“Fully artificial photo-electrochemical device for low temperature hydrogen production”

ArtipHyction
(Contract number: 303435)

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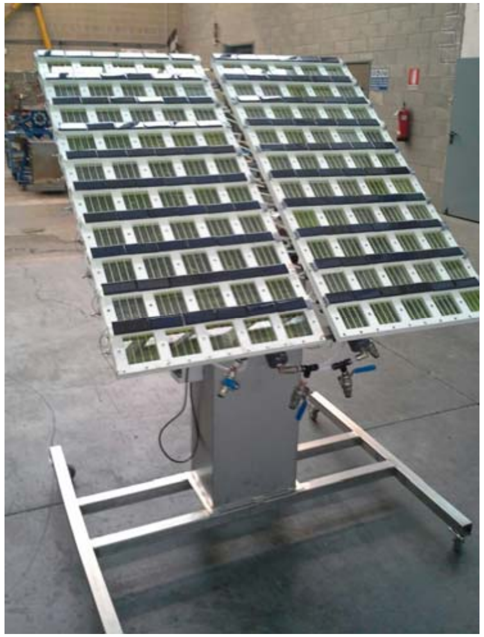
PROJECT OVERVIEW

- Call topic: SP1-JTI-FCH.2011.2.6
- Application Area: Hydrogen production (low temperature)
- Start and end date: 01/05/2012 - 31/10/2015
- Budget: **3.594.580,50 € (**FCH JU contribution: **2.187.039,80 €)**
- Consortium overview:

- <u>Short summary</u>: The ArtipHyction project aimed at delivering a photo-electro-chemical reactor for water splitting into hydrogen with at least 5% conversion of solar energy into hydrogen (3 g/h) chemical energy. The basic concept lies a tandem configuration of transparent anodic and cathodic electrodes carrying photoactive catalysts (Co,Mo-activated $BiVO_4$ and a molecular catalyst based on Co, respectively).
- Stage of implementation: ~100%

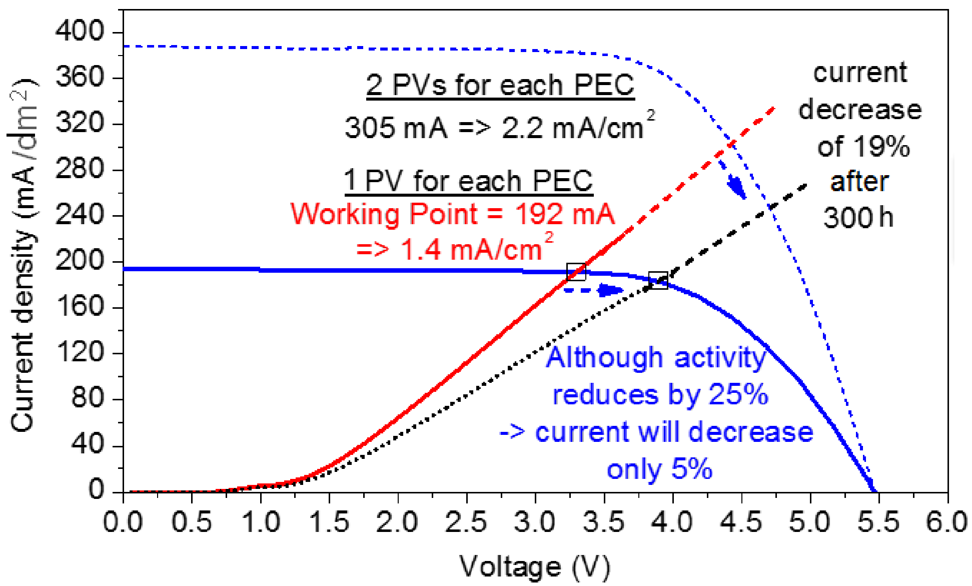
PROJECT TARGETS AND ACHIEVEMENTS

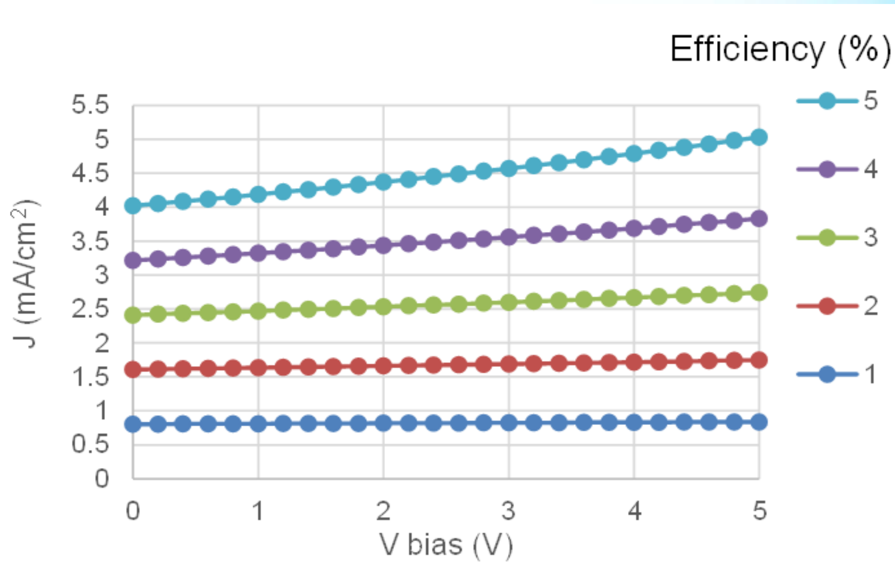
Programme objective/target	Project objective/target	Achievements to-date	Expected final achievements
MAIP			
low-temperature, photo-electrochemical processes for direct hydrogen production	scaling up the photo electro-chemical conversion to 1,6 m^2 irradiated surface	100%	100%



PROJECT TARGETS AND ACHIEVEMENTS

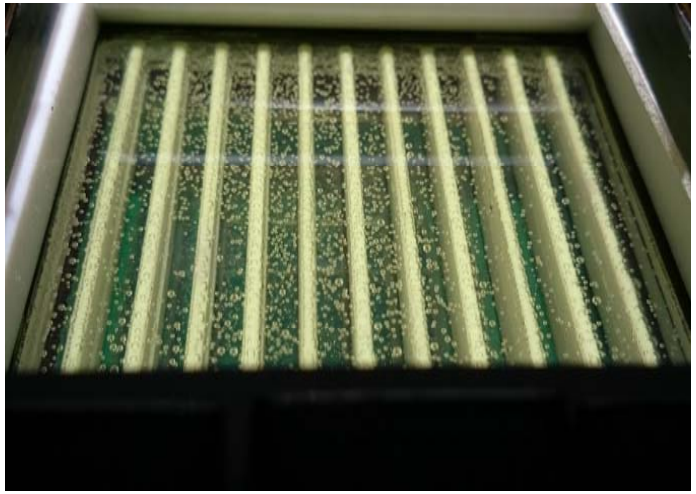
Programme objective/target	Project objective/target	Achievements to-date	Expected final achievements
AIP			
solar-to-hydrogen efficiency higher than 5% and a perspective lifetime of >10.000 h	5% STH efficiency targeted 1000 h operation tested in the project	50-66% (EFFICIENCY) 30% (LIFE TESTING)	50-66% (EFFICIENCY) 100% (LIFE TESTING)





PROJECT TARGETS AND ACHIEVEMENTS

Programme objective/target	Project objective/target	Achievements to-date	Expected final achievements
AIP			
small to medium scale applications ranging from 100 W for domestic use up to 100 kW (ca. 3 kg/h H_2 equivalent)	100 W scale (3 g/h of H_2) at a final prototype level	66%	66%

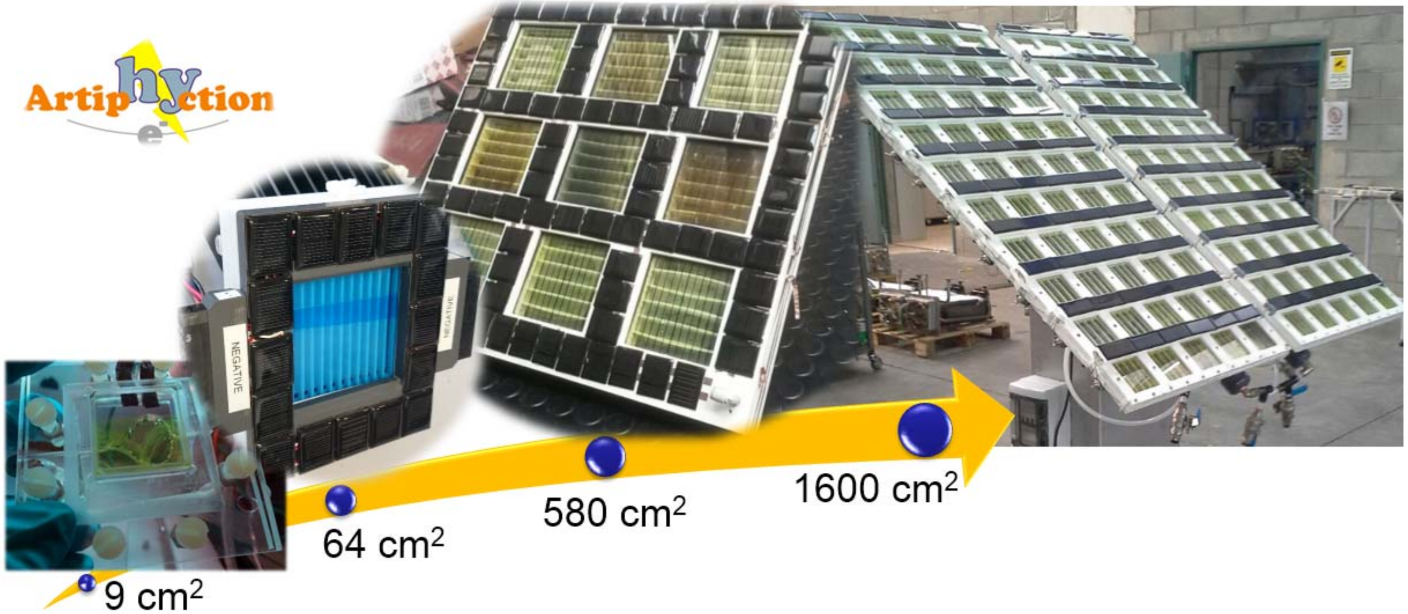


LIMITING FACTORS AT PROTOTYPE SCALE:

- ✓ limited electron transfer through wider electrode surfaces based on transparent conducting oxides layers;
- ✓ Impossibility to reduce the gap between the electrodes to minimise ohmic drops for large scale electrodes
- ✓ Ohmic losses linked to the Cu wires embedded in the prototype frame to connect the single photoactive electrode couples in parallel;
- ✓ need to provide a bias through Si PV hosted in the area around the photoactive windows.

PROJECT TARGETS AND ACHIEVEMENTS

- Additional target: avoidance of noble metals or materials → fully achieved.
- Main advancement compared to state of art: achievement of a full-scale module of a size comparable with PV panels.
- Four different designs developed



- Next steps: i) nano-structuring the electrodes to de-bottleneck STH efficiency. ii) adoption of cheap deposition techniques; iii) radically new designs coupling PVs and PEC modules.

RISKS AND MITIGATION

Target 1: Achieve improved and novel nano structured materials for photo-activated processes comprising photo catalysts, photo anodes interfaced with liquid or new polymer electrolytes

- Bottlenecks and risks: One of the key issues in achieving high efficiencies is the nanostructure of the electrodes for PECs. They should be able to conduct promote catalytic reactions (anode: water splitting; cathode: hydrogen recombination), convert chemical energy into electron excitation; conduct electrons, be transparent. To reduce the associated risks a tremendous amount of research is to be carried out.

- Remedial action: i) develop nanostructured photoactive anodes; ii) develop reactor architectures not requiring photoactive electrodes, but simply electrocatalytically active.

- Revision of targets: 3D structures are mandatory if 10% STH efficiencies are targeted with photo-active electro-catalytic materials

Target 2: Chemical systems for highly efficient low temperature water splitting using solar radiation

- Bottlenecks and risks: The major risks are associated to achieveing sufficient activity and stability.

- Remedial action : Attention has been finally focused only on noble-metal-free inorganic catalysts ($BiVO_4$ and Co-based at the anode and cathode, respectively) to achieve sufficient activity and stability, which were not possible with the formulations originally anticipated in the proposal (MOFs).

- Revision of targets: NO, keep on asking for noble-metal free materials.

RISKS AND MITIGATION

Target 3: Demonstration of solar to hydrogen efficiency > 5% with a perspective of >10.000 h lifetime

- Bottlenecks and risks: The higher the efficiency the lower the costs of the reactor. To achieve more confidently the target of 5% sun-to-hydrogen conversion, MJ-semiconductor cells coupled with sun concentrators will have to be exploited.
- Remedial action: move to combination of PVs and electrolysers
- Revision of targets: Ambition could/must be enhanced (20% STH efficiency)

Target 4: Small to medium scale applications ranging from 100 W for domestic use (ca. 3 g/h H_2 equivalent) to 100 kW (ca. 3 kg/h H_2 equivalent) for commercial use

- Bottlenecks and risks: The major risk is associated to cost effectiveness and the difficulties in preserving the STH efficiencies. Provisional calculation show that the projected costs should be compatible with the original project expectations (projected cost of 5-7 euro/kg of hydrogen). Revision of targets: NO, keep on asking for noble-metal free materials
- Remedial action : NO, the module size achieved appears adequate for large scale plants
- Revision of targets: NO, same as above.

SYNERGIES WITH OTHER PROJECTS AND INITIATIVES

- Main actions in progress in the field:
  - PECDEMO project (target: 8% STH efficiency, HHV basis)
- Extent to which project builds on previous FCH JU/EU-funded projects:
  - Starting point: SOLHYDROMICS (FET - FP7) (PEC for H_2 production; end: 2012)
  - Ongoing effort: Eco²CO_2 (NMP – FP7) (PEC for $CO_2 \rightarrow CH_3OH$; end: 2016)
- Description of any partnerships, joint activities formed with other FCH JU/EU projects
  - Possibly, with the PECDEMO partnership.
- Interactions with any international-level projects or initiatives:
  - AMPEA EERA initiative with an entire ongoing subprogram on Solar Fuels (http://www.eera-set.eu/eera-joint-programmes-jps/)
  - CO_2 as raw material (flagship initiative within the NMBP area of H2020)

HORIZONTAL/DISSEMINATION ACTIVITIES

- Training activities: Workshop for PhDs and Young researchers held in CERTH, Thessaloniki (25th June 2015)
- Newsletters issued for general public awareness
- Dissemination events held in Torino in October and in November, 2015, with prototype exhibition to generic public.
- Web site: www.artipHyction.org
- Scientific papers: about 20
- Conference presentations: >50
- Patents: 0

EXPLOITATION PLAN/EXPECTED IMPACT

- What has your project changed in the panorama of FCH technology development and/or commercialisation?
  - First time a full-scale module is produced.
  - A number od lessons learned on handling PECs at this scale.
- How will the project's results be exploited? When? By whom?
- RTD projects:
  - Same as above
  - Combination with PVs allows to cope with catalyst deactivation by a proper matching of bias-generation and exploitation curves.
  - Development of new combination of PVs and (photo)electrolysers
- Demonstration projects:
  - Develop full scale modules with increased efficiency (up to 20%)
- Cross-cutting:
  - Standardisation requires tight cooperation with current key industrial stakeholders in the area of electrolysers.