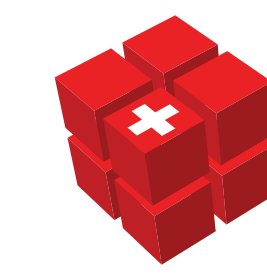


Perovskite solar cell research at the Laboratory for Thin Films and Photovoltaics

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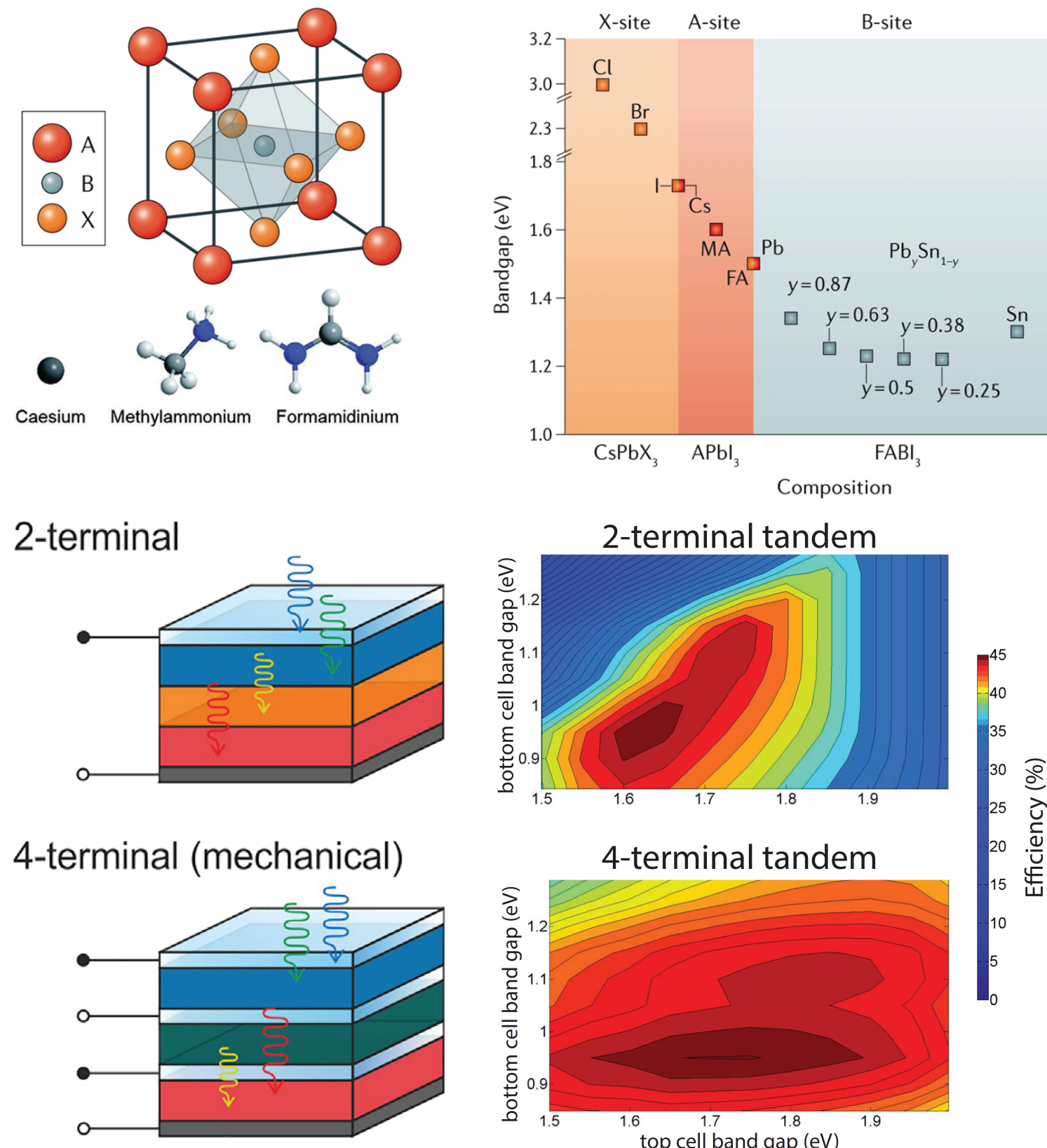


Empa

Materials Science and Technology

Perovskite research focus

Organic-inorganic metal halide perovskites



What are perovskites?

- Perovskite refers to ABX₃ crystal structure.
- It is a class of semiconductor materials with excellent opto-electronic properties for photovoltaic applications, etc.

What is the uniqueness of perovskites?

- High efficiency of 25.5 %¹⁾
- Broad bandgap tunability
- Solution-based fabrication, e.g. blade coating, dip coating or spin coating.

Why are we interested in perovskite?

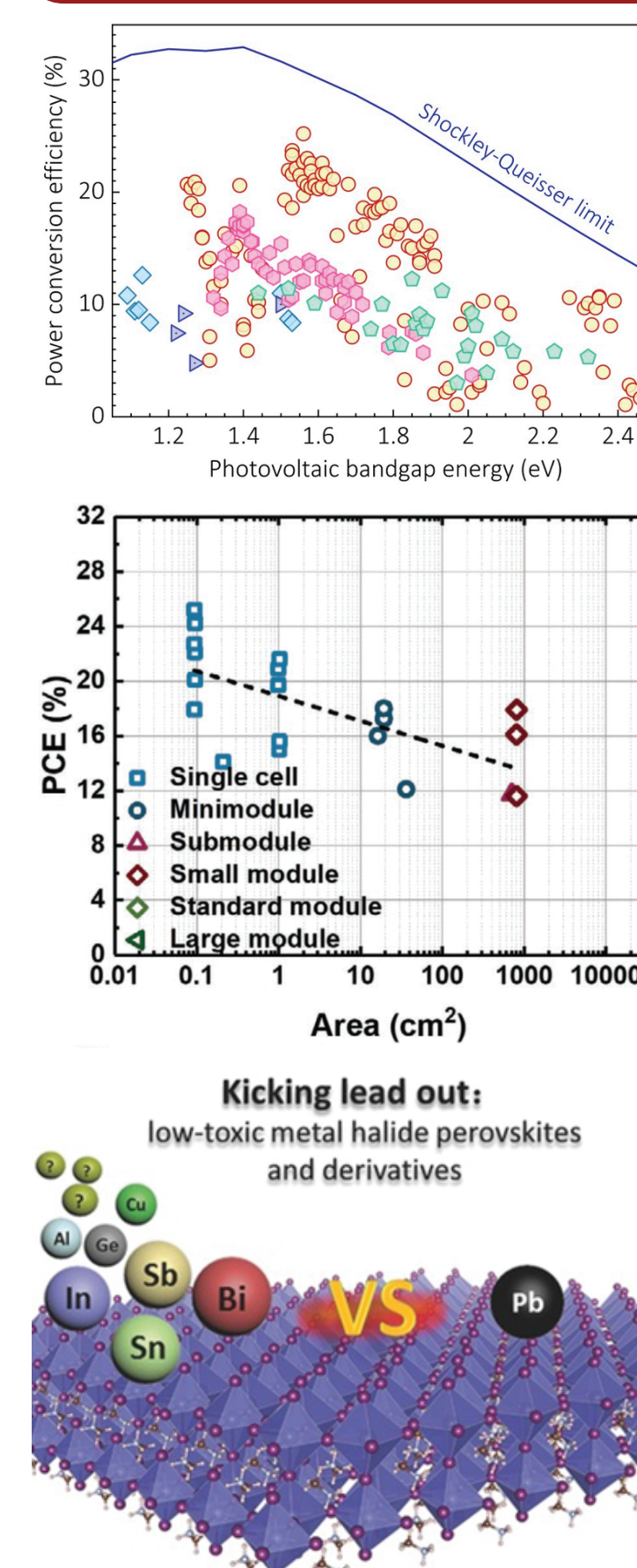
- Suitable for perovskite/silicon, perovskite/-CI(G)S or all-perovskite tandem solar cells (2-terminal, 4-terminal configuration) to break the Shockley-Queisser limit of single junction solar cells.

¹⁾ www.nrel.gov/pv/cell-efficiency

²⁾ Anaya, M. et al. (2017), Joule, 1(4), pp. 769–793.

³⁾ Eperon, G. E. et al. (2017), Nature Reviews Chemistry, 1(12).

Challenges of perovskite solar cells



What are the challenges for commercialization of perovskite solar cells ?

- Efficiency: Our aim is to develop highly efficient near-infrared-transparent wide bandgap perovskite top cells and narrow bandgap perovskite bottom cells for all-thin film tandem solar cells.
- Upscalability: We work on scalable deposition processes to fabricate high quality and uniform perovskite absorbers with green solvents.
- Stability: Advanced characterization techniques are used to understand the mechanisms which influence the stability of perovskite solar cells.
- Lead toxicity: Lead-free perovskite solar cells are developed for flexible all-perovskite tandem solar cell applications.

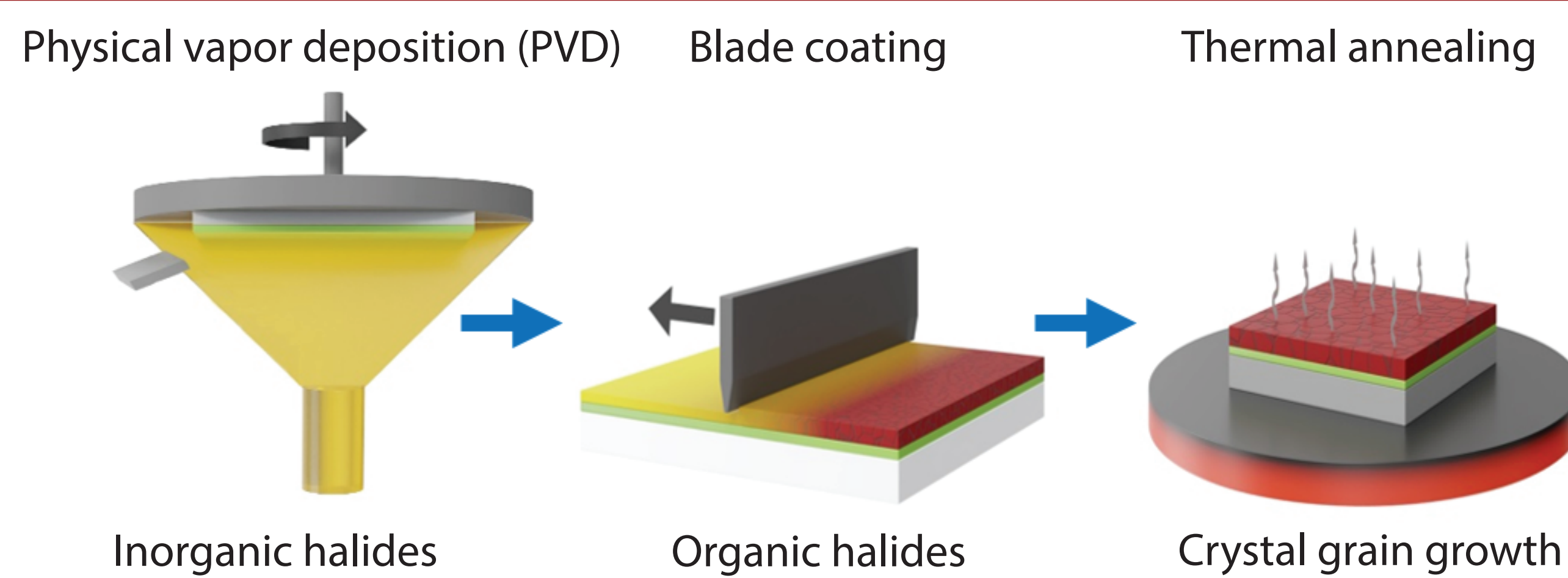
¹⁾ www.emerging-pv.org

²⁾ Lee, S. W. et al. (2020), Advanced Materials, 32(51), pp. 1–25.

³⁾ Lyu, M. et al. (2017), Advanced Energy Materials, 7(15).

Perovskite results

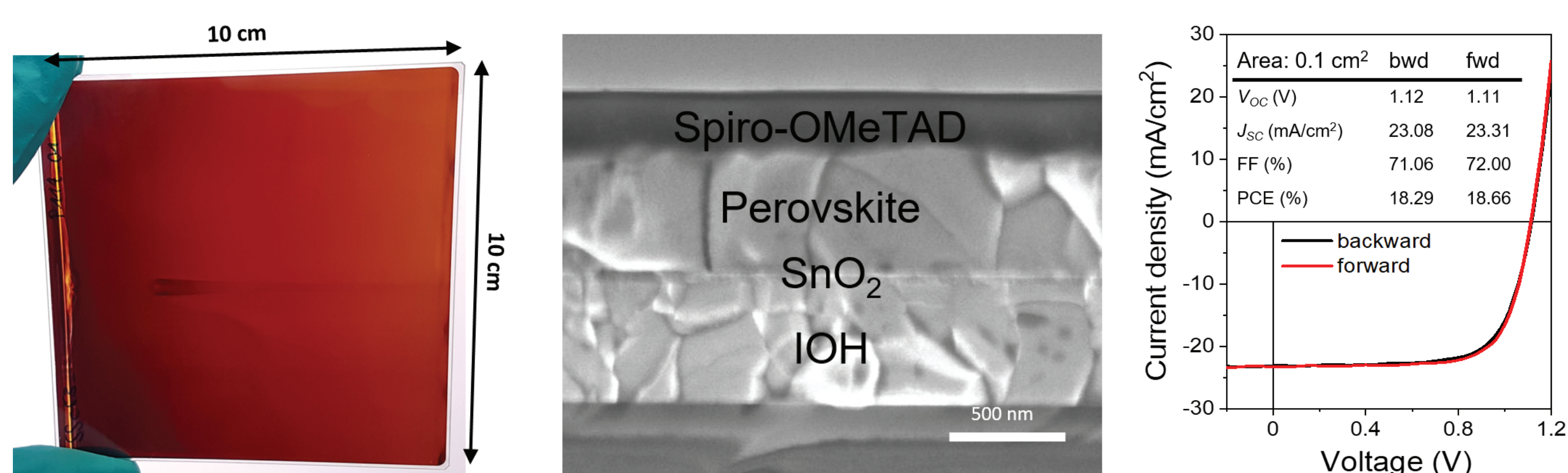
Physical vapor deposition and blade coating



Advantages:

- Perovskite absorber fabricated by industrial-scalable depositions only
- Only green solvents are needed (2-propanol)
- Uniform deposition on large-area substrates
- Suitable to conformally coat rough surfaces, e.g. textured silicon or CI(G)S solar cells

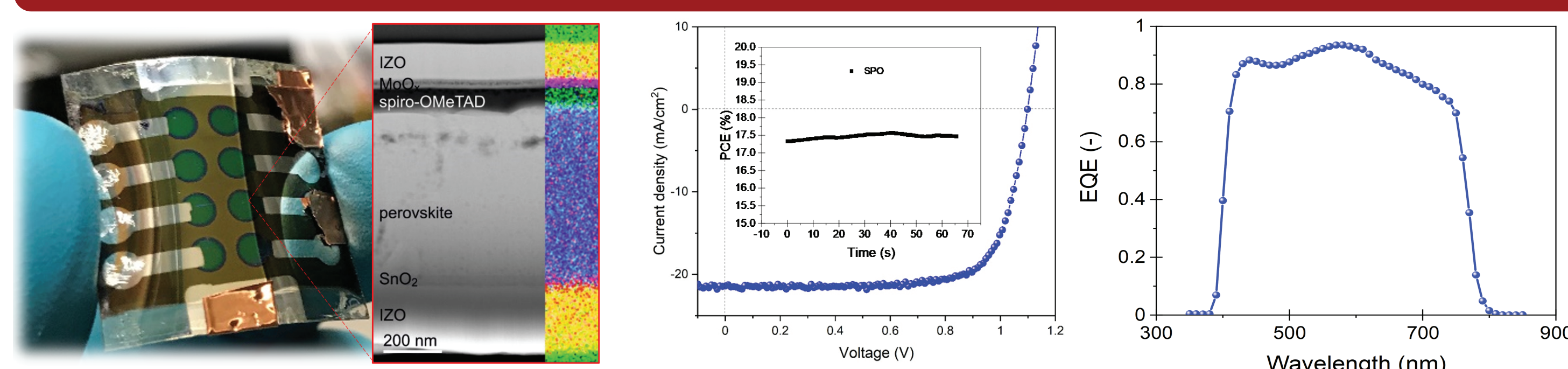
Scalable perovskite solar cells with green solvents



Main achievements:

- Efficiency > 18 % for perovskite solar cell on 5 x 5 cm² substrates
- Perovskite absorber fabricated by PVD and Blade coating
- Both charge transporting layers are blade coated
- Green solvents used: 2-propanol (perovskite), p-Xylene (Spiro-OMeTAD), water (SnO₂)

Flexible semi-transparent perovskite solar cells

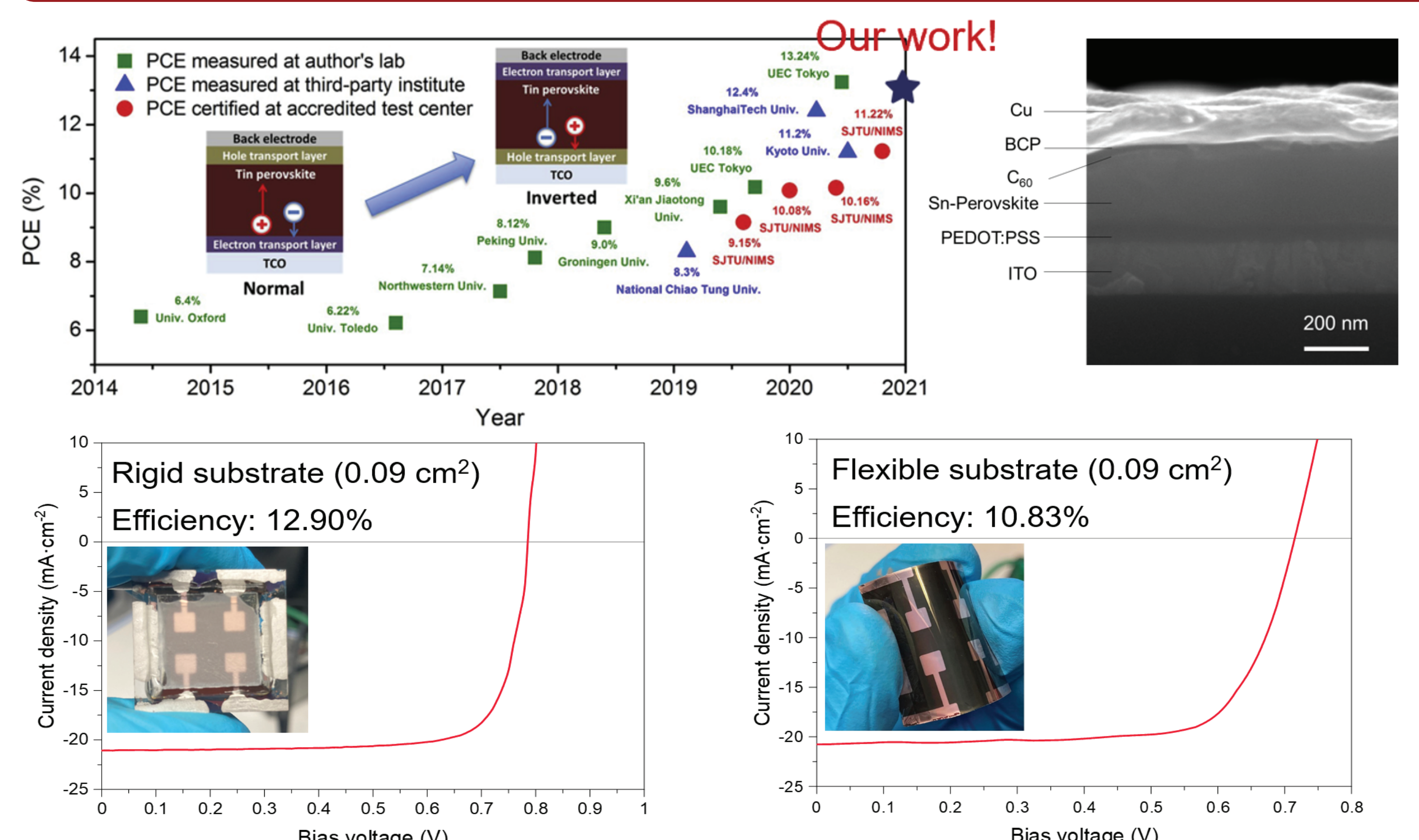


- Flexible near-infrared-transparent PSC with stabilized 17.5 % efficiency on CIGS frontsheet.
- Can be used for perovskite/CIGS tandem solar cells.

Acknowledgement

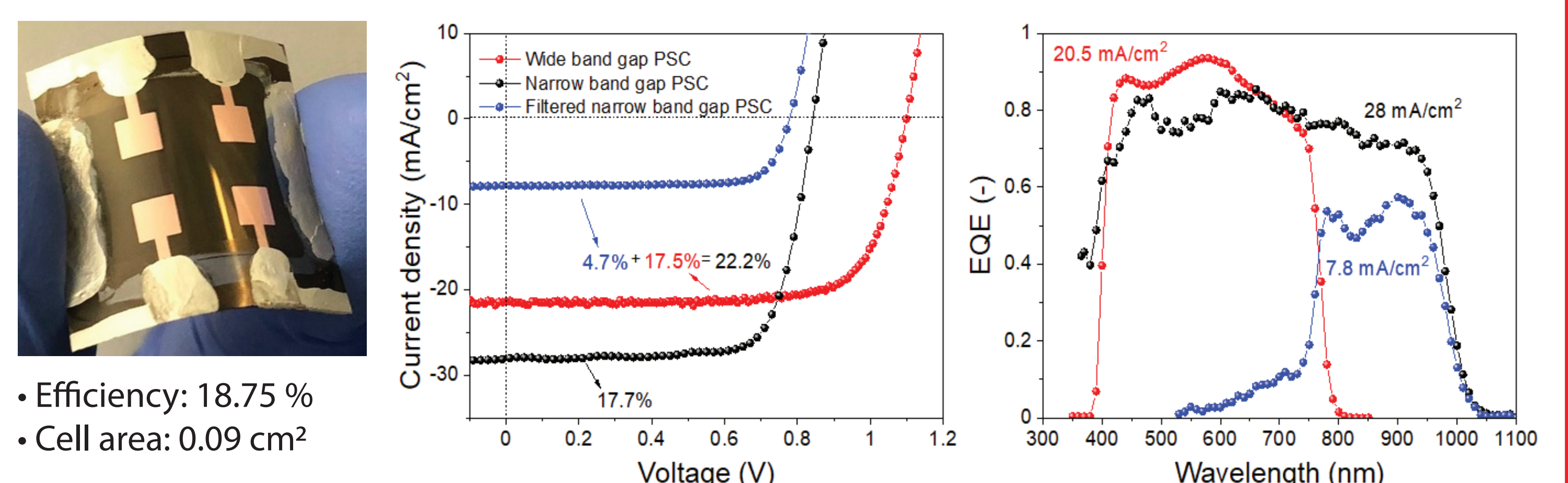
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Lead-free perovskite solar cells



- One of the best efficiencies (12.90 %) realized for Sn-based PSCs on rigid substrates.

Pb-Sn perovskite for flexible all-perovskite tandems



- Best cell efficiency: 18.75 % for 1.24 eV bandgap perovskite solar cell.
- Flexible 4-terminal all-perovskite tandem solar cell with 22.2 % efficiency.

Summary

- PVD and Blade coating is an industrial-scalable perovskite fabrication process without toxic solvents.
- 18.6 % efficient perovskite solar cell by fully scalable deposition methods and green solvents.
- Lead-free perovskite solar cell with 12.9 % efficiency on rigid and 10.8 % on flexible substrates.
- Narrow band gap perovskite solar cell on flexible substrates with 17.7 % efficiency.
- Flexible, near-infrared-transparent wide band gap perovskite solar cell with 17.5 % efficiency
- 22.2 % efficient 4-terminal all-perovskite tandem solar cell on flexible substrate.

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