Design and implementation of a new concept of photoelectrochemical cell for solar water splitting

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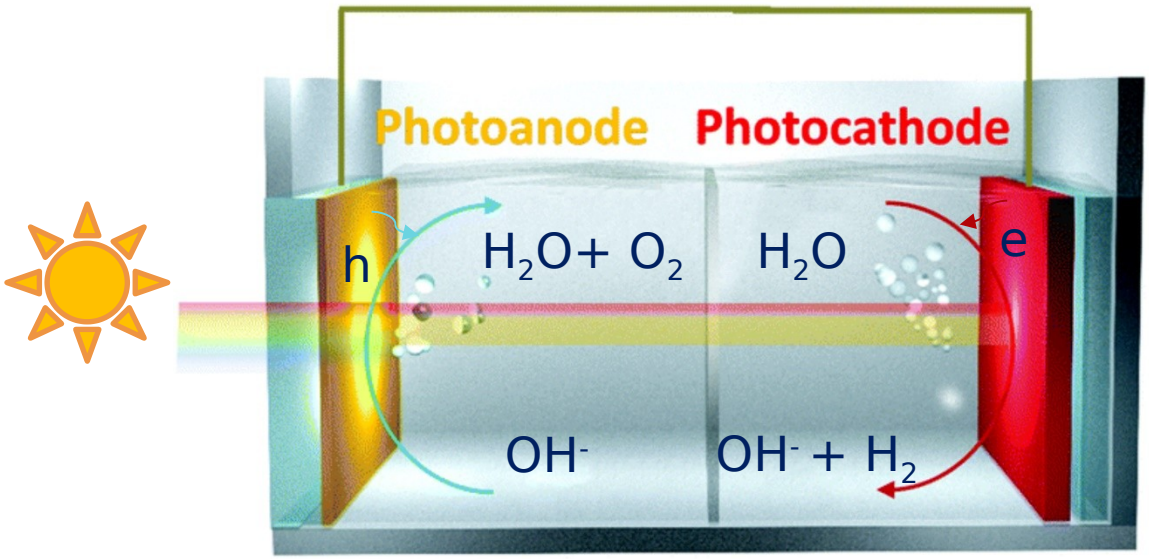
Overview

- Photo-Electrochemical water splitting
- The FotoH2 concept
- Experimental results
- Scaled up device design
- Comparison vs test cell
- Summary

Photo-electrochemical water splitting: Basics



Anode:

$4OH^- + 4h \rightarrow 2H_2O + O_2$

Cathode:

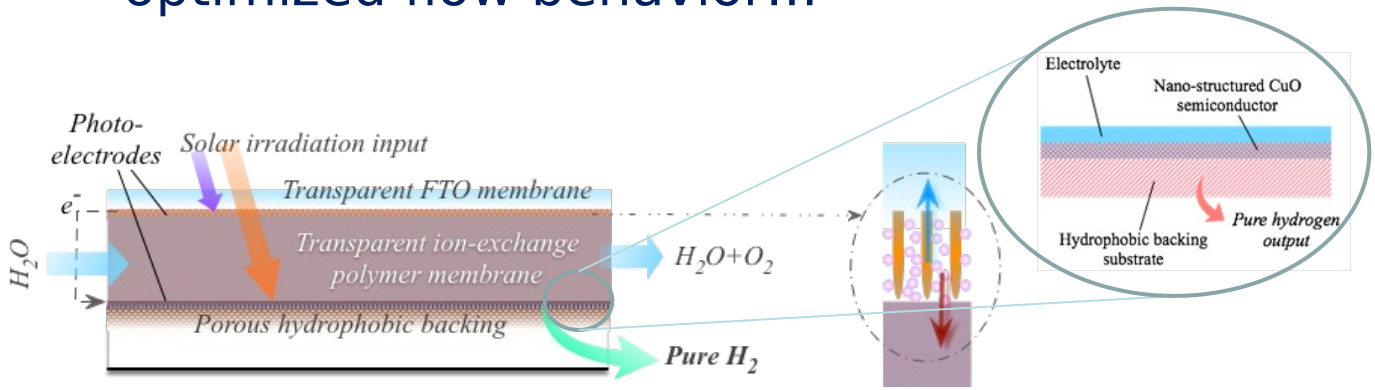
$2H_2O + 4e \rightarrow 2OH^- + H_2$

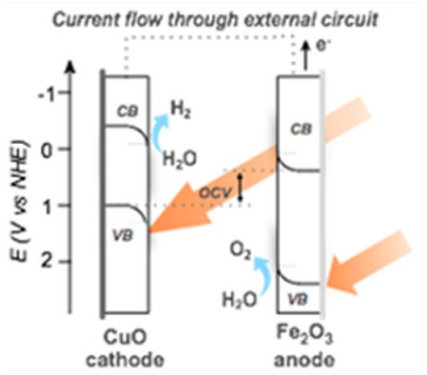
PEC cell : Photoelectrochemical cell for water splitting that converts solar energy directly to hydrogen fuel from photoelectrolysis. It comprises a photoelectrode and a counter electrode in contact with an electrolyte.

Photoelectrode: Photoelectrode is an electrode capable of initiating electrochemical transformations after absorbing light. In the solar water splitting context, photoelectrode is made of a semiconductor film on an electrically conductive material

The FotoH2 Concept

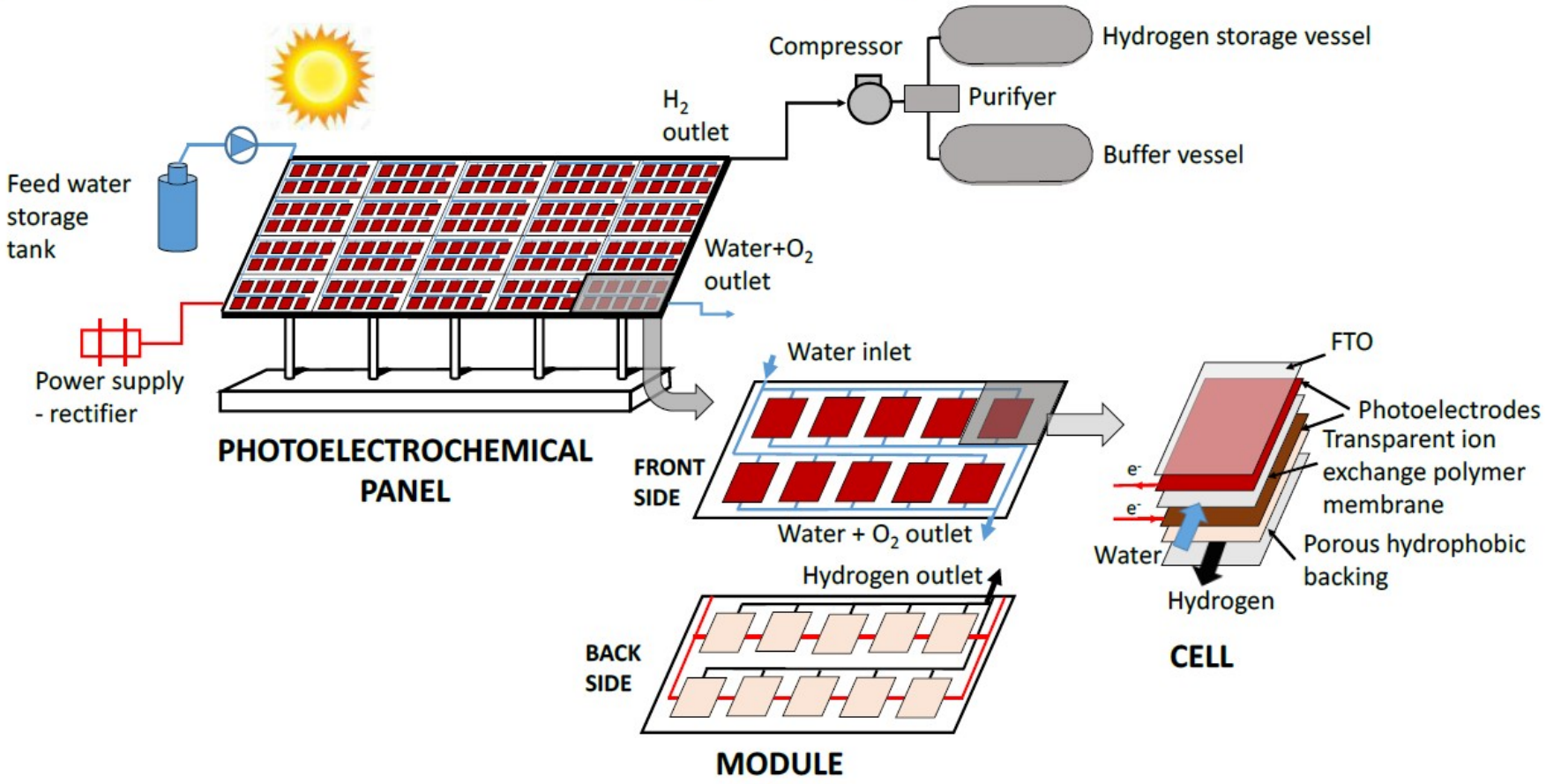
- Cheap photoelectrodes: Hematite (Fe_2O_3) and CuO
- Simple flow-cell design without corrosive electrolytes.
- Anion-exchange polymer membrane and porous hydrophobic backing concepts (solid electrolyte)
- Design of a tandem photo-electrochemical cell
- Large-scale prototyping and field testing
- Efficient low-cost photochemical water splitting reactors with optimized flow behavior…





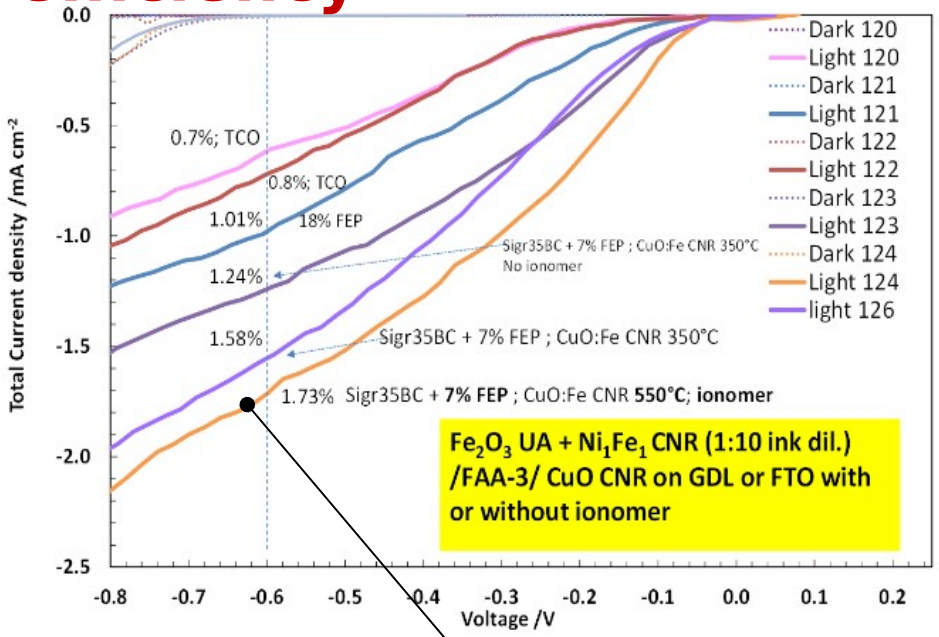
Transparent Membrane **Porous hydrophobic backing** **Tandem cell concept**

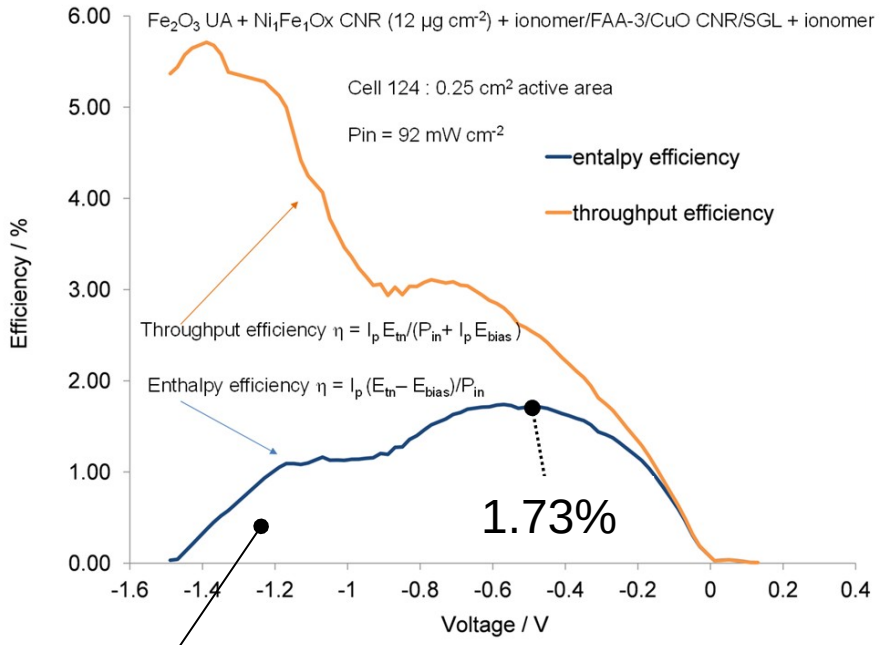
The FotoH2 Concept



Modular approach as in Photo-Voltaic systems

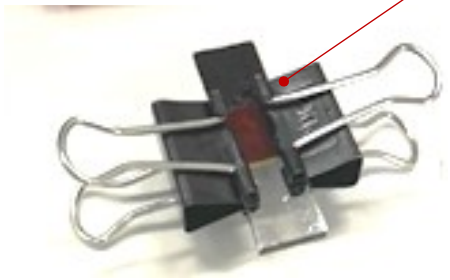
Lab Test cell results: Polarization and efficiency





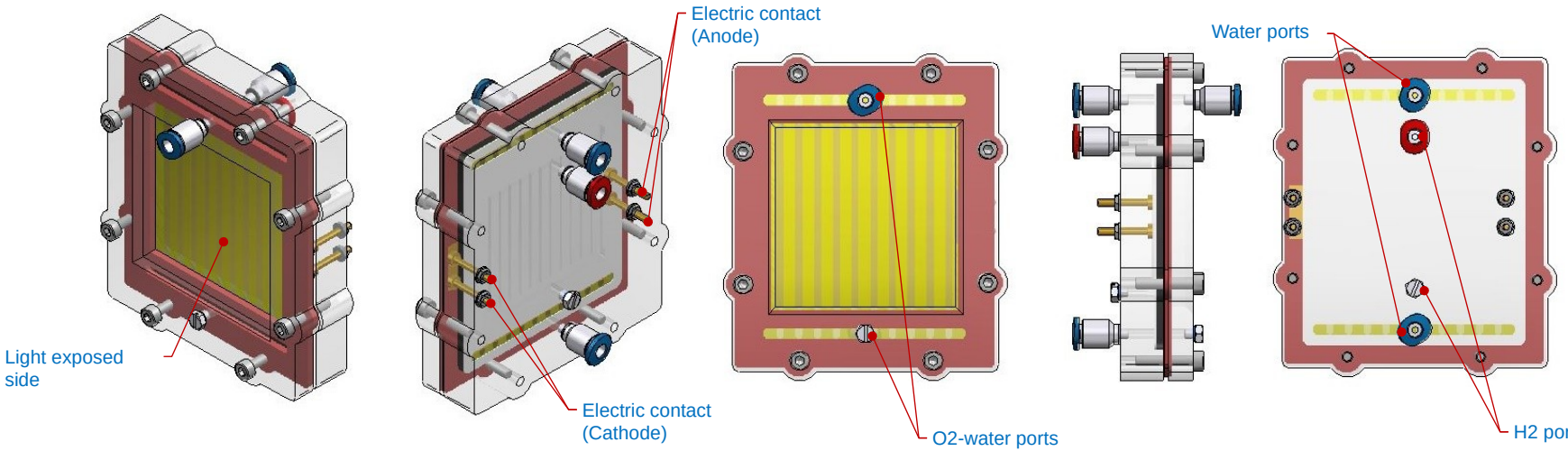
Electrode formulation screening

Efficiency calculation

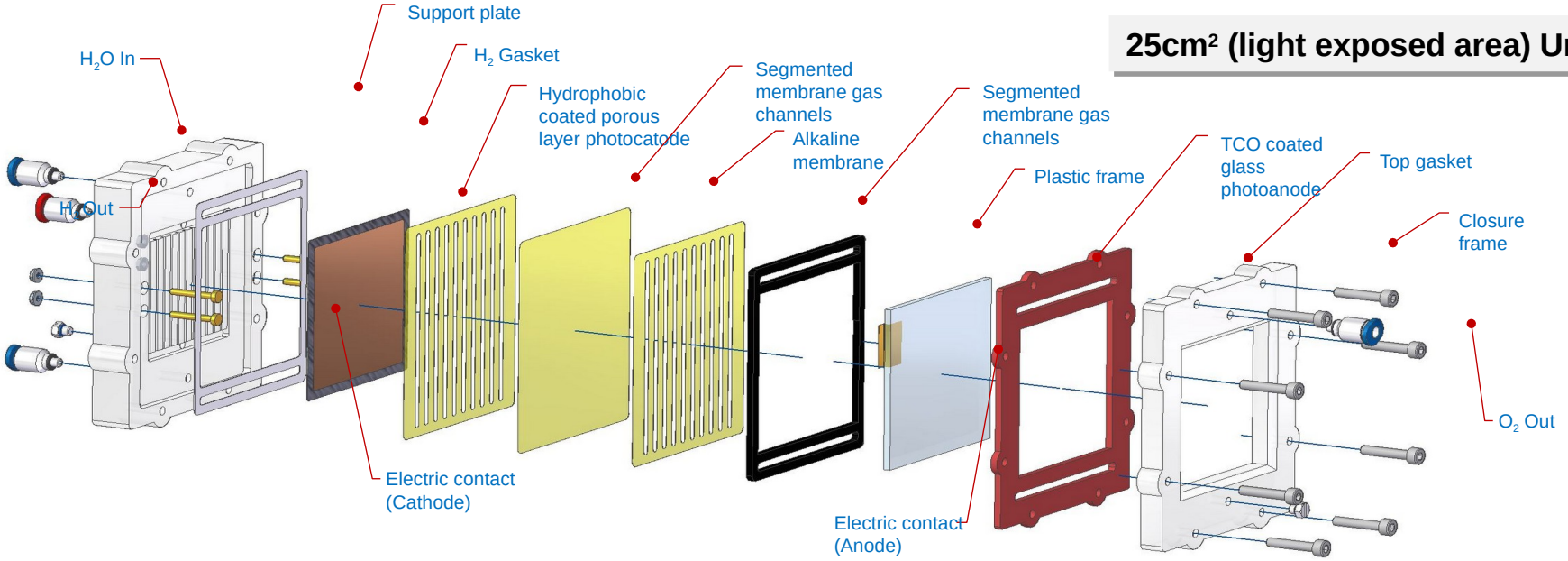


0.25cm²
lab test cell

Scaled up cell Design

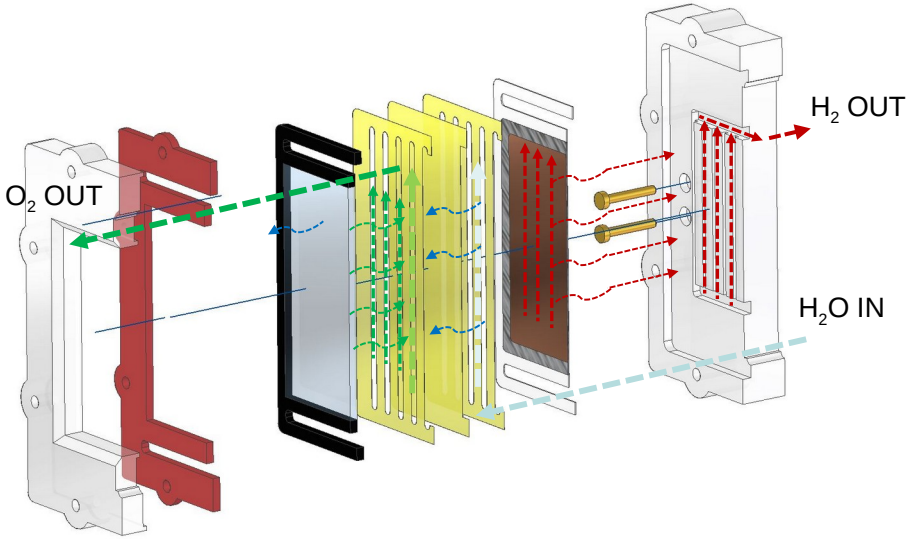


25cm² (light exposed area) Unit Cell

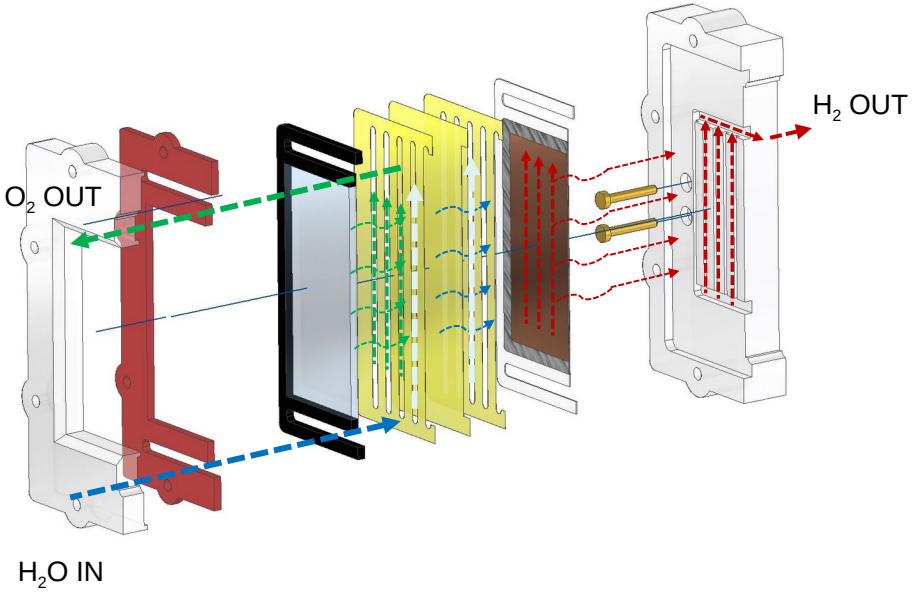


Reactants/Product Flow path

- Unit cell can operate by feeding water from anode and cathode respectively



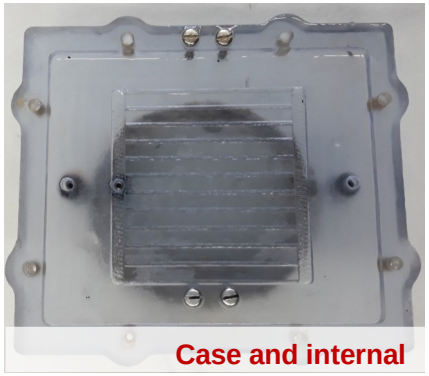
Water fed from the Cathode

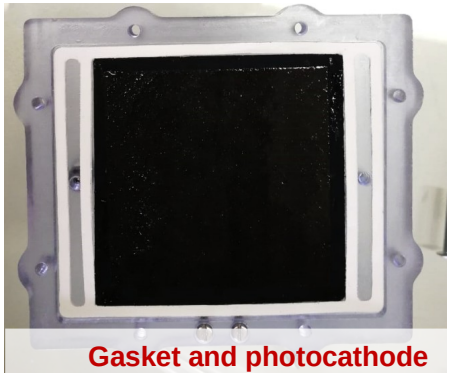


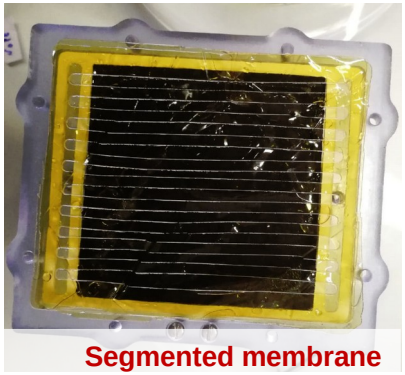
Water fed from the Anode

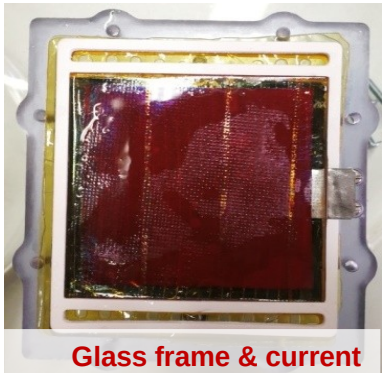
O_2 H_2 H_2O

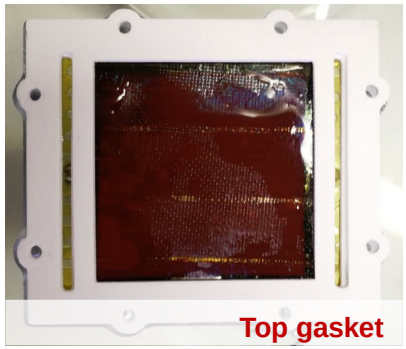
Unit cell components and assembly sequence

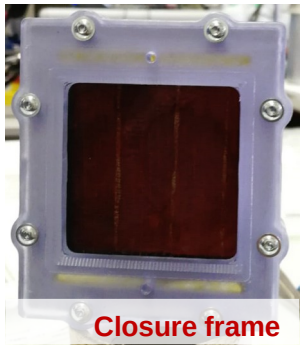

Case and internal connectors


Gasket and photocathode

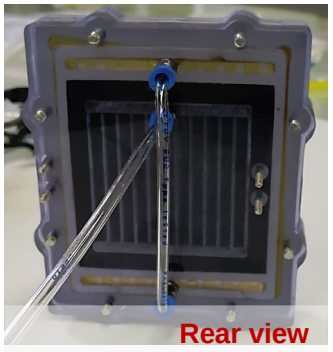

Segmented membrane


Glass frame & current slab

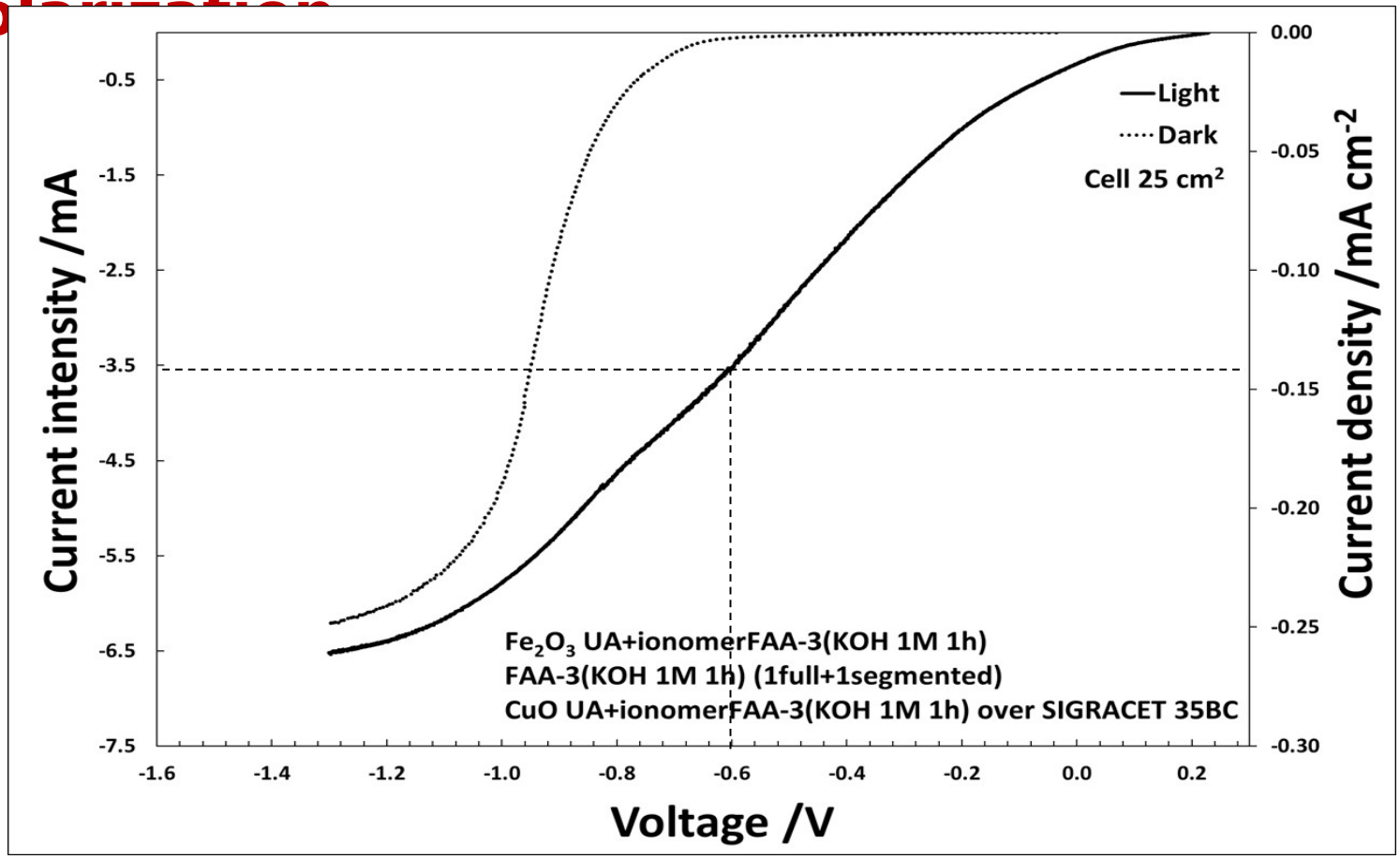

Top gasket


Closure frame


Front view


Rear view

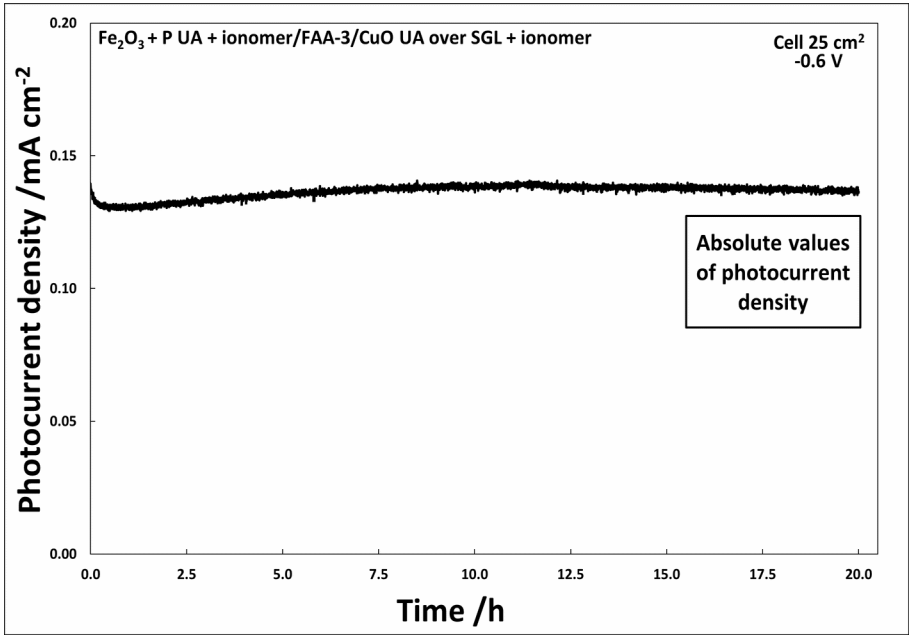
PhotoElectrochemical tests scaled up: Polarization

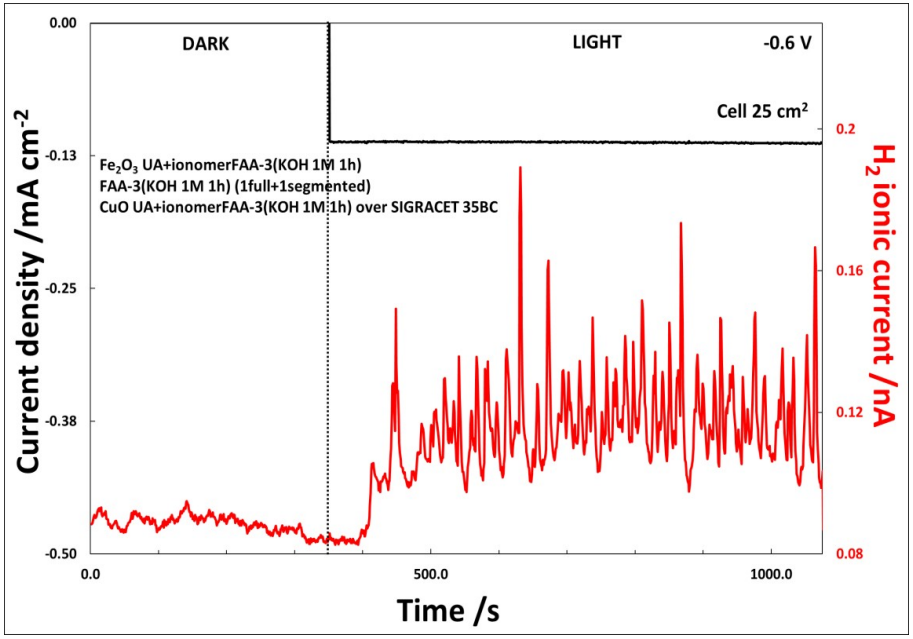


The photocurrent, in this case, is about **10 times lower** than the lab cell

PhotoElectrochemical tests : scaled up cell

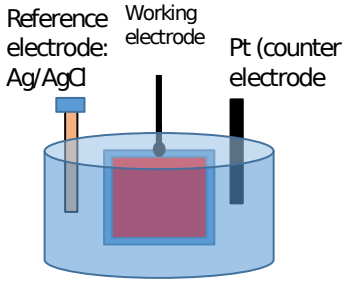
Stability test
the photocurrent degradation is not appreciable.



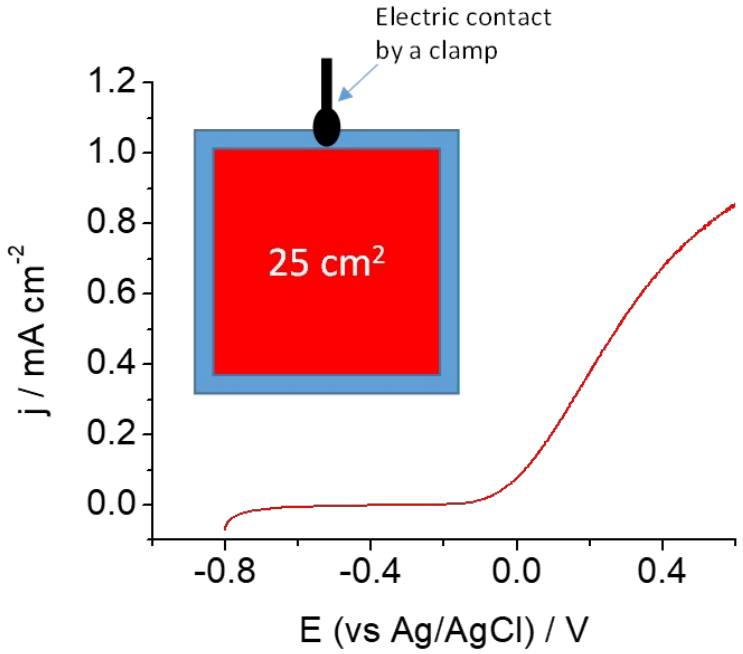


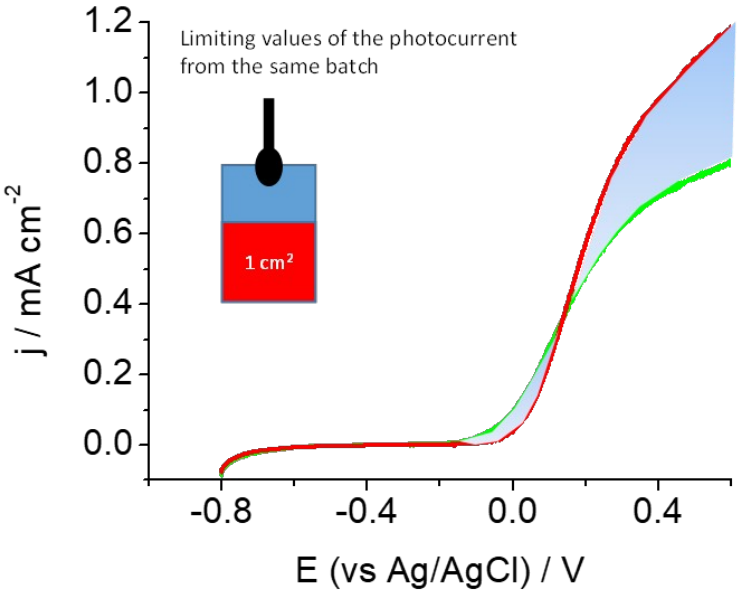
Mass spectrometer measurements at the cathode output revealed numerous spikes related to hydrogen generation.

Large area photoelectrode response: ex situ test



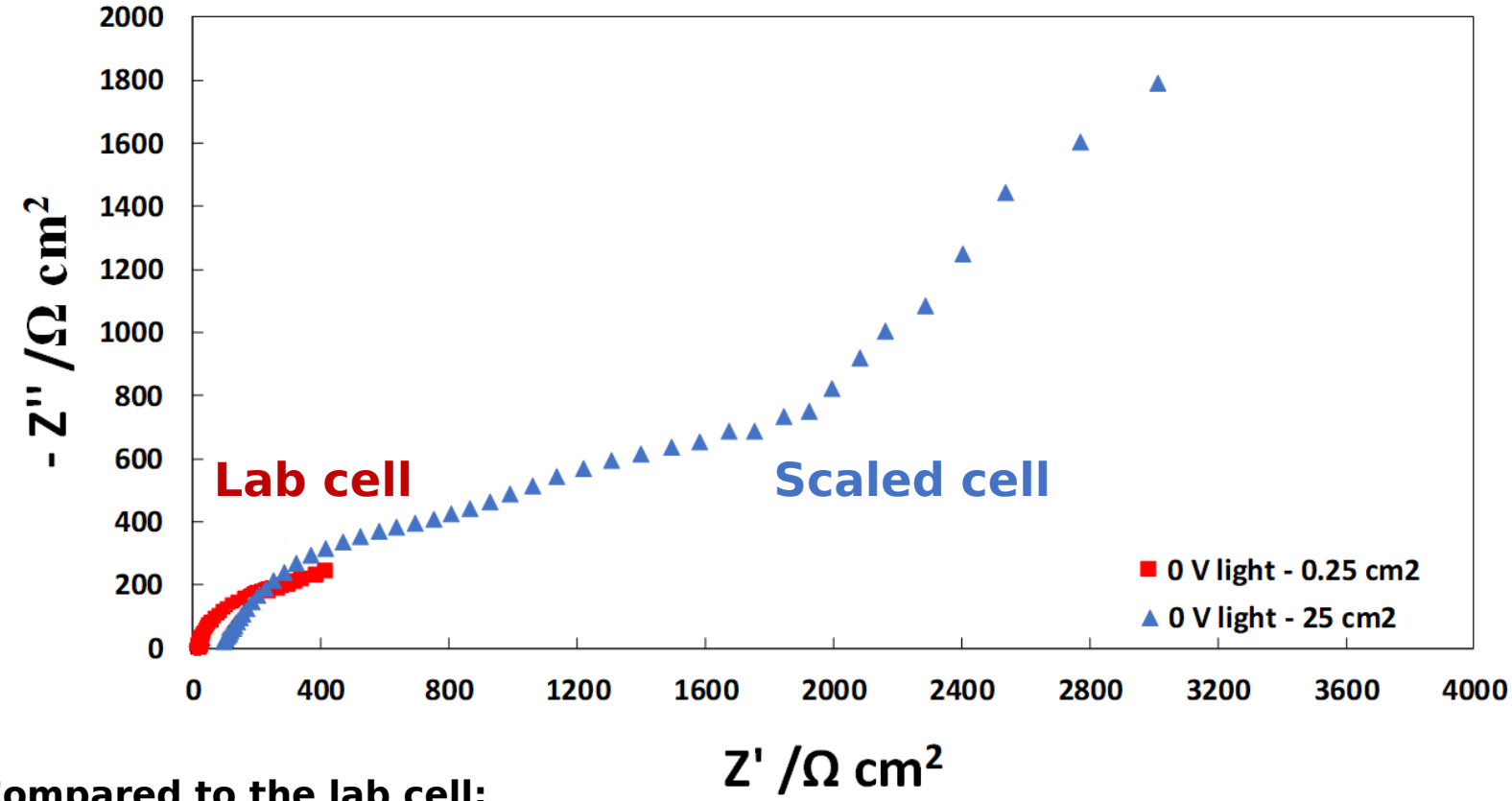
Effect of the FTO Conductivity in the 25cm² hematite Photoanode





Conductivity of the glass appears not being the main limitation of the photocurrent

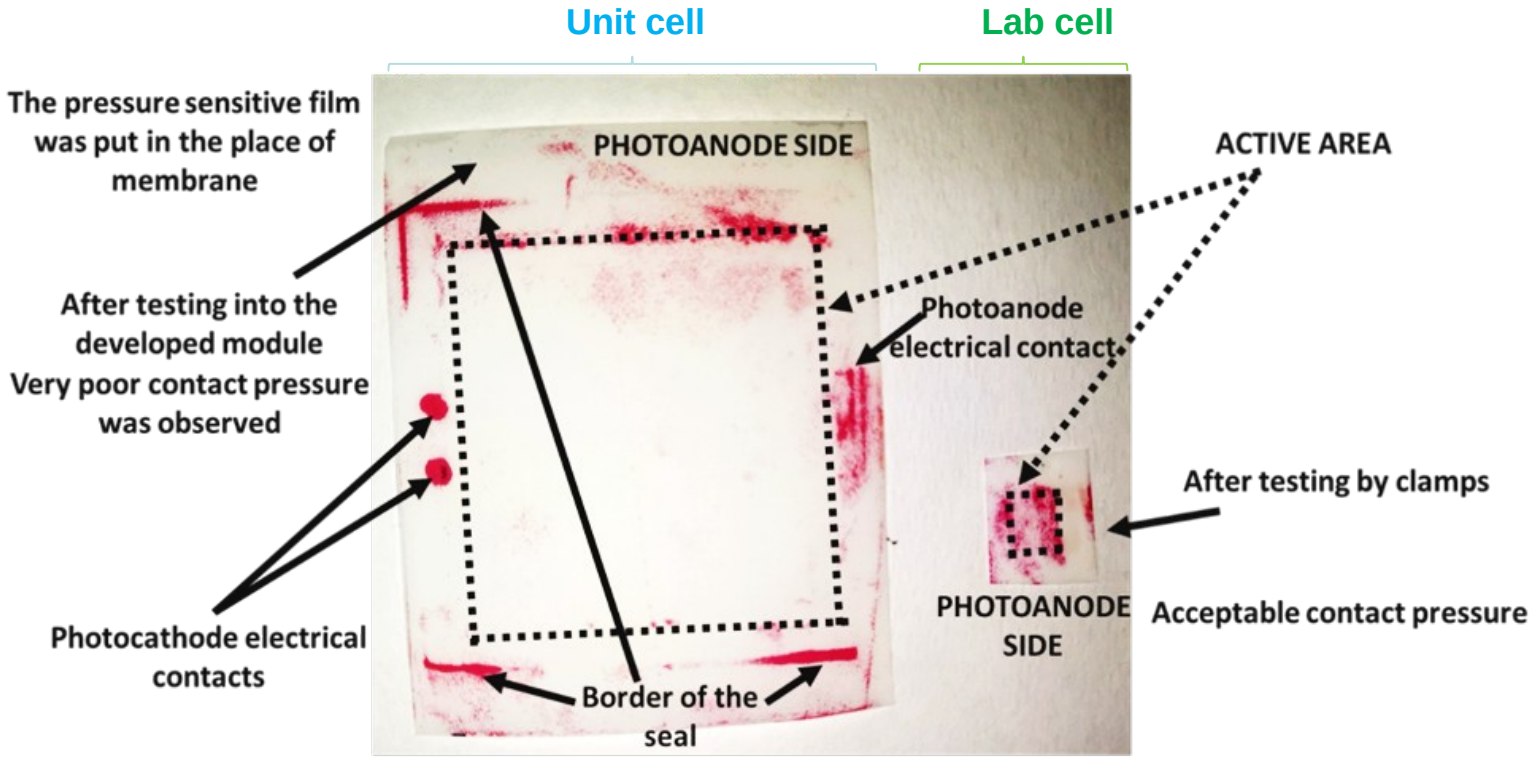
Unit Cell issues: EIS measurement



Compared to the lab cell:

- **High polarization resistance (Rp)**
- **High Series Resistance (Rs)**
- Main issues appear to be related to mass transfer at the photo electrode – electrolyte
- Recombination effect into the photoelectrode?

Contact pressure measurement



Contact pressure in the Unit Cell is lower than in the lab cell:

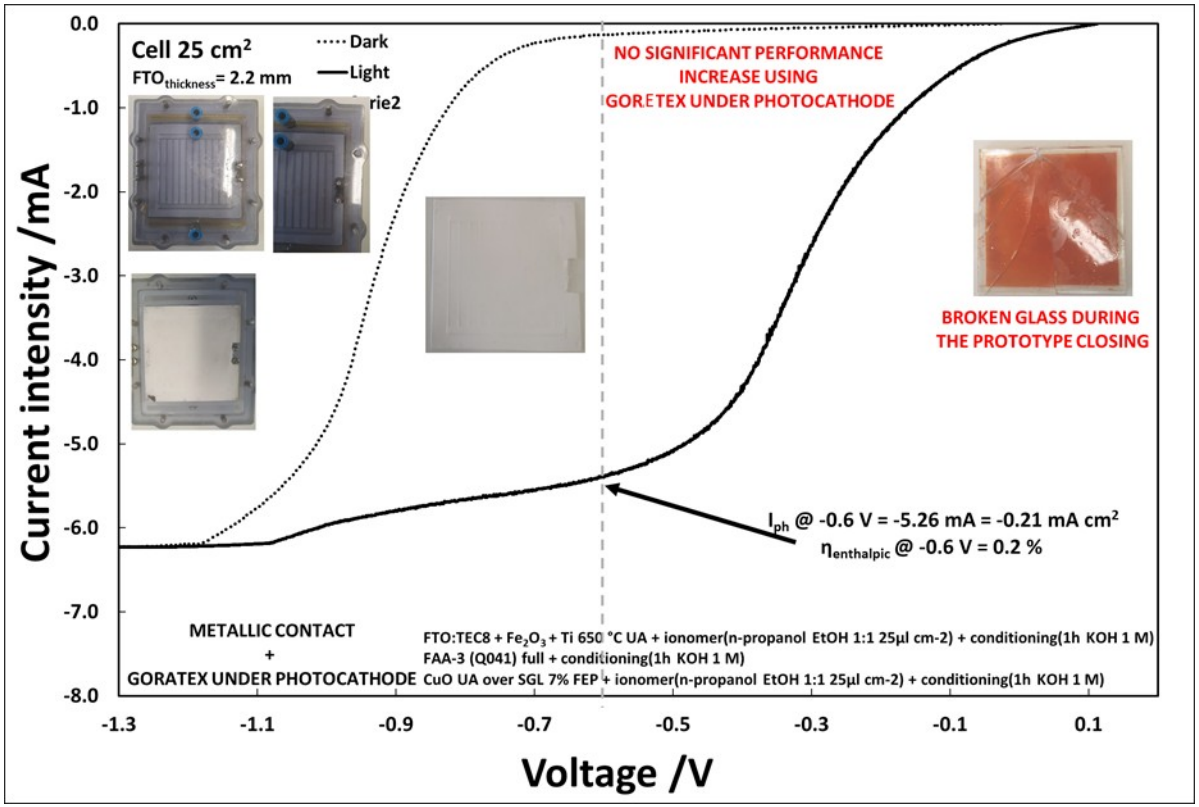
Possible Reasons

- Low clamping pressure applied
- Manufacturing tolerances inappropriateness
- Low closure frame stiffness

Early solutions

- Increase the clamping pressure
- Increase manufacturing tolerances i.e. planarity
- Stiffer material or design for closure frame.

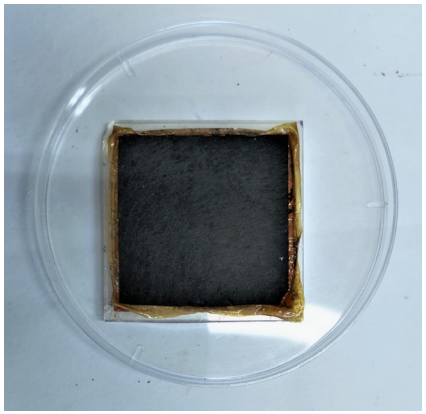
Increasing the contact area

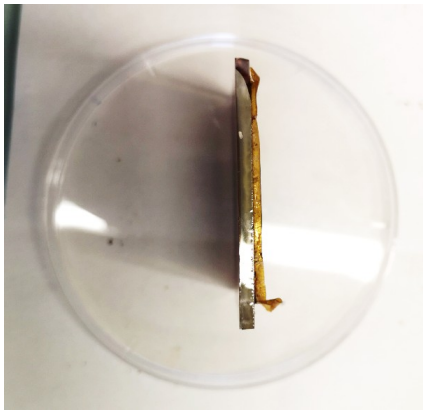


- Slight improvement in the photocurrent were recorded
- Mechanical issue due to differential displacements induced by Goretex

Approach to solve the present issues

- Improving the interface between photoelectrodes and membrane by ex situ assembly
  - **Hot pressing**
  - **Cold pressing “gluing process”**





- There are limiting factors in both approaches further work in needed.

Summary

A new concept of a PEC cell was demonstrated

The FotoH2 cell showed a solar to Hydrogen conversion of **1.74%**

A scale up to 25cm^2 cell was proposed and implemented

Assembly issues required the hematite syntesys on FTO to be adjusted.

Electrochemical tests showed lower efficiency than the test cell.

Causes of such lower performance have been identified

New concept of cell assembly is under investigation.

Aknowledgements

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Thanks for your kind attention

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