High efficiency perovskite single- and multi-junction photovoltaics

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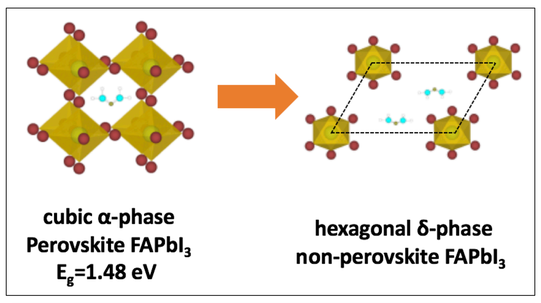
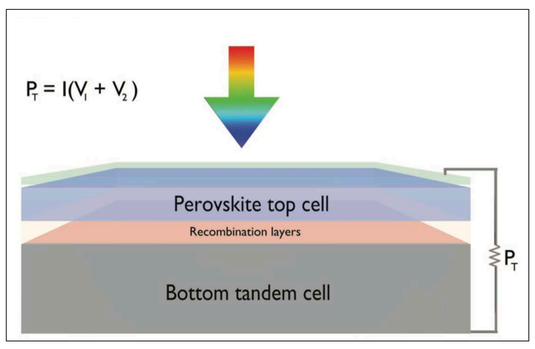
Introduction

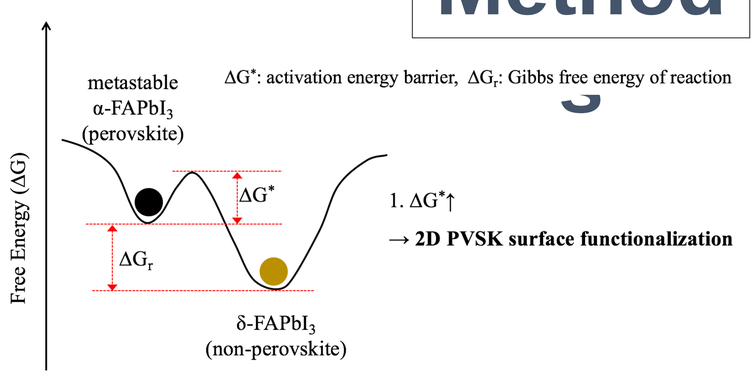
Third generation photovoltaic (PV) technologies offer promises of reduced costs, higher efficiencies, increased throughputs, and further versatility in applications. Among such technologies, hybrid lead halide perovskites PV are promising candidates, which can be fabricated via facile and low-cost solution-based processing techniques and achieve relatively high efficiencies. However, there remain issues that limit their deployment as a commercial PV technology. Perovskites suffer from instability issues for long-term use owed to extrinsic factors such as moisture, oxygen, heat, bias, irradiation, etc, and intrinsic factors such as crystal phase instability. Tandem devices have been explored and demonstrated, however, monolithic devices, in particular PVSK/CIGS, have proven challenging owed to the difficulty in creating smooth and high quality interconnecting layers. Here we demonstrate approaches to tackle these formidable challenges and fabricate high efficiency single junction and tandem PVSK cells reaching certified power conversion efficiencies of 19.77% and 22.43% for single junction and tandem PVSK and PVSK/CIGS tandem solar cells. These results pave the way towards developing technologies competitive with industry standard silicon-based PV with the advantage of greatly reduced fabrication costs.

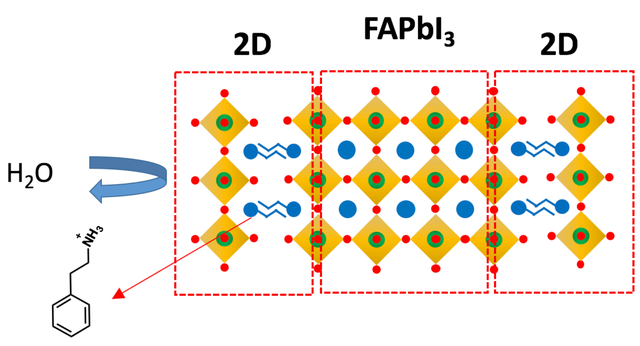




*adopted from ref. 3

Method

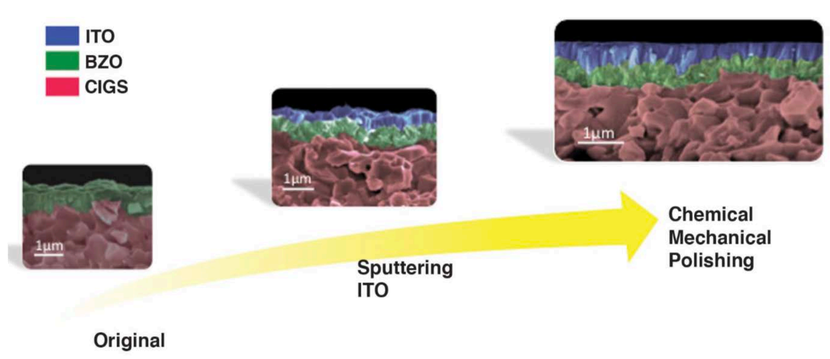




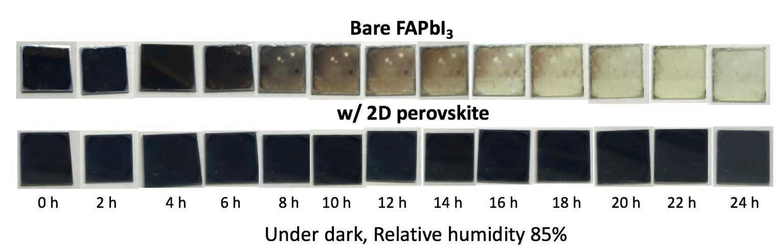
2D perovskite at grain boundaries of $FAPbI_3$
→Locking $FAPbI_3$ perovskite lattice to prevent phase transition

Single Junction PVSK: 2D PEA incorporation can modulate the Gibbs free energy activation barrier via surface functionalization, thus controlling the energetics and kinetics of grain growth. 2D PVSK can create phase-pure $FAPbI_3$ and prevent unwanted 'yellow phase' formation.[1]

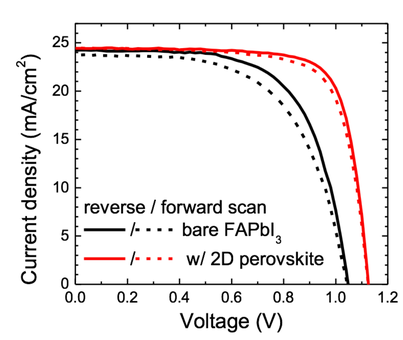
Tandem PVSK/CIGS: The interconnecting layer (ICL) is crucial to create reliable contact between the two subcells of the tandem device. Because the planar perovskite solar cell is composed of several functional layers (nm) that are sensitive to substrate roughness, the challenge is to ensure the integrality of the two subcells, which relies heavily on the transparent top electrode of CIGS. CMP is a widely-used method for ICs and suitable to create an ultra-smooth surface for PVSK to be deposited on. Thus, we explored this method for integration of the two subcells.[2]

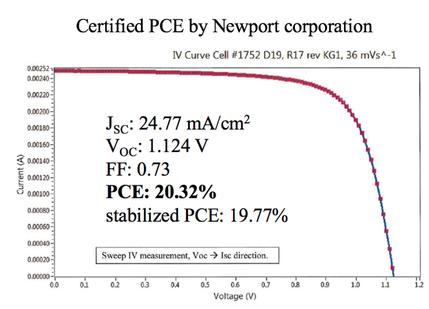


Results



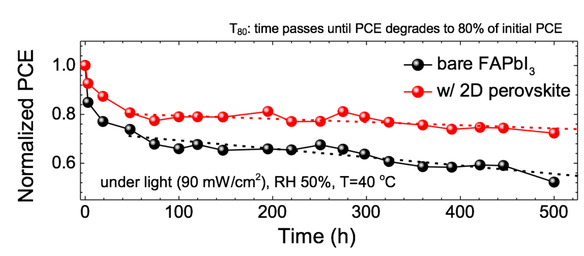
Single Junction PVSK: 2D PEA greatly enhanced PVSK stability and improved performances significantly via forming pure black phase PVSK, mitigating defects, and preventing moisture infiltration into the film.[1]





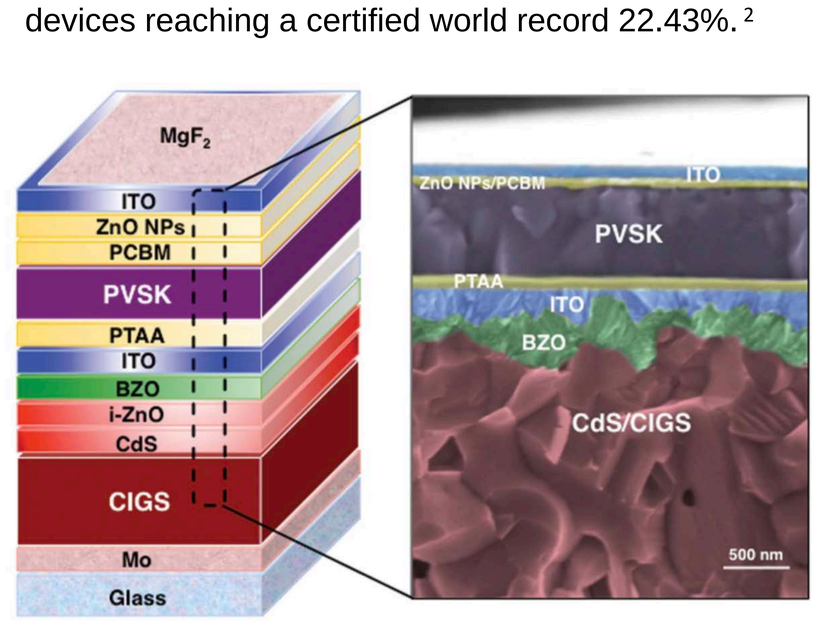
		J_{sc} (mA/cm²)
Bare $FAPbI_3$	Reverse scan	**24.23**
	Forward scan	23.70
w/ 2D Perovskite	Reverse scan	**24.44**
	Forward scan	24.46

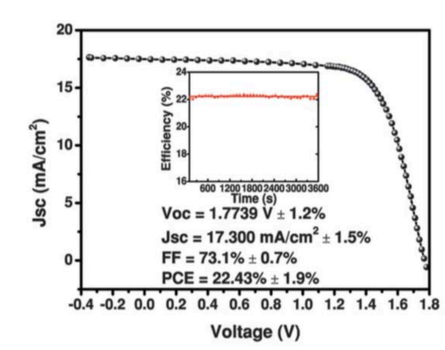
V_{oc} (V)	FF	PCE (%)
1.048	**0.646**	**16.41**
1.044	0.603	14.91
1.126	**0.765**	**21.06**
1.125	0.740	20.37

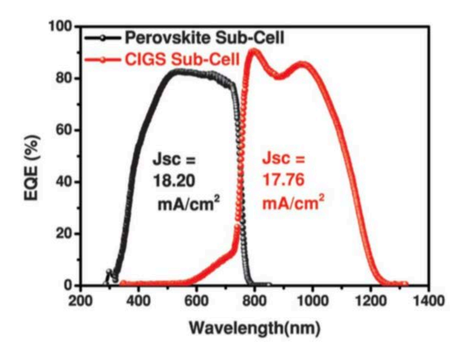


T_{80} lifetime:
592 h → 1362 h

Tandem PVSK/CIGS:
The use of CMP alongside an effective ICL design was able to overcome the limitations of sub-device integration and achieve high performance tandem devices reaching a certified world record 22.43%.[2]







Conclusions

A world record efficiency PVSK/CIGS tandem device was realized alongside a significantly improved longevity for a single junction PVSK device employing 2D/3D PVSK materials. These works are important milestones for realizing commercializable single junction and tandem PVSK based PV technologies in the near future.

References

1. J.-W. Lee and Y. Yang et al, *Nat. Commun.*, **2018**, 9, 3021.
2. Han et al., Science 361, 904–908 (2018).
3. *Adv. Energy Mater.* **2017**, 1602761.

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