Carbon-based Perovskite Solar Cell

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TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA

CHOSE

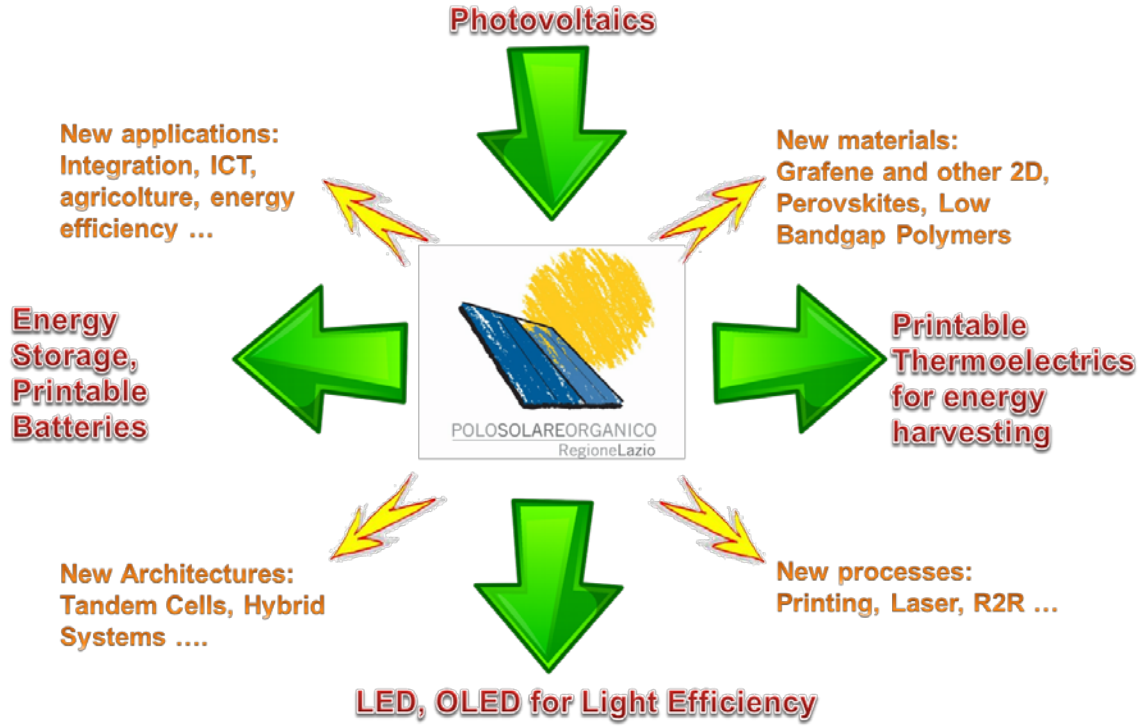
Outline

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

G-LYTE

Spin-off / Start up

TIBERLAB

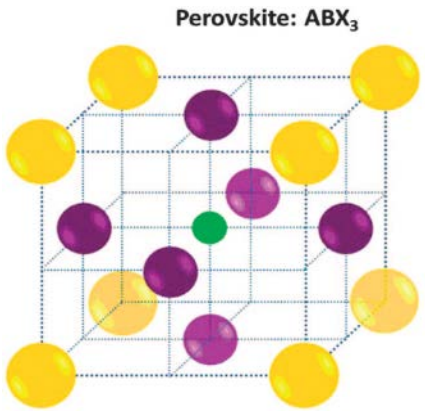
intellienergia s.r.l. renewableenergyengineering

cicci research

INGEM S.R.L.

dyepower

Perovskite solar cell

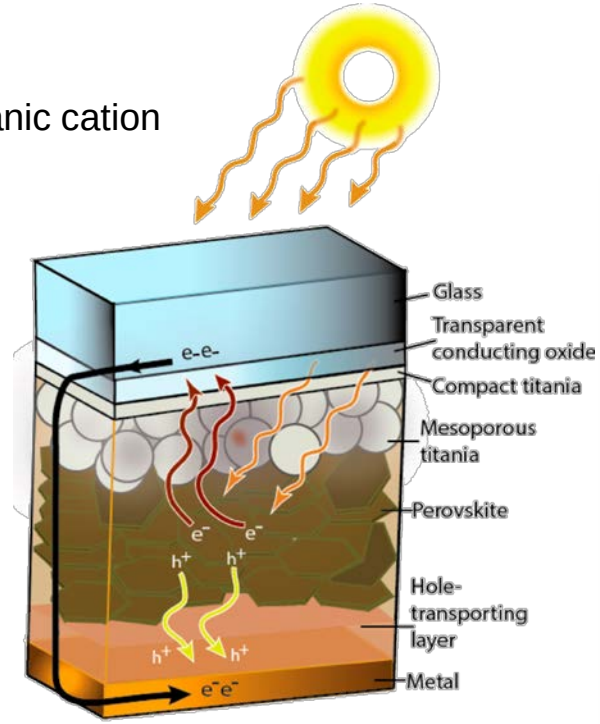


Organic/inorganic cation

metallic cation

tri-halide ion

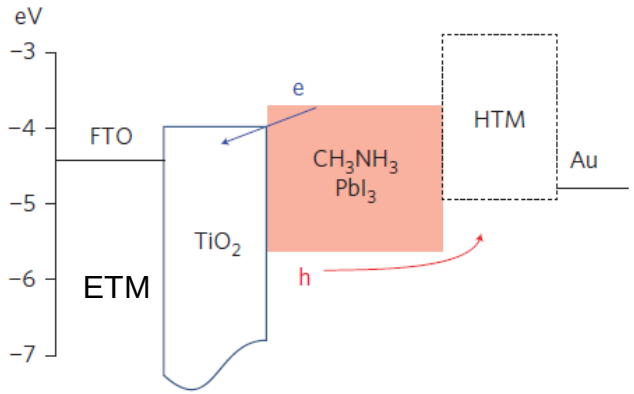
$CH_3NH_3PbI_3$



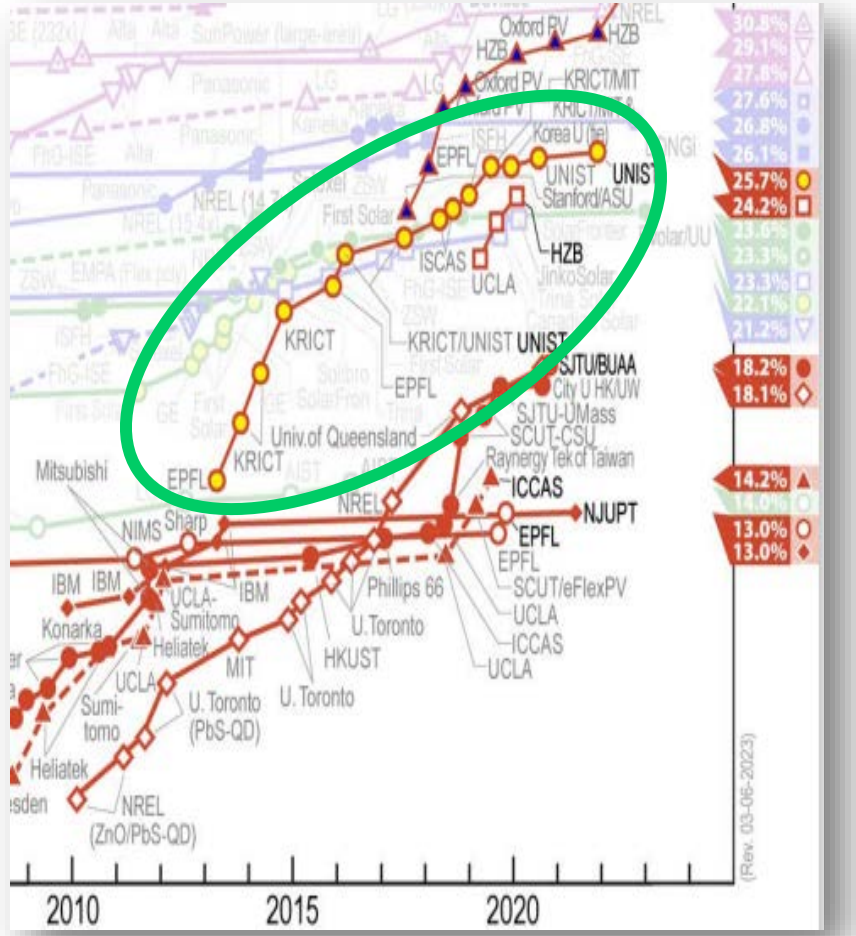
Working mechanism

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



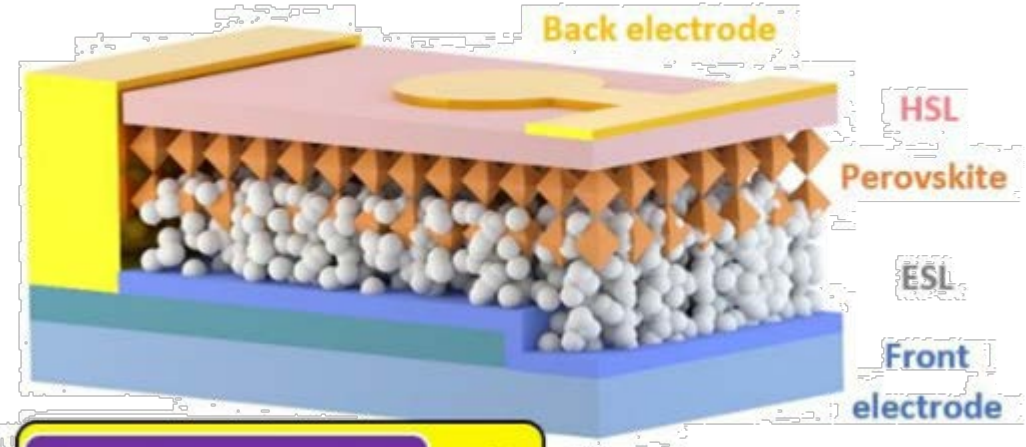
Rapid efficiency improvement



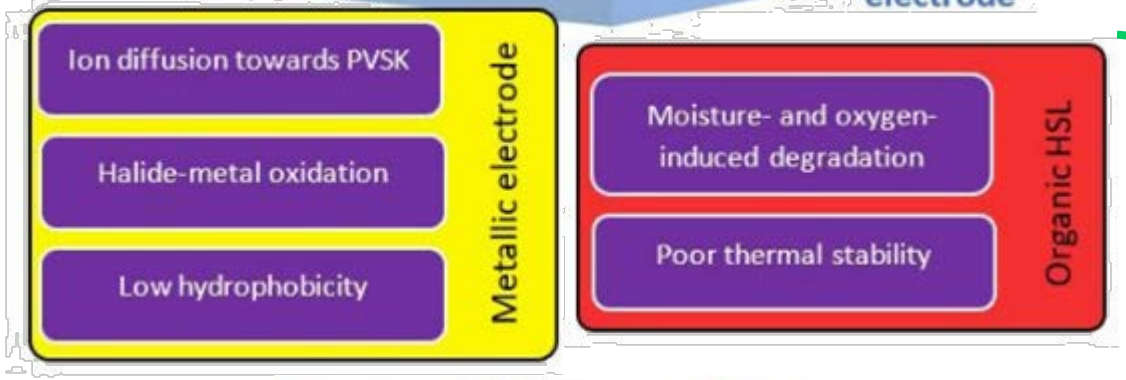
NREL, Best Cell Efficiency Chart

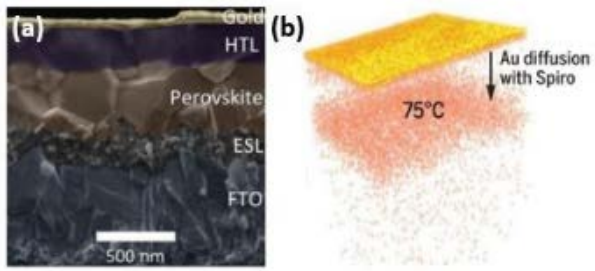
M. A. Green, et al., ACS Energy Letters, 2, 822-830, 2017.
J. H. Heo et al., Nature Photonics, 7(6), 486-491, 2013.

Motivation behind perovskite solar cells with carbon-based electrode



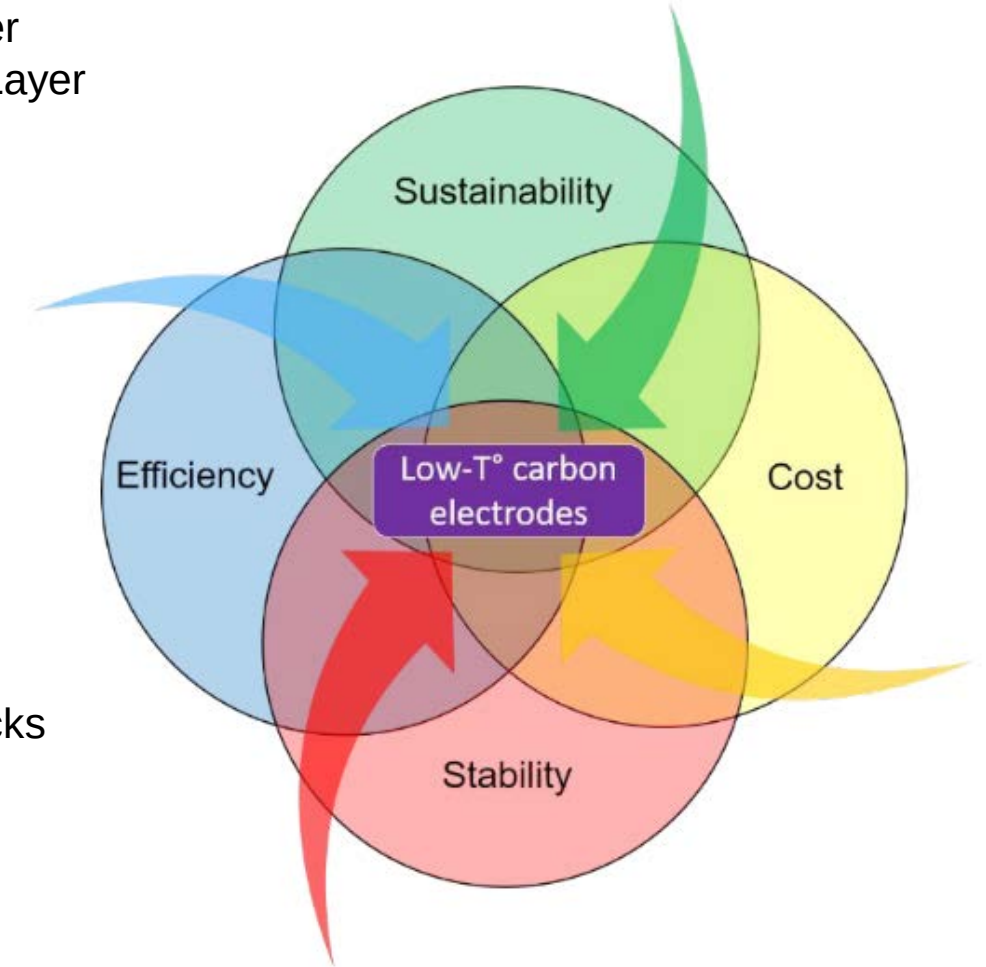
HSL: Hole Selective Layer
ESL: Electron Selective Layer





Main drawbacks

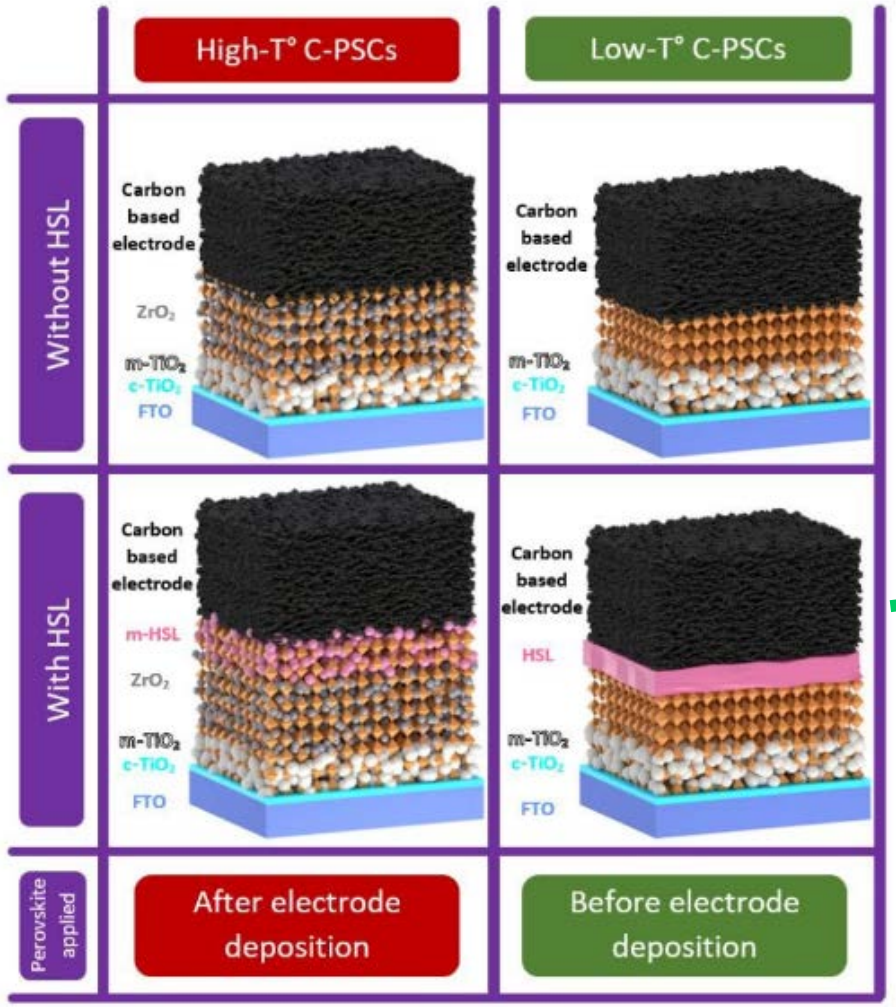
The HTM and the metal top-electrode can be replaced by a cheap low temperature firing carbon black/graphite layer



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

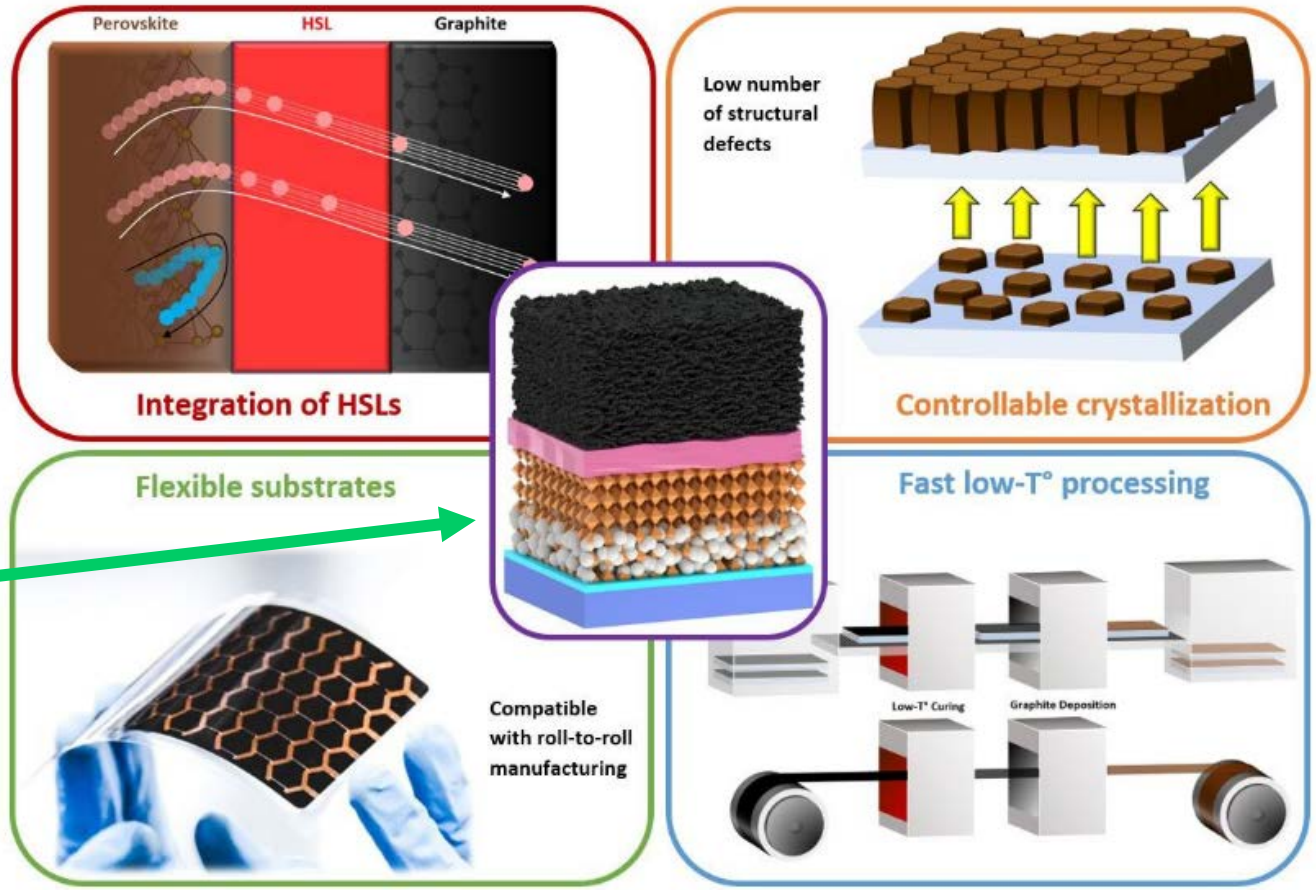
D. Bogachuk, et al., Energy and Environm. Sci., 13 (11), 3880-3916, 2020

Key advantages of the low-temperature processed electrodes



Two possible ways

Key advantages…



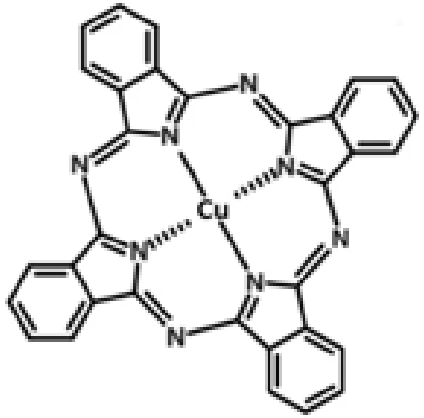
…but still low efficiency

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

D. Bogachuk, et al., Energy and Environm. Sci., 13 (11), 3880-3916, 2020

Materials and methods 1/2

Copper Phthalocyanine molecule as HTM



PRO

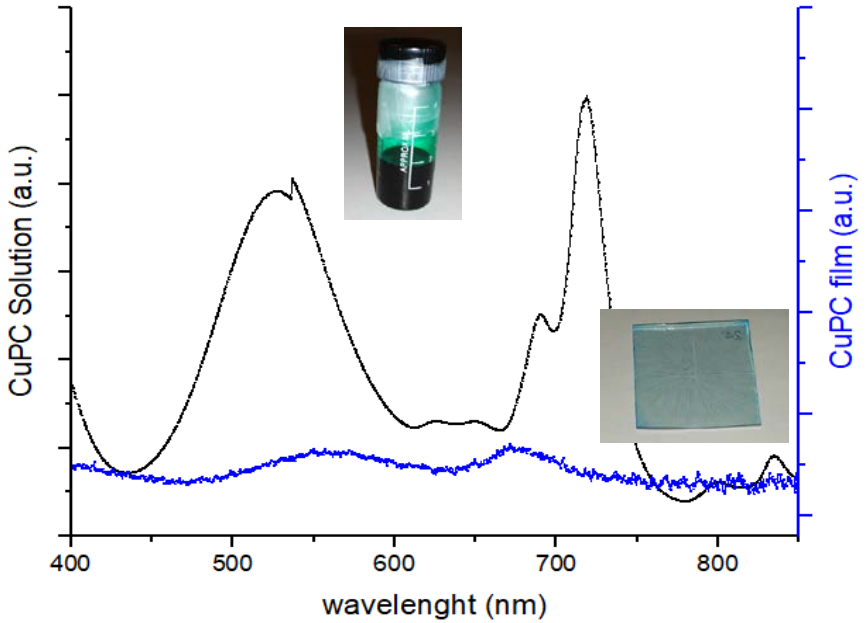
- High carriers mobility
- Stable over 200°C
- Cheaper than other HTM
- Tuning phase stacking can improve conducibility

ISSUE

- No literature on devices with u-CuPC deposited by a solution process method
- Unsoluble in common solvents
- Easy aggregation

Solvent Engineering approach:

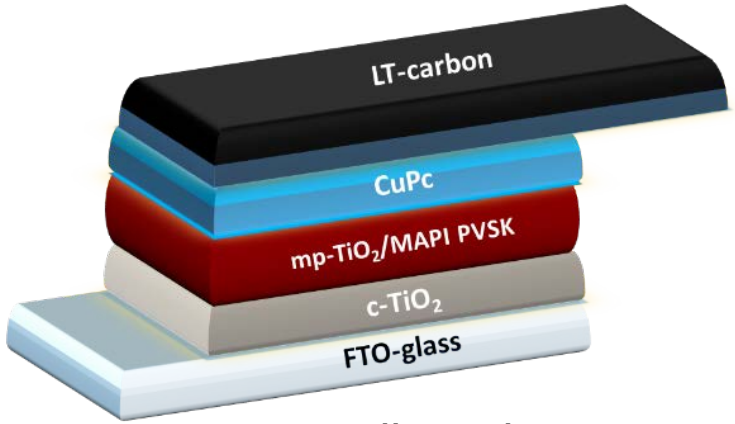
- Melting CuPC in acid solution to avoid aggregation by strong π-π interactions



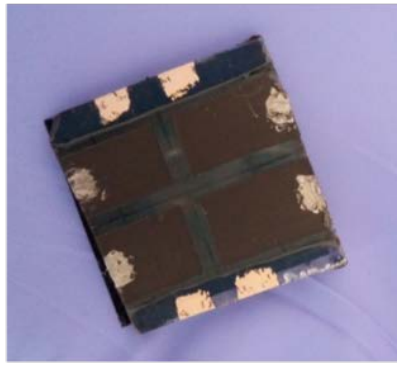
Comparison beween UV-vis spectra of CuPC solution and CuPC (thin film)

Manuscript in preparation

Materials and methods 2/2

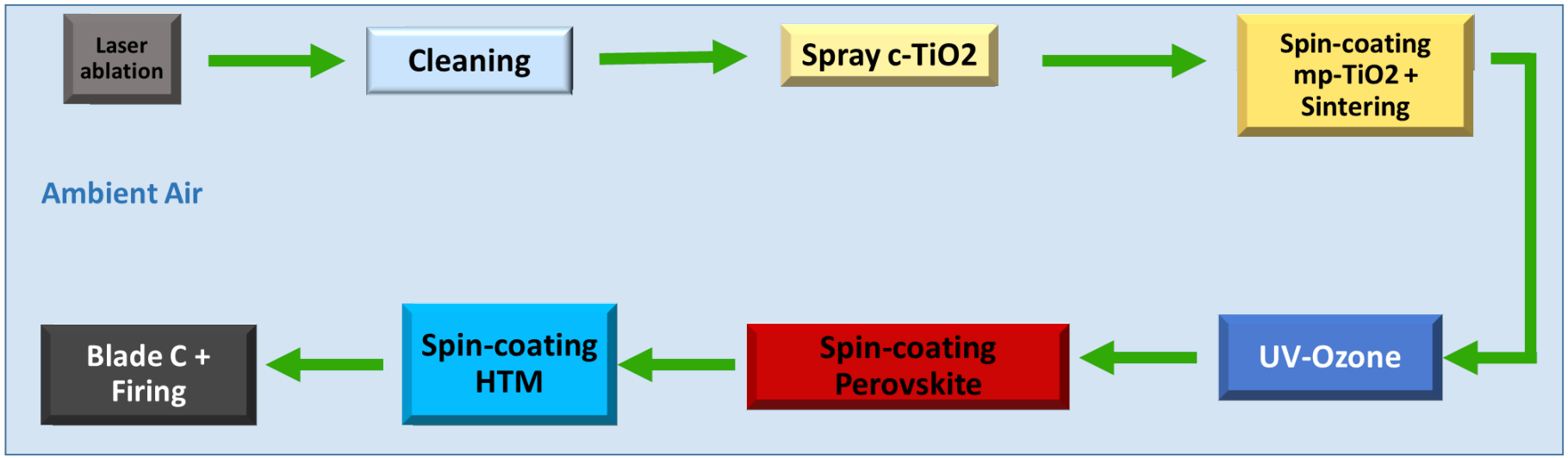


Cell stack



- 4 small area cells (0.09 cm^2 active area) for each substrate
- The carbon ink is blade coated as counter-electrode and then fired 20 min at 120 °C

Simple and low-temperature solution process in ambient air



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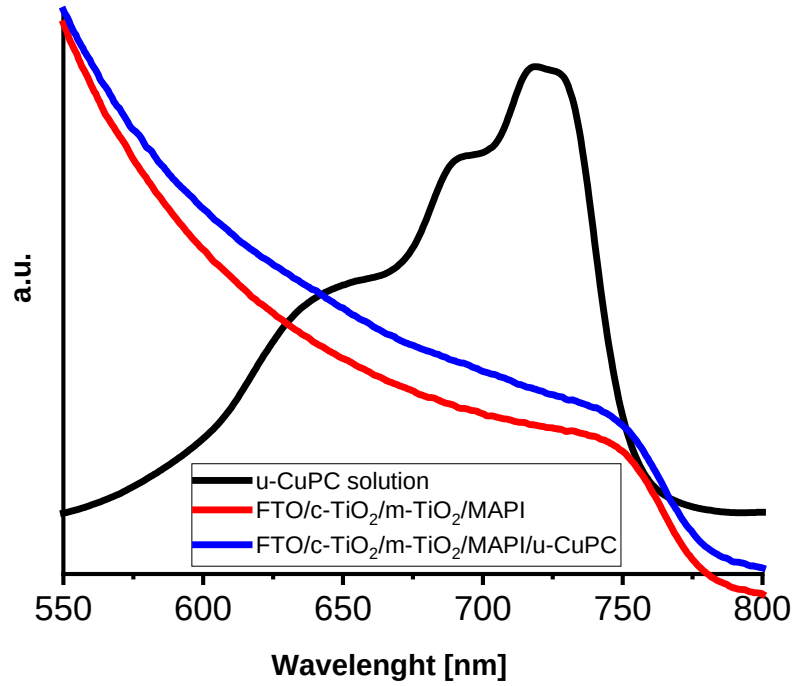
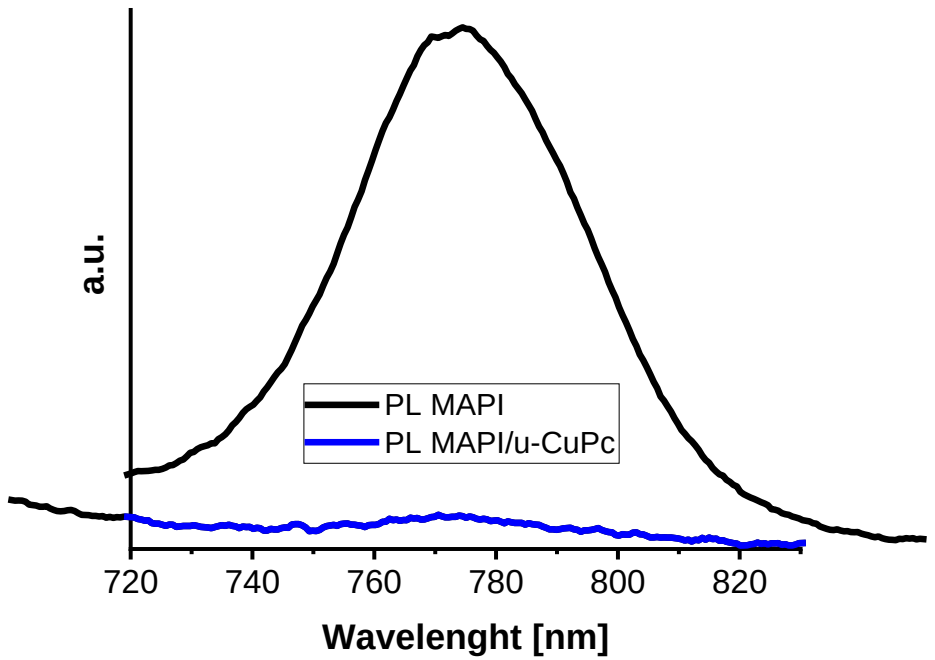
Results – film characterization 1/2





The presence of the CuPc thin layer ontop of the Perovskite improves the absorbance UV-vis spectrum in the near infrared region

The steady-state photoluminescence (PL) of TiO_2/$MAPbI_3$ and TiO_2/$MAPbI_3$/u-CuPc permits to evaluate the hole extraction capability. The coated CuPc HTL introduces consistent quenching effect and hole extraction

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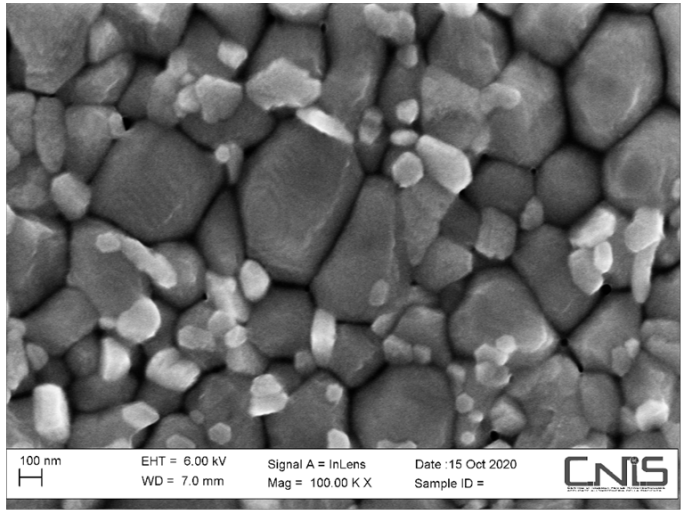
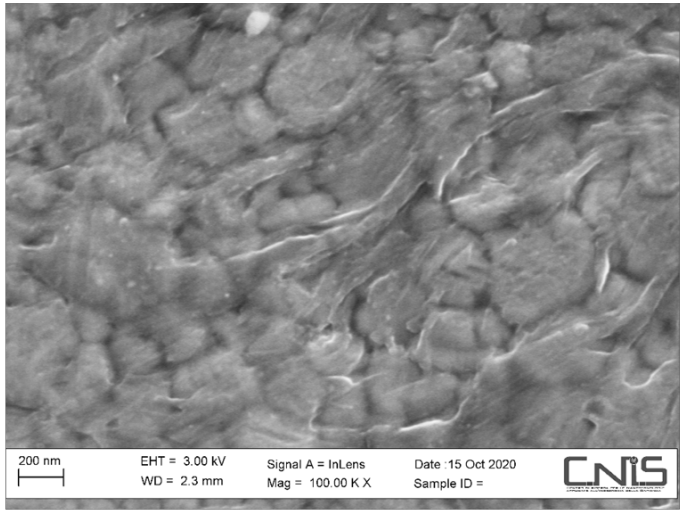
Results – film characterization 2/2



SEM top views



MAPI PVSK

MAPI PVSK/u-CuPc

Fully covered and pin-holes free PVSK layer by u-CuPc engineered HTM

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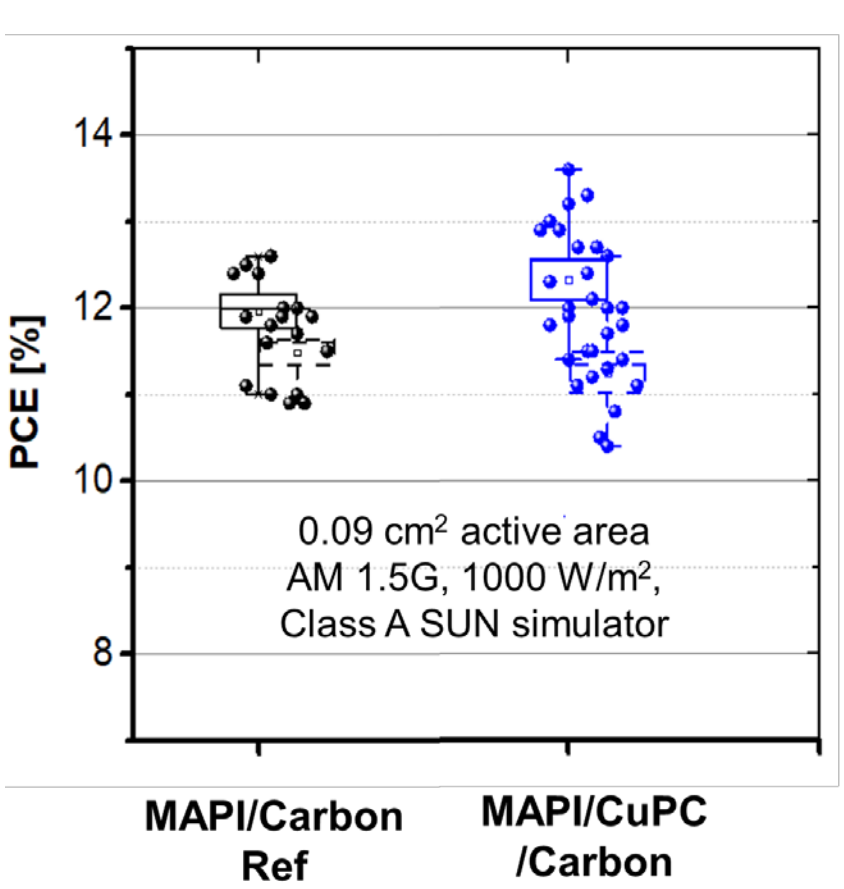
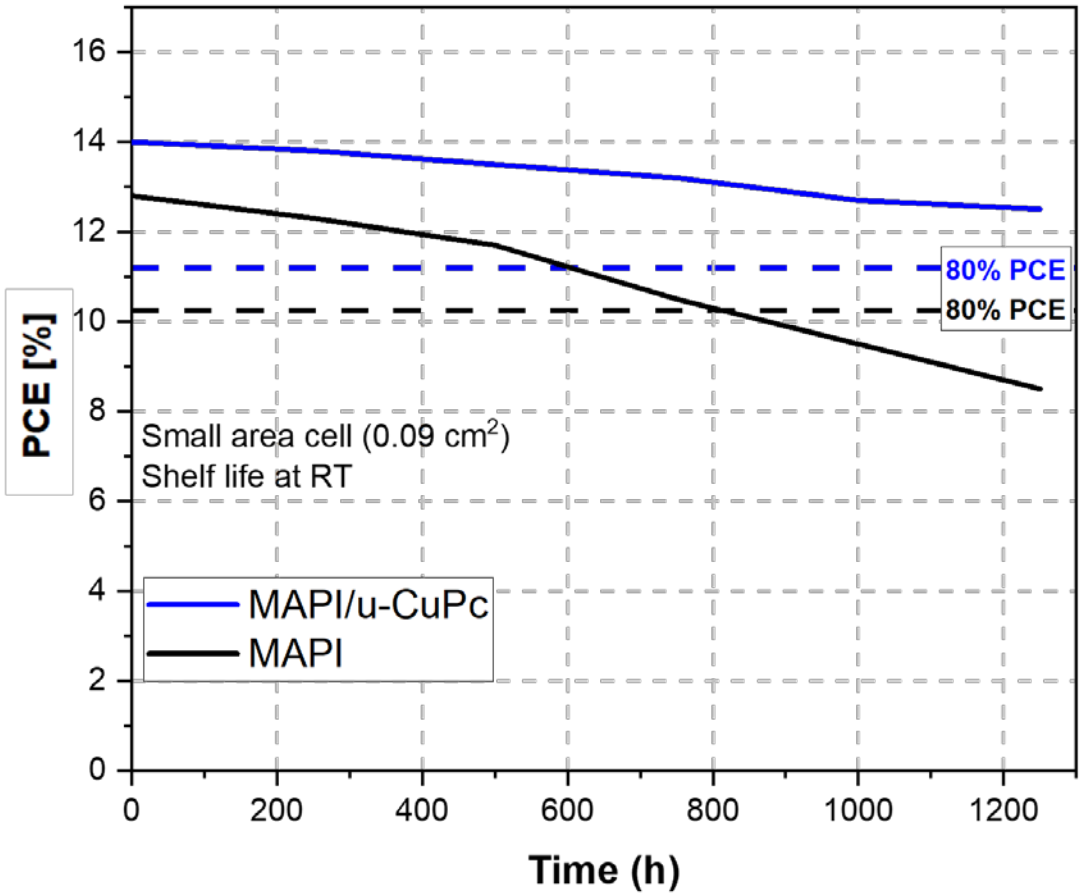
Results – Photovoltaic performance





Higher efficiency (1 SUN) and higher stability (ISOS-D-1) by adding u-CuPc

Manuscript in preparation

Conclusion and future development

- Device fabrication out of glove box
- Solution process method (first time in literature) to deposit the thermally stable unsubstituted-phthalocyanine family HTM
- u-CuPC devices show higher efficiency respect to the reference one (about 15% more) due to better charge extraction and carriers mobility from perovskite to carbon electrode
- Thermal and chemical stability of u-CuPC film grant to devices stability in ambient air for more than 1000 hours
- Solution processed u-CuPC open to low-cost scalable process for large area module fabrication
- Life Cycle assessment (LCA) to be completed
- Materials deposition by blade-/clot-die coating techniques to be confirmed for the full stack
- Scaling up to module is mandatory to face the technological aspects

Thank you!

Acknowledgments and contact information

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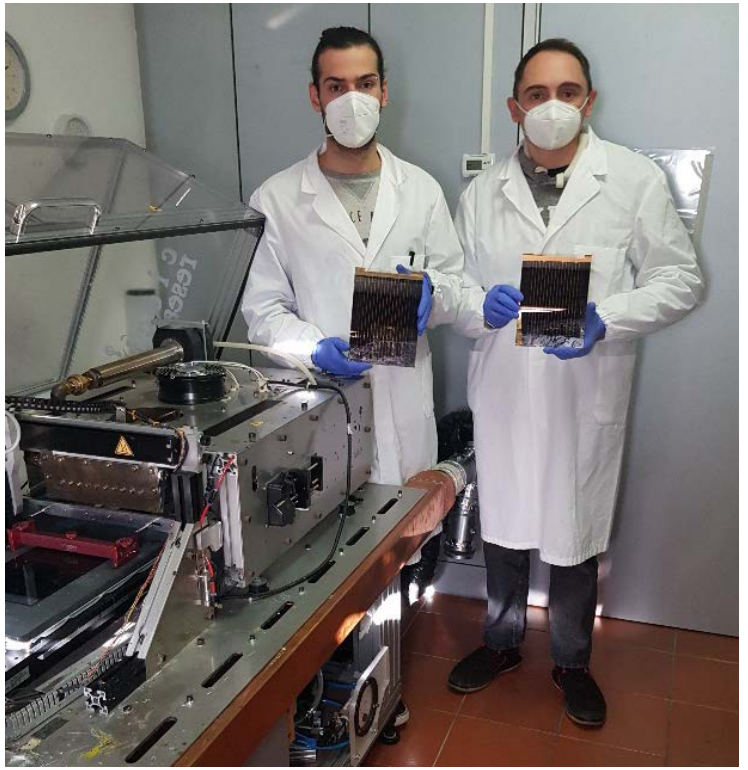
CHOSE POLO SOLARE ORGANICO REGIONE LAZIO

CNR Istituto di Struttura della Materia



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