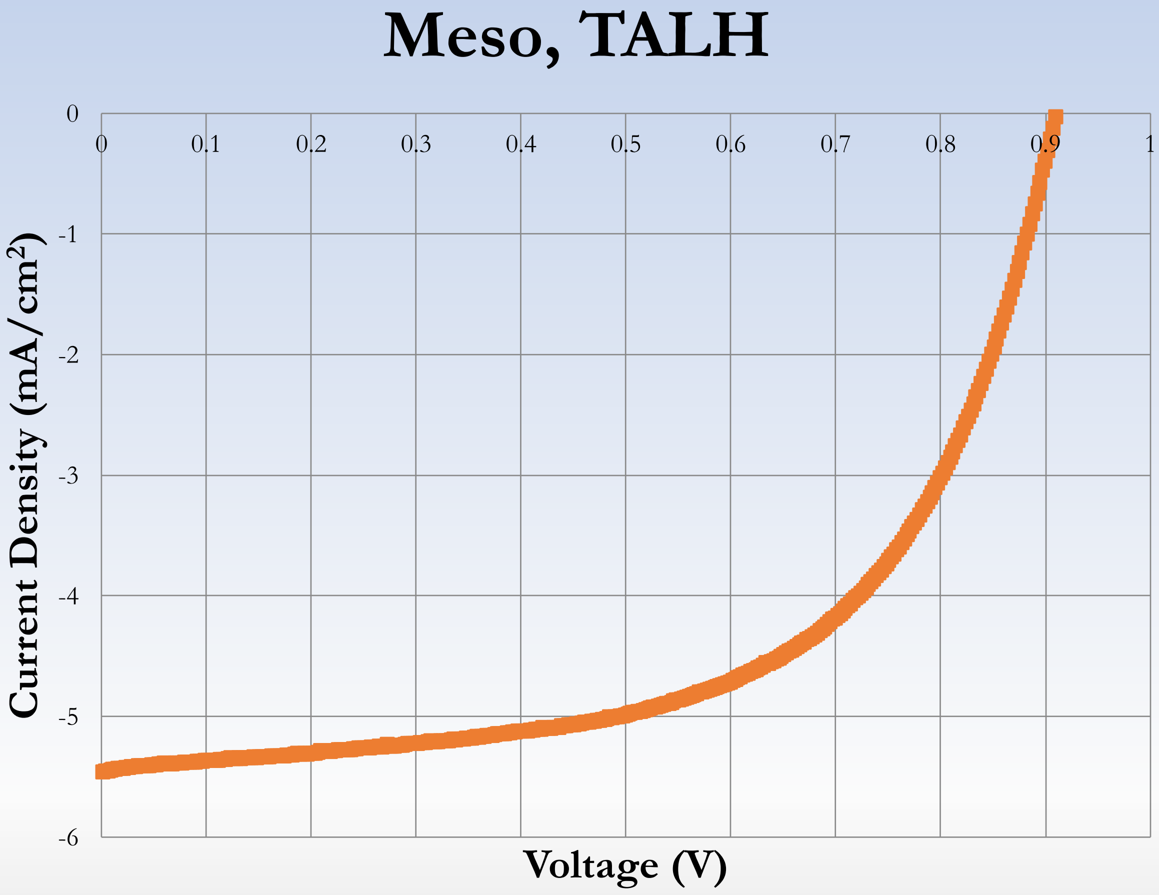
JV Characterization:



	V_{oc} (V)	J_{sc} (mA/cm^2)	PCE	FF
Average	0.936	5.38	1.51%	39.39%
Max	0.995	7.50	2.94%	43.14%
σ	0.042	1.62	1.26%	2.66%

- Good performance of cells with only mesoporous TiO_2 and TALH as the electron transport layer

Conclusions:

- Successfully fabricated working flexible devices using IPL-sintered TiO_2 with efficiencies up to 3%, displaying the viability of IPL and roll-to-roll manufacturing
- Poor performance with the TTIP compact layer suggests further study needs to be done on the TTIP, though the results with mesoporous-only cells could mean the compact layer is not required
- Further optimization needed with TiO_2, perovskite, and spiro-OMeTAD layers to improve efficiency

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