nano-tera.ch
swiss scientific initiative in health / security / environment systems

Synergy RTD 2013

FNSNF

Perovskite-CIGS Tandem Structure Solar Cell

Fan Fu, Johannes Loeckinger, Lukas Kranz, Timo Jaeger, Patrick Reinhard, Benjamin Bissig, Fabian Pianezzi, Ayodhya N. Tiwari, Stephan Buecheler

Laboratory for Thin Films and Photovoltaics, Empa - Swiss Federal Laboratories for Materials Science & Technology, Duebendorf, Switzerland

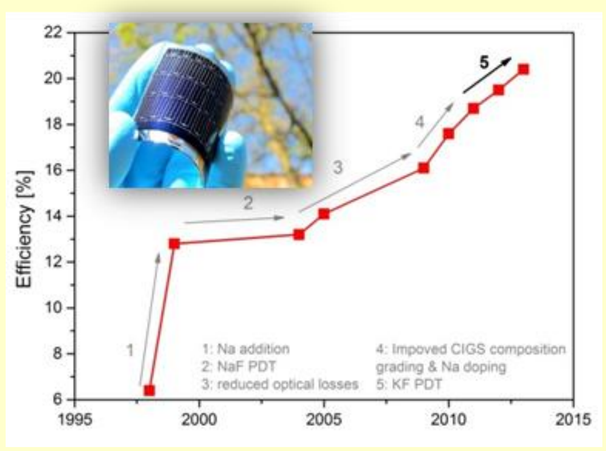
Introduction

The organic-inorganic hybrid $CH_3NH_3PbI_3$ perovskite solar cells have experienced unprecedented advancement in the past 5 years, and independently certified power conversion efficacy of 17.9% has already been achieved by KRICT, South Korea.[1]

The large band gap coupled with suitable current density make the perovskite solar cell an ideal candidate for the top cell of a tandem structure with $Cu(In,Ga)Se_2$ (CIGS). Here we present results on vapor deposited perovskite solar cells, and discuss the potential of combining perovskite and CIGS solar cells to construct tandem devices.

[1] CNRE, Best Research Cell Efficiency, http://www.nrel.gov/ncpv/images/efficiency_chart.jpg (2014.05)

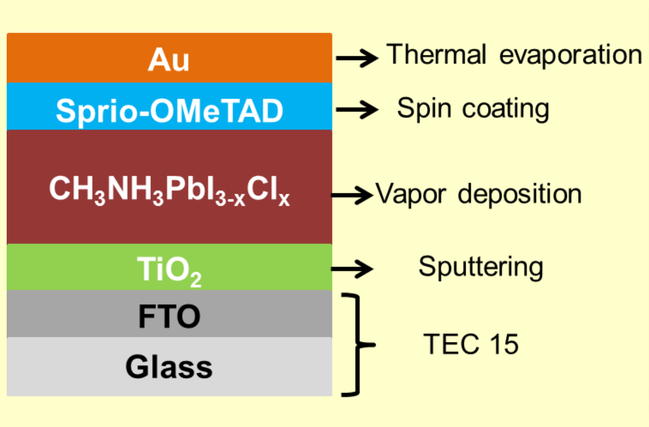
Flexible CIGS Solar Cell on Plastic Film

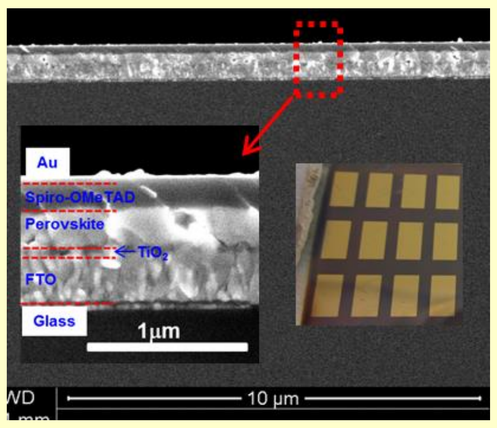


Flexible CIGS solar cell with 20.4% efficiency by low temperature deposition process

A. Chirila, P. Reinhard et al, *Nature Materials* **12**, 1107 (2013)

Preparation of Planar Perovskite Solar Cell



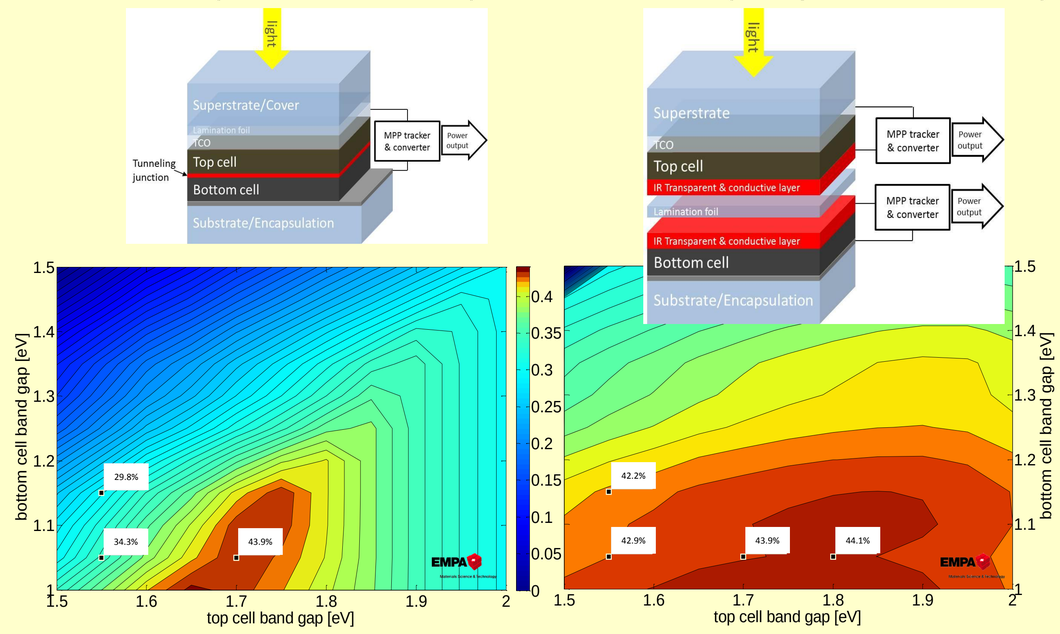


- Schematic illustration of planar perovskite solar cell architecture
- Flat and homogeneous thin film layers on 5x5 cm² FTO glass

[2] Vapor deposition following: Liu, Johnston, Snaith, *Nature* **501**, 395 (2013).

Performance potential of Tandem Solar Cell

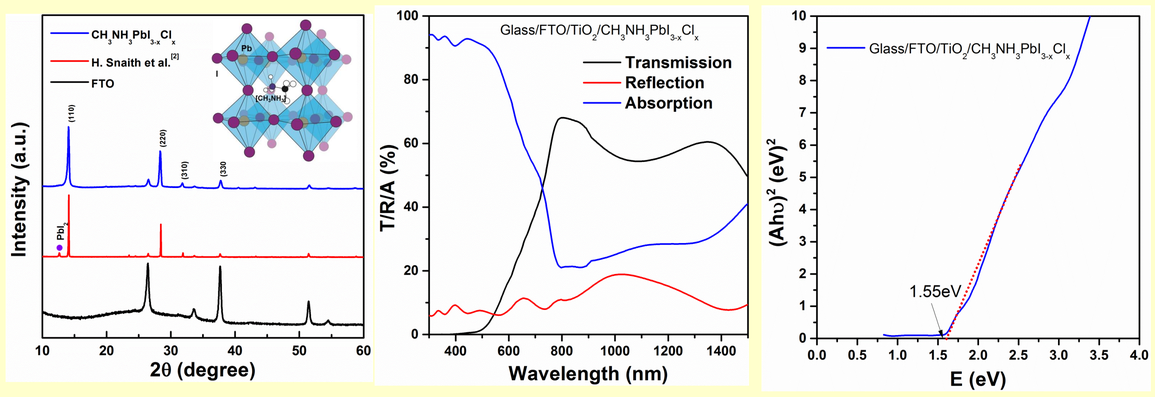
2-terminal (current matched) 4-terminal (independent circuits)



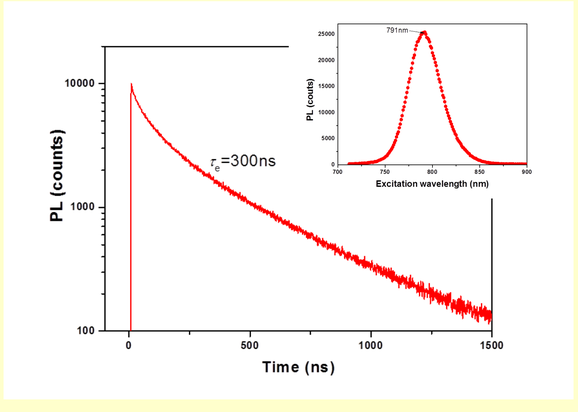
Detail balance analysis w/o optical losses in the transparent contacts

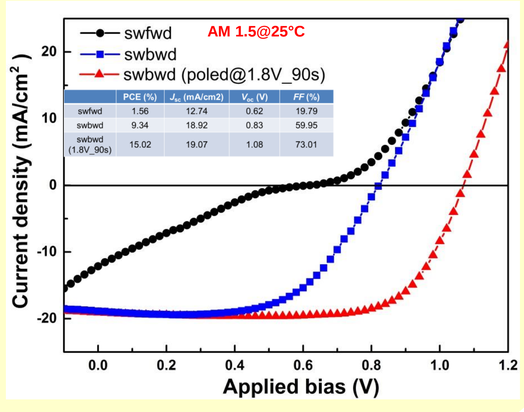
W. Shockley, H.J. Queisser, J. Appl. Phys., 32, 510 (1961)

Structure and Performance of Perovskite Cells



- Single phase $CH_3NH_3PbI_{3-x}Cl_x$
- High absorption above Eg
- High transmission below Eg
- Large carrier life time of ~300ns
- Strong hysteresis is observed
- Reverse measured IV: 15% efficiency

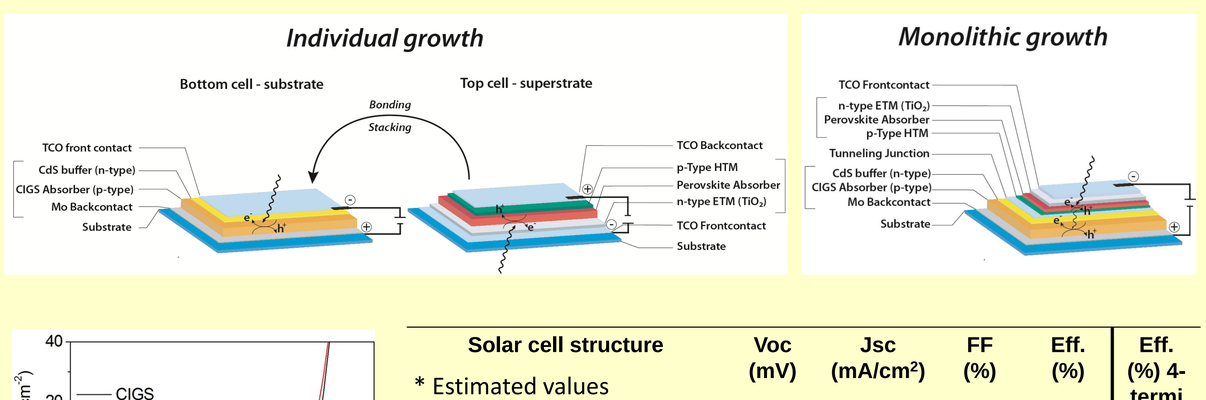


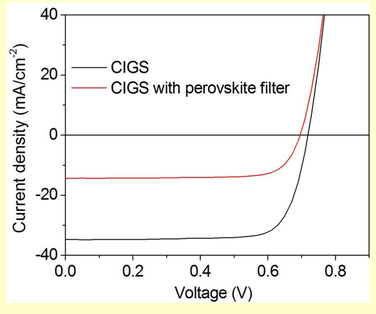


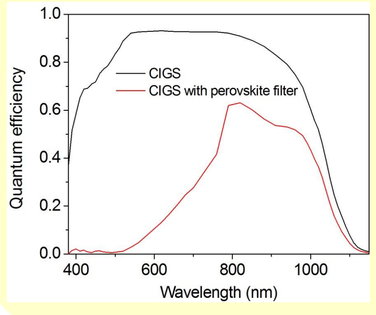
	PCE (%)	J_{sc} (mA/cm2)	V_{oc} (V)	FF (%)
swfwd	1.56	12.74	0.62	19.79
swbwd	9.34	18.92	0.83	59.95
swbwd (1.8V_90s)	15.02	19.07	1.08	73.01

[2] Liu, Johnston, Snaith, *Nature* **501**, 395 (2013).

Perovskite-CIGS Tandem Structure







Solar cell structure * Estimated values	Voc (mV)	Jsc (mA/cm²)	FF (%)	Eff. (%)	Eff. (%) 4-termi
State of the art CIGS on PI	719	34.8	77.2	19.3	-
CIGS with Perovskite filter	695	14.4	77.2	7.7	-
State of the art Perovskite	1078	19.1	73	15.0	-
Perovskite-CIGS Tandem state-of-the-art*	*1773*	*14.4*	*73*	*18.6**	*22.7**
Perovskite-CIGS Tandem reduced reflection*	*1773*	*16.5*	*73*	*21.4**	*23.9**
CI(G)S-Perovskite Tandem shifted CIGS Eg*	*1708*	*19.1*	*73*	*23.8**	*24.3**
*CI(G)S-Perovskite Tandem * optim. perovskite*	*1780*	*19.1*	*77*	*26.2**	*29.3**

Conclusion

- Wide band gap solar cell with 15.0% (Perovskite) achieved
- Perovskite-CIGS tandem solar cells:
  - above 26% in 2-terminal configuration feasible
  - Towards 30% in 4-terminal configuration possible in mid term

Contact: stephan.buecheler@empa.ch

EMPA Materials Science & Technology