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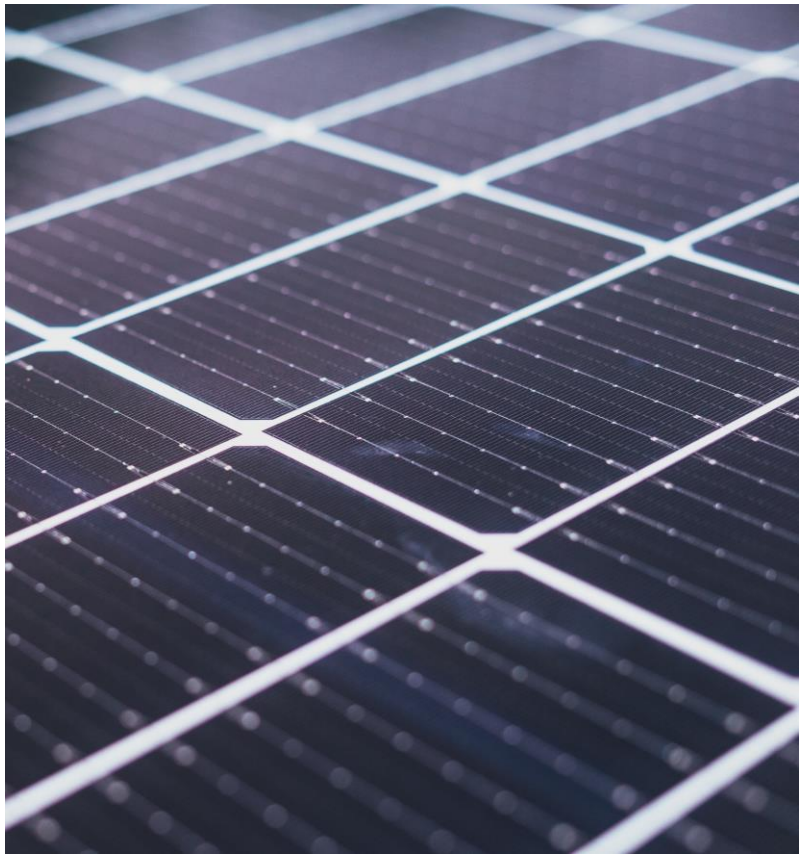

Advancements in Perovskite-Based Solar Technology

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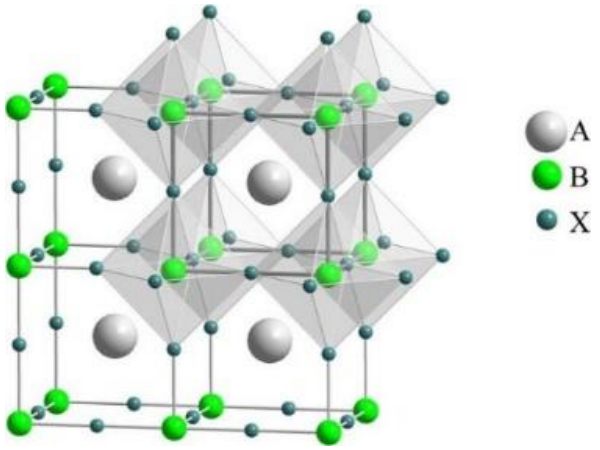
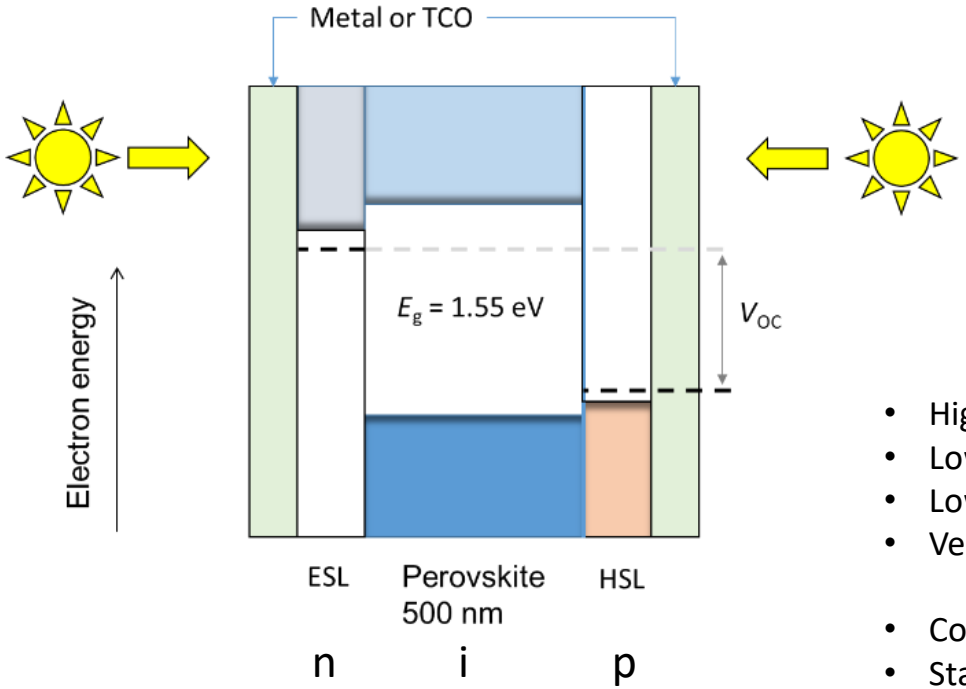
Perovskite solar cells

Lead halide perovskite semiconductors: the new superstar in opto-electronics



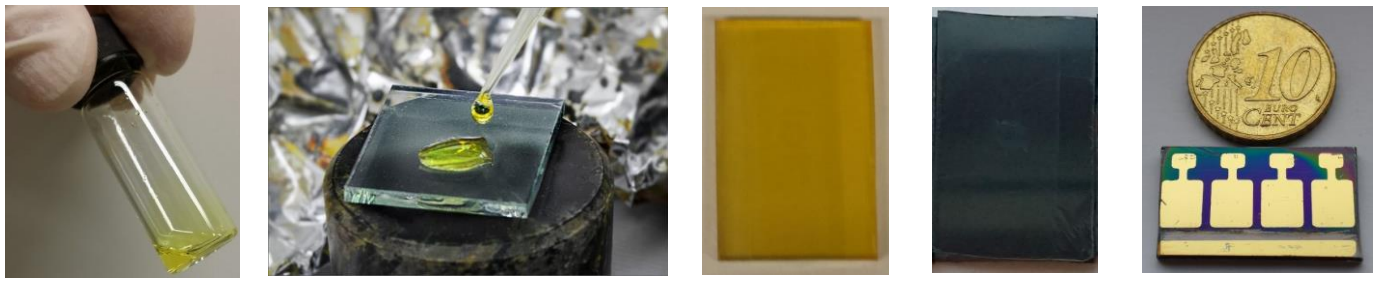
ABX_3
Lead halide perovskite
$MAPbI_3$



- High solar cell efficiency (>26%)
- Low cost
- Low-temperature processing
- Versatile device configurations

- Contains lead (Pb), toxic
- Stability issues

Wet-chemical processing of perovskite solar cells



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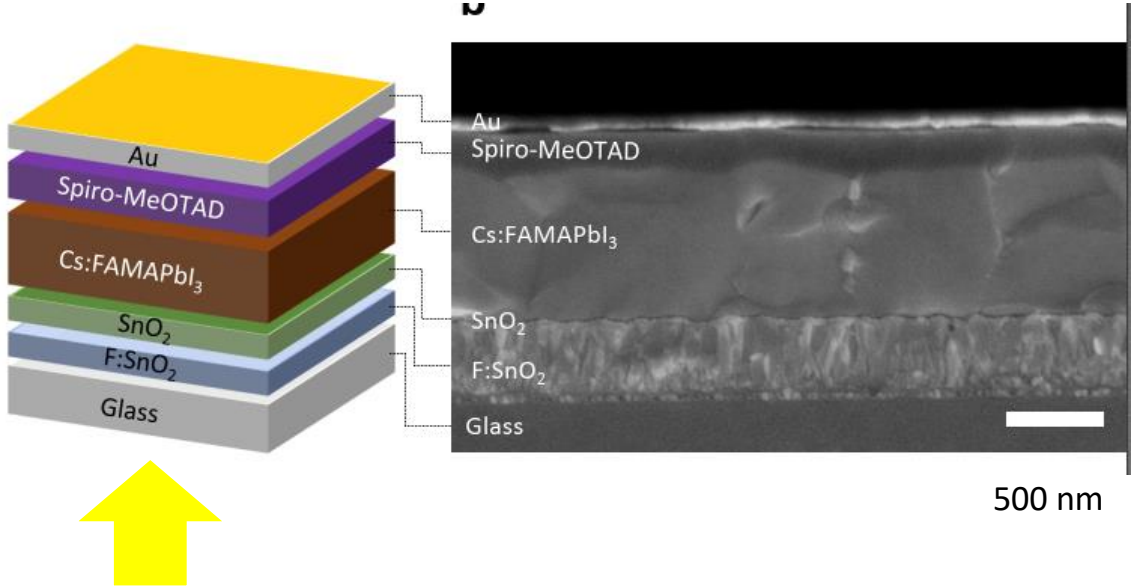
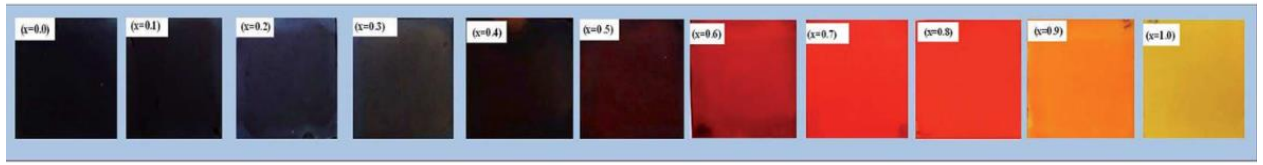
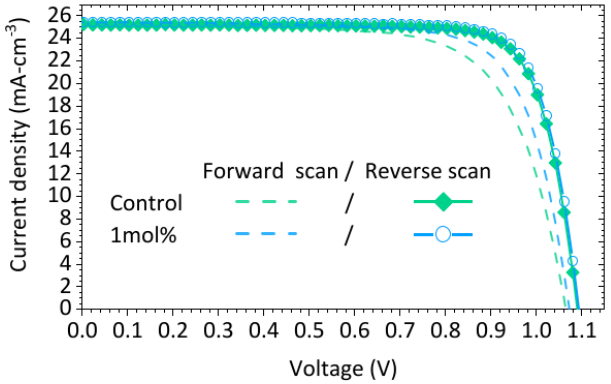
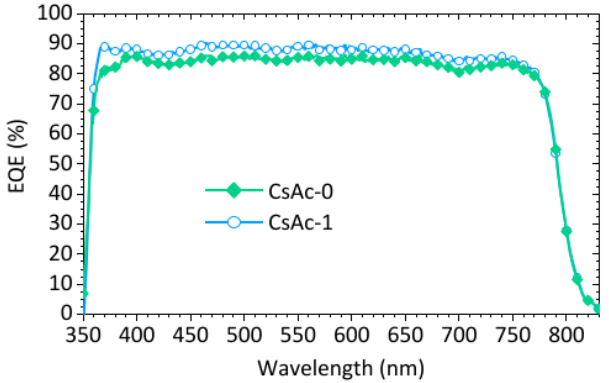




Tuning of the bandgap by iodide to bromide substitution in $MAPbI_3$

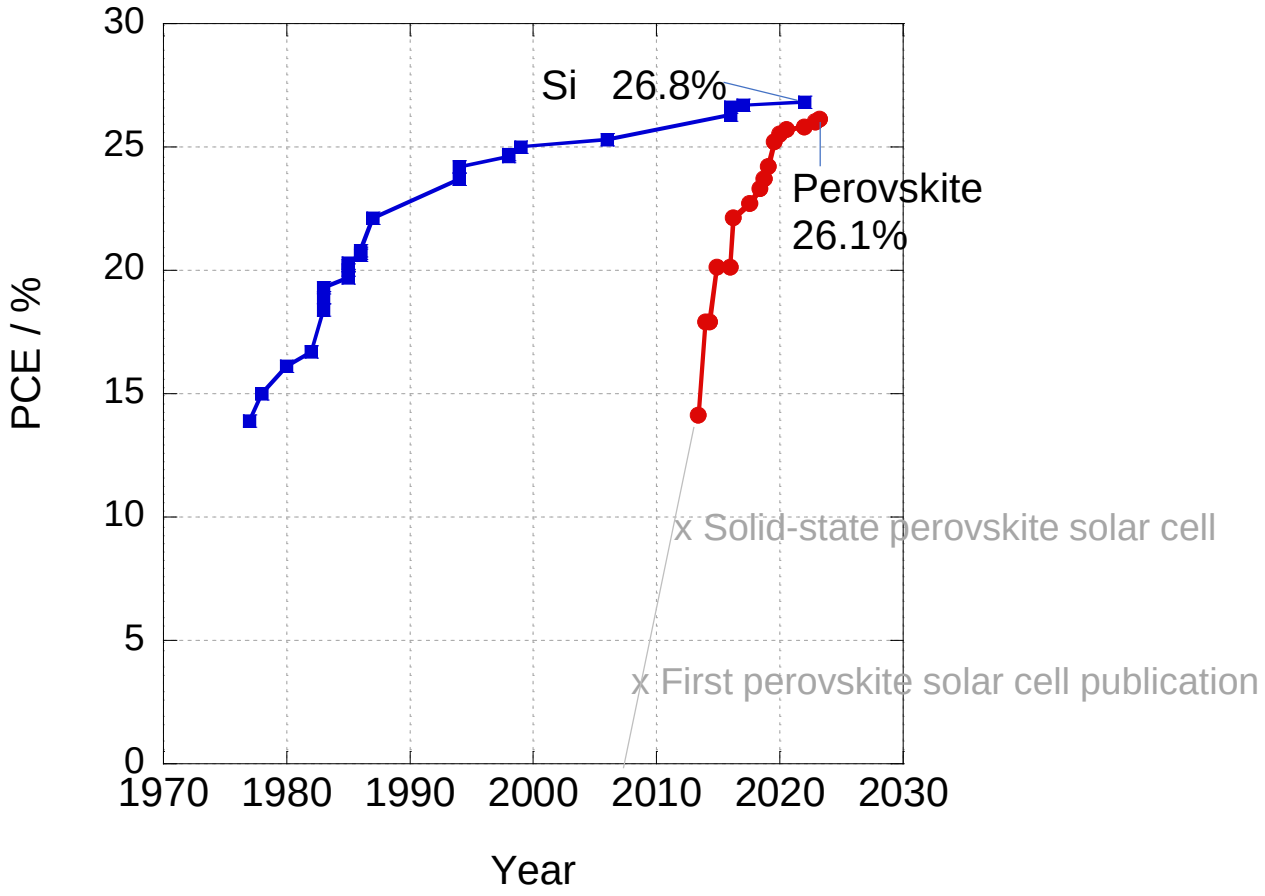




Stability:
- Defects, ion movement
- Phase instability
- Chemical degradation
- Water sensitive
- Perovskite / metal

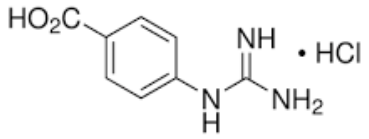
Efficiency:
- Carrier recombination at defects / interfaces
- Energy losses
- Optical losses

NREL chart: certified solar cell efficiencies



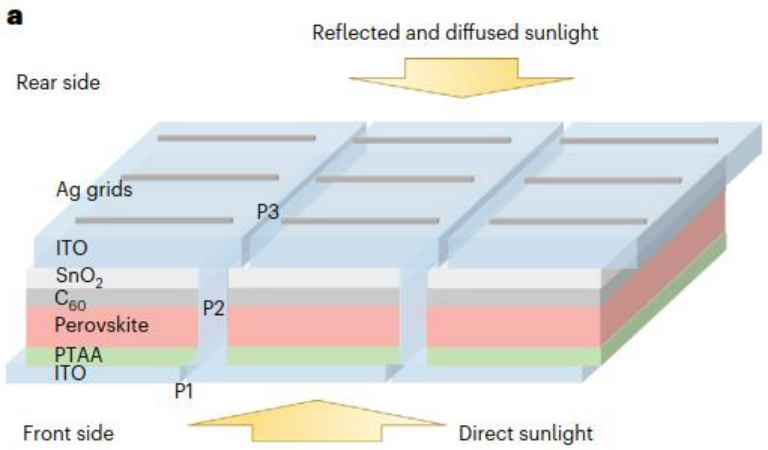
- There is still progress in the PCE of perovskite single junction solar cells
- U. of Science and Technology of China
  - $FAPbI_3$ (FA= formamidinium)
  - polycrystalline
  - Device structure: n-i-p
  - PCE: 26.1% A =0.05127 cm^2
  - V_{OC} 1.20 V , J_{SC} 25.7 mA cm^{-2}, FF 84%
- Progress in Photovoltaics (Solar cell efficiency tables (version 62)
  - 24.35 ± 0.5% 1.007 cm^2 (1.159/ 25.60/ 82.1)
  - 22.4 ± 0.5% 26.02 cm^2 minimodule, 8 cells (1.127/ 25.61/ 77.6)
  - 18.6 ± 0.7% 809.9 cm^2 (44.7/ 0.479/70.3) 39 cells
  - 17.1% 1.2 m x 0.6 m UtmoLight (China)

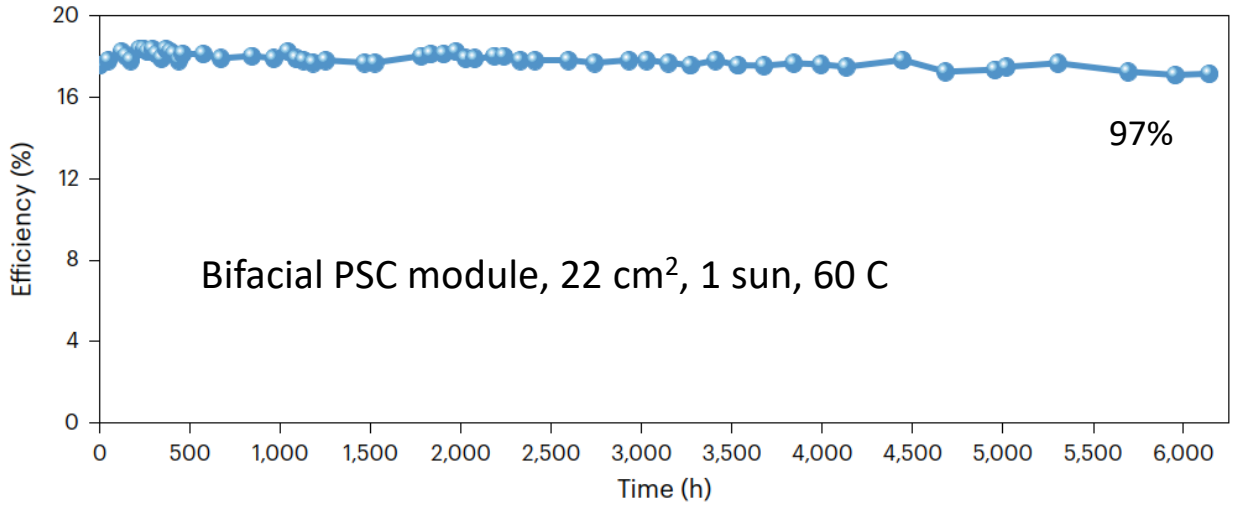
- What's new in the perovskite solar cell field?
  - Self-assembled molecules (SAMs) as hole-selective contact (p-i-n solar cells)
  - Additives in perovskite precursor solution
  - Interfacial modifiers
  - Heterojunction Pb/Pb-Sn perovskite
    - A 3D Pb perovskite layer on top of mixed Sn-Pn to improve solar cell properties
  - Co-deposition of hole-selective contact and perovskite
    - SAM (Me-4PACz) in perovskite precursor solution
    - 24.5% PCE; X. Zheng, .., Nature Photonics 2023
  - P-i-n catches up with n-i-p: 25.6 % for p-i-n (Alex Jen, Hongkong)
    - SAM
    - Additive in perovkite precursor solution
    - Surface passivation



Stability - reliability

- commercial solar modules degrade with 0.5% per year of the rated power output, amounting 40 years life time for 80% of its performance





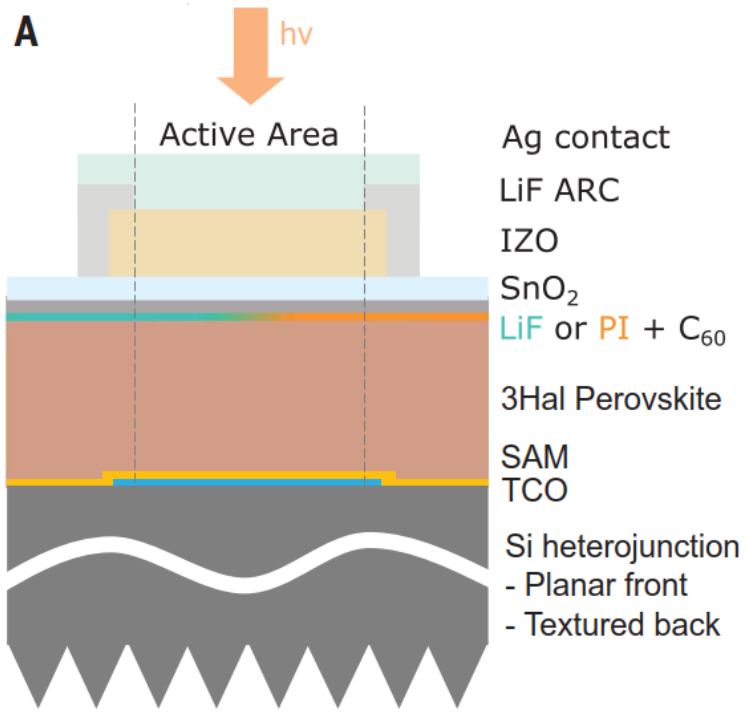
Hangyu Gu, .., Jinsong Huang, Nature Energy 2023 https://doi.org/10.1038/s41560-023-01254-3
(Chapel Hill USA)

Tandem solar cells

- Perovskite on Si, 2-T
  - Oxford PV 28.6% 258 cm^2 1.909V/ 19.11 mA cm^{-2}/ FF 78.3
  - KAUST 33.7% 1.0035 cm^2 1.974 V/ 20.99 mA cm^{-2} / FF 81.3
  - Helmholtz 32.5% : triple halide perovskite

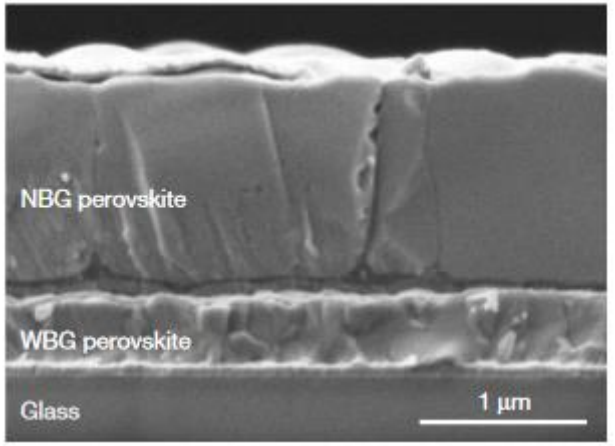
$Cs_{0.22}FA_{0.78}Pb(I_{0.85}Br_{0.15})_3$ + 5% $MAPbCl_3$: bandgap 1.68 eV

SAM: 2-PACZ
Top passivation: piperazinium iodide PI
V_{OC} for single junction: up to 1.28 V, tandems up to 2.0 V



Mariotti et al., Science 381, 63–69 (2023)

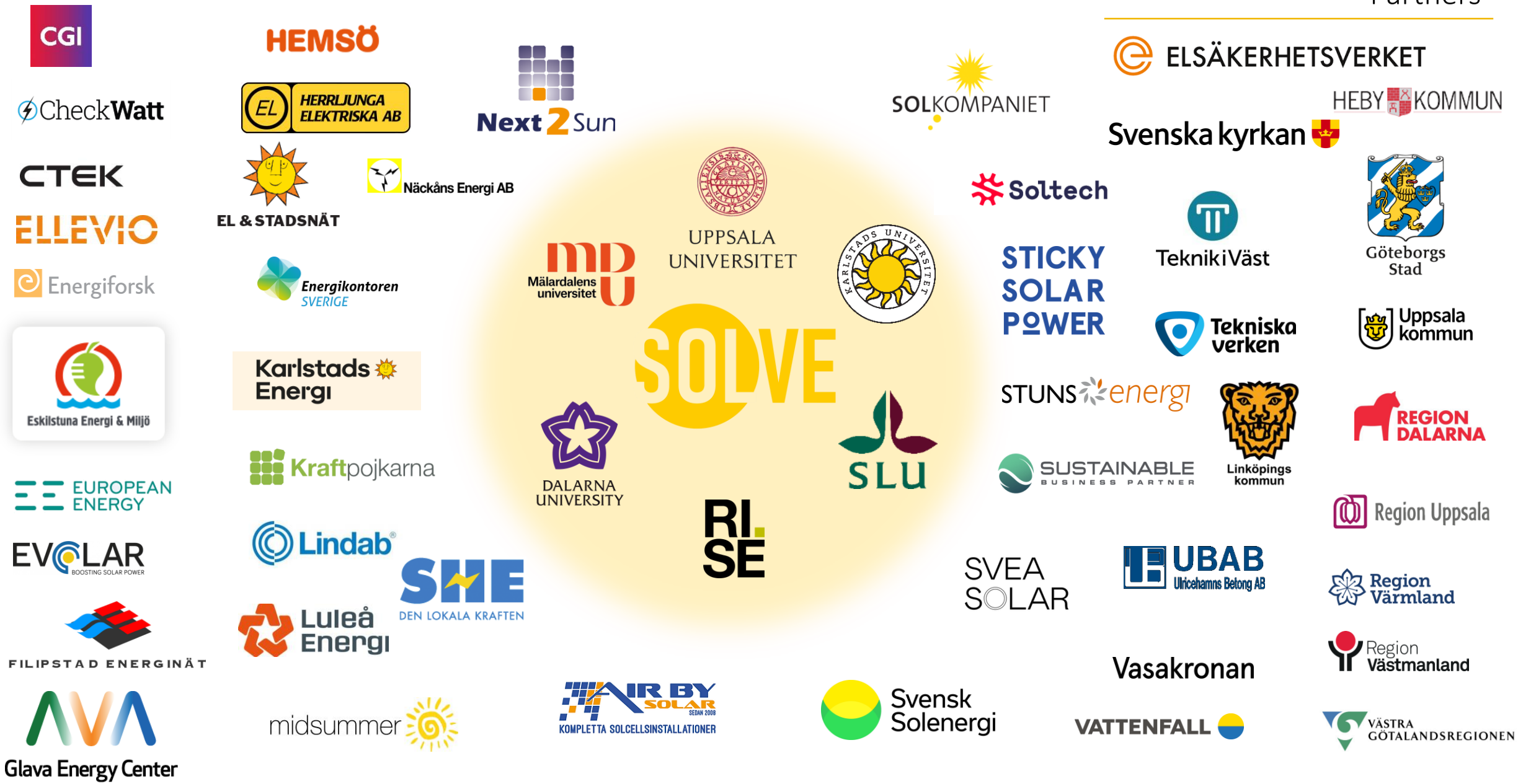
- Tandem solar cells: *other*
  - Perovskite double junction
    - Pb perovskite (1.8 eV) + Sn-Pb perovskite (1.2 eV)
    - 29.1 ± 0.5% 0.0489 cm^2 (2.154 V/16.51 mA cm^{-2} / FF 81.7)
    - 28.2 ± 0.5% 1.038 cm^2 (2.159 V/ 16.59 mA cm^{-2}/ FF 78.9)
    - Hairen Tan et al. , Nature | Vol 620 | 31 August 2023



  - Perovskite triple junction
    - 25.2% lab, 23.9% certified

  - Perovskite / organic 25.2%
  - Perovskite / CIGS 24.2%

Partners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To be continued …

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