ArtipHyction

"Fully artificial photo-electrochemical device for low temperature hydrogen production"

FCH JTU 2011 call

Grant agreement: 303435

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

Guido Saracco
Politecnico di Torino

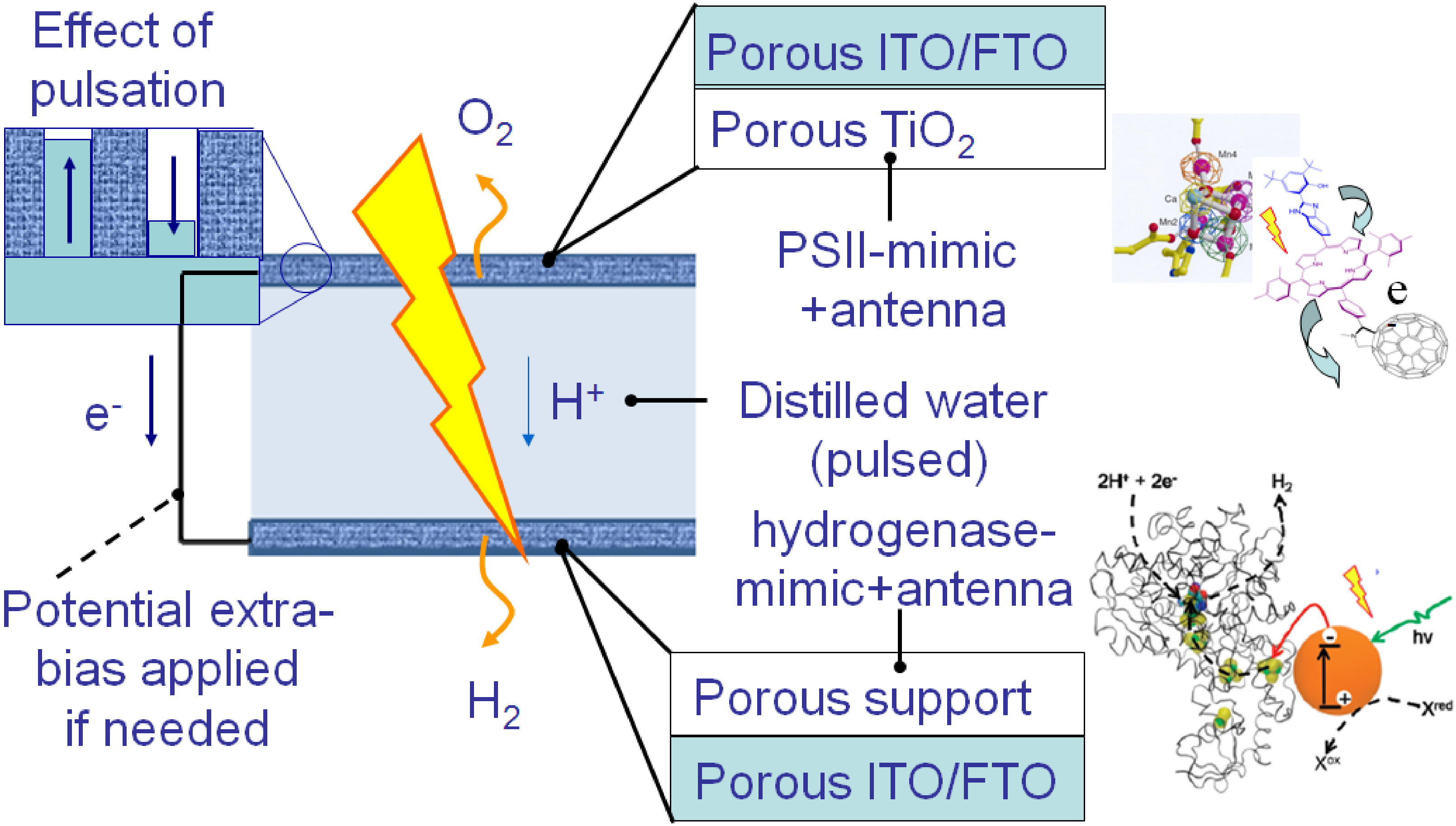
Partnership

0. Project and partnership presentation (slide 1)

N	Name	Logo	Nation	Key investigators	Main roles in the project	Reasons for selecting this partner
1	**Politecnico di Torino**		IT	Prof. G. Saracco Prof. J. Barber Prof. E. Garrone Prof. E. Tresso	Water-splitting catalyst developments, electrode development, modelling, LCA	POLITO is a member of the FCH JTI.Prof. Saracco coordinates the precur-sor project Solhydromics and itakes part in other EU projects. Prof. Barber is a world-class scientist in photosynthesis. Prof. Ruggeri and Tresso owns vaste expertise on anaerobic digestion and Si semiconductors, respectively.
2	**HySyTech srl**		IT	Ing. M. Antonini Ing. S. Solaro	Coordination, System modelling, Prototype design, test rig development	Member of the FCH JTI and of the previous Solhydromics project. The company produces and sells hydrogen production systems based on patents as WO Patent WO/2005/117,176 by Antonini et al.; PCT/EP2004/051207 by Antonini et al., etc. (www.hysytech.com)
3	**Commissariat à L'Energie Atomique**		FR	Dr. V. Artero Prof. M. Fontecave Dr. S. Palacin	Hydrogenase mimics development	Member of the FCH JTI. Prof. Fontecave's group has a leading role worldwide on hydrogenase mimics and hydrogen producing microorganisms, and is one of the major groups in the field of artificial photosynthesis
4	**Chemical Process Eng. Res. Institute**		EL	Prof. A. Kostandopoulos	Microporous electrode engineering, modelling	Member of the FCH JTI. Prof. Kostandopoulos has a huge expertise in the engineering of porous media. His involvement was generated by cooperation with POLITO in the ATLANTIS project, coordinated by Kostandopoulos and related to nanostrcturing of porous catalytic reactors.
5	**Solaronix SA**		CH	Dr. T. Meyer	Electrodes and electrodes assembly development	World supplier of nanocristalline TiO_2, ruthenium bipyridine complexes and electrolytes, mainly for the dye solar cell community since 1996. Producer of light soaking test equipment & solar simulators via unique "sulfur-plasma" lamp (www.solaronix.com). Partner of Solhydromics.
6	**Lurederra Foundation**		ES	Dr. C. Fernandez	Synthesis and characterization of ITO, FTO, AZO powders	The synthesis of micorporous transparent conducting oxides is one of the most innovative challenges in ArtièHyction. Top level performance of this research centre convinced the other partners that this is the best candidate to face this challenge and develop the needed synthesis routes.
7	**Tecnologia Na-varra de Nano-productos SL**		ES	Dr. I. Sancet	Engineering and production of ITO, FTO, AZO batches	Tecnan is the natural industrial exploitation environment for the development achieved at Lurederra. It has the expertise and the apparatus to drive lab synthesis to large scale industrial production techniques.
8	**Pyrogenesis SA**		EL	Dr. M. Vardavoulias	Engineering and preparation of electrodes	Partner of the above mentioned IP project ATLANTIS, Pyrogenesis was selected in the presen project for its capability to make design directives on microporous materials a reality via a number of industrially amenable techniques effectively used in a number of earlier developments.

Concept&objectives

1. Project achievements (slide 1)

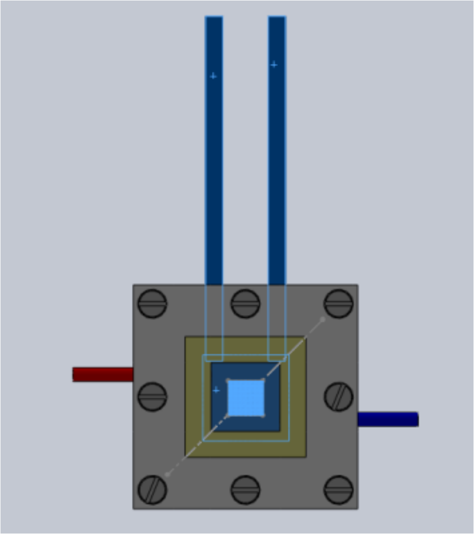


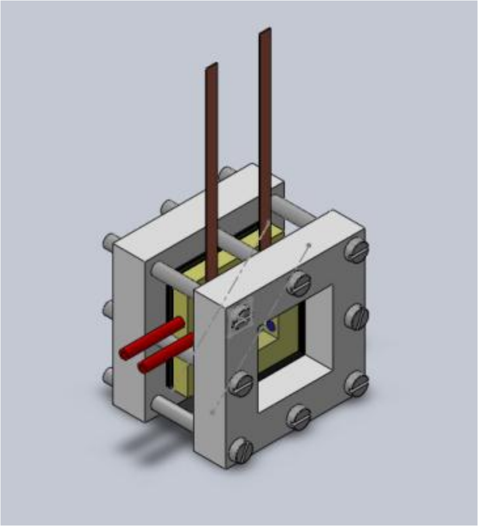
- -) **10% conv. of solar energy into pure H_2**
- -) **>1000 h durability tested**
- -) **without using expensive noble metals**
- -) **proof of concept at 3 g/h H_2 equivalent**

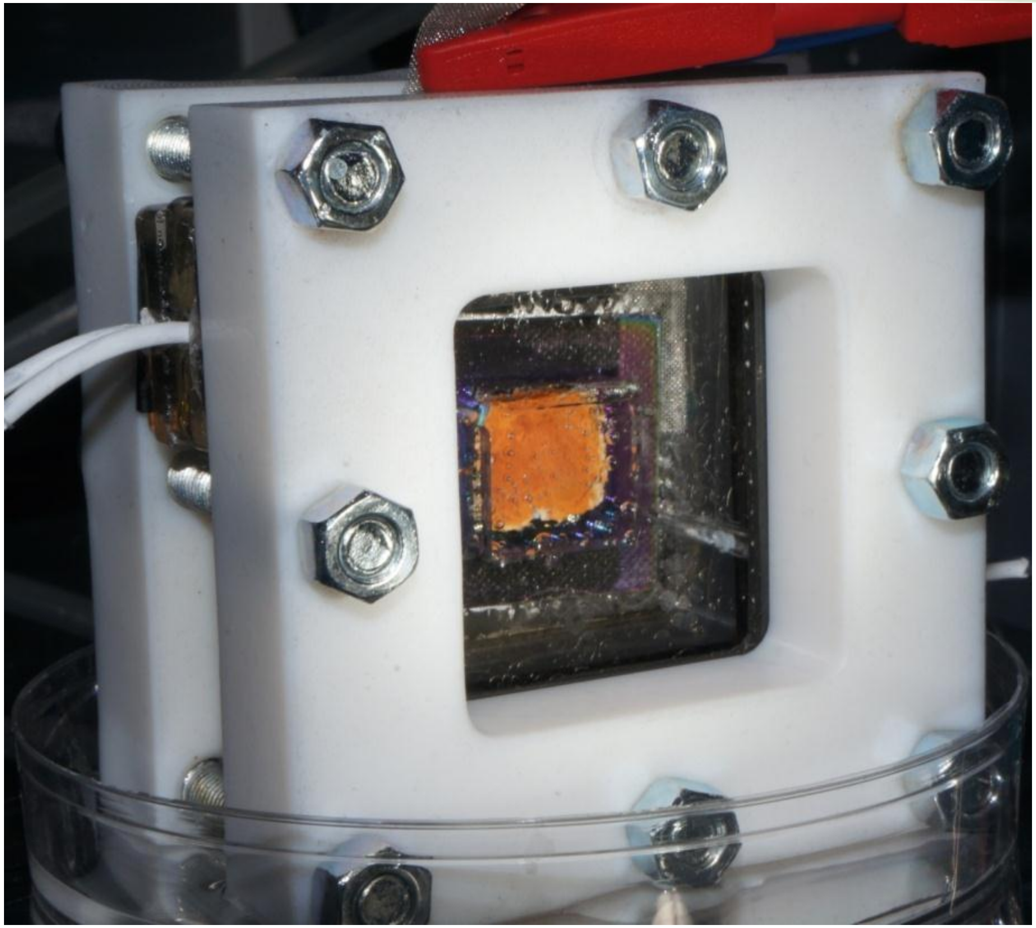
The Solhydromics prototype as starting point

1. Project achievements (slide 2)

www.solhydromics.com



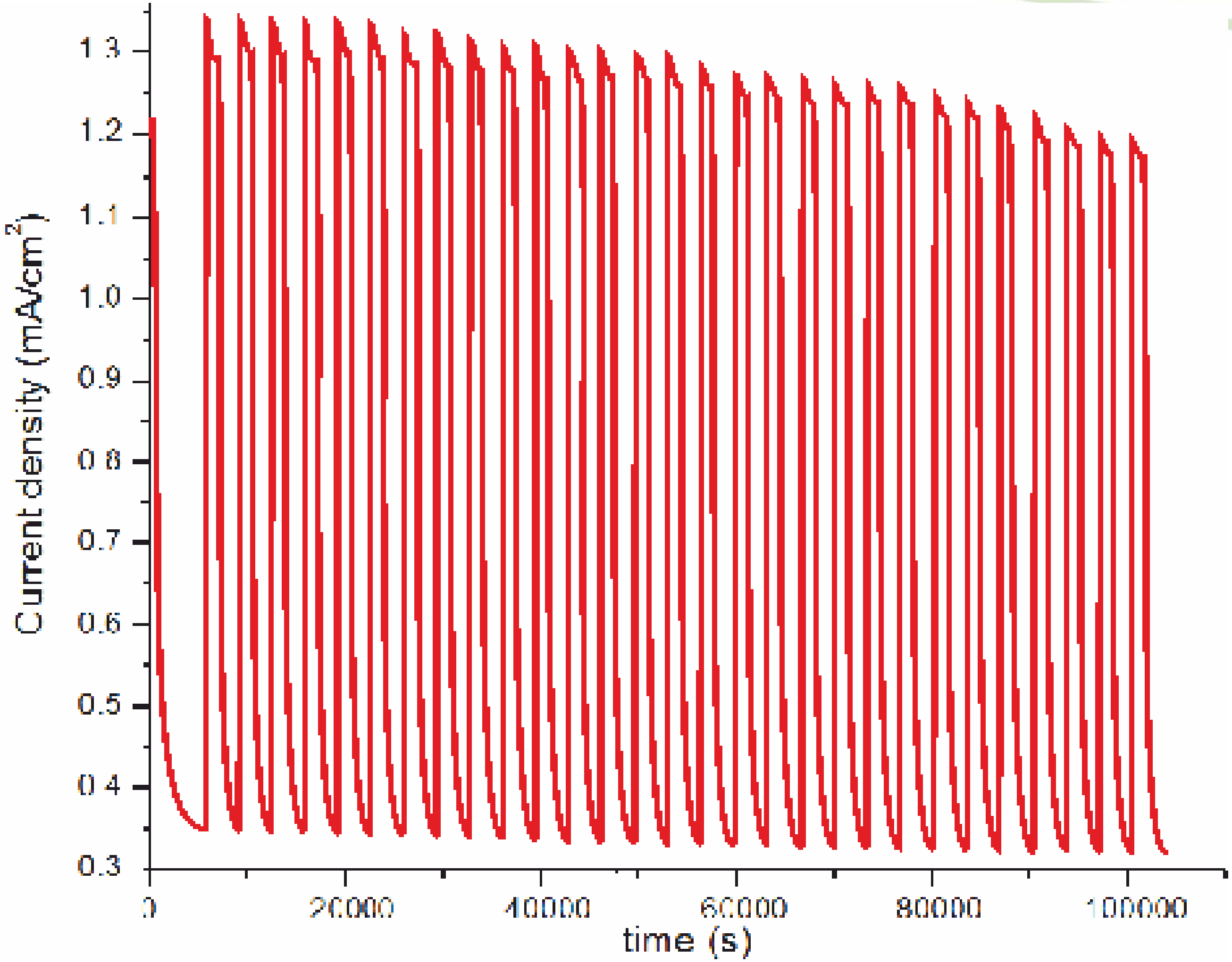




The Solhydromics prototype as starting point

1. Project achievements (slide 3)

www.solhydromics.com



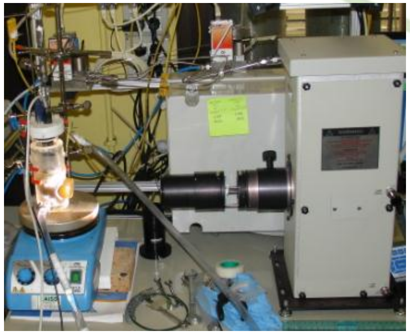
1% solar energy conversion efficiency, improved stability:

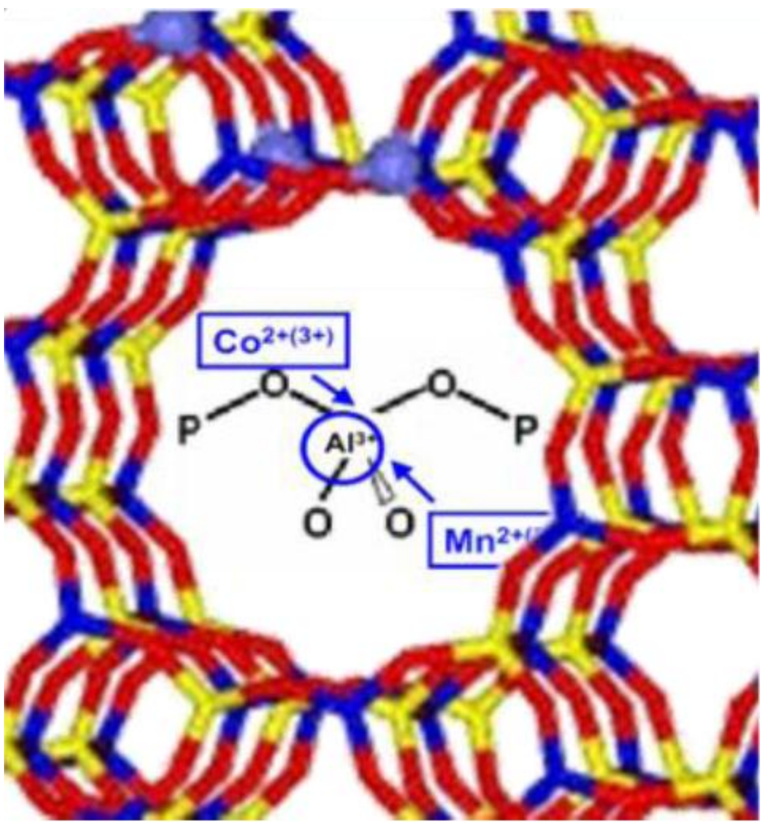
→ Better nanostructuring needed for electrodes

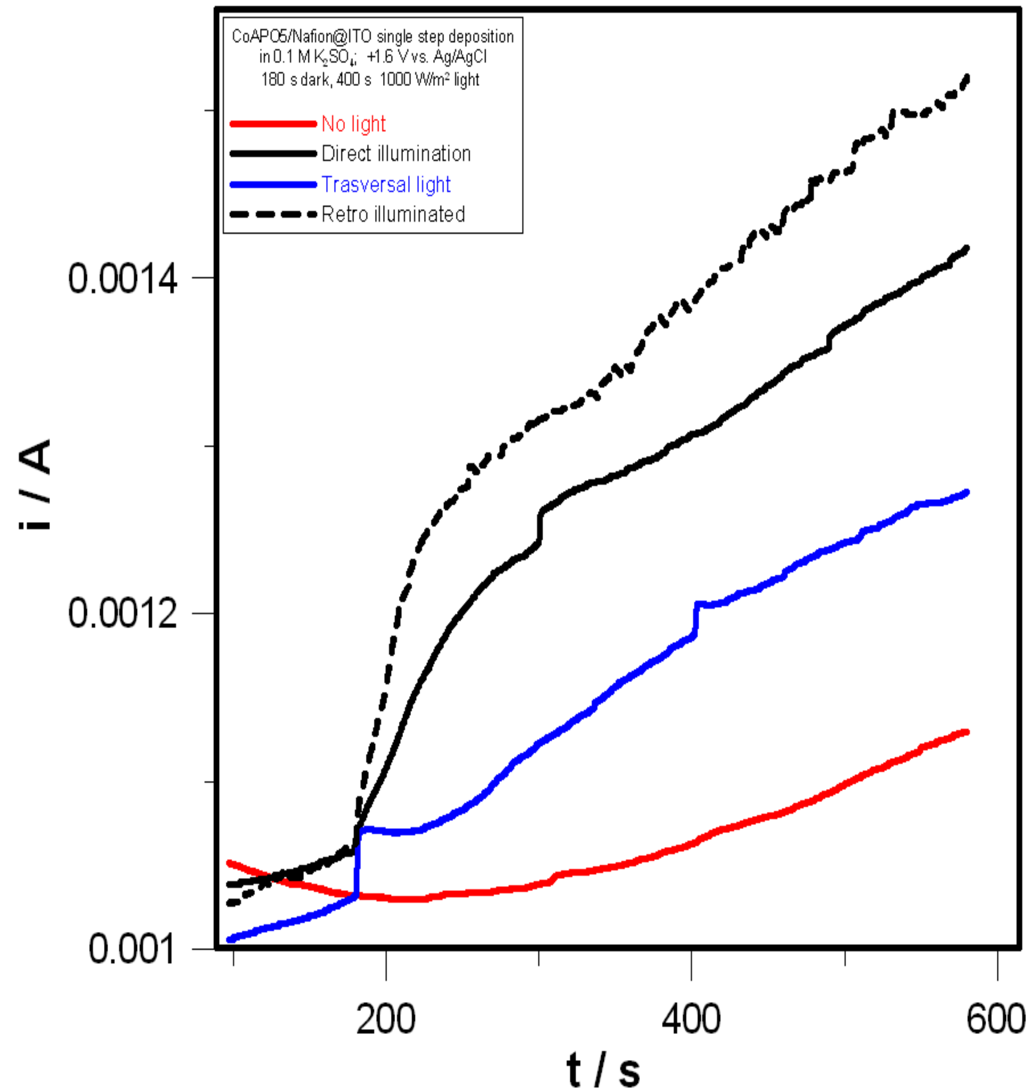
→ Addition of chromophores for >450 nm wavelengths needed

New water-splitting catalyst patented

1. Project achievements (slide 4)





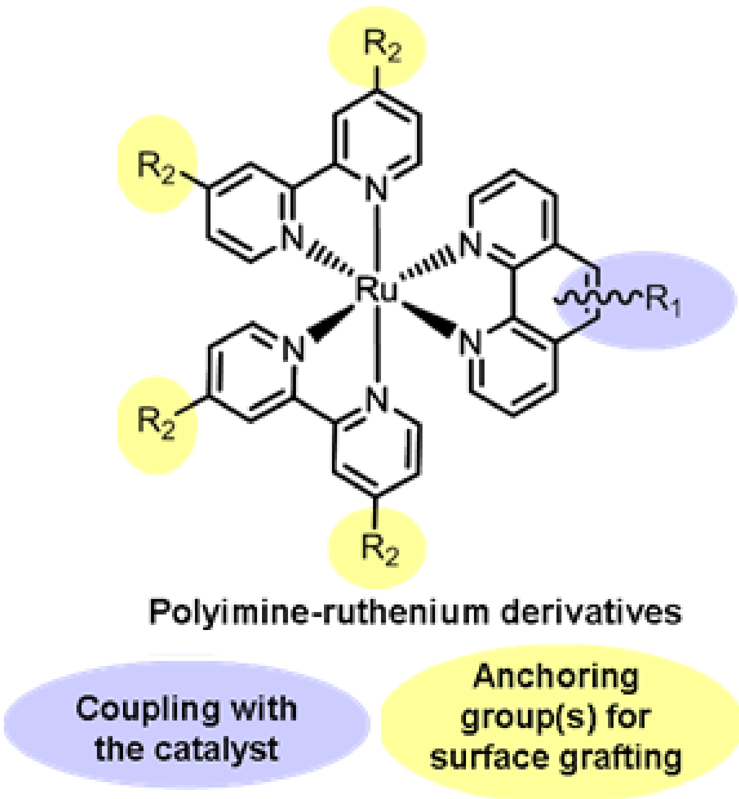


Our water splitting catalyst at work

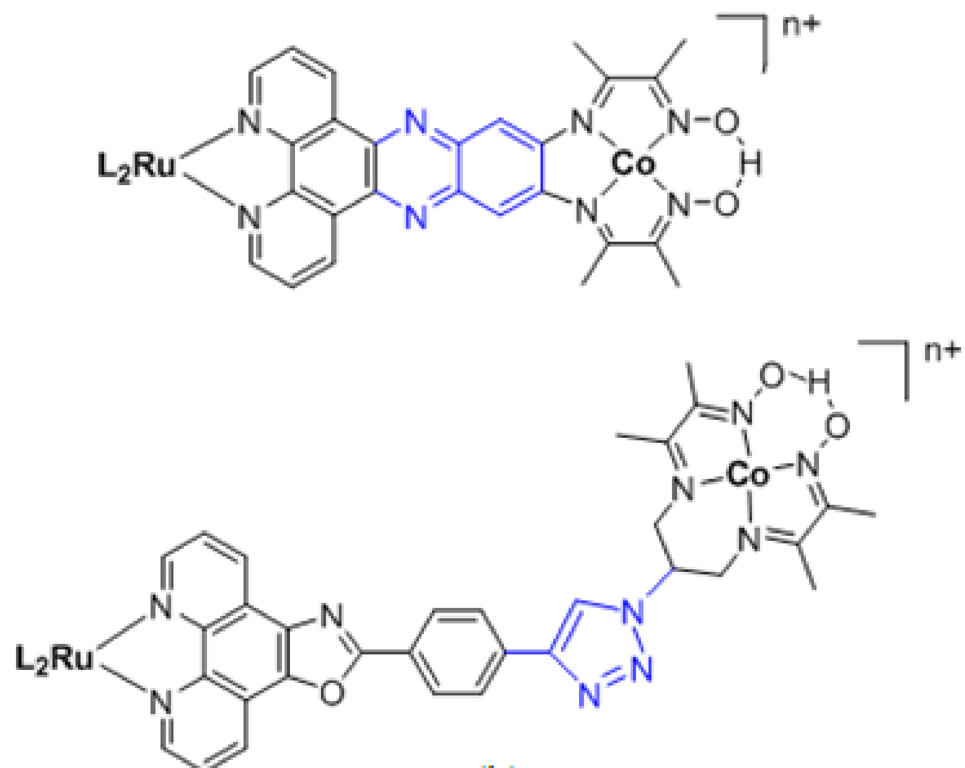
1. Project achievements (slide 5)

Hydrogen evolution catalysis

1. Project achievements (slide 6)



(a)

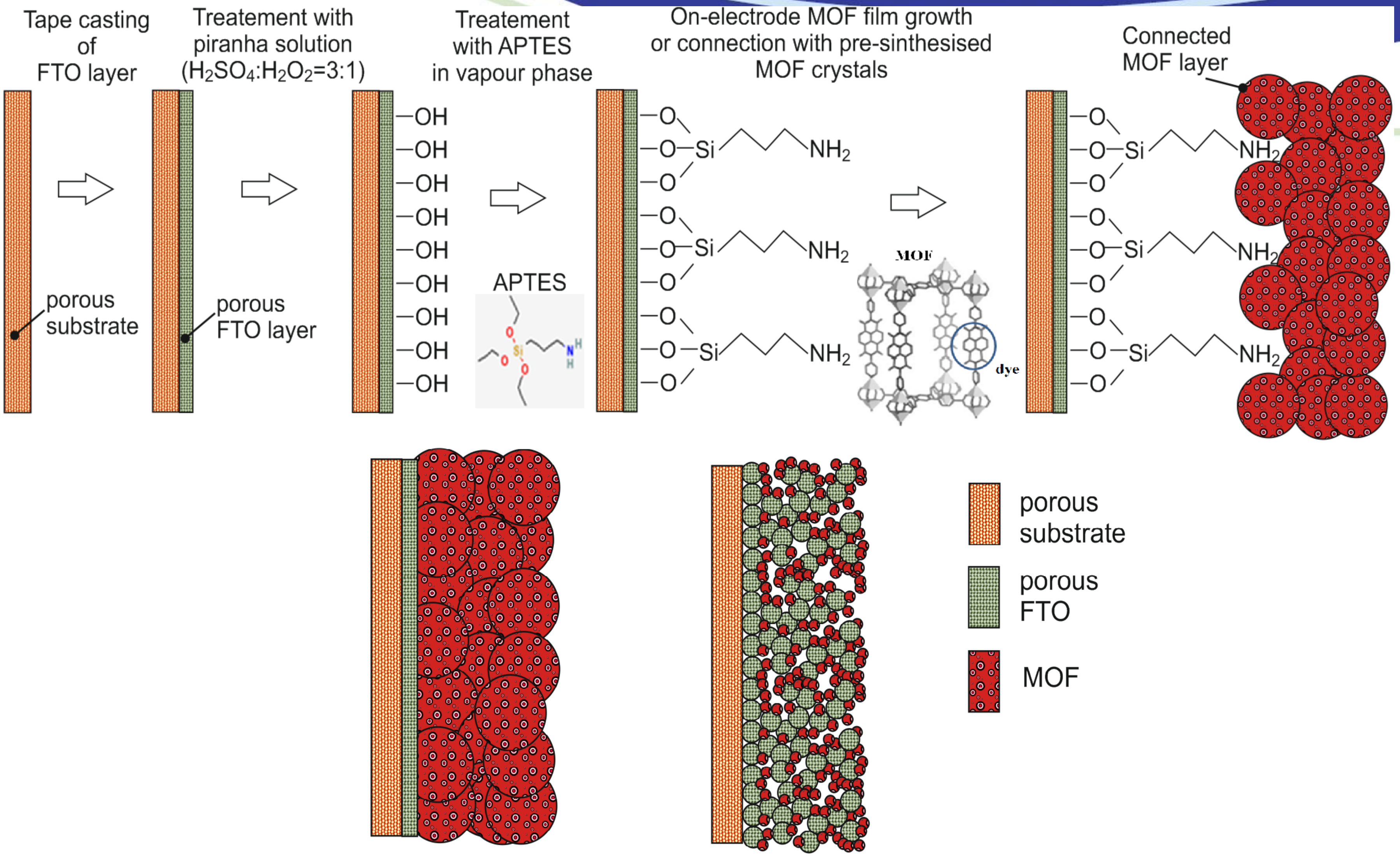


(b)

Photosensitizers investigated in ArtipHyction: (a) metal diimine complex (b) new photocatalytic organic tandem-molecules synthesized either using a heteroditopic phenantroline ligand.

Need of engineered volumetric electrodes

1. Project achievements (slide 7)



Related Topic in the AIP

2. Alignment to MAIP/AIP (slide 1)

Topic SP1-JTI-FCH.2011.2.6: Low-temperature H_2 production processes	Development of efficient chemical or biological systems converting solar energy into chemical energy for water splitting. Efficient, easy to handle chemical or biological systems shall be developed and the low temperature hydrogen production shall be demonstrated in small scale reactors.

Main targets/expected impacts

- Improved and novel nano structured materials for photo processes comprising photo catalysts, photo anodes interfaced with liquid or new polymer electrolytes
- Chemical systems for highly efficient low temperature water splitting using solar radiation
- Demonstration of solar to hydrogen efficiency > 5%
- Demonstration of systems with a perspective of >10.000 h lifetime (for solar water splitting processes)
- Small to medium scale applications ranging[1] from 100 W for domestic use (ca. 3 g/h H_2 equivalent) up to 100 kW (ca. 3 kg/h H_2 equivalent) for commercial use.
- Design and construction of a reactor for providing hydrogen for consumers at low costs

Efficiency targets

2. Alignment to MAIP/AIP (slide 2)

- This is a field at the borderline between science and technology in which stringent market constraints are difficult to fix.
- **Efficiency** targets should be **referred to a precise fraction of the spectra** (e.g. >400 nm).
- The efficiency target of 5% of Topic FCH.2011.2.6 is challenging but not enough ambitious for a short term market entry. Daniel Nocera recently achieved this with a triple-junction Si PV cell lined at opposite sides with inorganic catalysts.
- Conversely, the 5% conversion efficiency might be appropriate for solar fuels obtained via CO_2 reduction, which is though outside the mission of the FCH JTI initiative.
- Despite unlikely to be achieved, **the efficiency target of 10% conversion into hydrogen is mandatory to achieve market penetration** on the grounds of simple cost analysis.

Cost analysis

2. Alignment to MAIP/AIP (slide 3)

It is perhaps time to start including cost indications in this area

With a **solar light to hydrogen conversion efficiency of 10 %** and an average solar radiation input of 1000 kWh per m^2 in Europe, one gets **3 kg of solar H_2 per year per m^2 of exposed PEC converter surfac**e. If a 7 €/kg cost of solar-electrolytic hydrogen is considered, each single panel will provide an equivalent hydrogen value of about 24 €/m^2/y. Assuming a lifetime of 20 years of the Solhydromics panels (i.e. a depreciation of 5 % p.a.) and a money capitalization of 5 %, **one can afford costs up to 200 €/m^2 of the Solhydromics panels including the installation**.

Neighbouring technologies designed for 10,000 hrs lifetime

DSC cells	**PEM fuel cells**
Today 500 €/m^2	Today 60 €/m^2
Projected 80 €/m^2	Projected 30 €/m^2

Dissemination and public awareness

3. Cross-cutting issues (slide 1)

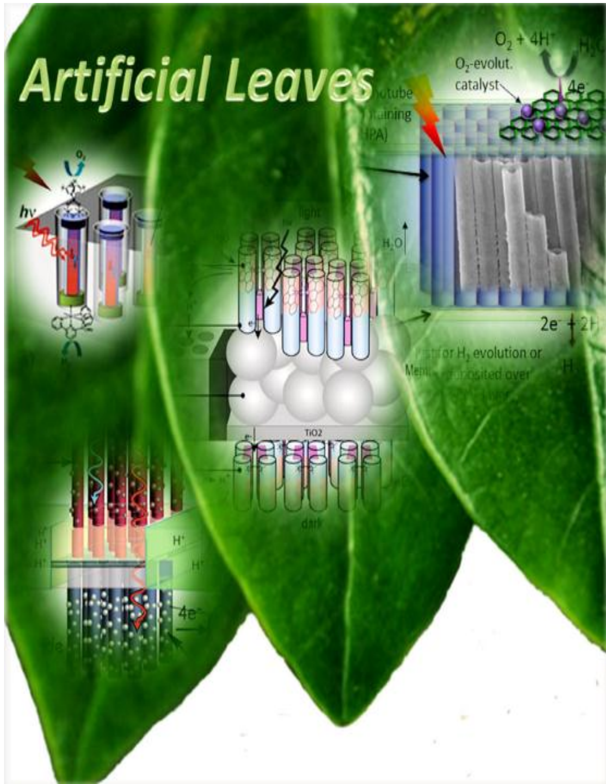
Recent Papers

- C. Pagliano, F. Chimirri, G. Saracco, F. Marsano, J. Barber, *Photosynthesis Res.* ***2011, 108, 33-46.***
- C. Pagliano, S. Barera, F. Chimirri, G. Saracco, J. Barber, *Biochimica et Biophysica Acta (BBA) – Bioenergetics,* ***2011, doi:10.1016/j.bbabio.2011.11.001***
- S. Barera, C. Pagliano, T. Pape, G.Saracco, J. Barber, *Philosophical Transactionis of the Royal Society,* **2012, in press**.
- S. Bensaid, G. Centi, E. Garrone, S. Perathoner, G. Saracco 'Artificial leaves for solar fuels from CO2' *ChemSusChem,* ***2011, 10.1002/cssc.201100661***
- Morra S., Valetti F., Sadeghi, S.J., King P.W., Meyer T., Gilardi G. *Chem Commun* ***2011, 47, 10566-568***
- S. Bensaid, G. Saracco, in Advanced membrane science and technology for sustainable energy and environmental applications (Ed.s A. Basile, S. Nunes), Series in Energy No. 25, Woodhead Pub. Cambridge, UK **2011, 610-644.**
- Ijeri V., Cappelletto L., Bianco S., Tortello M., Spinelli P., Tresso E., *J. Membr. Sci.*, ***2010, 363, 265-270.***
- M. Tortello, S. Bianco, V. Ijeri, P. Spinelli, E. Tresso, *J. of Membr. Sci.*, **2012, in press**: DOI: **http://dx.doi.org/10.1016/j.memsci.2012.05.018**
- S. Zanarini, S. Vankova, S. Hernandez, V. S. Ijeri, M. Armandi, E. Garrone, B. Bonelli, B. Onida and P. Spinelli, Chem. Commun., **2012**, **48, 5754–5756**

Patent

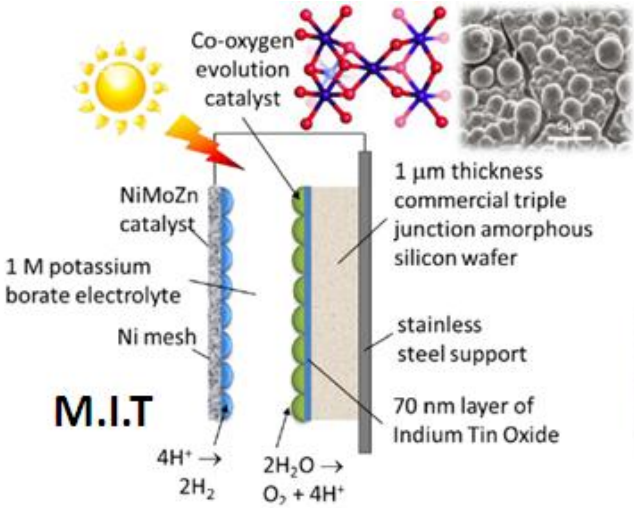
- E. Garrone, B. Bonelli, S. Vankova, G. Saracco, Use of alumino-phosphates substituted with transition metals as water splitting catalysts, Italian Patent Application on 27-07-2011

Web site:
www.artipHyction.org

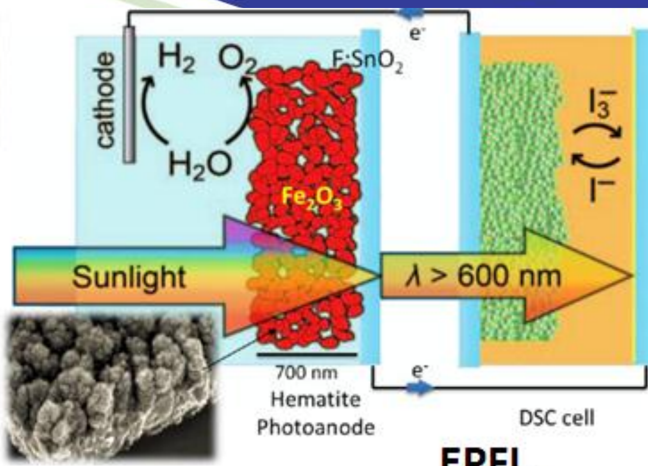


Competing efforts to which we are linked

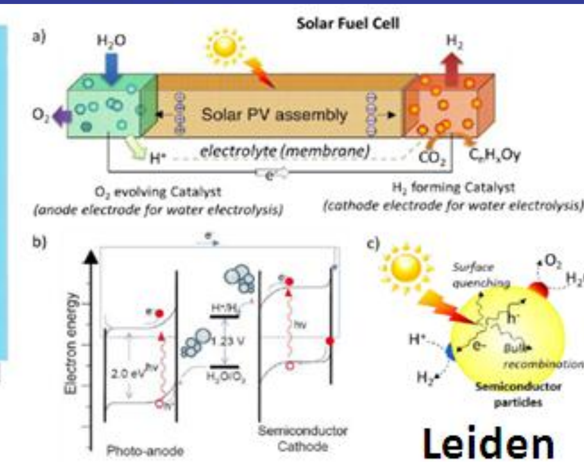
4. Enhancing cooperation and future perspectives (slide 1)



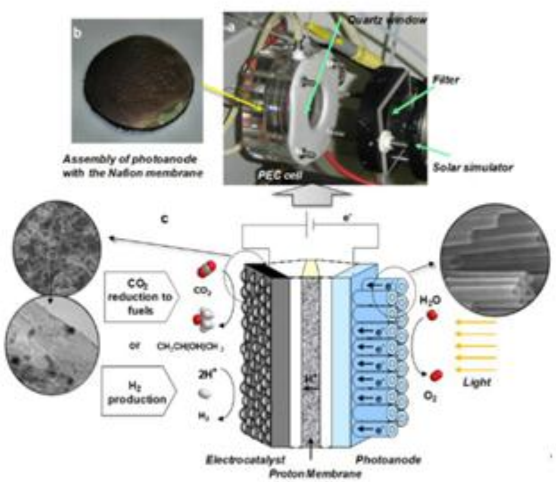
M.I.T



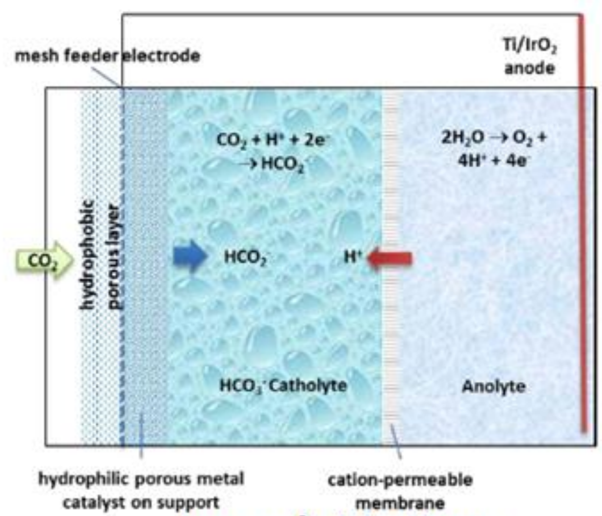
EPFL



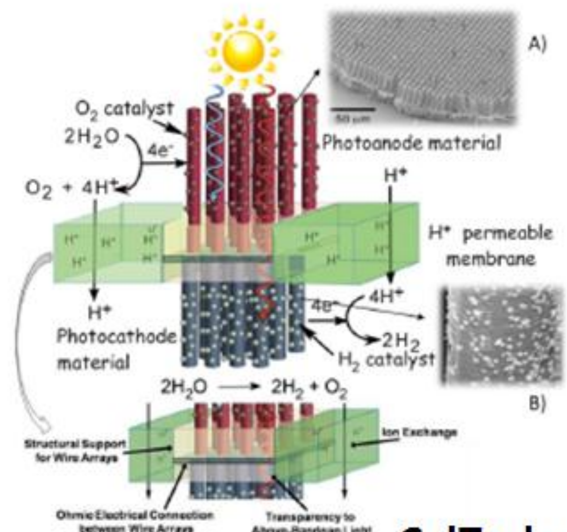
Leiden



Univ. Messina



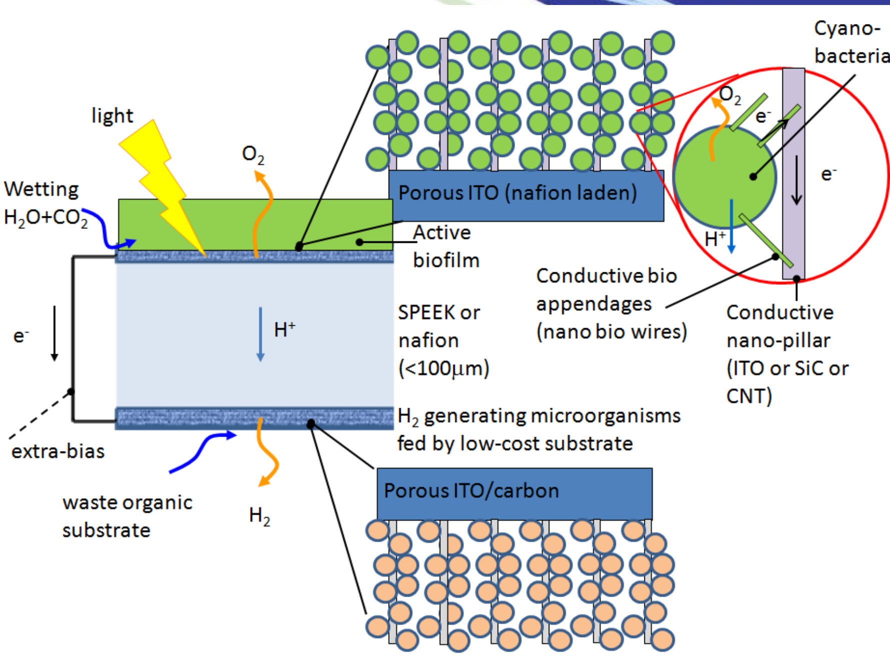
Imperial College

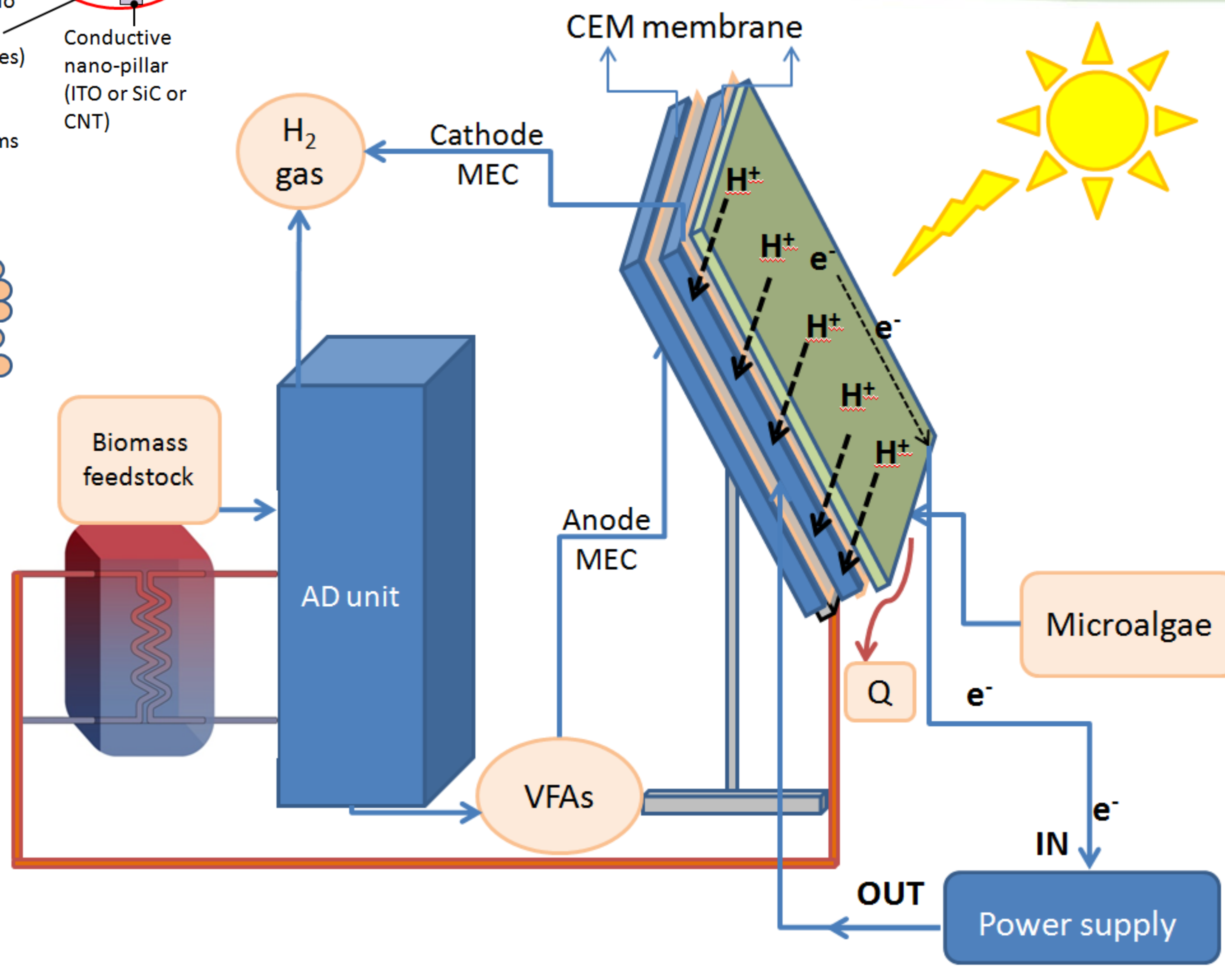


CalTech

The monocellular leaf perspective

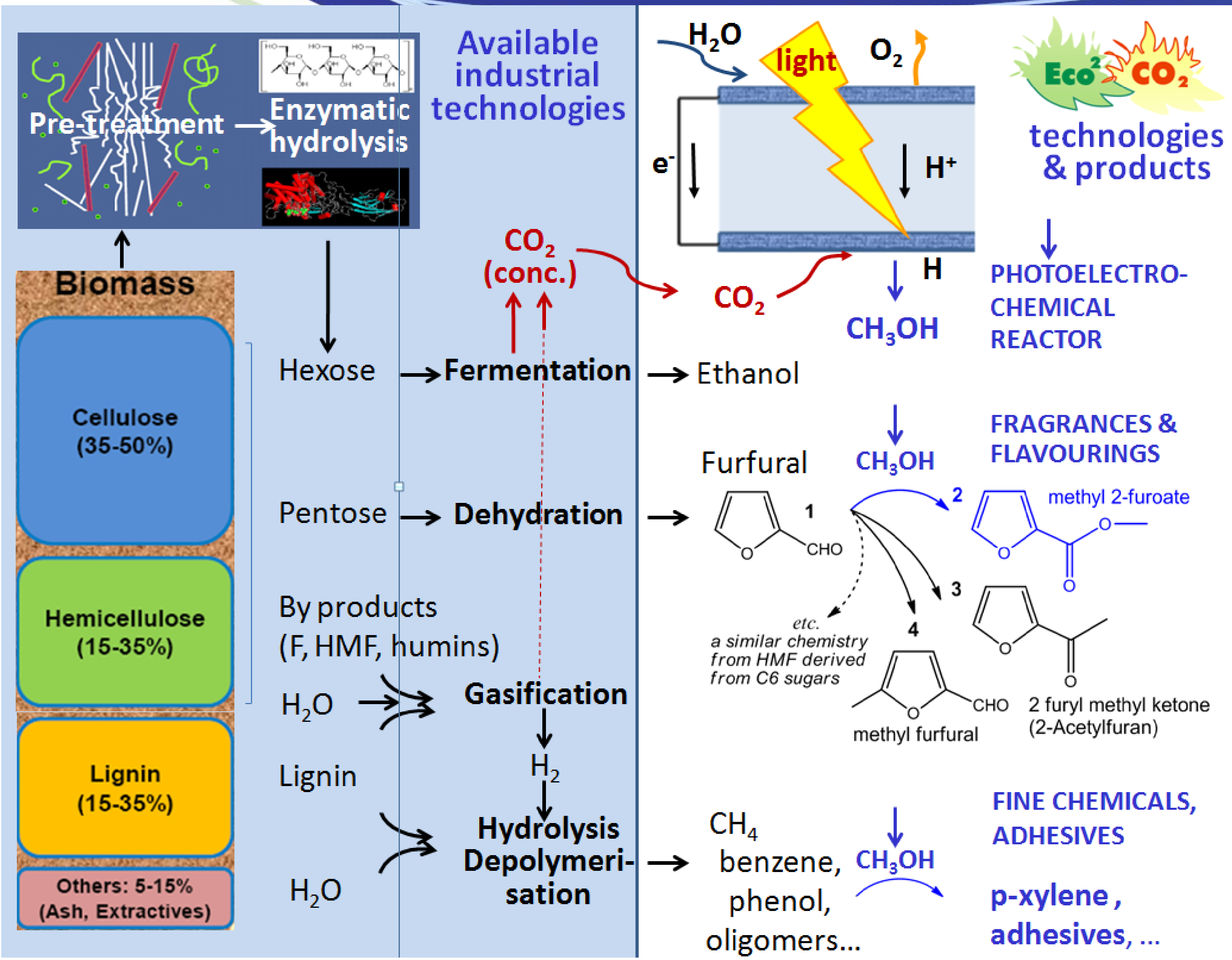
4. Enhancing cooperation and future perspectives (slide 2)





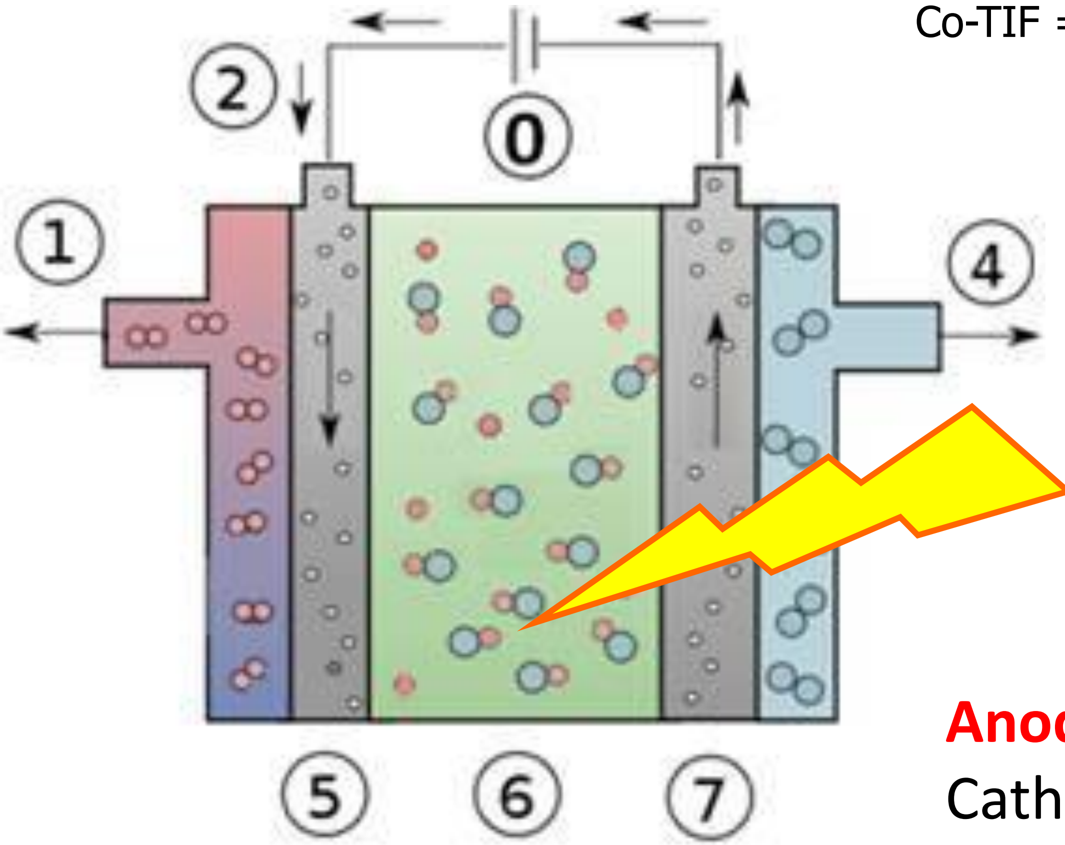
Application in a biorefinery

4. Enhancing cooperation and future perspectives (slide 3)

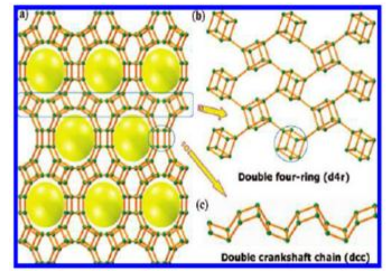


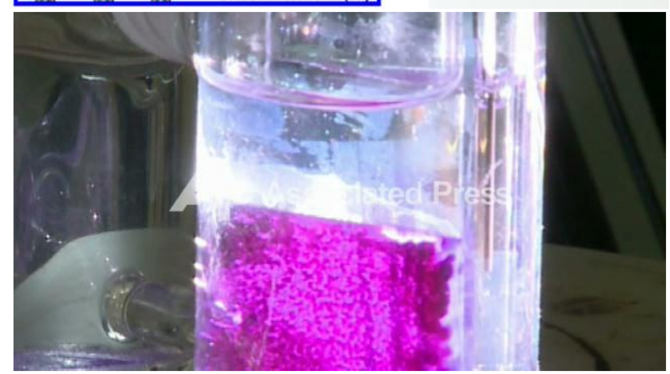
Photoactive alkali electrolyser

4. Enhancing cooperation and future perspectives (slide 4)



Co-TIF = Co-tetrahedral imidazolate framework





Anode: $2OH^{-} \rightarrow 1/2O_2 + H_2O + 2e^{-}$

Cathode: $2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$

Legend: : 0: Current generator, 1: Hydrogen, 2: Electron flow, 3: Load, 4: Oxygen, 5: Cathode, 6: Electrolyte, 7: Anode, 8: Water, 9: Hydroxyl ions, 10. Metal hydroxide.