



UNIQUE

Carbon Based Perovskite Solar Cells with UNI-Directional Electron Bulk Transport: in the QUEst of a Short Time to Market

Dr. Markus Kohlstädt

Fraunhofer Institute for Solar Energy Systems ISE

Heidenhofstraße 2, 79110 Freiburg, Germany

markus.kohlstaedt@ise.fraunhofer.de

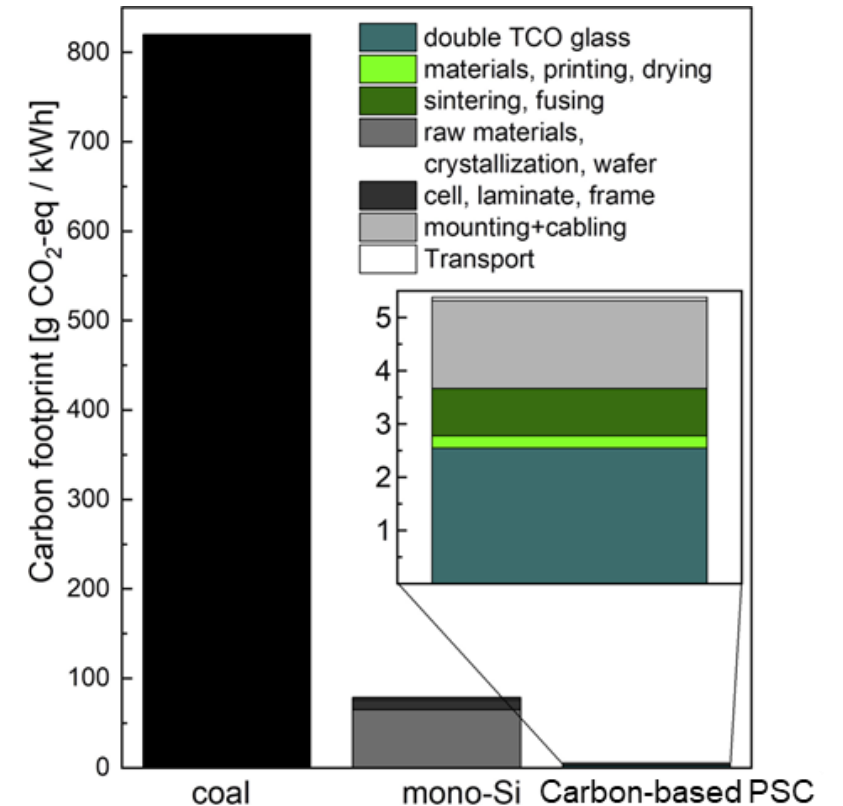
Scientific, technical, commercial challenge(s) addressed

- Photovoltaic research and commercial products that focus on sustainability and foster the future of local PV production in Europe are currently an imperative commitment
- Collaboration of main European centers developing carbon-based perovskite solar cells and related materials to achieve this vision
- **UNIQUE aims to bring back the EU strategic PV manufacturing know-how and value chain to Europe**



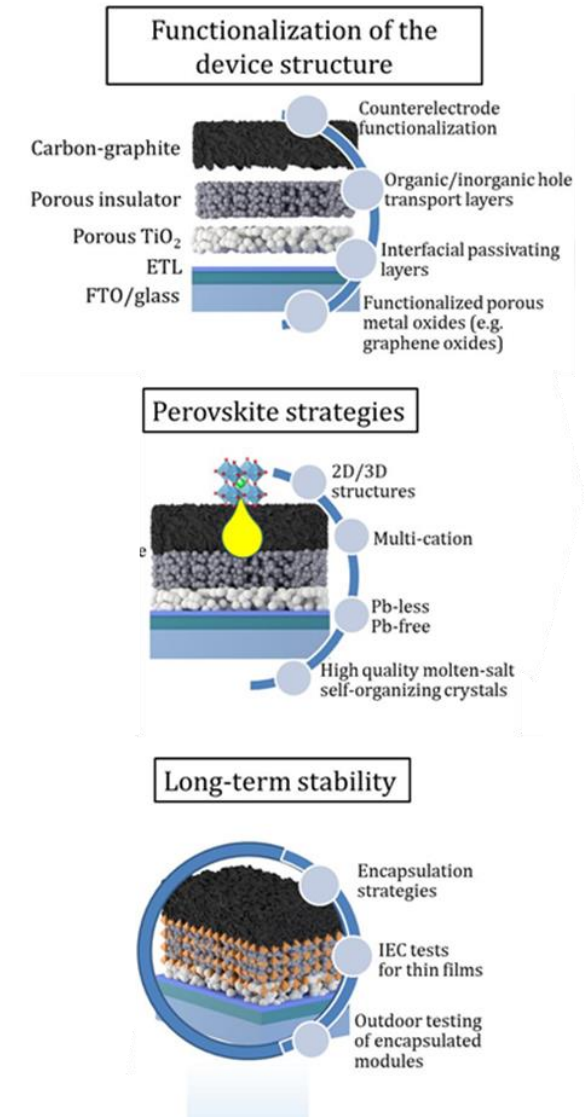
Benefits of carbon electrode based perovskite PV

- Abundant materials
- Low material criticality, can be produced locally
- Low temperature printing process
- Low CO₂ footprint
- Stable electrode
- Easily upscalable



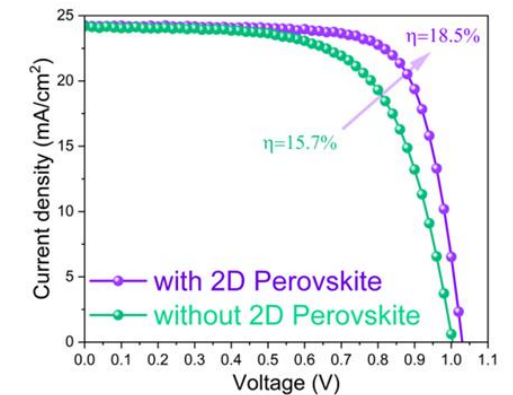
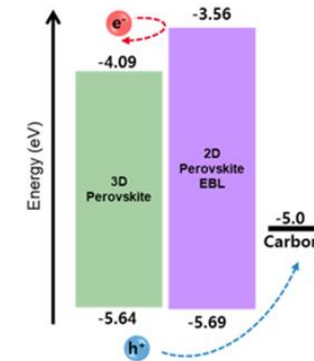
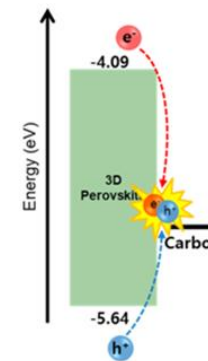
Challenges and Aims

- Reduction of lead-content
- Demonstration of high device efficiency
 - Unilateral charge transport / selective interfaces
 - Enhanced perovskite absorbers
 - Passivation Strategies
- Demonstration of scalable module fabrication in industrial environment
- Outdoor testing of demonstrator module
- Detailed characterization of materials and PV devices



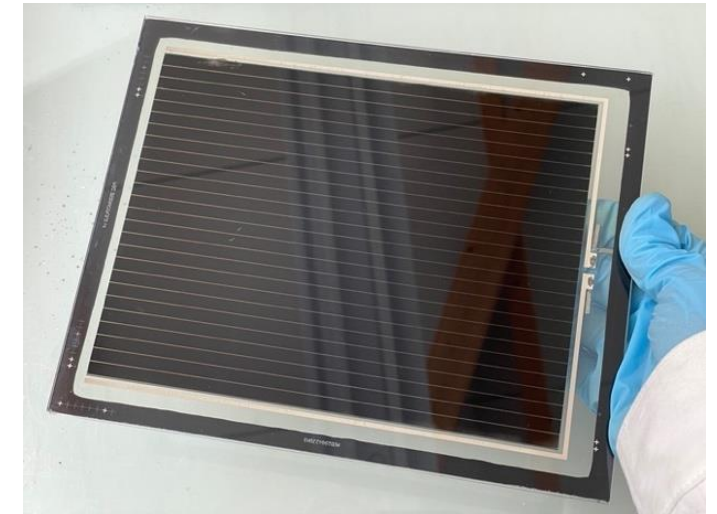
Key outcomes, results and benefits

- Novel Pb-free and Pb-less perovskite absorber materials developed
 - Measured PCE was below par → focus on optimization and upscaling was on Pb-based perovskite materials
- High device efficiency of 18.5% reached
 - Certified PCE of 15.5% for HT route
 - Record values at the time of publication

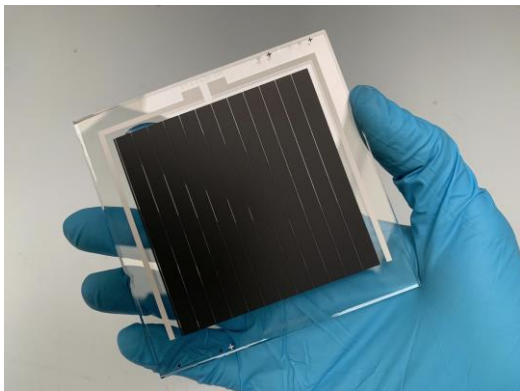


Key outcomes, results and benefits

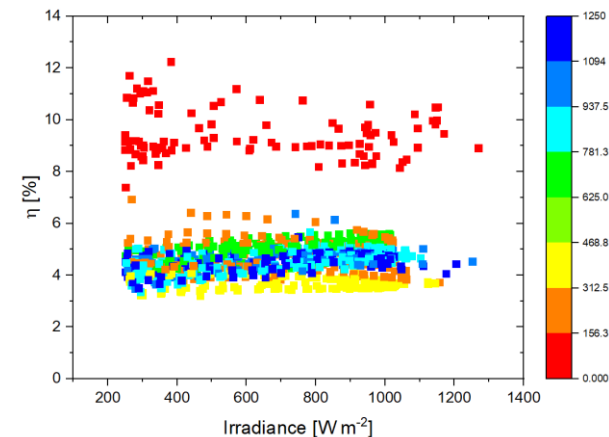
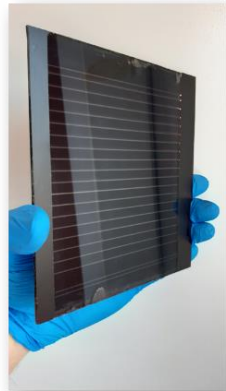
- Scalable module fabrication process established
 - For both two alternative fabrication strategies
 - PCE of 13.8% on 100 cm² area (HT-route)
 - PCE of 8.1% on 80 cm² (LT-route)
 - Scale-up to 500 cm² submodule demonstrated
 - Outdoor testing of demonstrator modules under operating conditions



HT-route module

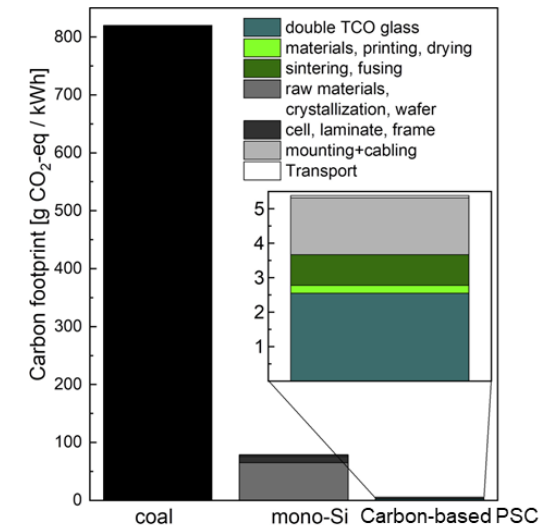


LT-route module



Key outcomes, results and benefits

- Levelized Costs of Electricity: 3.66 €cents per kWh
 - Based on reached module efficiency of 13.9% for 57 cm² module and expected lifetime of 15 years
- Greenhouse Gas Emissions: 3.55 g/CO₂ eq / kWh) [1]
- Greenhouse Gas Emission Decrease: 95% [1]
- TRL 3 → TRL 4/5



[1] Wagner, L., Mastroianni, S., Hinsch, A. (2020). *Joule*, 4 (4), 882–901.

Experiences gained in transnational set-up

- Successful collaboration on a European level, linking academic and industrial partners along the value chain from materials to PV modules
- Academic partners have profited from IP/Know-How generation, networking with partners and dissemination of project results:
 - 38 peer reviewed articles, 397 citations (05/2023)
- Industrial partners continue their activities with respect to material development for Perovskite PV and perovskite module fabrication
- Some partners continue collaboration in the framework of an ongoing Horizon Europe project
 - Project DIAMOND, <https://diamond-horizon.eu>

Critical factors and lessons learned

- SOLAR-ERA.NET provides an excellent platform for transnational projects and enables efficient research to address European SET plan
- Possibility to collaborate on transnational level without the boundaries of Horizon Europe projects (large consortia, large administrative effort)
- Different project start and end times can complicate joint research efforts and reporting

Thank you for your attention!