

Process Engineering for Low-temperature Carbon-based Perovskite Solar Modules

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Outline

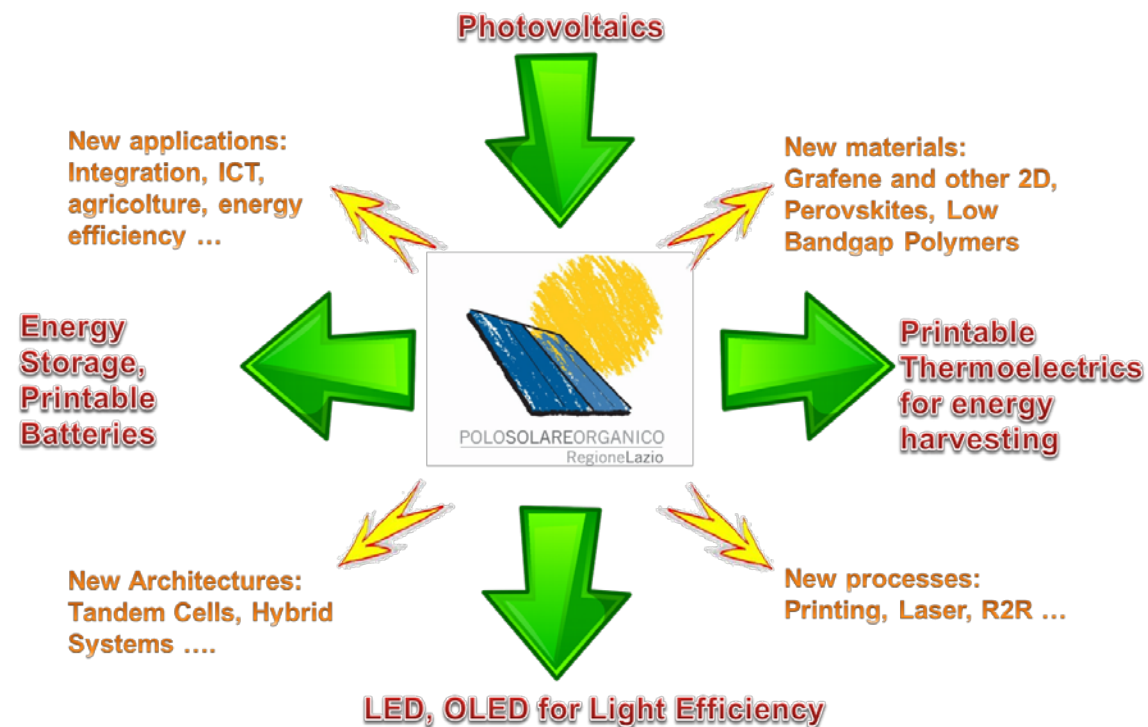
- CHOSE group and laboratories
- Perovskite solar cell technology
- Perovskite solar cell issues
- Carbon-based perovskite solar module
- Results and conclusion



CHOSE: Centre for Hybrid and Organic Solar Energy

Objectives

- Printed electronics
- R&D on organic, dye sensitized and perovskite photovoltaics
- Device design and scaling-up
- **Technology transfer to Industry**



Basic Research

CHOSE

Industrialization

Technology Transfer

Spin-off / Start up

G-LYTE

TIBERLAB

intellienergia S.r.l.
renewableenergyengineering

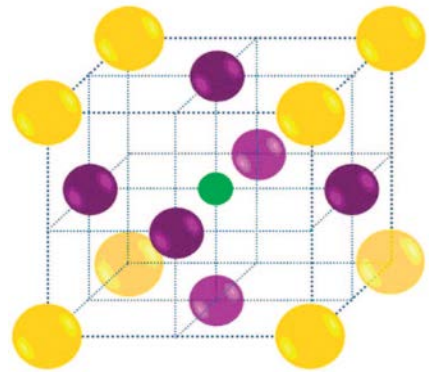
cicci
research

INGEM S.R.L.

dyepower

Perovskite solar cell

Perovskite: ABX_3

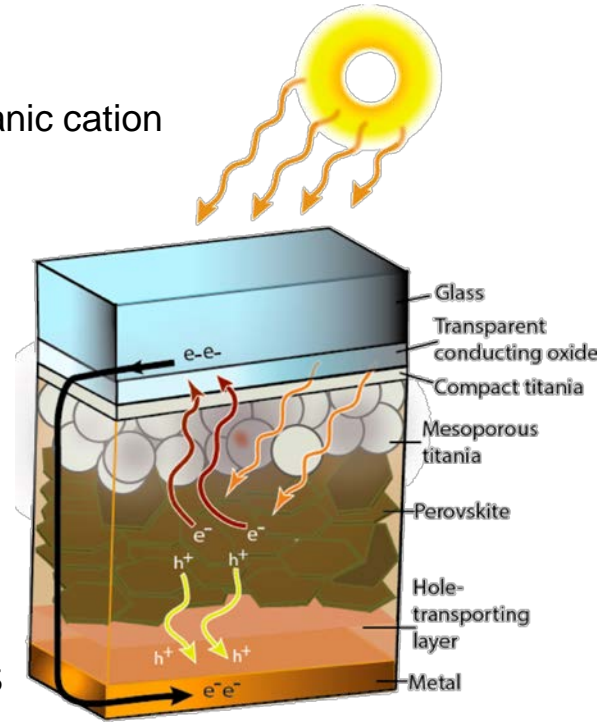


- A = Cs, RNH₃ Organic/inorganic cation
- B = Sn, Pb metallic cation
- X = Cl, Br, I tri-halide ion

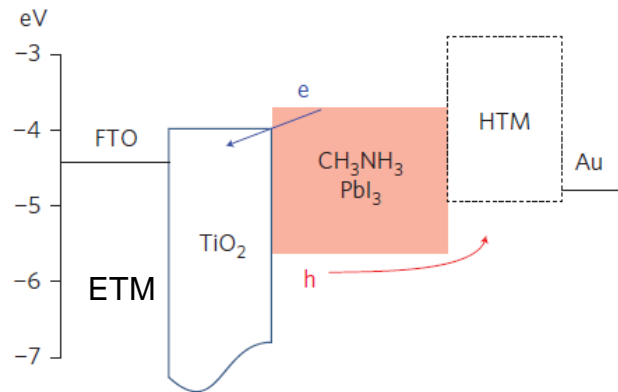


Working mechanism

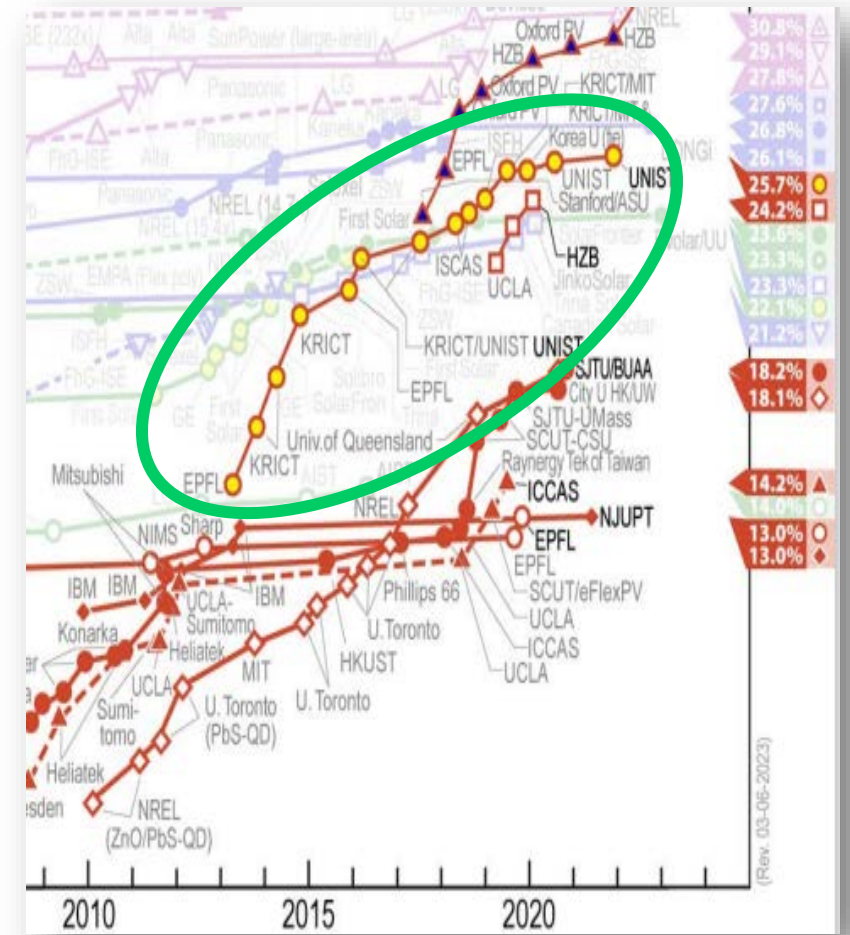
1. Exciton photogeneration and dissociation
2. Selective injection at HTM and ETM interfaces
3. Injection in positive and negative contacts



HTM: Hole Transporting Material
ETM: Electron Transporting Material

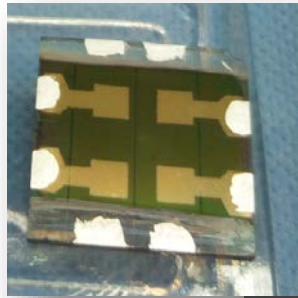


Rapid efficiency improvement

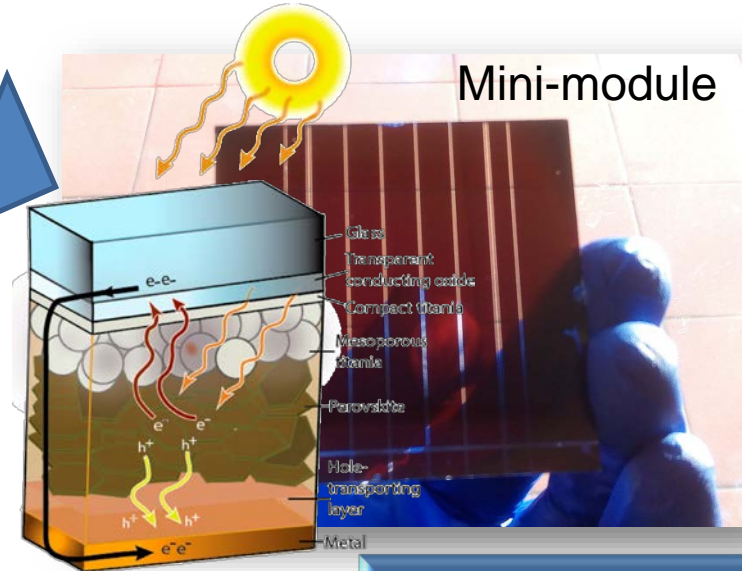


NREL, Best Cell Efficiency Chart

Perovskite solar cell scaling up



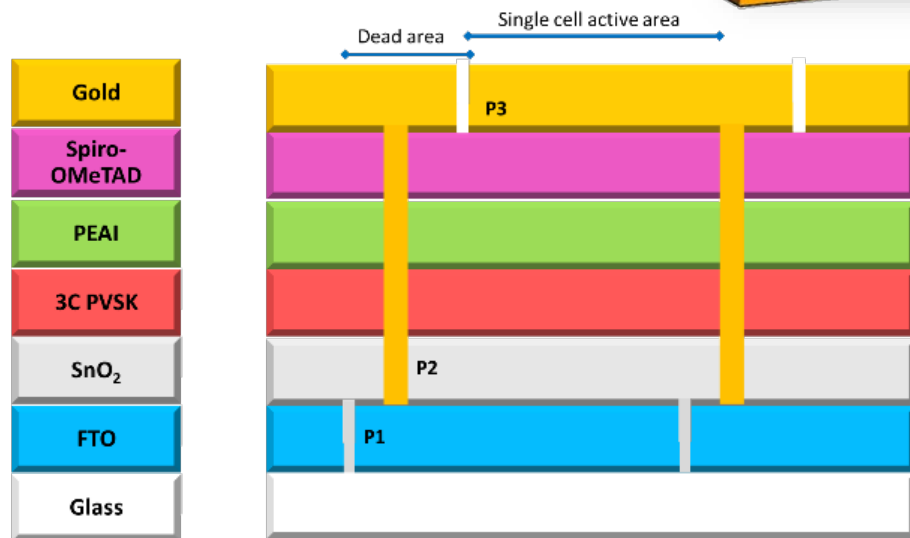
Lab-scale cell



Mini-module

Device	Size (cm ²)
Lab-scale cell	< 1
Mini-module	< 200
Sub-module	≥ 200 (≤ 800)

M. A. Green, et al., Prog. Phot. Res. Appl. 2022
NREL, Champion PV module efficiency chart



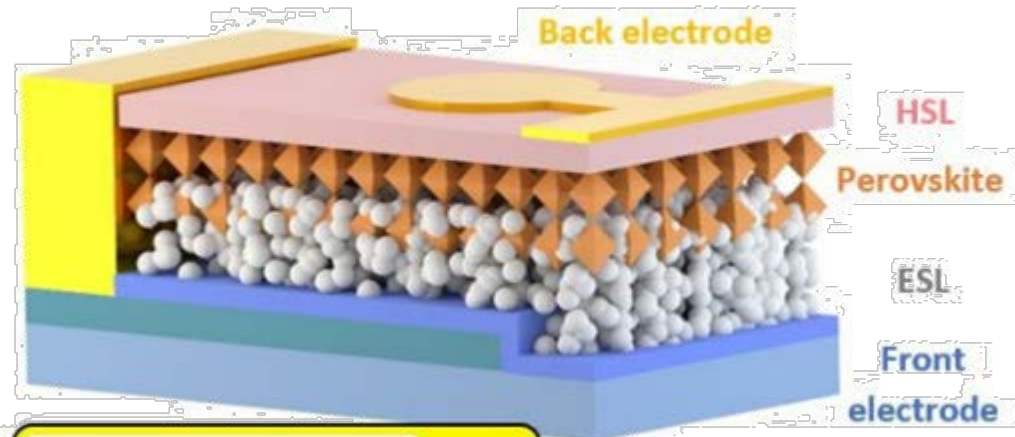
M. A. Green, et al., ACS Energy Letters, 2017

L. Vesce, et al., submitted

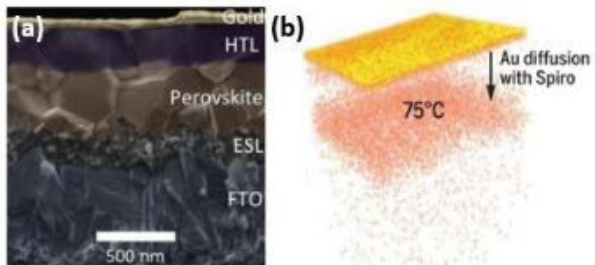
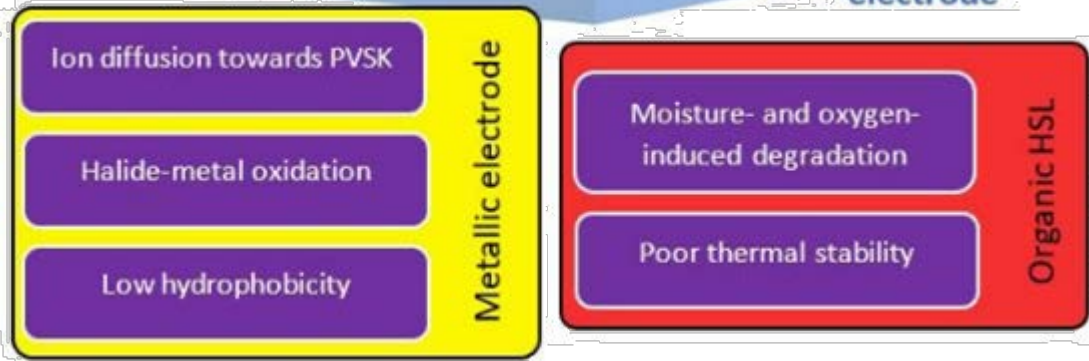
Issue	Mitigation
Front contact sheet resistance	Low sheet resistance substrate Cells series connection Cell width optimization
Interconnection dead-area	Narrow interconnection and separation line (laser process)
Interconnection resistance	Optimization of the laser process
Layer inhomogeneity	Coating technique Material composition Deposition environment

L. Vesce, et al., Solar RRL, 2021

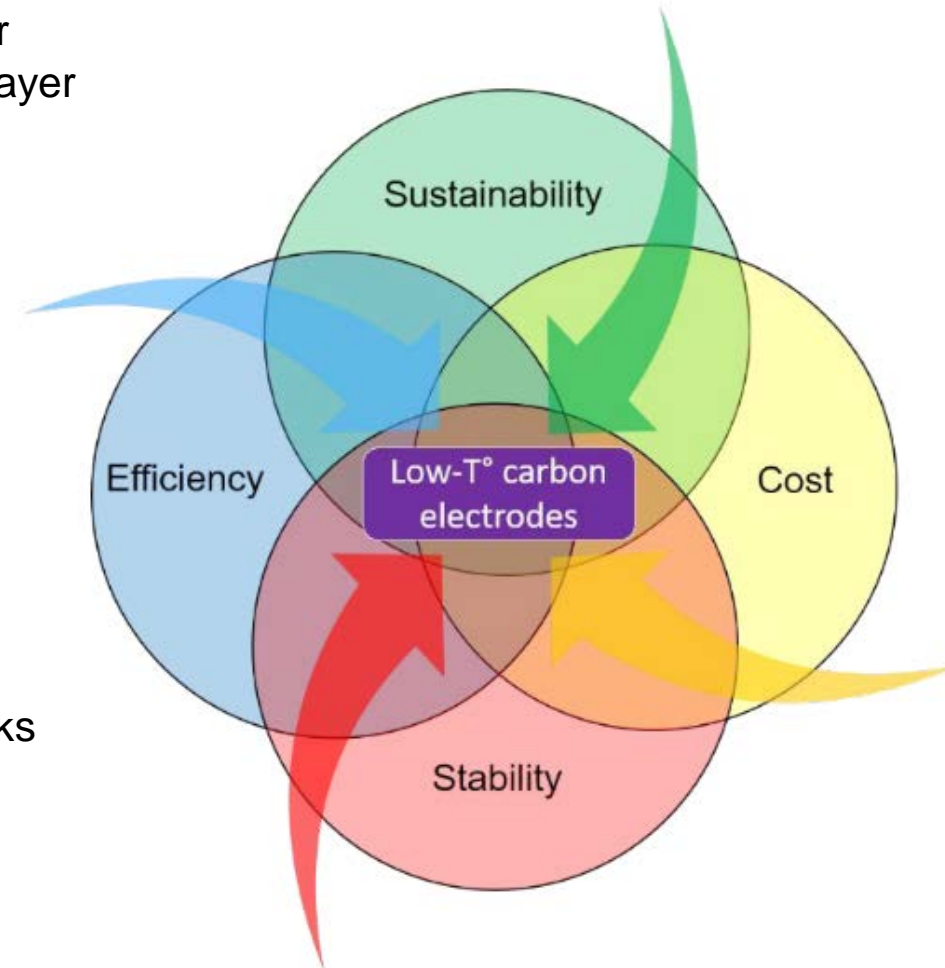
Motivation behind perovskite solar cells with carbon-based electrode



HSL: Hole Selective Layer
ESL: Electron Selective Layer

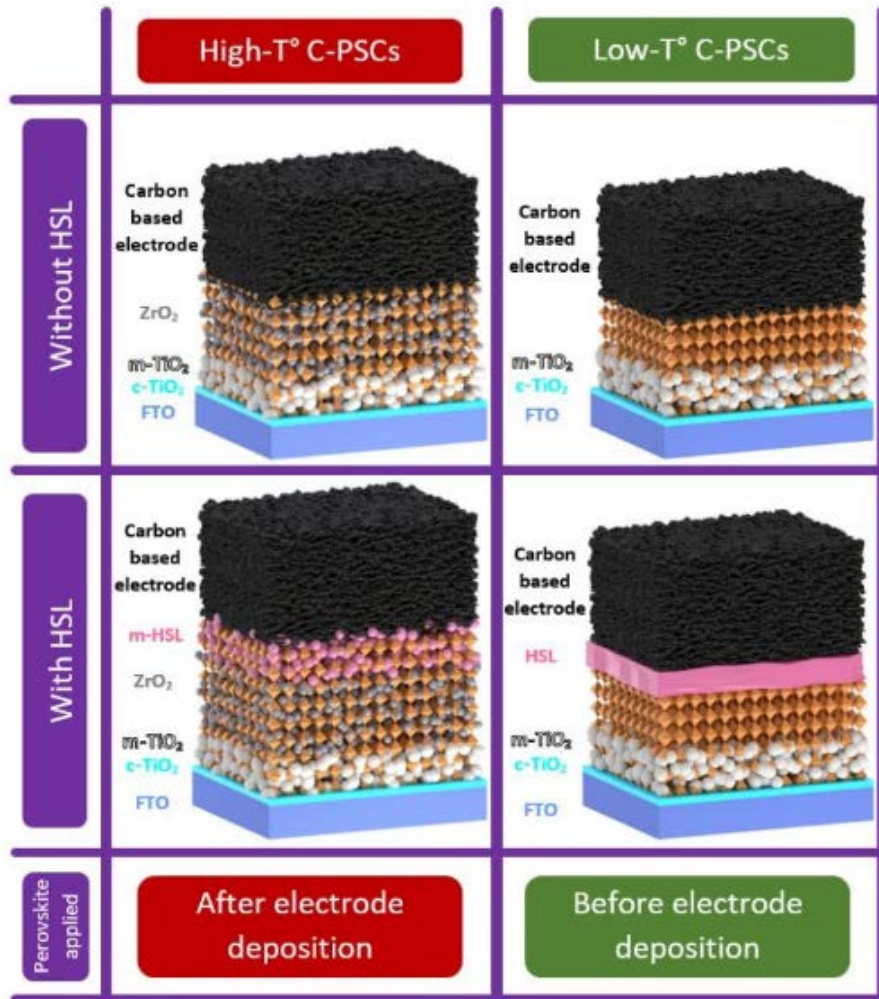


The HTM and the metal top-electrode can be replaced by a cheap low temperature firing carbon black/graphite layer



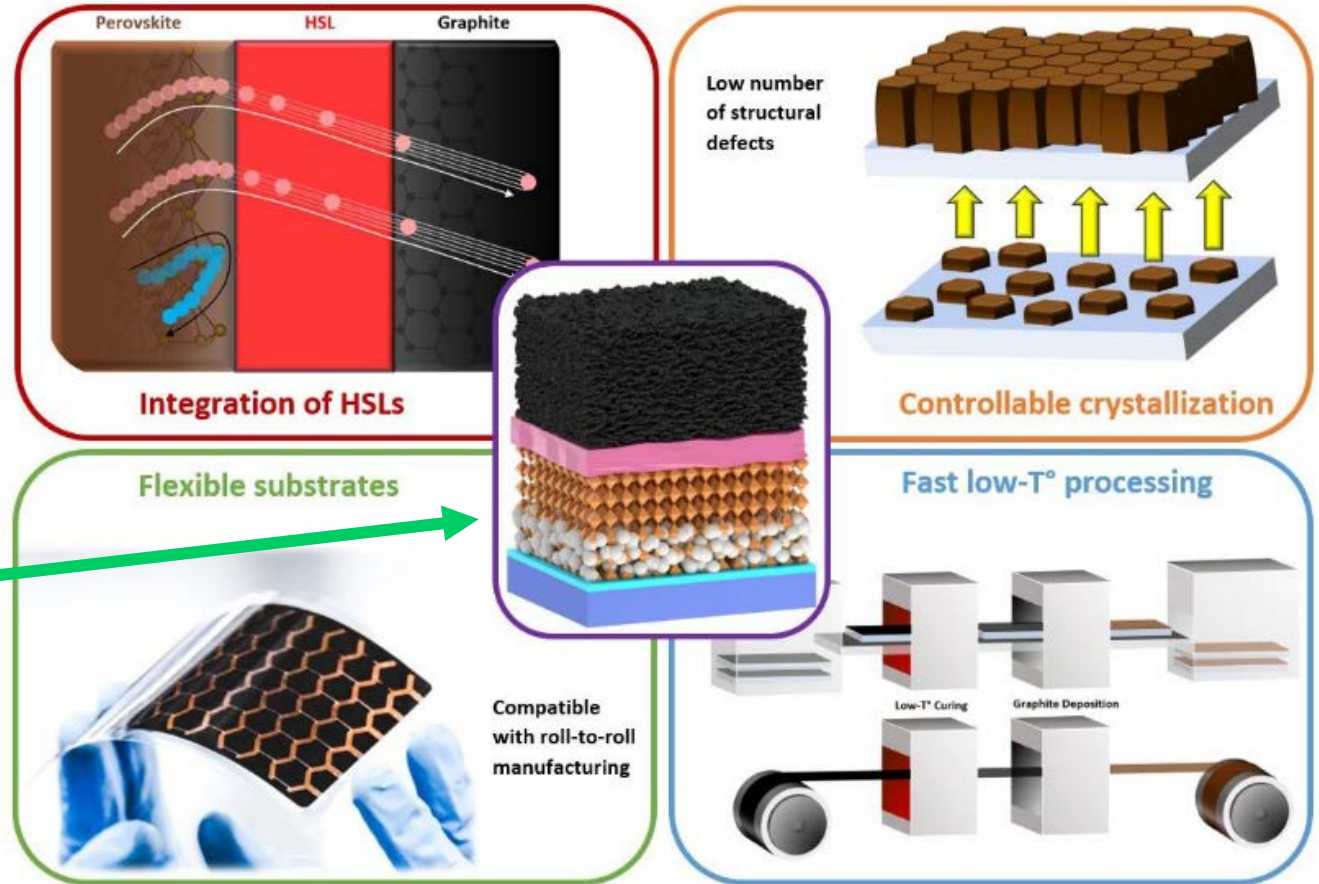
Low-temperature carbon back electrode is the key element to reach the goal: PVSK as new generation photovoltaic technology

Key advantages of the low-temperature processed electrodes



Two possible ways

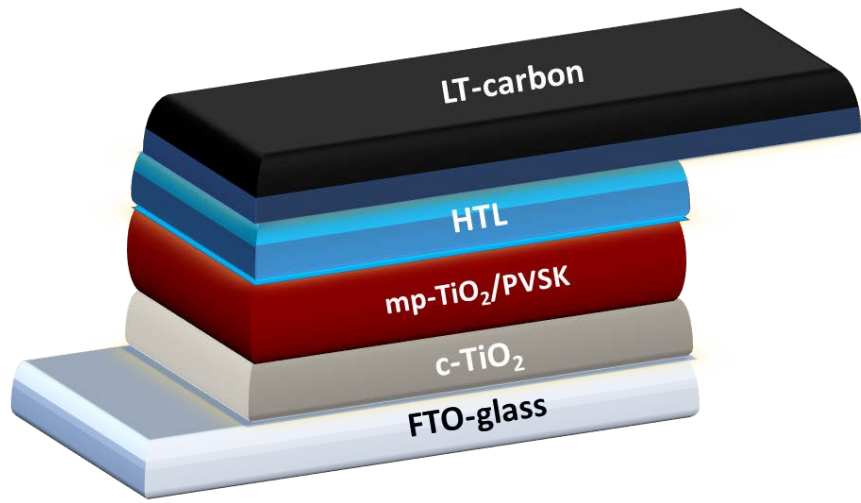
Key advantages...



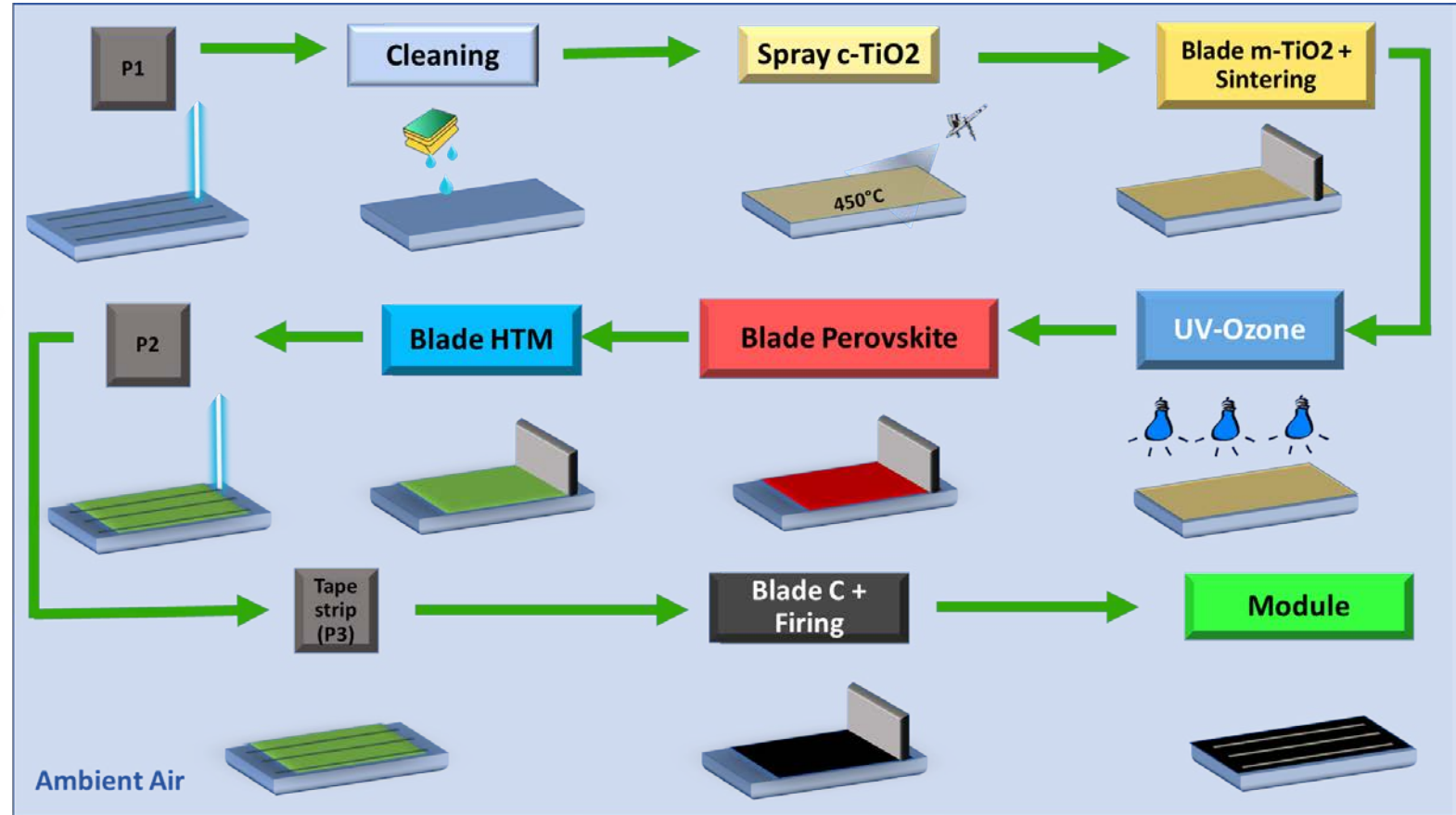
...but still low efficiency

We aim to demonstrate a stable HTM for low temperature carbon based perovskite solar cell deposited by coating technique

Materials and methods

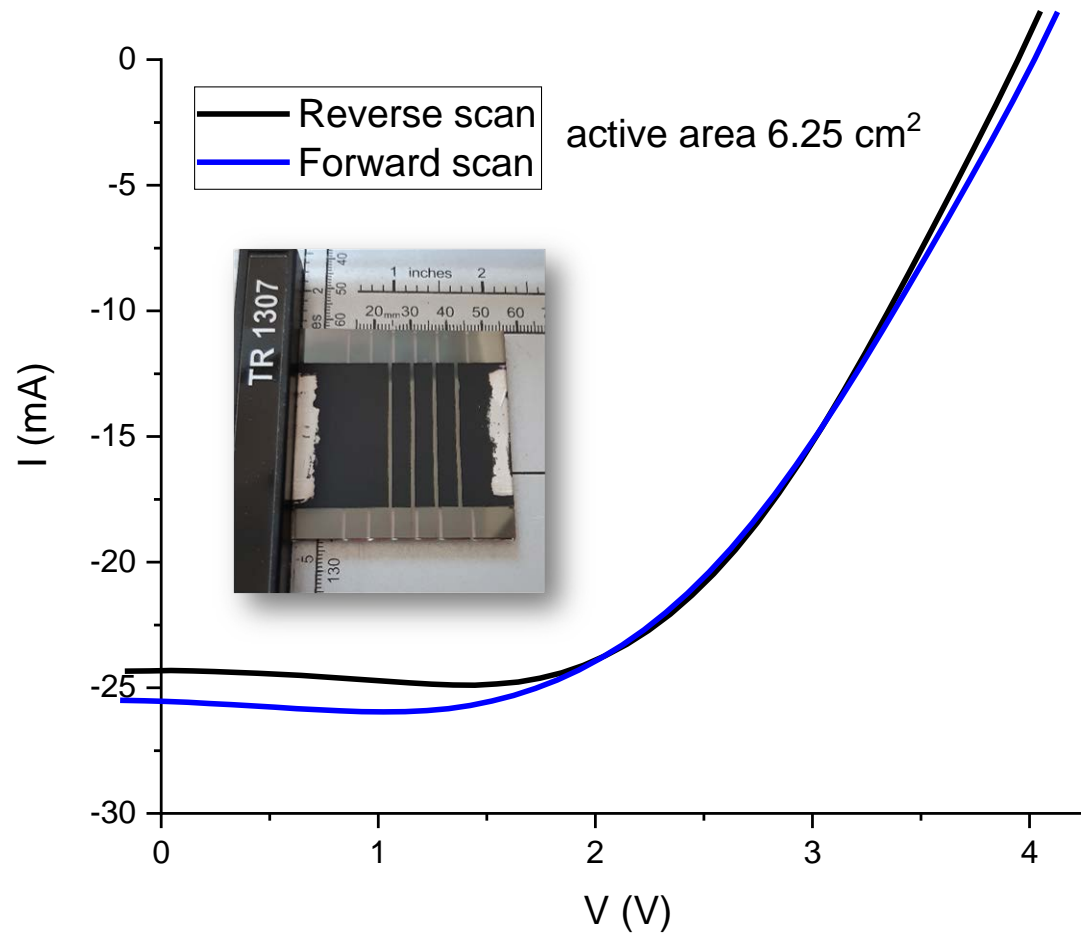


Perovskite solar cell stack



Process steps for the module fabrication

Results – Photovoltaic performance



8.4% Efficiency and near zero Hysteresis

Conclusion and future development

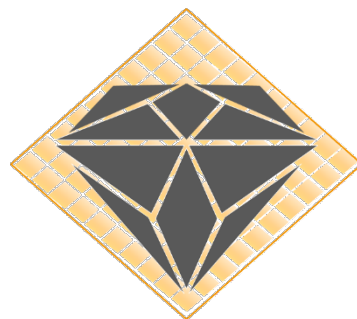
- Low cost and low temperature carbon-based counter electrode
- Full process flow out of glove box by printing techniques
- Process ready for pilot line environment and adaptable for different materials
- Life Cycle assessment (LCA) to be completed

Thank you!

Acknowledgments and contact information



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della Materia



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