Tech4Win: Disruptive Sustainable Technologies for Next Generation PV Windows

A. Pérez-Rodríguez[1,2], A. López-García[1], E. Saucedo[1], J. Romaní[1], J. Salom[1], N. Lemaitre[3], B. Vermang[4], G. Brammertz[4], E. Gutiérrez[5], E. Rico[6], J.M. Jiménez[6], T del Caño[6], C. L. Chochos[7], M. Bertrand[8], P. Santilli[9]

[1]Institut de Recerca en Energia de Catalunya (IREC), Barcelona, Spain; [2]IN2UB, Dept. d'Engineria Electrònica i Biomédica, Universitat de Barcelona, Barcelona, Spain; [3]INES, CEA-LITEN, Chambery, France; [4]IMEC, Leuven, Belgium; [5]IK4- Tekniker, Eibar, Spain; [6]Onyx Solar Energy S.L., Ávila, Spain; [7]Advent Technologies, Patras, Greece; [8]ARMOR S.A., Nantes, France, [9]Kenosistec S.r.l., Milan, Italy.

The project *Disruptive sustainable TECHnologies FOR next generation pv WINdows* is co-funded by the European Union under GA 826002

OUTLINE

1. Introduction
2. Tech4Win strategy: Project concept & underlying technology principles
3. Project objectives, KPIs and quantitative targets
4. Tech4Win Consortium: Main roles
5. Main results
6. Conclusions

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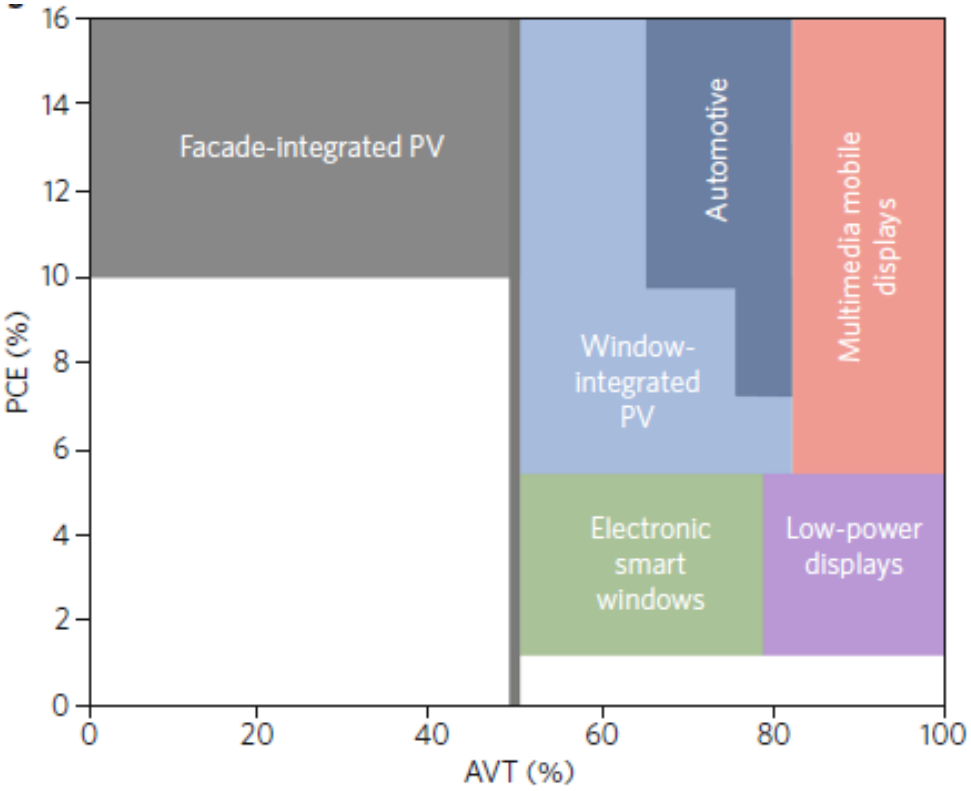
Introduction

Emergency of **highly transparent PV: New paradigm in PV deployment for the opening of solar markets that is required to consolidate PV as real alternative to non-renewable energy technologies**

Solar smart windows: Strong interest for development of near zero energy buildings (NZEB) allowing increase of effective area in the building for collecting sunlight.

BIPV: Need for new generation of transparent PV technologies allowing development of smart solar windows with:

- ➔ *High stability (need for lifetimes up to 25 years)*
- ➔ *Non intrusiveness (no visual impact)*
- ➔ *High transparency*
- ➔ *Higher efficiency*



Traverse et al Nature Energy 2017

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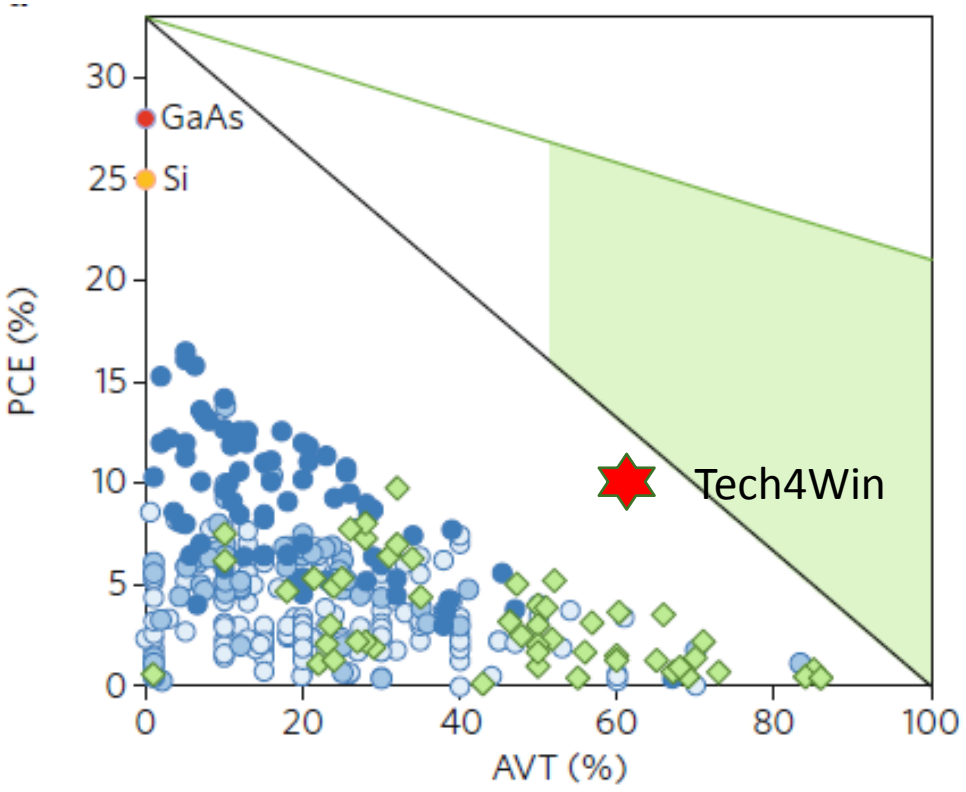
Disruptive sustainable **Tech**nologies **for** next generation PV **Win**dows

State of the art (semi)transparent technologies: Strong decrease of PCE with increase of transparency

Transparency > 50% ➔ efficiency < 5%

Solutions already available in the market are mainly based in non selective segmented devices: Transparency achieved combining transparent and opaque regions in the device

Tech4Win: Disruptive concept based in tandem-like structures that combine a UV selective solar cell with a IR selective solar call. Targeted goals at end of project: PCE > 10% with AVT > 60%



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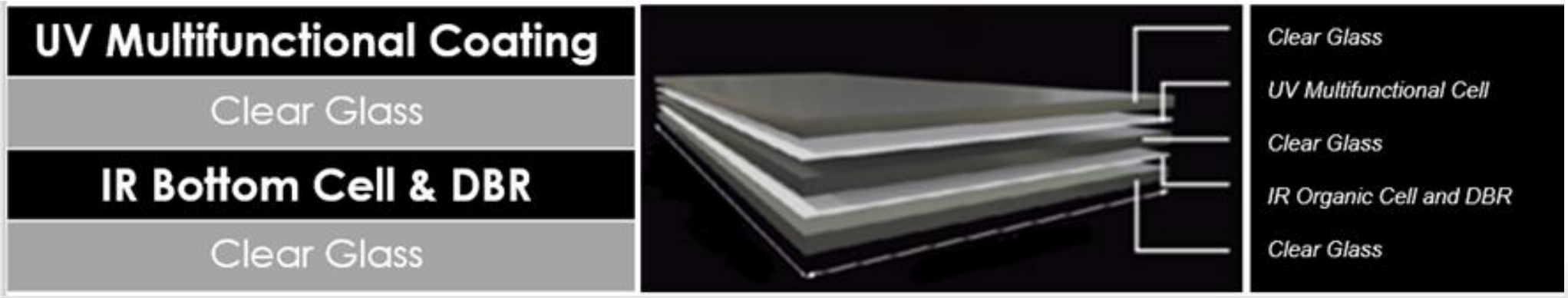
Disruptive sustainable **Tech**nologies **for** next generation PV **Win**dows

Project concept:

Tech4Win proposes an innovative transparent PV window based on the combination of an inorganic UV selective multifunctional coating **(UV filter + UV selective solar cell)** that is deposited on the first glass of the window, and an **organic IR selective solar cell** that is implemented on the second glass of the window. The IR device architecture includes **optical management strategies** (DBR: internal distributed Bragg reflector) for enhancing of PV conversion efficiency

Tandem inspired structure:



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Tech4Win presents a very innovative transparent photovoltaic (PV) window concept based on the adoption of a tandem inspired structure combining an inorganic UV selective multifunctional coating (including UV filtering and UV selective PV functionalities) with an organic IR selective PV device.

Disruptive sustainable technologies for next generation PV windows

MOTIVATION:

Exploiting IR efficiency potential of organic based solutions with robustness and stability of inorganic thin film solutions combining sustainable and industrial compatible technologies with demonstrated potential for cost reduction.

INNOVATION:

Capacity of the tandem inspired structure to protect the most active PV layer (IR selective organic cell) through the filtering of the UV radiation by the UV multifunctional coating, extending the lifetime of the PV hybrid device from 10 years at the end of the project until 25 years.

TECHNOLOGY PRINCIPLES:

UV multifunctional coating (UV filter + UV thin film top solar cell) based in chalcogenide/oxide thin film industrial technologies (sputtering based)

IR selective bottom solar cell based in organic materials and printing technologies (RtR solution based processes)

Light management concepts: Distributed Bragg Internal reflector (multi-stacked layered structures deposited with sputtering based processes)

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Project objectives:

Development of CRM-free hybrid UV and IR selective PV cell prototypes which can be integrated within a wide portfolio of smart windows and capable to meet the requirements and standards demanded by the construction sector.

Main objective: *To develop a set of transparent PV window prototypes (S and M sizes) with strong improvements in level of transparency and visual quality in the visible region, energy generation, advanced filtering capacities, thermal behaviour and energy impact. They will be exhaustively tested in a relevant environment for demonstrating their feasibility as a smart window.*

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Tech4Win Roadmap:

From "proof of concept" to "mass market penetration"

Tech4Win project phase

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KPIs and Quantitative Objectives:

KPIs		Target at end of project (2022)	Long-term Target (2026)
	Photo-conversion efficiency (PCE)	Demonstration (at cell level) of a PCE ≥ 10% (2.5% at UV selective top coating, 7.5% at bottom IR selective device).	PCE ≥ 12% at module level on large size (L, XL) windows
	Average Visible Transparency (AVT)	Demonstration of a medium size (30x30 cm^2) window prototype with an Average Visible Transmission (AVT, as defined in the window industry to weight the integration of the transmission spectrum against the photonic response if the human eye) ≥ 60%.	Upscaling of AVT ≥ 70% on large size (L, XL) windows.
	Lifetime	Demonstration (at prototype medium size window level) of a projected lifetime of ≥10 years.	Lifetime ≥ 25 years at large area (L, XL) window level.
	Colour Rendering Index (CRI)	Demonstration of a medium size (30x30 cm^2) window prototype with a CRI ≥ 70 (defined using AM1.5G as reference light) compatible with a high optical quality window ensuring unhampered transmission of visible light through the window.	Upscaling of CRI ≥ 70 on large size (L, XL) windows.
	Size	Demonstration of small size (2x2 cm^2 at cell level, 5x5 cm^2 mini-module level) lab scale devices (S format). Demonstration of medium size (30x30 cm^2) window prototype (M format).	Upscaling of processes to large: L(1x1m^2) XL(3x1.5m^2) size formats
	Manufacturing Costs	Selection of key materials capable to estimate manufacturing costs around 250-300 €/m^2.	Manufacturing costs of 160-200 €/m^2

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Disruptive sustainable **Tech**nologies **for** next generation PV **Win**dows

Tech4Win Consortium / Main roles

Project coordinator. Development of UV multifunctional coatings: oxide based strategies. Assessment of upscaled sputtering processes. Modelling of passive properties of window solutions

Industrial coordinator. Exploitation &Innovation Manager. Prototyping & Demonstration: Implementation and assessment of PV window prototypes

Development of IR selective OPV devices

Optical modelling for optimised device architectures. LCA

Development of UV multifunctional coatings: chalcogenide based strategies. Upscaled sputtering processes

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Disruptive sustainable **Tech**nologies **for** next generation PV **Win**dows

Tech4Win Consortium / Main roles

Development and implementation of IR internal Bragg reflector (DBR). Upscale of DBR processes to M-size devices

Transfer of OPV processes to R2R industrial process conditions. Upscaling of processes for development of M-size modules

Design and synthesis of new high conjugated polymers for optimised IR selective devices

Industrial techno-economic assessment of sputtering processes. Design of industrial equipment

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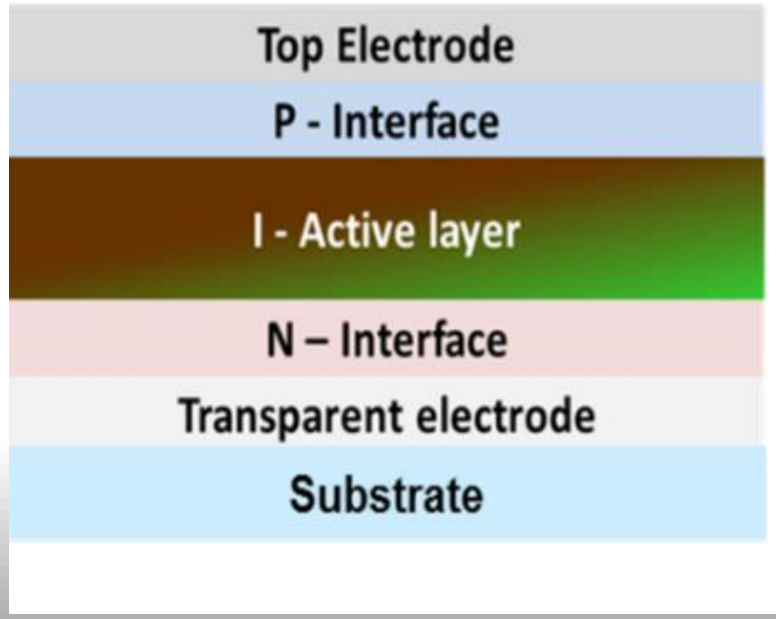
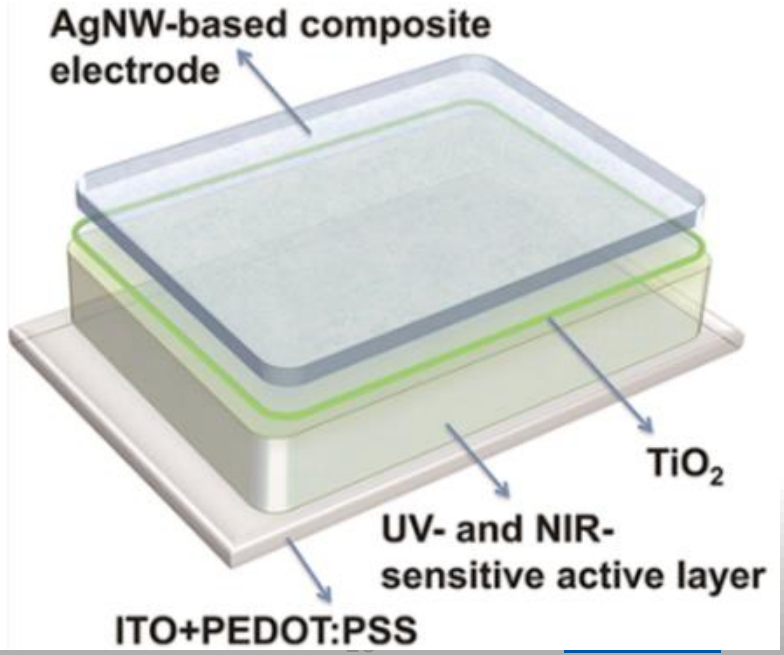
IR Cell development: Main results

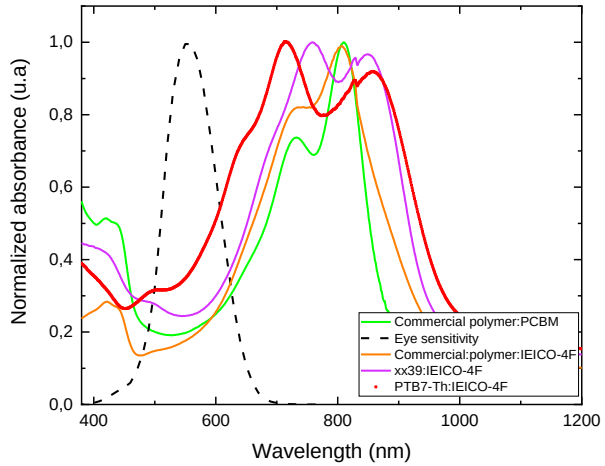
MAIN OBJECTIVES

- Development of IR bottom solar cell and the IR internal Bragg reflector, to be integrated into the window solution.
- Demonstration of CRM free proof-of-concept devices at lab scale with PCE ≥ 7,5%, AVT ≥ 60%, lifetime compatible with longer term targets (≥ 25 years).





IR Cell development: Main results



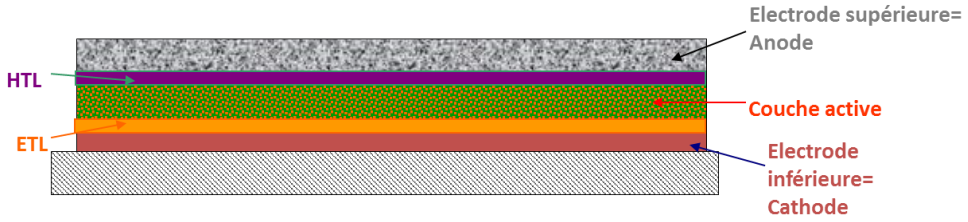
Selection of donor polymers for active layer

- Most interesting candidates: xx39 (developed in the project), Commercial polymer, PTB7-Th from Ossila
- Low optical absorption in visible region ➔ AVT target ≥ 60%

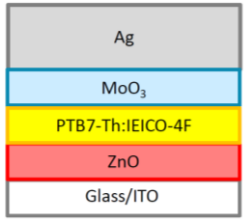
Integration in OPV devices

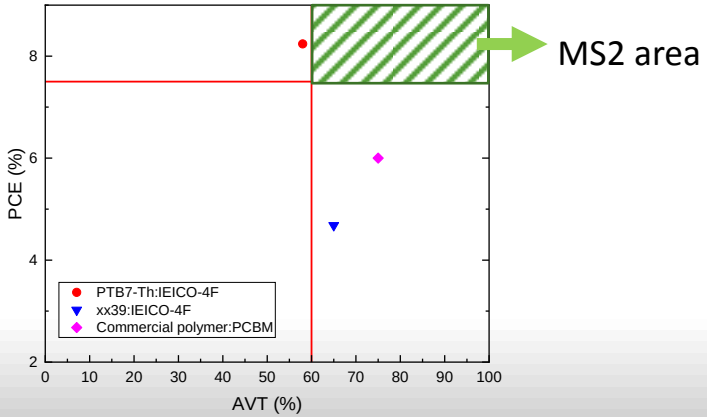
- Definition of the first non transparent structure of test

Substrate/ ITO / ETL / Active layer / HTL / Ag



- Optimization of absorber composition (donor polymer & acceptor) and thickness, HTL and ETL layers: Very promising results achieved with:
  - ***Commercial polymer:PCBM: AVT = 71%, PCE = 5.99%***
  - ***PTB7-Th:IEICO-4F: AVT = 58%, PCE = 8.24%***





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Multifunctional UV coatings: Main results

OBJECTIVES

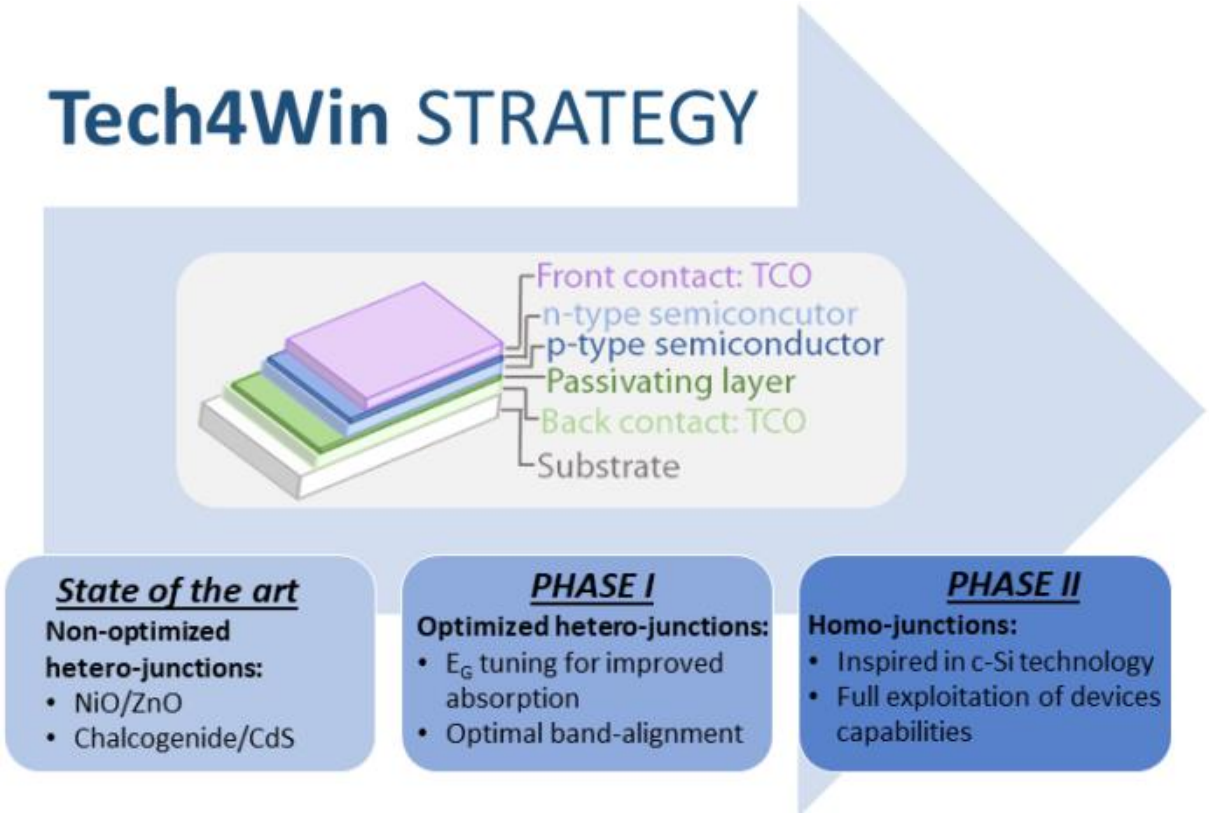
- 2 functionalities: UV filter and UV-selective PV
- Final efficiency 2.5%, UV absorption > 99% with CRM free layers

Optimal bandgap: 2.7 eV- 2.9 eV

➔ Two strategies: Zn(O,S) / Zn(S,Se)

STATUS

- First coatings with filter-functionality
- Demonstration of first UV selective solar cells



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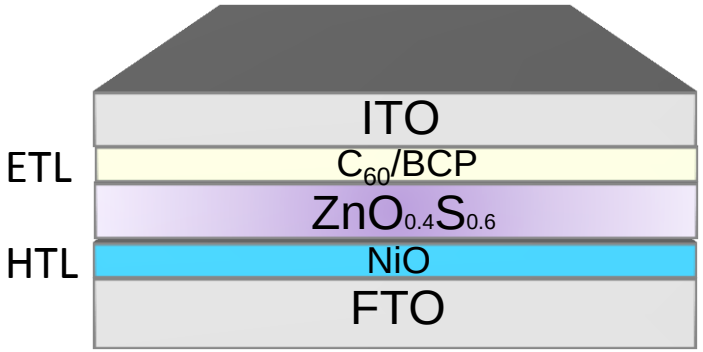
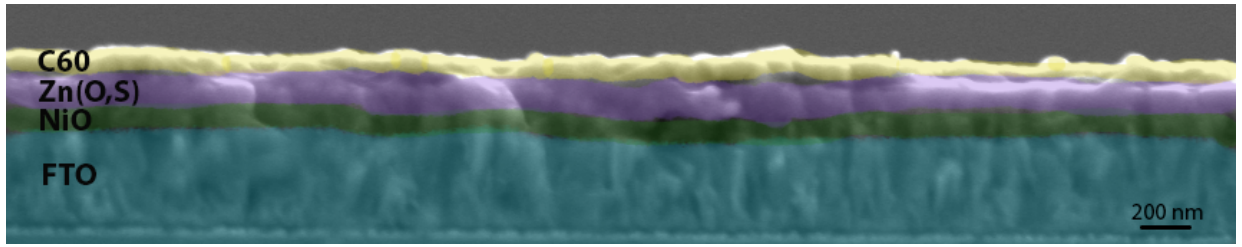
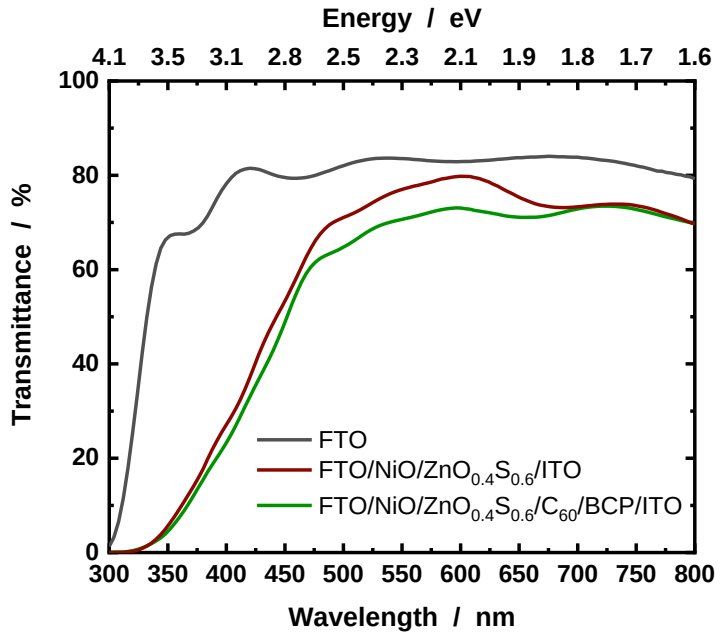
Multifunctional UV coatings: Main results (oxides)







Zn(O,S): layers with suitable composition (Eg 2.8 eV) are compact and without holes. However: need to increase grain size

C_{60}: Presence of inhomogeneities with some hole formation ➔ need to optimize process of deposition at

Optical properties: good transparency in visible region (AVT 69%). However UVF = 95% ➔ need to increase thickness of absorber

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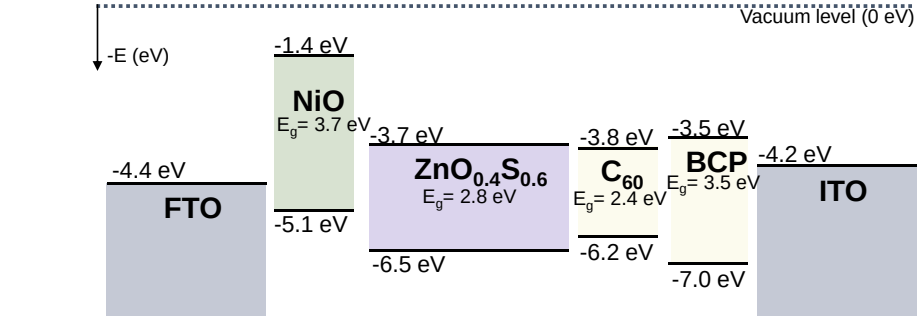
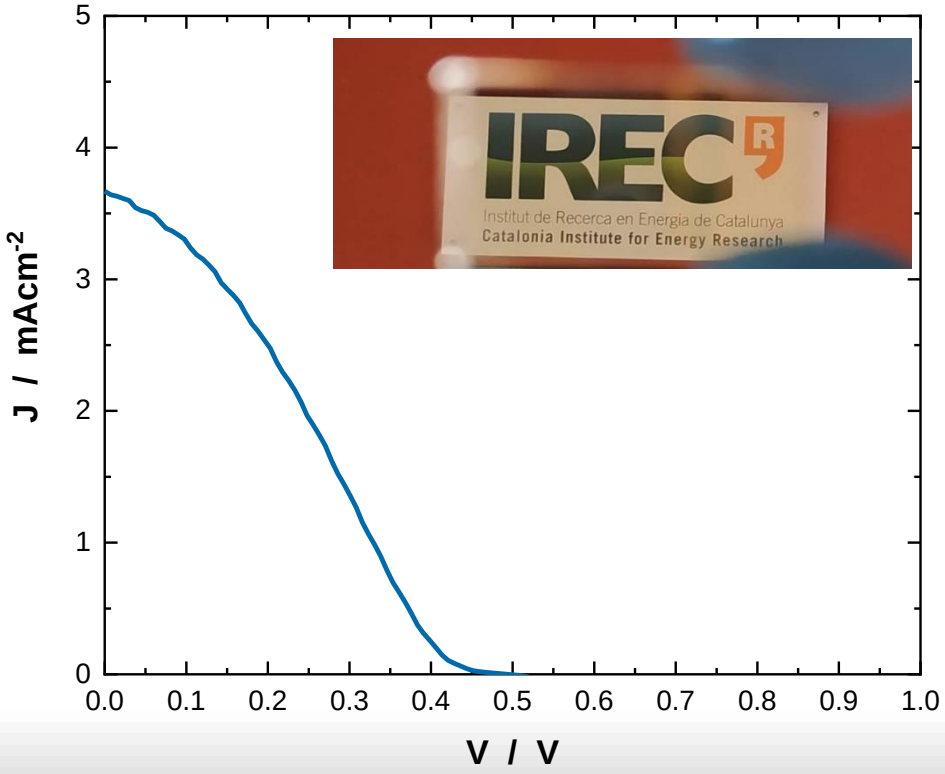
Multifunctional UV coatings: Main results (oxides)

DEVICES

- Demonstration of first UV selective solar cell prototype with PCE = 0.49% and AVT = 69%: best reported oxide based devices in terms of LUE (0.34%)

- Increase of efficiency:
  - Optimisation of Zn(O,S) composition & crystalline quality
  - Optimisation of deposition of C60 ETL
  - Replacement of NiO: Identification of optional HTL (MoO_3, MoS_2, Rubrene…)





Lopez-García et al, Solar RRL (2020), https://doi.org/10.1002/solr.202000470

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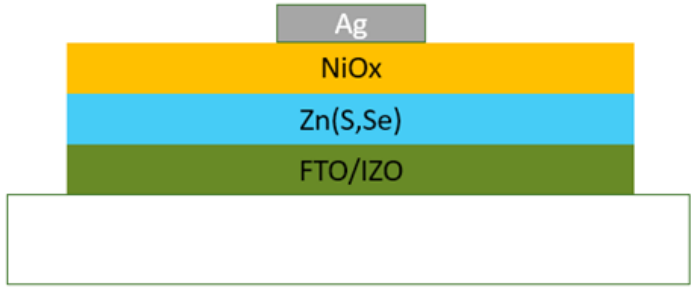
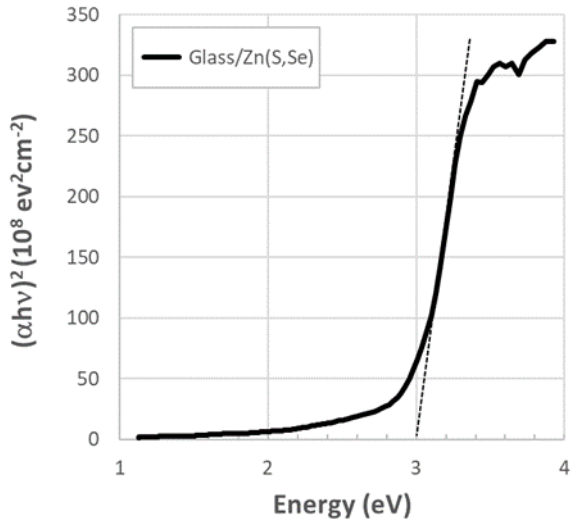
Multifunctional UV coatings: Main results (chalogenides)

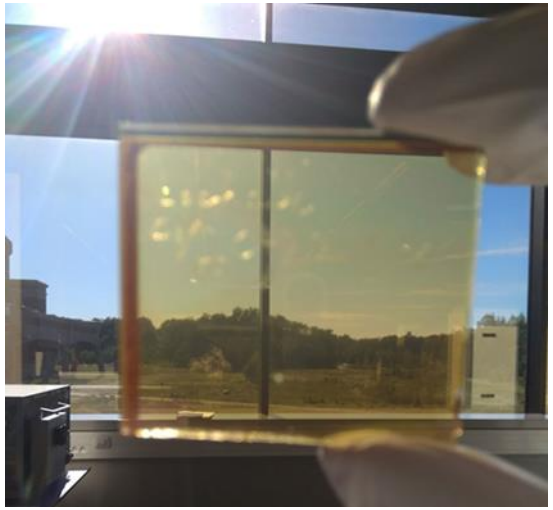


	Resistance (MOhm)
i-ZnSSe	10000
Zn(S,Se):LiF	10000
Zn(S,Se):Al	286
Zn(S,Se):Ge	111
Zn(S,Se):MgF2	1111
Zn(S,Se):Cu	150
Zn(S,Se):Sn	125

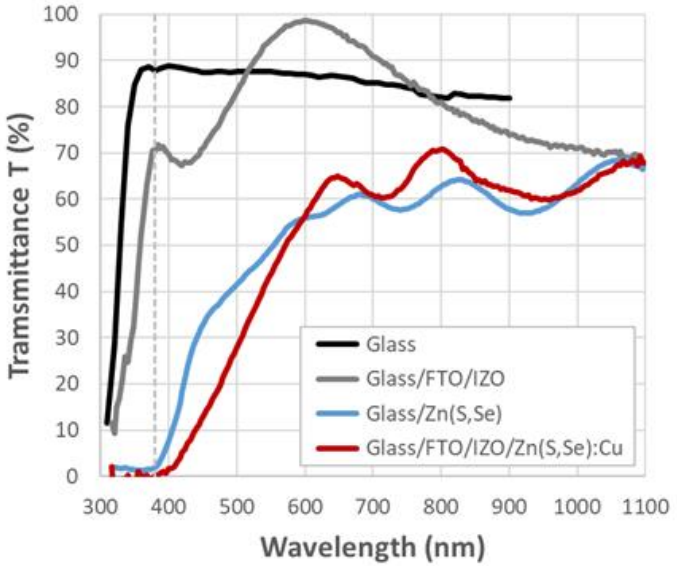
OPTIMIZATION OF CONDUCTIVE AND OPTICAL PROPERTIES



3 eV band gap



Yellowish color (IZO)



Excellent filtering below 380 nm

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Conclusions:

- Definition of the requirements and specifications of the glazing system proposed for the Tech4Win ➔ design of Tech4Win proposed window
- Implementation of modelling tools for electro-optical modelling of window device structure ➔ optimization of tandem device architecture
- IR selective devices: Identification of polymers compatible with KPIs. Demonstration of OPV operative devices:
  - *Commertial polymer:PCBM: AVT = 71%, PCE = 5.99%*
  - *PTB7-Th:IEICO-4F: AVT = 58%, PCE = 8.24%*
- UV multifunctional coatings:
  - Demonstration of UV filters (UV absorption > 99%)
  - Demonstration of first proof of concept of oxide based UV selective solar cells (AVT 69%, PCE 0.5%)

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www.tech4win.eu

Thanks for your attention!!

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