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Development of Near Infrared Transparent Perovskite Solar Cells for Tandem Application combined with $Cu(In,Ga)Se_2$

EMPA Materials Science & Technology

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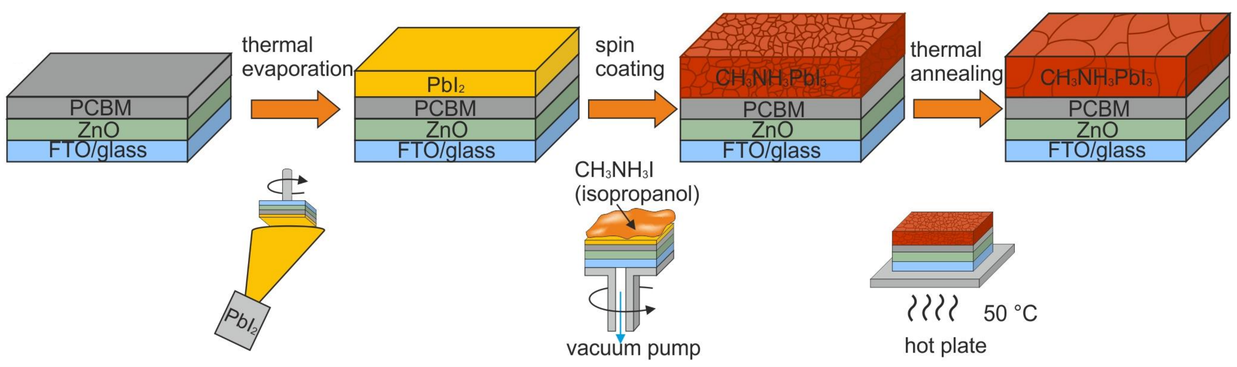
Abstract

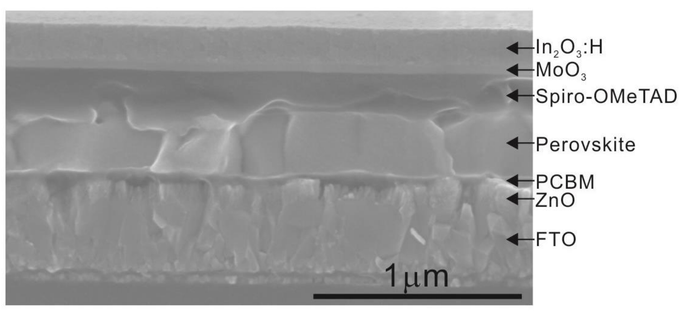
An effective approach for highly efficient photovoltaics is to combine solar cells with wide and narrow band gap to tandem devices. The high efficiency of perovskite solar cells and the wide band gap of the absorber which is tunable over a large range (≥ 1.57 eV) make them well suitable for the application as top cells in a tandem structure with CIGS bottom cells. A prerequisite for such tandem cells is the development of perovskite solar cells with high near infrared (NIR) transmittance.

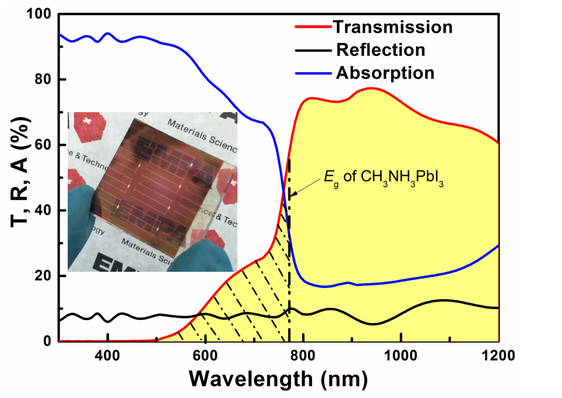
Here we show that room temperature sputtering deposited high-mobility In_2O_3:H is a suitable transparent electrode for planar perovskite solar cells with high transmission in the NIR region. The NIR transparent perovskite was implemented as a top cell together with a CIGS bottom cell in a 4-terminal tandem device, which yield high efficiency of 20.5%. Invert the polarity of perovskite still deliver efficiency above 15%, which pave the way for efficient 2-terminal perovskite-CIGS tandem devices

Hybrid thermal evaporation/spin coating method



NIR-transparent perovskite solar cells

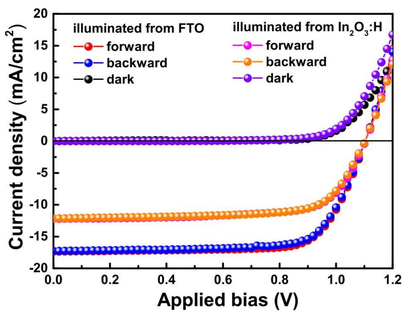


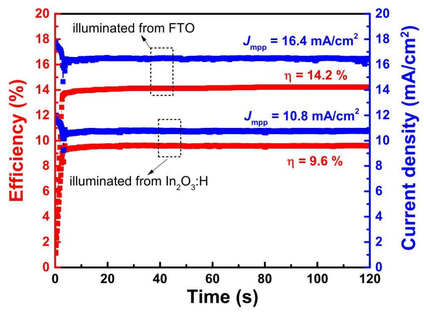


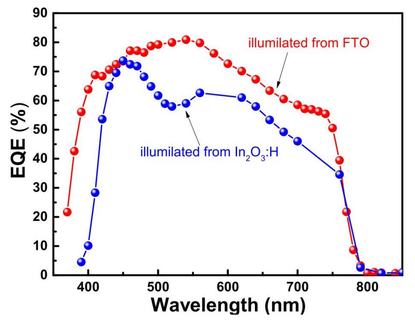
J-V curve: AM1.5G, scan rate: 0.3V/s, delay time:10ms backward: 1.2V to -0.1V

EQE: with light bias, chopping frequency: 260 Hz forward: -0.1V to 1.2V

- Above 72% average transmission between 800-1150nm





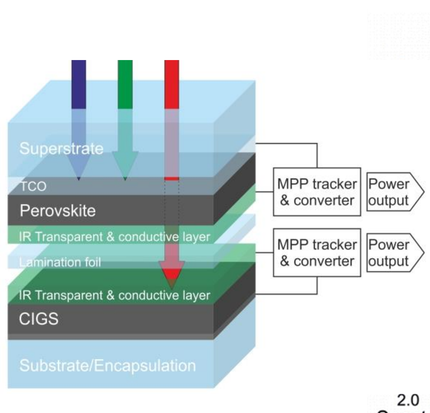


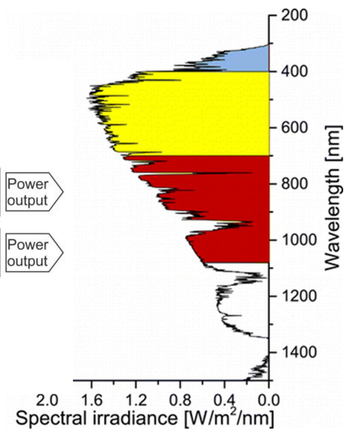
14.2% and 9.5% NIR-transparent perovskite solar cell achieved with illumination from FTO and from In_2O_3:H side, respectively.

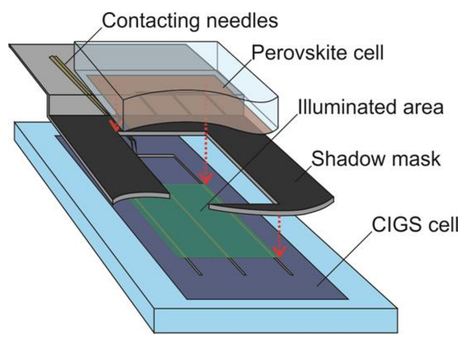
F. Fu et al., *Nature Communications* 6:8932 (**2015**), DOI:10.1038/ncomms9932

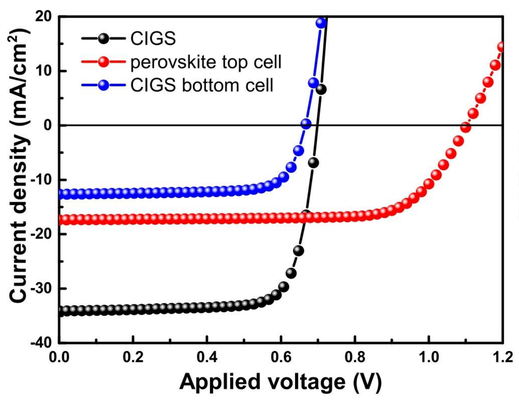
Development of high efficiency polycrystalline thin film tandem solar cells

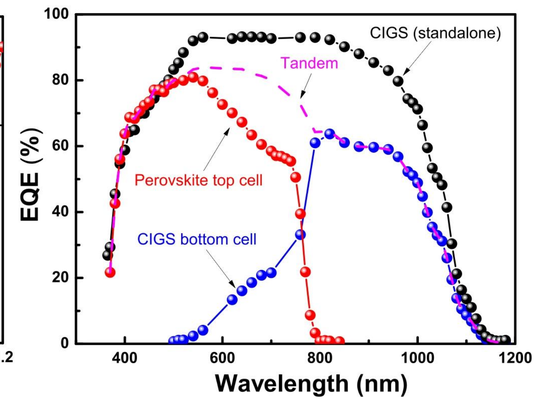
4-terminal Perovskite-CIGS tandem solar cells







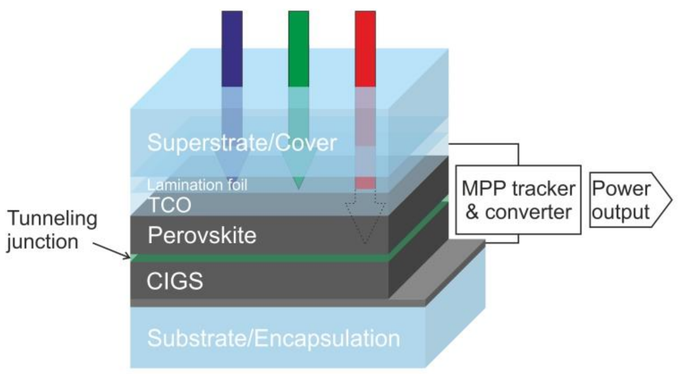


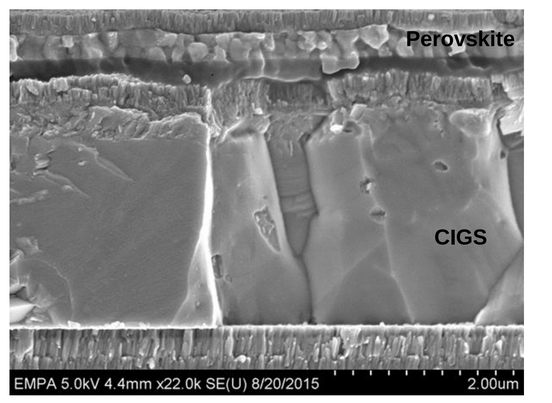


	V_{oc} (mV)	J_{sc} (mA/cm²)	FF (%)	Eff. (%)	Steady-state eff. (%)	Area (cm²)
CIGS	698.6	34.1	76.7	18.3	18.3	0.213
CIGS bottom cell	667.4	12.7	74.9	6.3	6.3	0.213
Perovskite top cell	1104	17.4	73.6	14.1	14.2	0.517

Perovskite-CIGS tandem solar cell with 20.5% efficiency achieved in 4-terminal configuration

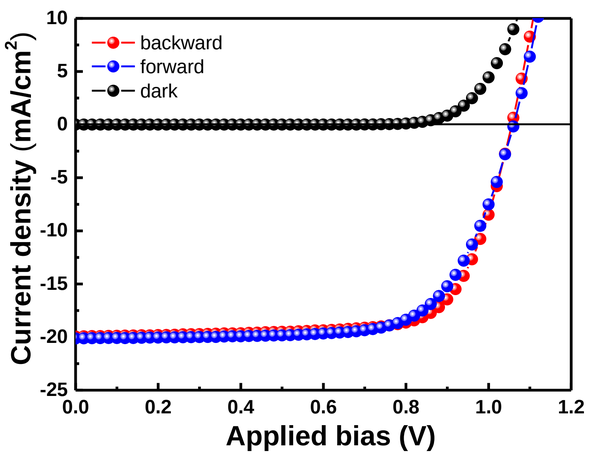
2-terminal Perovskite-CIGS tandem solar cells

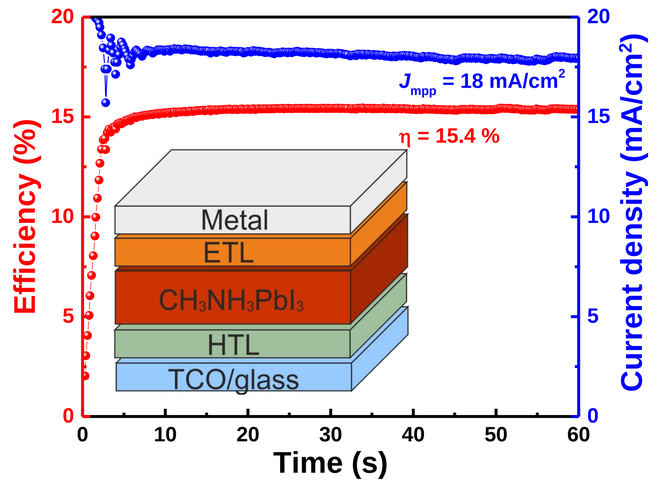




Development of high efficiency inverted NIR-transparent perovskite solar cells is critical for 2-terminal perovskite-CIGS tandem devices

- **Inverted planar perovskite solar cells**





15.4% efficient inverted perovskite solar cell is realized with opaque metal contact, which pave the way for 2-terminal perovskite-CIGS tandem solar cells

Conclusions

- **NIR transparent electrode**
  In_2O_3:H was successfully applied as rear transparent electrode for perovskite solar cells, exhibiting an average transmission above 72% in the 800-1150 nm region.
- **NIR-transparent perovskite solar cells**
  NIR-transparent perovskite cells demonstrated a steady state output efficiency of 14.2% and 9.5% from FTO and In_2O_3:H side illumination, respectively.
- **Inverted perovskite solar cells**
  Inverted perovskite solar cells are realized with steady state efficiency of 15.4%.
- **Perovskite-CIGS tandem solar cells**
  4-terminal perovskite-CIGS tandem solar cell shows a high efficiency of 20.5%.

Outlook

- **4-terminal Perovskite-CIGS tandem solar cells**
  Further efficiency improvement will be feasible by reducing the parasitic absorption losses.
- **Monolithic perovskite-CIGS tandem solar cells**
  Tailoring band gap of perovskite and CIGS for efficient monolithic tandem solar cells

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