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(APRIL 2022 – SEPTEMBER 2025)
DURATION OF EXTENSION : 5 MONTHS

LEAP-RE

Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

Pillar-1 project

The LEAP-RE project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

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Consortium

Project coordinator:

- Raphaël Schneider, Université de Lorraine, **France**

Project partners:

- University of Liège (**Belgium**),
- Université de Lorraine (**France**),
- Mohammed V University in Rabat (**Morocco**),
- Mohammed VI Polytechnic University (**Morocco**)
- University of the Witwatersrand (**South Africa**)

Aim of the project

● Develop new QDSSCs using heavy metal-free QDs as absorbing material in the visible and infrared regions for optimal use of the solar spectrum.

● Optimize the interface between Cu-In-Zn-Se or $CsSnX_{3-x}Y_x$ QDs and the TiO_2 photoelectrode using wet and vacuum deposition processes.

Relevance vs MARs

● Find new materials and better design PV cells to **make more efficient solar panels and decrease their cost for generating clean and renewable electricity**.

● Develop devices that will **allow not only autonomous but also decarbonated production of electricity and thus ensure energy independence.**

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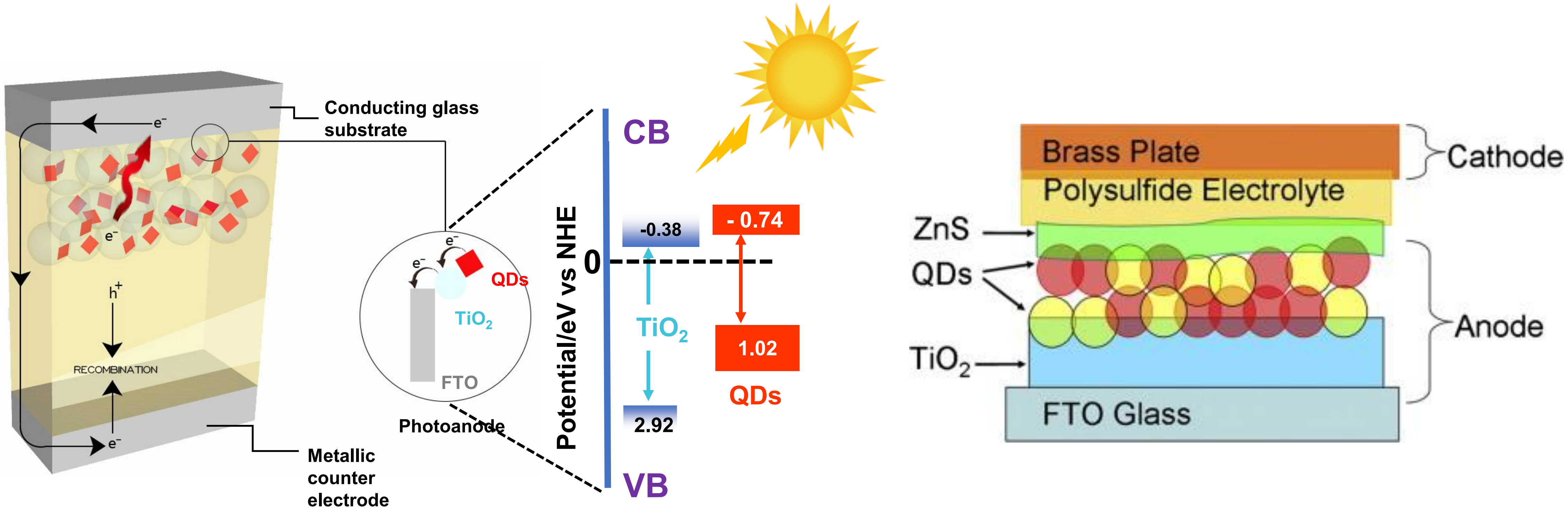
Presentation of scientific and/or technical objectives

Quantum Dot-Sensitized Solar Cells (QDSSCs)



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Presentation of scientific and/or technical objectives

1. Develop new syntheses of Cu-In-Zn-Se and $CsSnX_{3-x}Y_x$ QDs with optimal electronic and optical properties for use in QDSSCs.
2. Optimize the structure and the electronic properties of the dense TiO_2 layer via magnetron sputtering and of the porous TiO_2 layer by wet-based templating strategies.
3. Control the microstructure of the TiO_2 porous network, in order to form continuous and highly condensed interpenetrating nanochannels allowing to maximize QDs to TiO_2 charge injection and minimize recombination.
4. Establish the excited state and charge transfer properties of Cu-In-Zn-Se and $CsSnX_{3-x}Y_x$, as well as their interaction with TiO_2 to further boost the QDSSCs efficiency.

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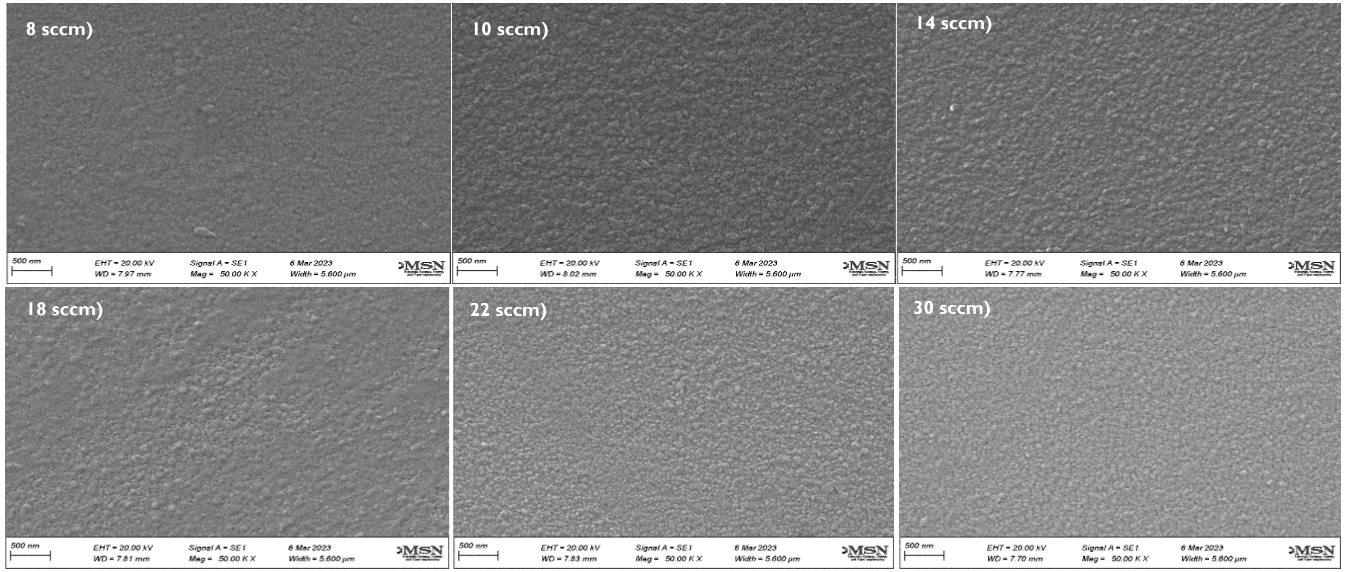
High-power impulse magnetron sputtering (HiPIMS)



Morphology of TiO_2 deposited by **HiPIMS** at different O_2 flow rates

- All films **had a dense and crack-free microstructure of spherical-like grains,**
- **HiPIMS films are denser** than the direct current magnetron sputtering (DcMs) films due to the increased energy brought on by the incident particles,
- **The grain size of the HiPIMS-deposited films is l**ower than the grain size of the DcMS-deposited films

The **increased ionization rate** provided by **HiPIMS** process causes the ion energy to increase which **enhances the diffusion ability**, increases the nucleation rate, **reduces the grain size**, and increase the grain boundaries*

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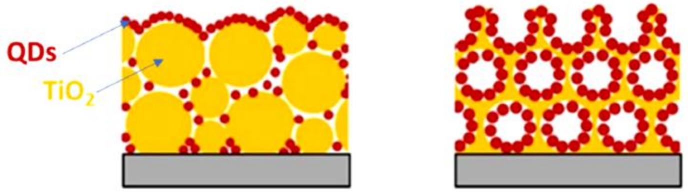
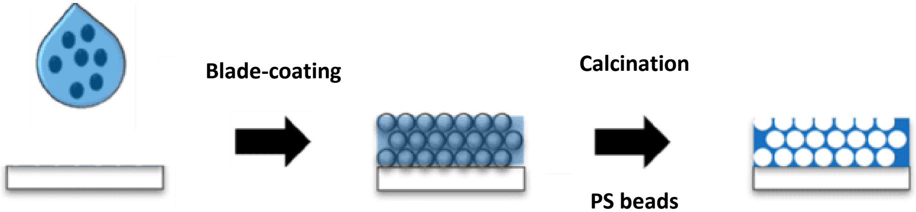


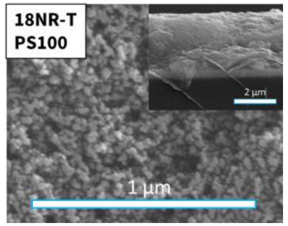
Random organization

Structured layer

Objectives

- ➔ Increased TiO_2/QDs interface area
- ➔ Improved QDs loading
- ➔ Enhanced light absorption
- ➔ Increased PV efficiency

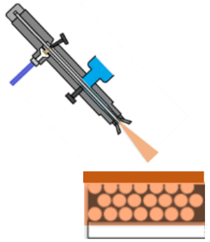




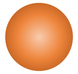
PS beads diameter: *60nm (=PS60)* **OR** *100nm (=PS100)*
TiO_2 precursor: *18NR-T TiO_2 nanoparticles paste)*

QDs adsorption

Air-brush



Dipping



CuInZnSeS QDs

« Standard »

$Mg(OH)_x$-assisted adsorption

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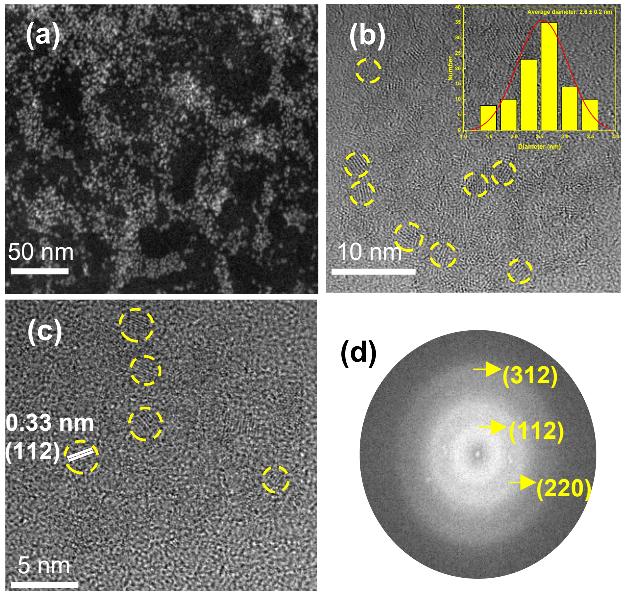
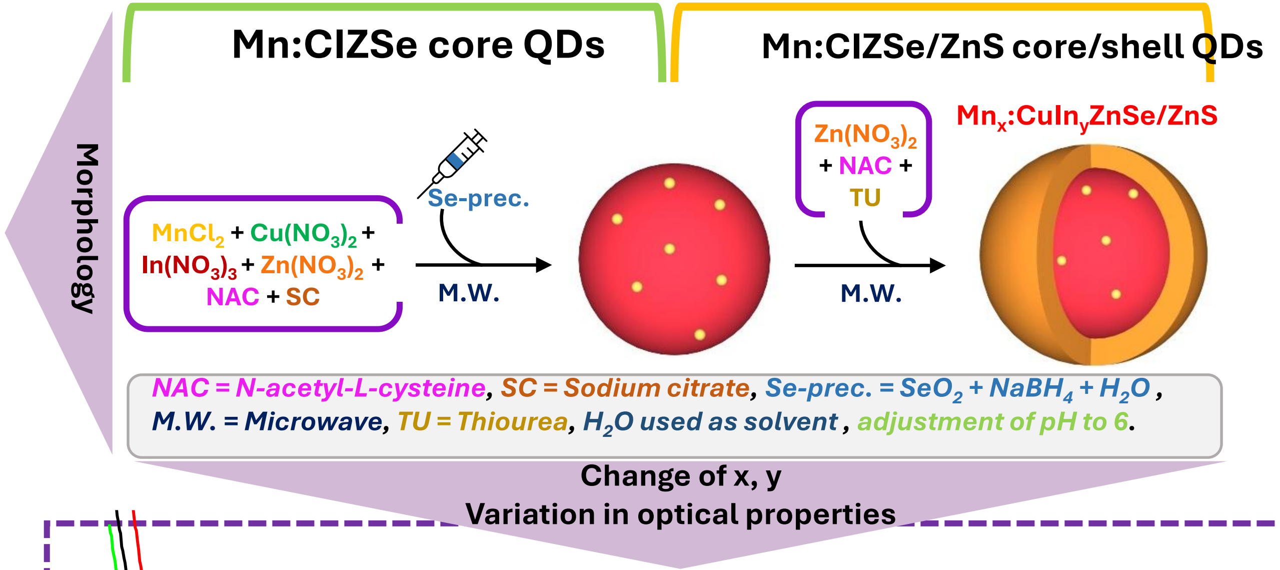
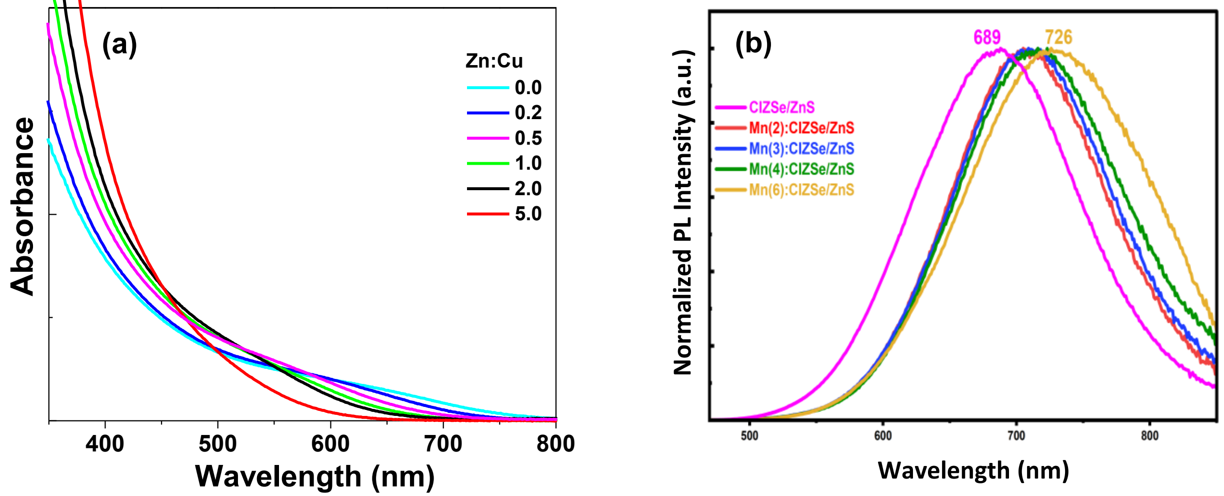


(a) HAADF-STEM, (b) TEM wherein the inset shows the avg. size distribution of 2.6 nm, (c) HR-TEM images and, (d) associated SAED pattern of Mn(6):CIZSe/ZnS QDs.





(a) UV-vis absorption, and (b) PL emission profiles of Mn:CIZSe/ZnS QDs with varying Mn^{2+} loading (%).

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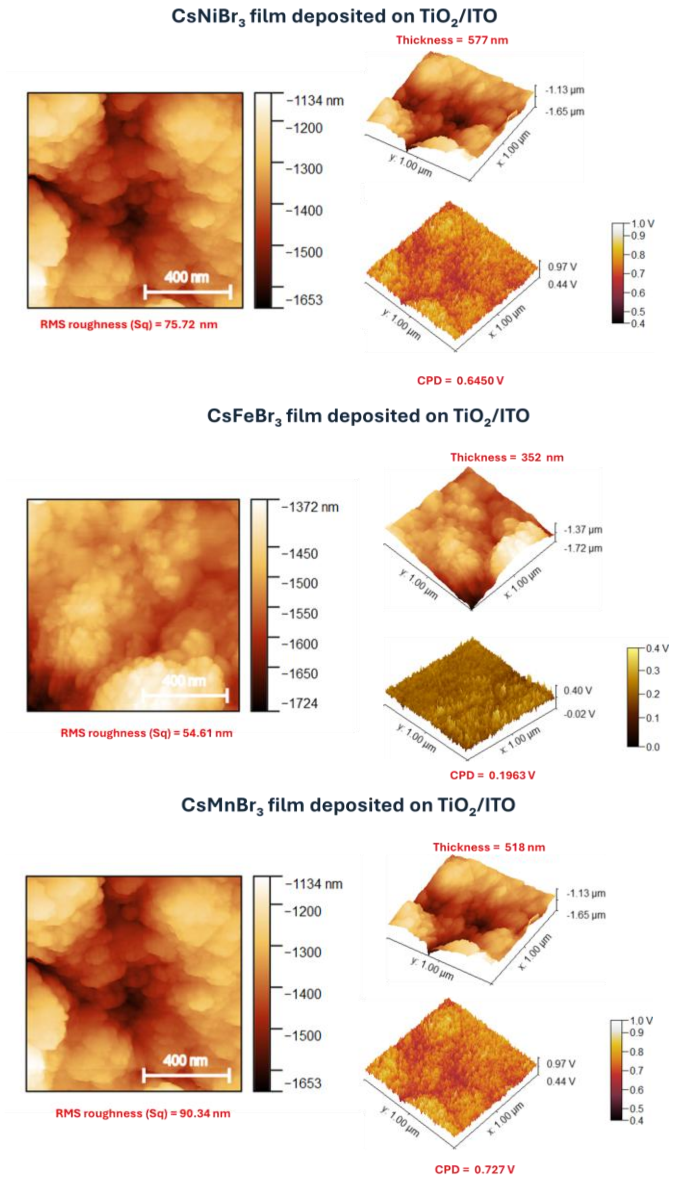

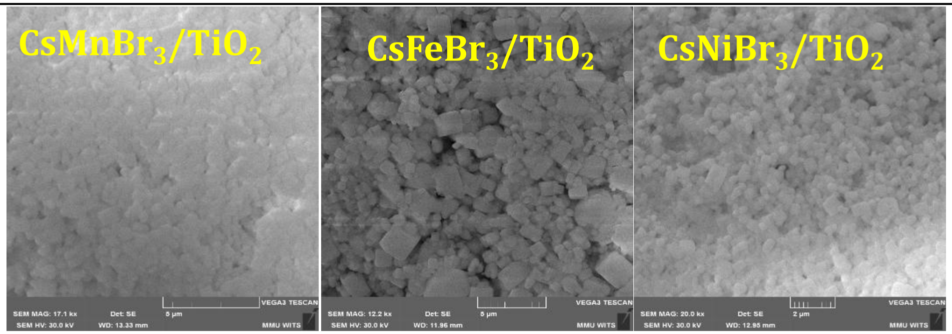

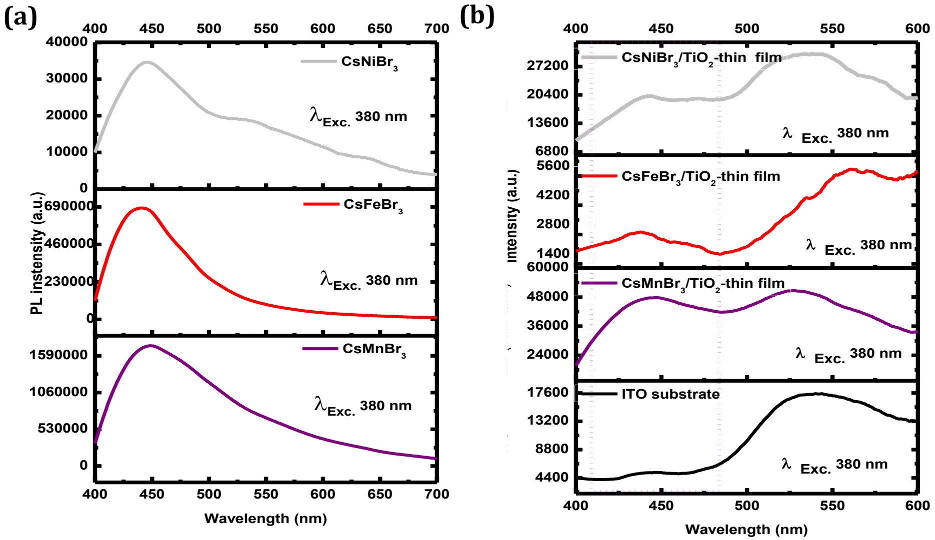

(a) Steady state PL spectra of perovskite NCs and (b) perovskite-based thin film deposited onto TiO_2/ITO

- **SEM:** $CsNiBr_3$ films are denser with uniform grains, aiding charge transport.
- **AFM:** $CsNiBr_3$ is smoother, ensuring better TiO_2 contact.
- **KPFM:** $CsNiBr_3$ shows uniform surface potential and good energy alignment.
- **PL:** Strong quenching confirms efficient charge transfer at the interface.

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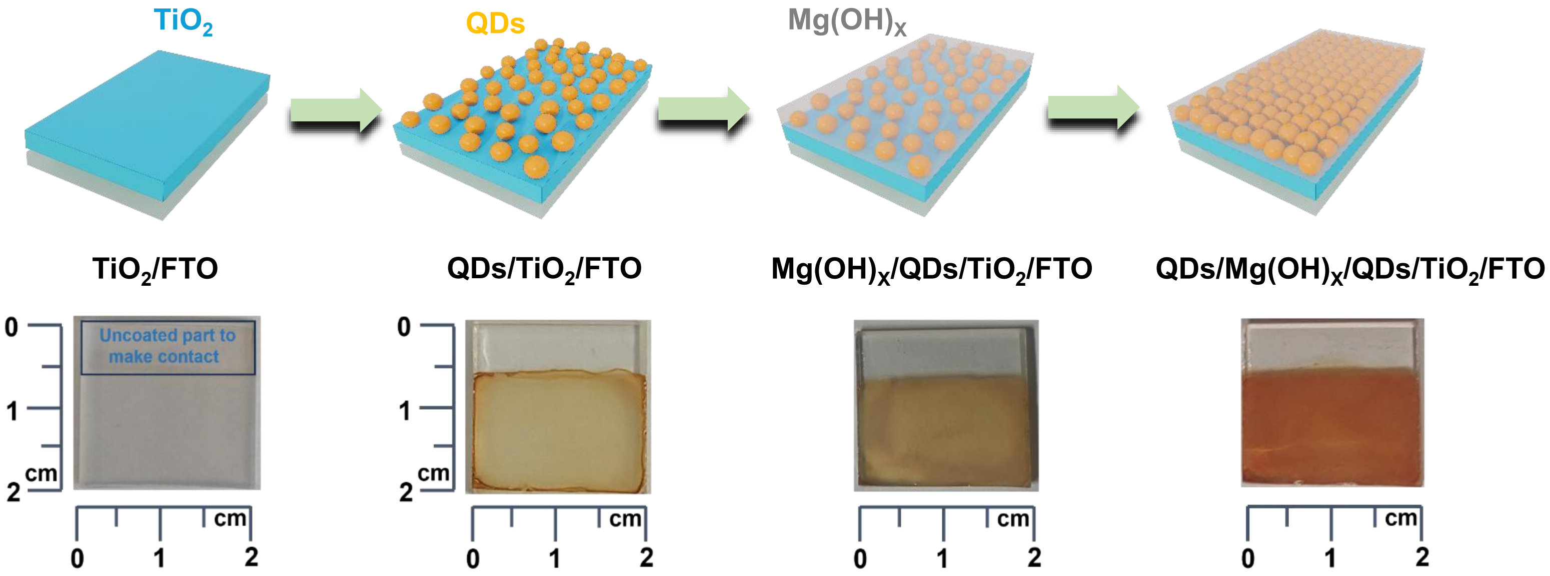
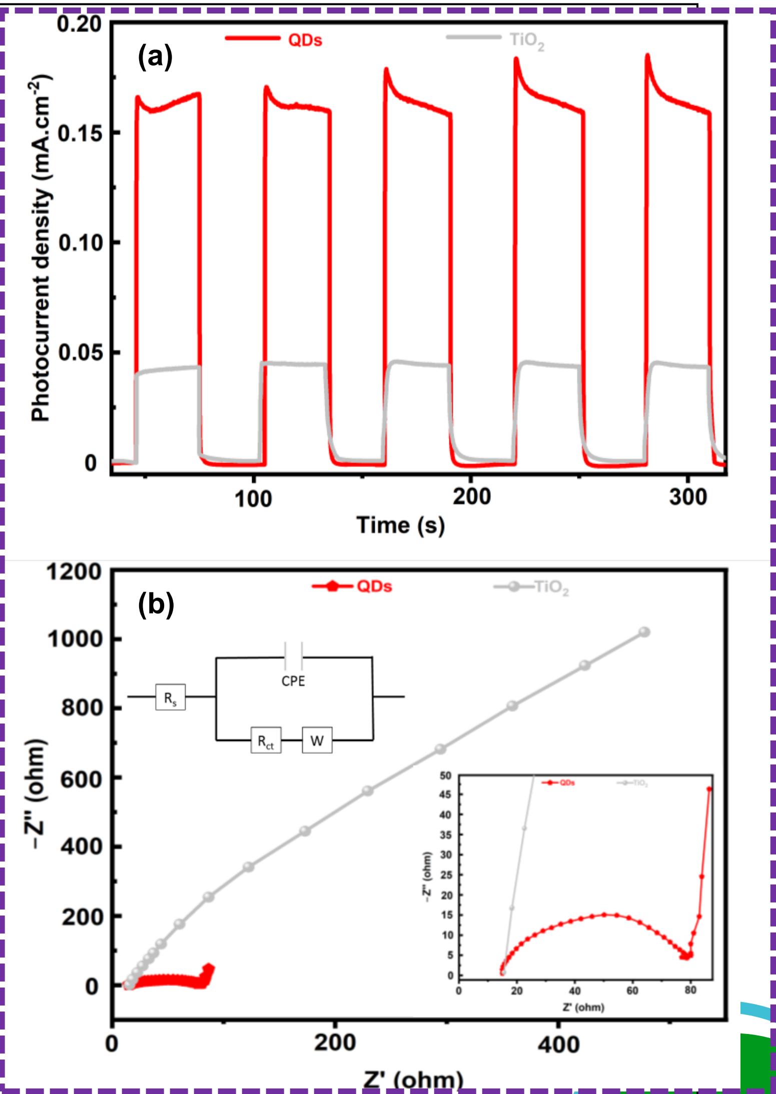
Quantum dot-sensitized photoanode



Schematic illustration of fabrication of QDs/$Mg(OH)_x$/QDs/TiO_2/FTO photoelectrodes. Representative digital photos of the electrode at each fabrication step while using Mn(6):CIZSe/ZnS QDs as photoabsorber.

Photoanode	R_{ct} (Ω)
TiO_2 /FTO	2493
QDs/$Mg(OH)_X$/QDs/TiO_2/FTO	47



(a) Transient photocurrent response and (b) Nyquist curves obtained using 0.5 M Na_2SO_4 as electrolyte at a bias of -0.65 V vs Ag/AgCl (saturated KCl) in dark of Mn(6):CIZSe/ZnS QDs-sensitized and TiO_2/FTO photoanodes. All the measurements are performed on QDs/$Mg(OH)_x$/QDs/TiO_2/FTO and TiO_2/FTO structured photoanodes.

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- ***Results achieved***
- **All the components of the photovoltaic cell were prepared by the project partners.**
- **Initial assembly tests were carried out in order to develop the prototype (25 cm^2).**
- ***Progress in compare with the state of the art***
- **At the current stage, it is difficult to evaluate the cell's performance compared to the literature.**
- **The structuring of the cell will undoubtedly need to be further improved, for example by adding a ZnS layer in order to isolate the photoanode from the electrolyte.**
- ***Increase in TRL***
- **Increase from TRL2 to TRL3-4. Proof-of concept, validation in relevant environment is still required.**

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- ***Possible evolutions of the objectives in progress of the project (explain), problems encountered during the project***
- **No major problem encountered during the project. However, the architecturation of the cell has been modified, mainly due to the detachment of nanocrystals from the mesoporous TiO_2 layer.**
- ***Specify whether the project has resulted in new products or developments***
- **The project enabled the development of new inorganic photoabsorbers that do not contain heavy metals as well as processes for the preparation of nanostructured TiO_2 layers.**
- **Record : 4 published articles in rank A journals, 12 communications (5 articles are either in preparation or already submitted).**
- ***Specify how id the project contribute to a gender equal societal development ?***
- **The expected scientific and technical results of QDSOC project are aimed at covering the need of the whole population, regardless of sex, gender or age. Hence, no direct output of the project affects directly women or men.**

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- ***Planned follow-up work, new pathway to explore…***
- **In a first step, review and improve the structuring of the cell to be able to test it in real conditions. These results will condition the evolution of the photovoltaic cell components.**

- ***Become of the consortium set up on this project***
- **The consortium has expressed interest in continuing the collaboration.**

- ***New collaborations initiated thanks to the results of the project (following publications, conference presentations, etc.)***
- ***New collaborations planned for the future (to answer what problem? Industrial or other perspectives?…)***
- **Photo-absorbing nanocrystals have also shown strong potential in other applications such as photocatalysis. Tests were carried out both for the degradation of persistent molecules in aqueous effluents and for the photoproduction of decarbonated hydrogen.**

- ***New funded projects and/or funding applications (what type(s) of funding?)***
- **At present, the partners have applied for national calls but plan to continue the collaboration by responding to the appropriate calls.**

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Expected outcomes in case of success of the project (2030)

1. **Development of tailored materials exhibiting high efficiency in the solar spectrum region, involving in-depth fundamental investigations of their operation mechanisms.**
2. **Engineering of new and highly efficient photovoltaic cells containing no heavy metals and allowing maximum use of sunlight.**
3. **Development of reliable stand-alone system architecture that can be easily and widely deployed in off-grid African rural and remote areas, but also in other regions of the world**

Profits

- **Sustaining fundamental research and applied developments in the fields of solar cells chemistry, physics, surface sciences and materials engineering.**
- **Giving access to affordable energies to the largest number of beneficiaries.**

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Contribution of the project to AU – EU R&D partnership

A scientific and fruitful collaboration has been developed between the partners.

The opening of the collaboration to other partners more specialized in the building of photovoltaic cells (at pilot scale) is sought.

Interest of Consortium members in participating in LEAP-RE clustering activities

Integration of photoabsorbing nanocrystals into existing photovoltaic cells.

Change in scale.

On site experimentation.

THANK YOU

CONTACT US FOR MORE INFORMATION

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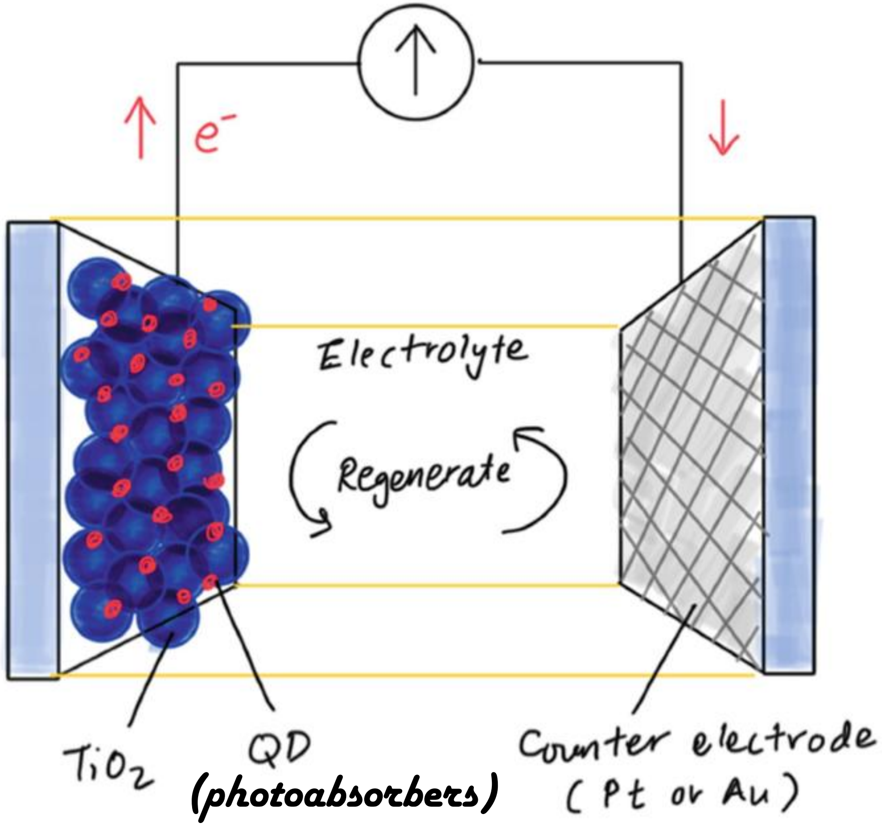

e-
Electrolyte
Regenerate
TiO2
QD
(photoabsorbers)
Counter electrode
(Pt or Au)