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

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Perovskite crystal


- 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

- 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.

P. S. Whitfield et al., Scientific Reports 6, 35685 (2016).
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. 2 – Hysteresis of JV curves
Fig. 3 – Origin of Hysteresis

- 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

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