Direct Solar Hydrogen Generation at 20% Efficiency Using Low-Cost Materials

Astha Sharma[1]*, Yuan Wang[3]*, The Duong[1], Fiona J. Beck[1], Chuan Zhao[3], Kylie Catchpole[1] and Siva Karuturi[1,2]

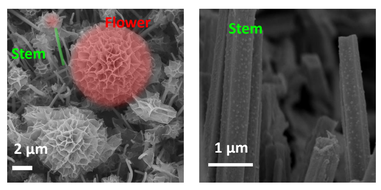
ACT-H2 HYDROGEN RESEARCH

Background

- Direct solar hydrogen generation (DSTH) is a promising alternative for renewable hydrogen generation
- Current issues with existing technology:
  - ➢ Use of high-cost noble metal catalysts and/or semiconductors
  - ➢ Efficiency limitations for low-cost high bandgap semiconductors
- Our solution:
  - ➢ An all-low-cost system for direct solar hydrogen generation with 20 % solar-to-hydrogen conversion efficiency
  - ➢ Pathway to achieve US-DOE 2025 target

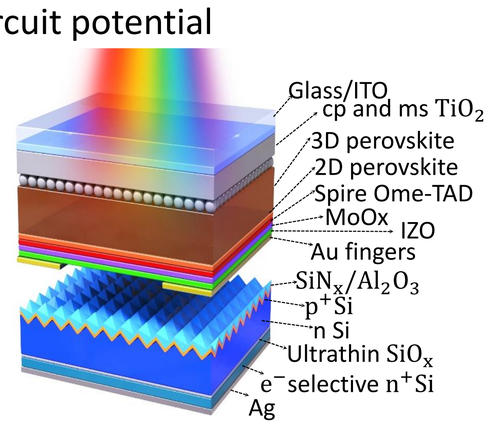
Methodology

- NiMo HER catalyst with flower stem morphology and record HER performance



SEM images of NiMo flower-stem morphology

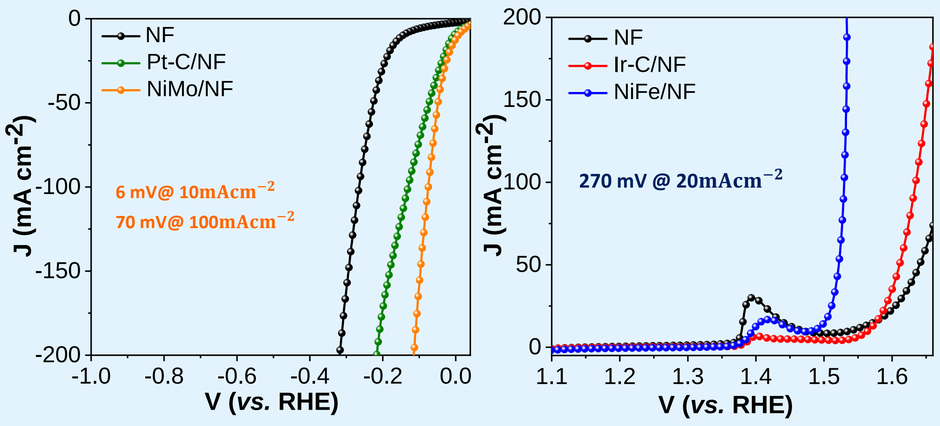
- Perovskite-Si tandem solar cell with record open circuit potential



Schematic illustration of the device architecture of series-connected perovskite-Si tandem cell.

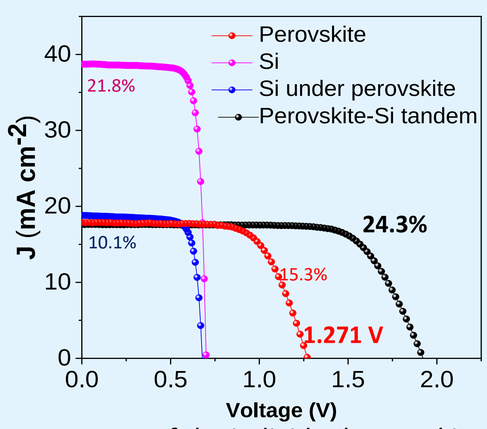
Results

1 Catalyst microstructure



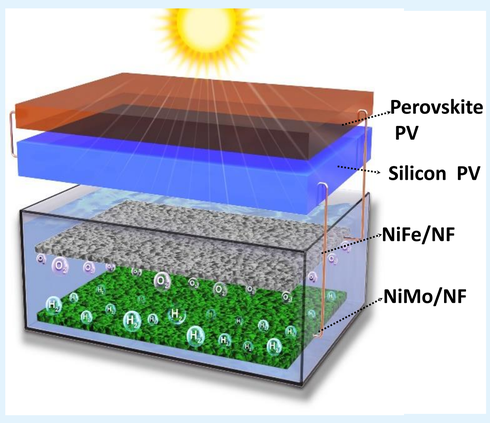
Linear sweep voltammetry (LSV) curves of, left: NiMo/NF, Pt-C/NF and NF electrodes for HER, right: NiFe/NF, Ir-C/NF and NF for OER

2 Perovskite-Si tandem PV

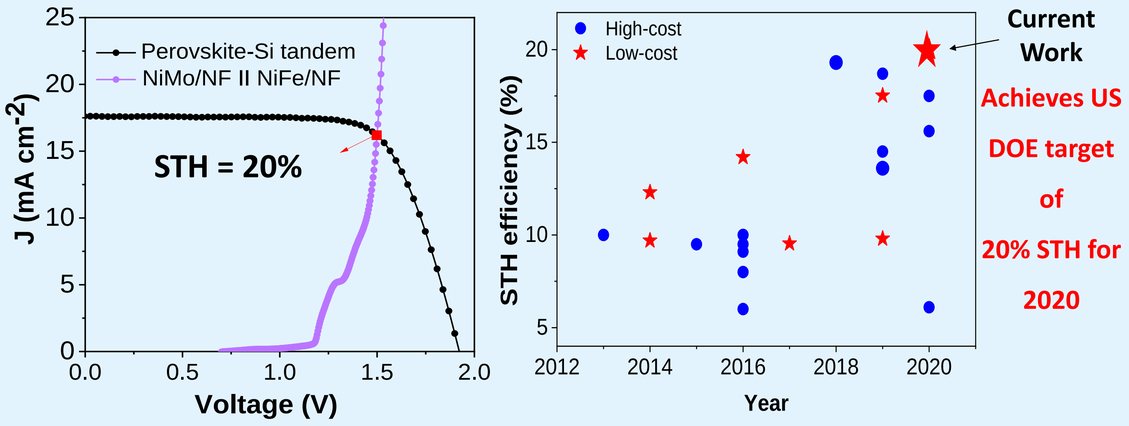


J–V curves of the individual perovskite and Si solar cells and the series-connected tandem PV under AM1.5G illumination

3 Direct solar hydrogen generation

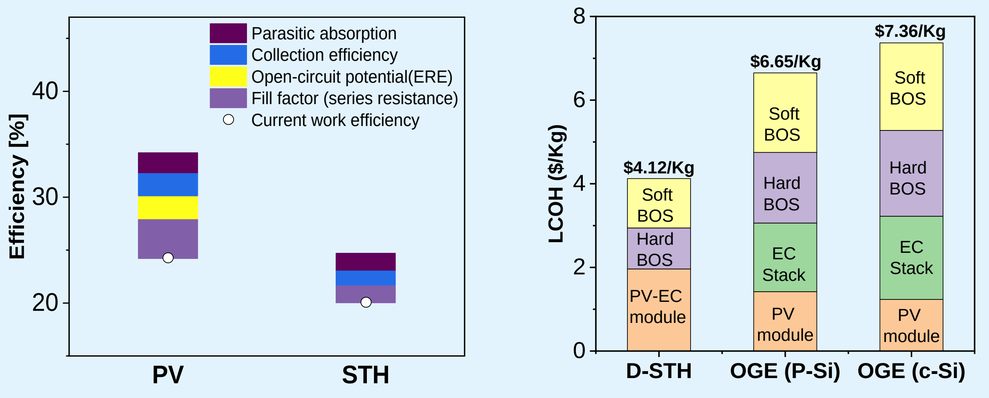


perovskite-Si tandem PV integrated electrocatalyst direct solar hydrogen generation system

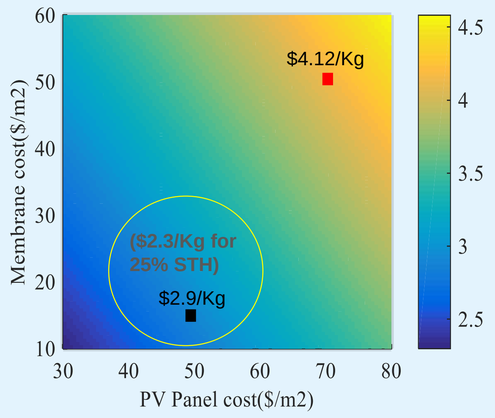


Left: J–V curve of perovskite-Si PV with the LSV curve of NiMo and NiFe electrodes, right: Comparison of the STH efficiency achieved in this work with the reported values in literature

4 Technoeconomic analysis and efficiency improvements



Left: Realistically achievable STH conversion efficiencies by improving the perovskite solar cell performance. Right: LCOH for DSTH and off-grid electrolyzer (OGE) systems.



Surface plot of the LCOH for the DSTH system as a function of PV module and electrocatalyst costs

Conclusion

- Key takeaway:
  - ➢ Record STH efficiency of 20% for direct solar hydrogen generation
  - ➢ NiMo electrodes with flower-stem morphology, exceptional HER performance
  - ➢ Improved perovskite top cell with a record open circuit voltage
  - ➢ Improvement in perovskite cell could enhance the STH efficiency to 25%
  - ➢ LCOH of $4.1/Kg at 20% STH efficiency
  - ➢ LCOH ~2 $/Kg, for 25% STH efficiency and cost reduction

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Further Information

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astha.sharma@anu.edu.au
siva.karuturi@anu.edu.au

Australian National University

[1]School of Engineering, The Australian National University, Canberra ACT 2601, Australia
[2]School of Physics, The Australian National University, Canberra ACT 2601, Australia
[3]School of Chemistry at the University of New South Wales (UNSW)