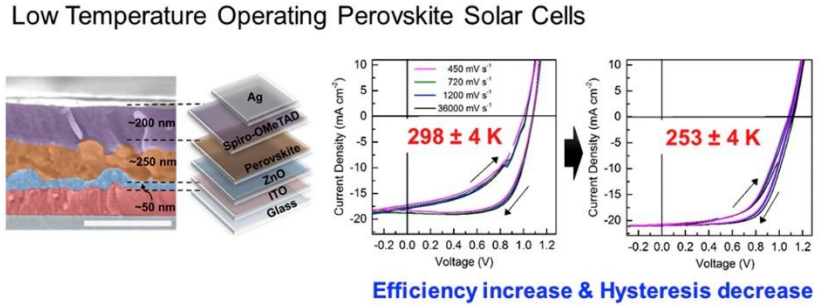
Low-temperature operation of perovskite solar cells: With efficiency improvement and hysteresis-less



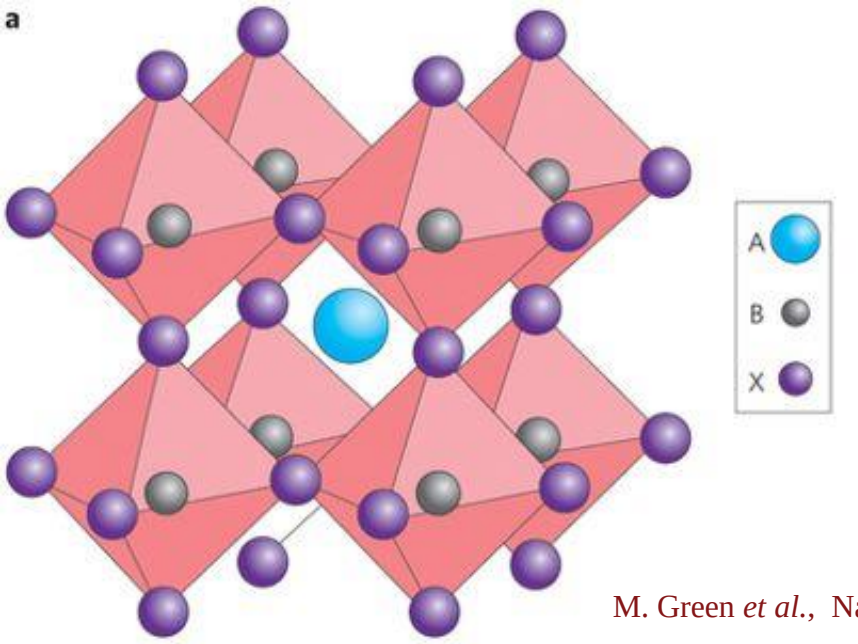
Condensed Matter Journal Club

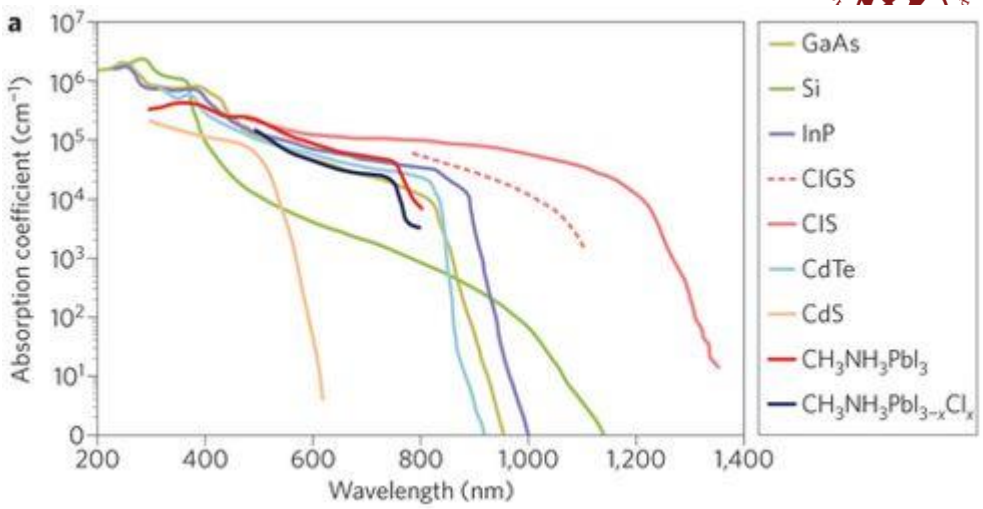
Collin Brown

Sep 11th, 2018

R. T. Ginting, E.-S. Jung, M.-K. Jeon, W.-Y. Jin, M. Song and J.-W. Kang, "Low-temperature operation of perovskite solar cells: With efficiency improvement and hysteresis-less," *Nano Energy*, **27**, 569 (2016).

Perovskite crystal

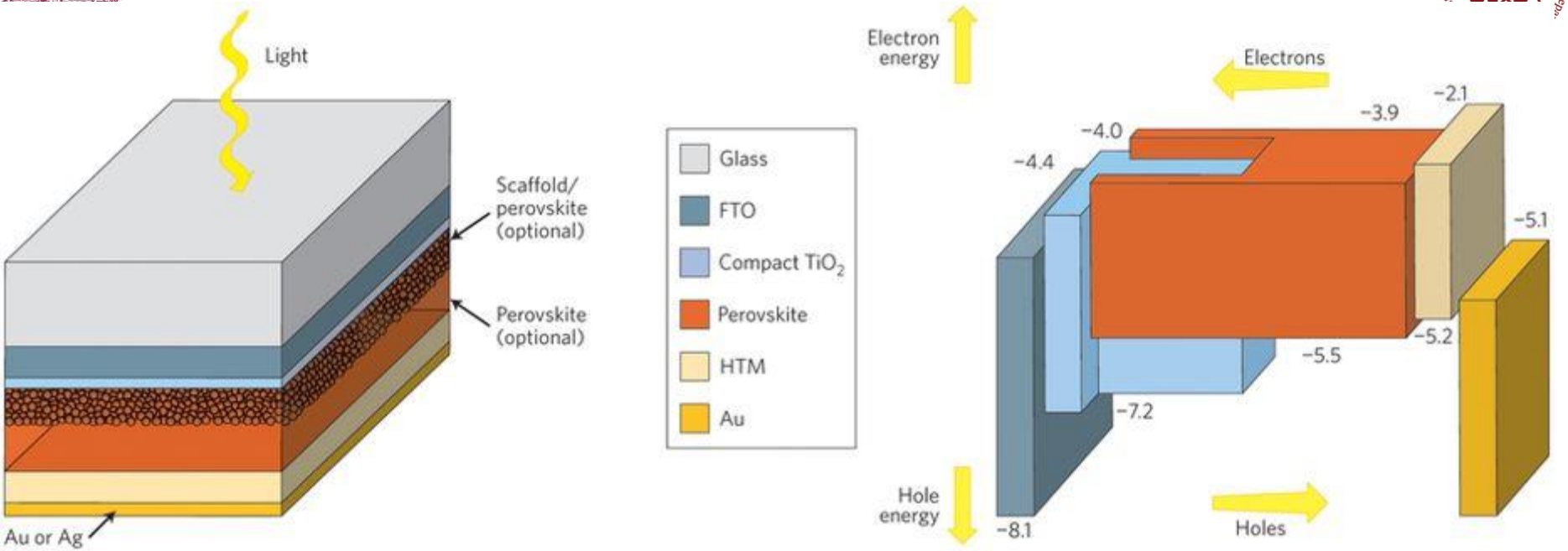




M. Green *et al.*, Nature Photonics **8**, 506 (2014).

- ABX crystal structure – Can be Cubic, Tetragonal, or Orthorhombic
  - A – Cation – Cs, Organic – MA, FA
  - B – Pb or Sn
  - X – Halide – I, Br, Cl
- Hybrid Lead perovskites – strong absorption via direct transition to 800nm
- Reverse ordering of band-edge states – splitting of conduction band rather than valence band – leads to a band gap that increases with increasing temperature
- Low non-radiative recombination rates = high Voc compared to Eg/q

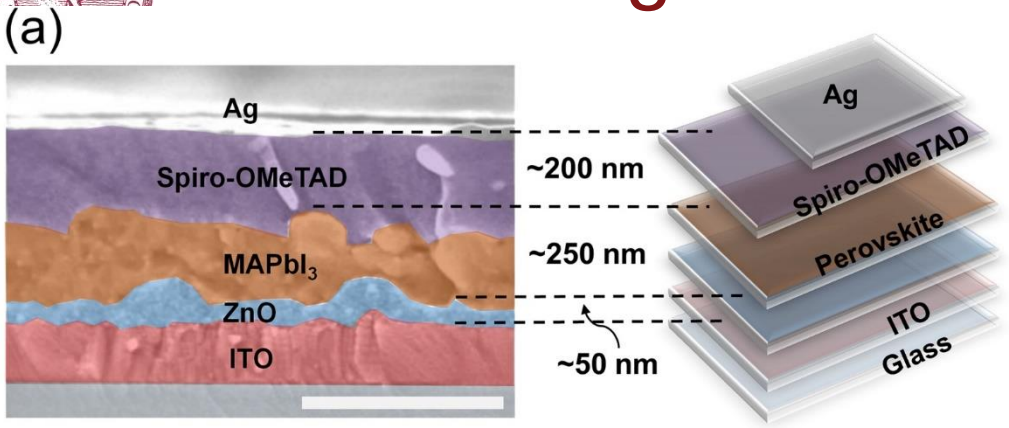
Basic PSC structure

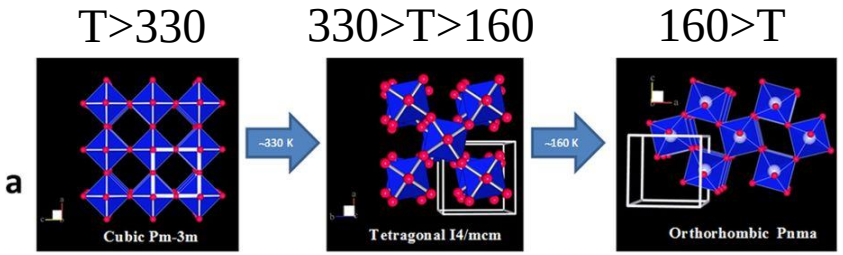


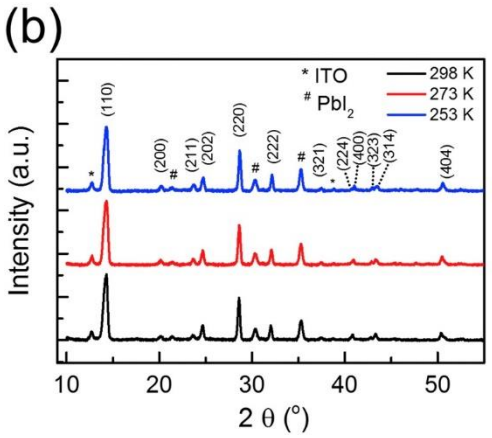
- Fabrication –
  - Start with glass, pattern with TCO
  - Spin on Perovskite, then anneal
  - Then spin on HTM, typically Spiro-OMeTAD doped with Li
  - Then evaporate on back contact

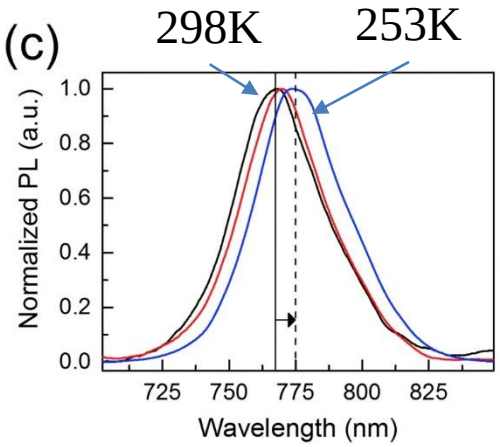
- Initial work from dye-sensitized cells had a scaffold, but later developments rendered the scaffold unnecessary in perovskite cells.

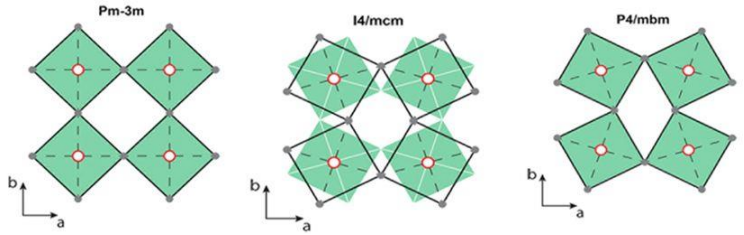
Fig.1 – Device Structure











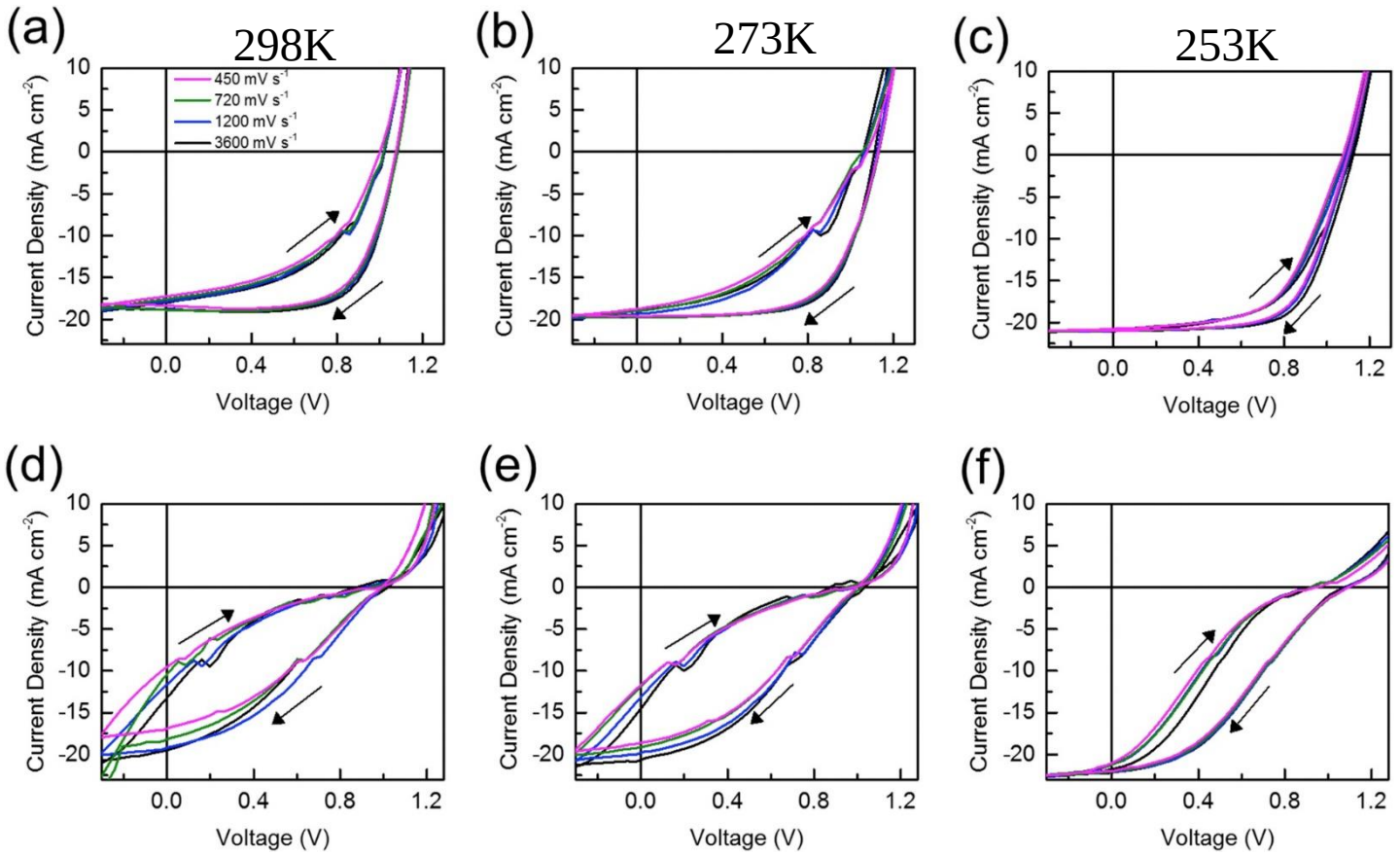
P. S. Whitfield *et al.*, Scientific Reports **6**, 35685 (2016).

- Here, they use ITO and ITO/ZnO for their transparent conducting oxides
- The PL shifts to higher wavelength/lower energy with decreasing temperature, which is to be expected in Perovskites – thus lower temp will move the gap closer to the optimum for solar in the case of PSCs
- XRD data shows peaks consistent with Tetragonal phase of MAPbI3

Fig.2 – Hysteresis of JV curves

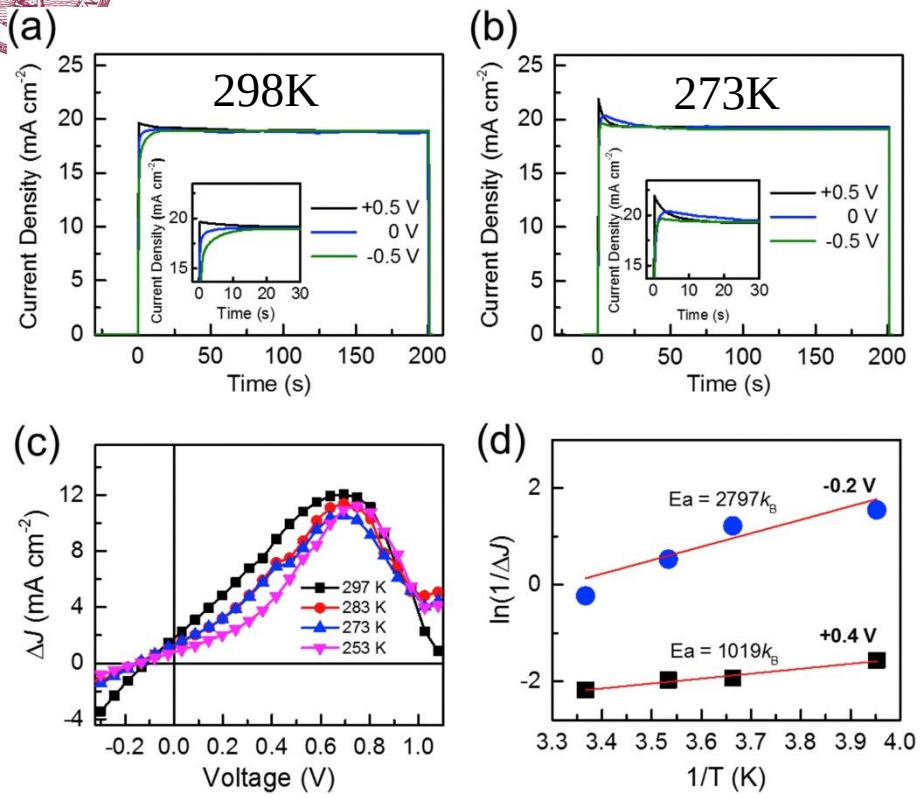
ITO/ZnO

ITO only



- Hysteresis in the Current-voltage curve is seen in almost all PSCs
  - May be due to ionic motion
  - Large difference in PCE – 14.2% in Reverse, 9.0% in Forward
  - Hysteresis decreases with Temperature – others have seen increase

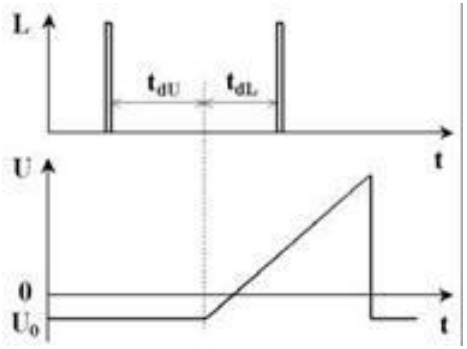
Fig.3 – Origin of Hysteresis



- Activation energies extracted from hysteresis
- Values are comparable to MA+ and I- migration
- However, only 4 data points in Arrhenius plot

- Device held at field for a certain amount of time – transient chronoamperometry
- Positive poling effect – migration of ions and vacancies near the interface of contacts – ion doping impurity
- Negative poling – accumulation of ionic defect vacancies in opposite direction
- Poling process may freeze out at lower temperature

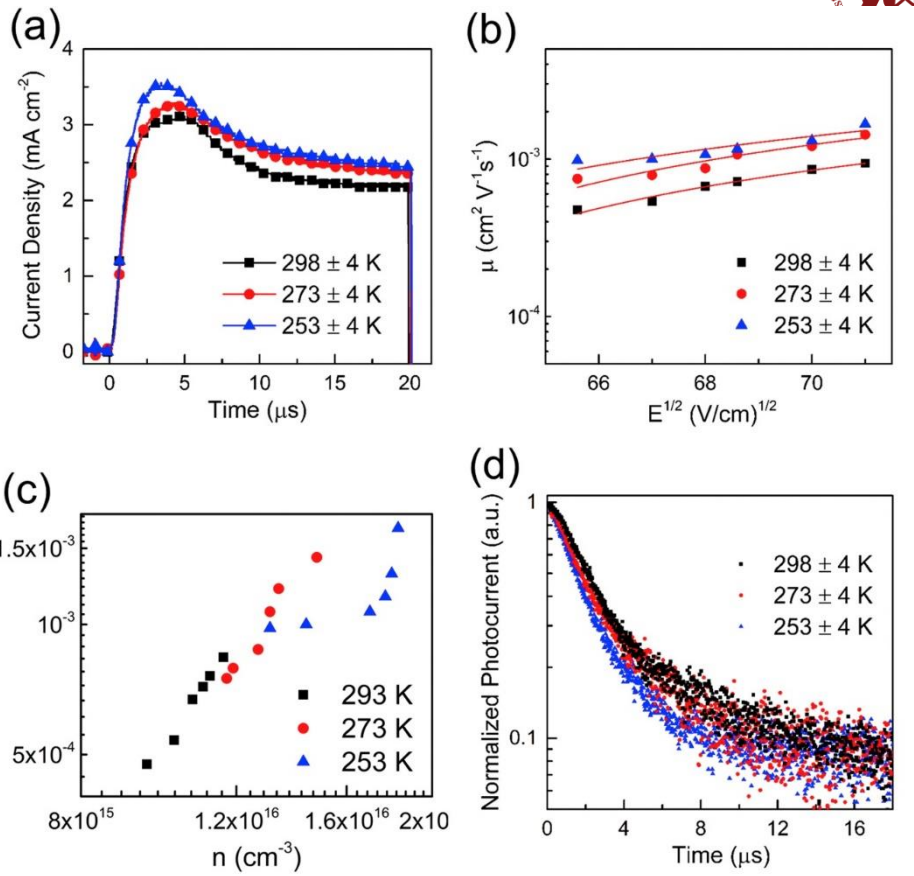
Fig.4 – Jsc Improvement

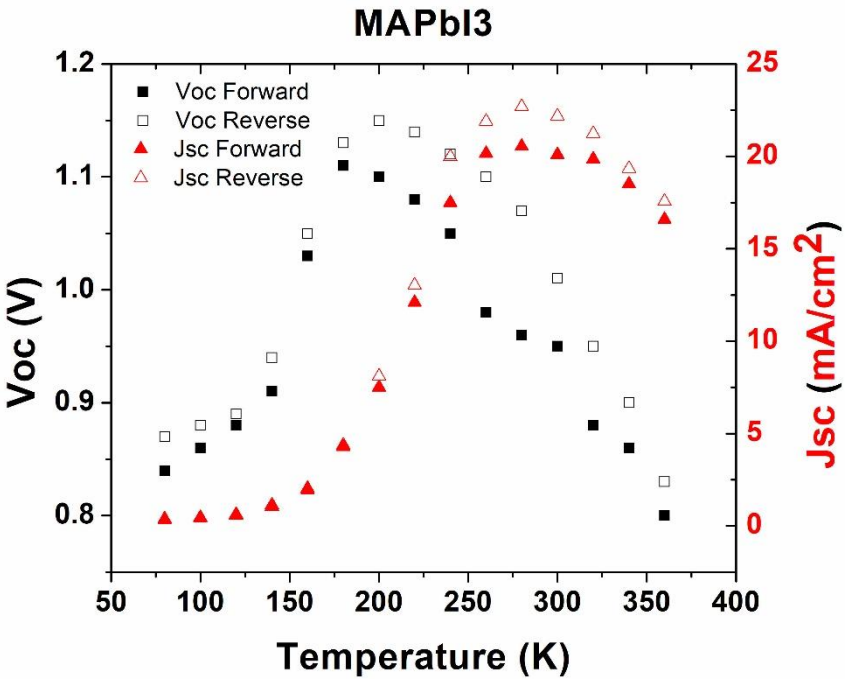


http://energyprofessionalsymposium.com/?p=16284

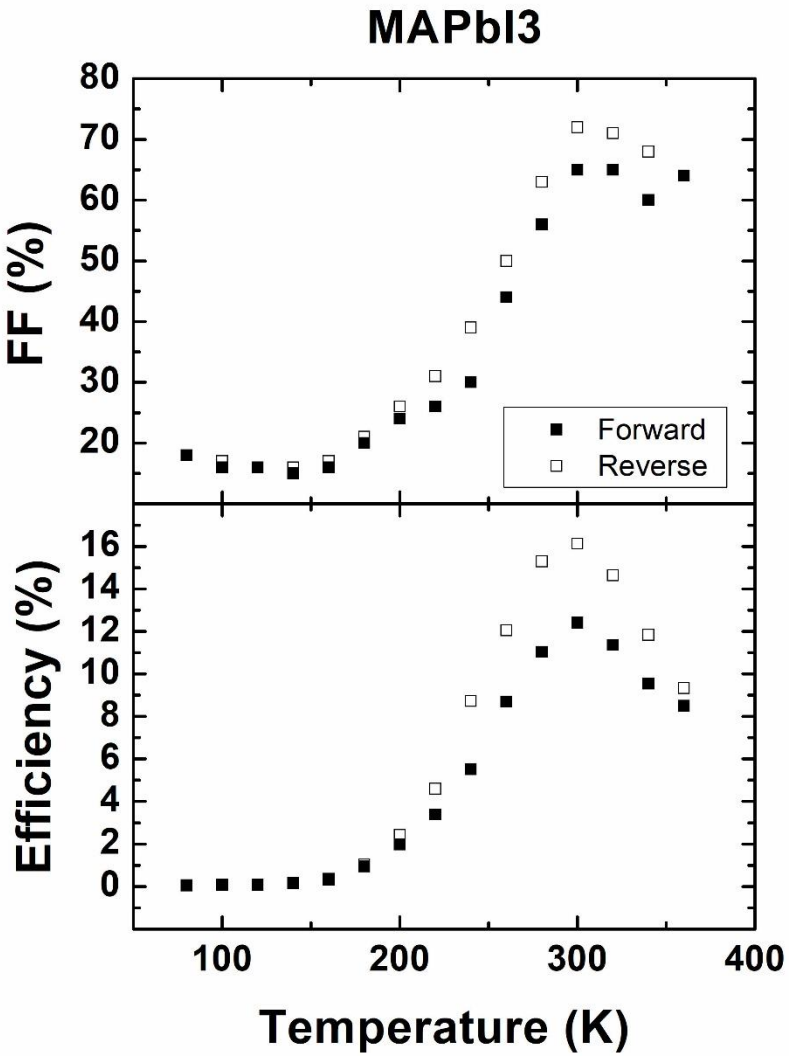
Photoinduced charge extraction by linearly increasing voltage (Photo-CELIV

- Short pulse of light from a laser
- Carriers are extracted by linear increasing voltage after the pulse
- Investigates relaxation of charge carrier density and mobility





Data plotted from
H. Zhang *et al.*, Journal of Materials Chemistry A **3** (22), 11762 (2015).



Questions?