Dye sensitized solar cells - a successful research

Adélio Mendes

Porto & FEUP, February 23, 2016

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO
Chemical Engineering Department

Portugal & Porto

Universidade do Porto
FEUP Faculdade de Engenharia

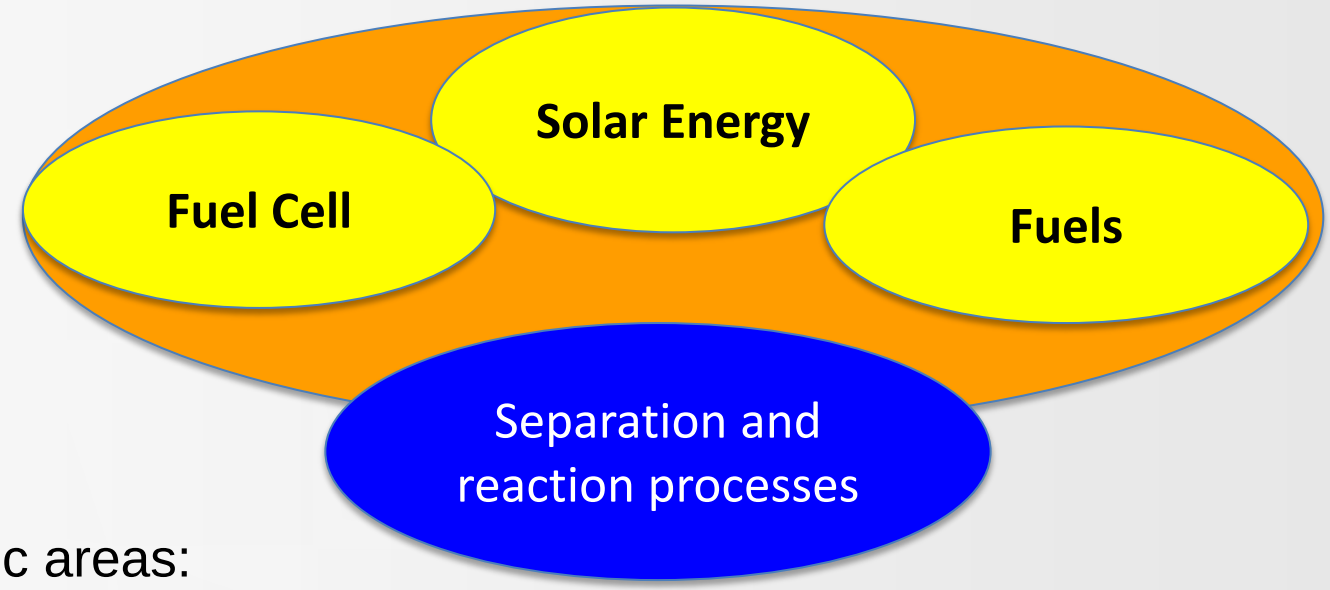
Chemical Engineering Department

New research laboratory space (1800 m^2)

Research team

Universidade do Porto
FEUP Faculdade de Engenharia

Technological areas



Scientific areas:

- Electrochemistry
- Photoelectrochemistry
- Reactions engineering
- Separation processes – adsorption and membranes
- Catalysts and catalysis

On-going international funded projects with industry

Most relevant on-going international collaborations

- **NASA** (USA) – development of a VPSA unit for the space station;
- **Air Products** (USA) – development of new adsorbents and improvement of PSA processes;
- **SerEnergy** (DK) – high temperature polymer electrolyte fuel cells (HT-PEMFC);
- **Innovia Films** (UK) – Carbon molecular sieve membranes;
- **VisBlue**(DK) – redox flow battery;
- **Dyesol** (Australia) – dye sensitized solar cells and perovskite solar cells.

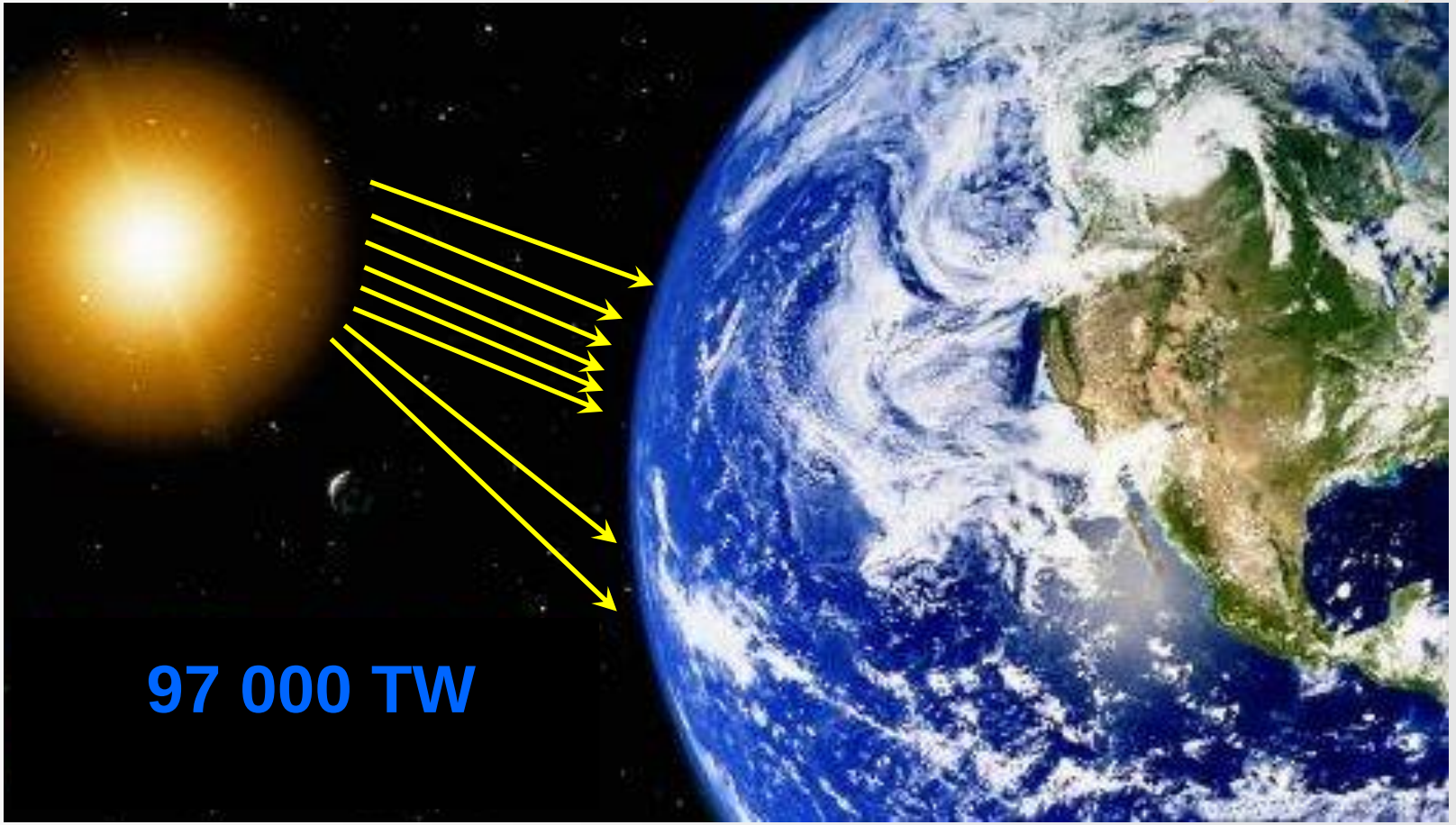
Most relevant on-going international collaborations

- **EFACEC** (PT) – development of DSCs and concentrated solar power units.
- **CUF-QI** (PT) – development of a new electrochemical membrane reactor for process intensification and improvement of the chlor-alkali process.
- **SysAdvance** (PT) – development of PSA units.
- **CIN** (PT) – development of paints for photo-inactivation of microorganisms, self-clean surfaces and photo-abatement of atmospheric contaminants.
- **InnovaCat** (PT) – development of a new catalysts.

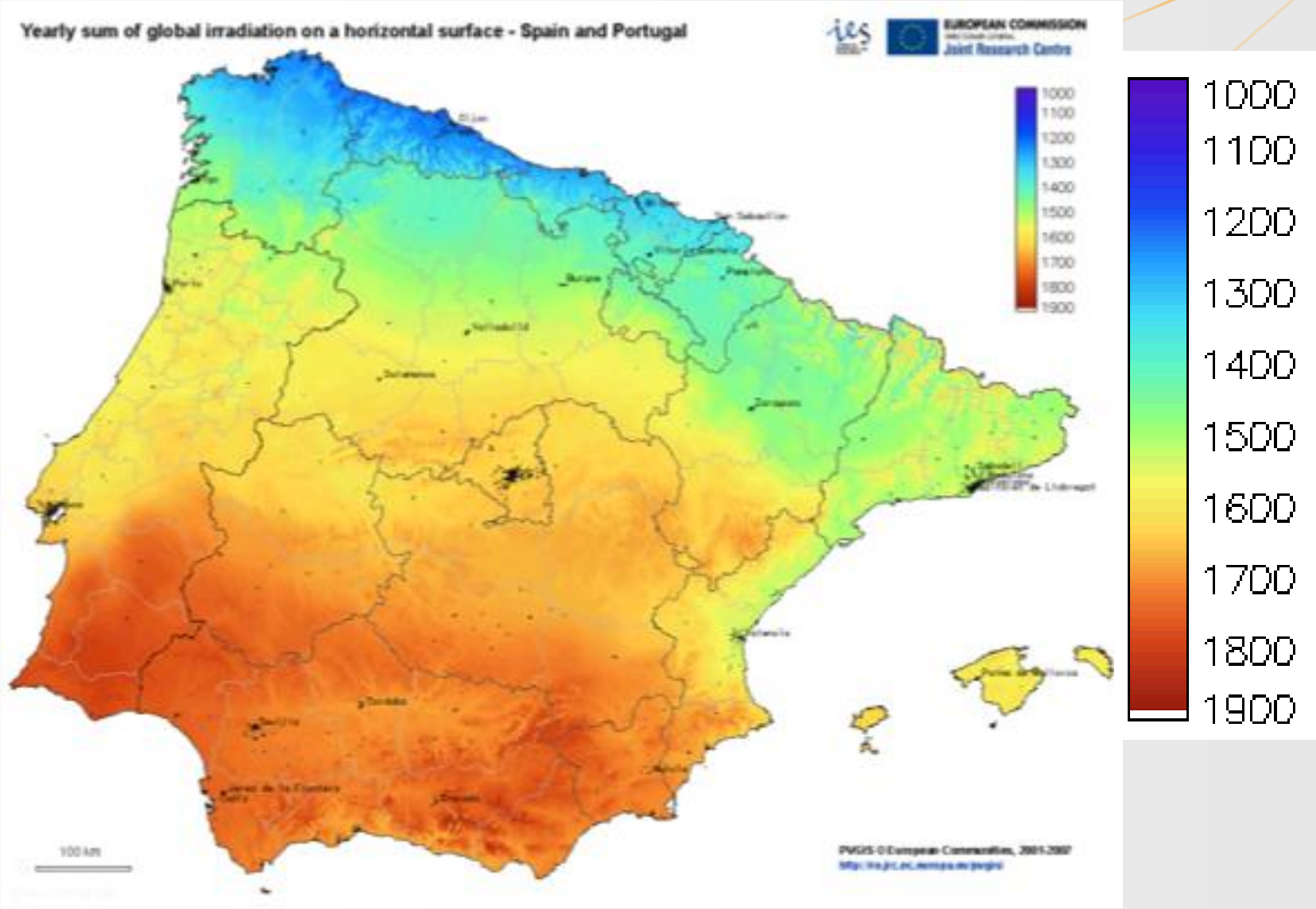
Framing PV

The sun

SUN – A nuclear fusion reactor located at a safe distance



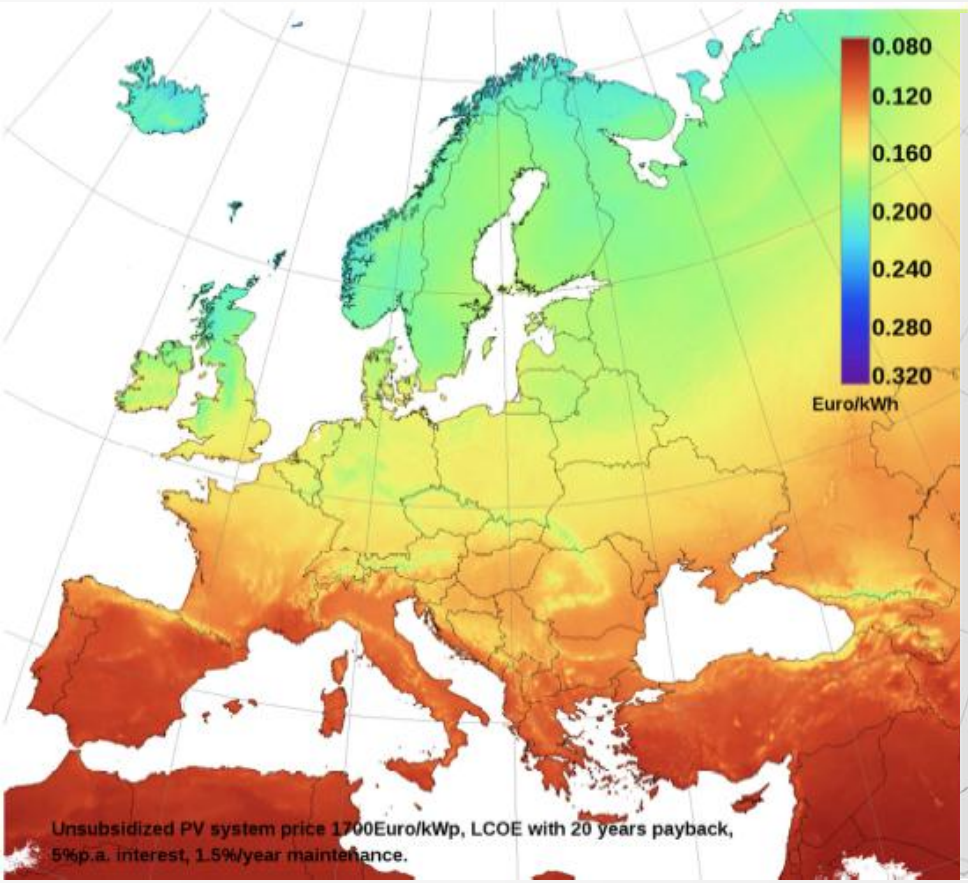
The sun


Yearly sum of global irradiation on a horizontal surface - Spain and Portugal
EUROPEAN COMMISSION
Joint Research Centre
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900

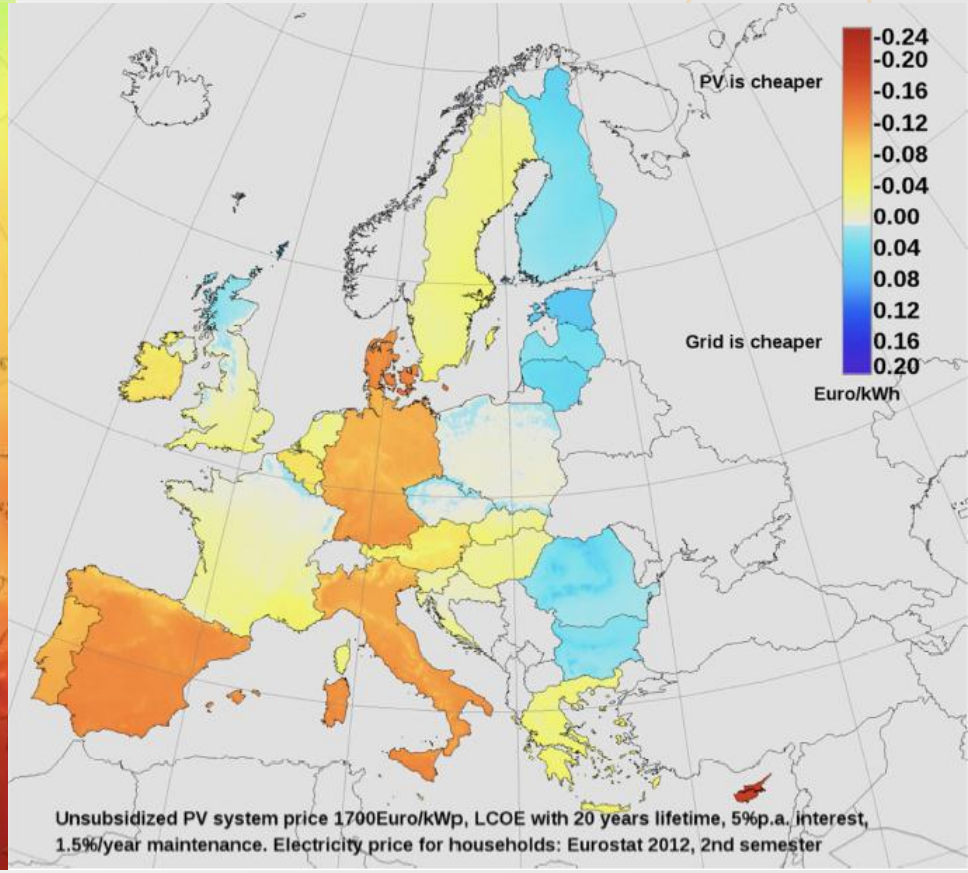
The sun

Levelled cost of electricity from photovoltaics

LCOE from PV.



Difference between the grip and the PV prices.



http://iet.jrc.ec.europa.eu/remea/sites/remea/files/reqno_jrc83366_jrc_83366_2013_pv_electricity_cost_maps.pdf

Nearly zero-energy buildings

Nearly zero-energy buildings

Nearly zero-energy buildings – (Directive 2010/31/EU):

> "*Member States shall ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings; and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings".*

Nearly zero-energy buildings

A nearly zero-energy building is defined in Article 2of the EPBD recast as:

> *"The nearly zero or very low amount of energy required should be covered to a* ***very significant extent by energy from renewable sources****, including energy from renewable sources* ***produced on-site or nearby****".*

DSC
Dye Sensitized Solar Cells

Photovoltaic technologies – dye sensitized solar cells

Michael Grätzel, EPFL - Lausanne

Photovoltaic technologies – Dye Sensitized solar cells

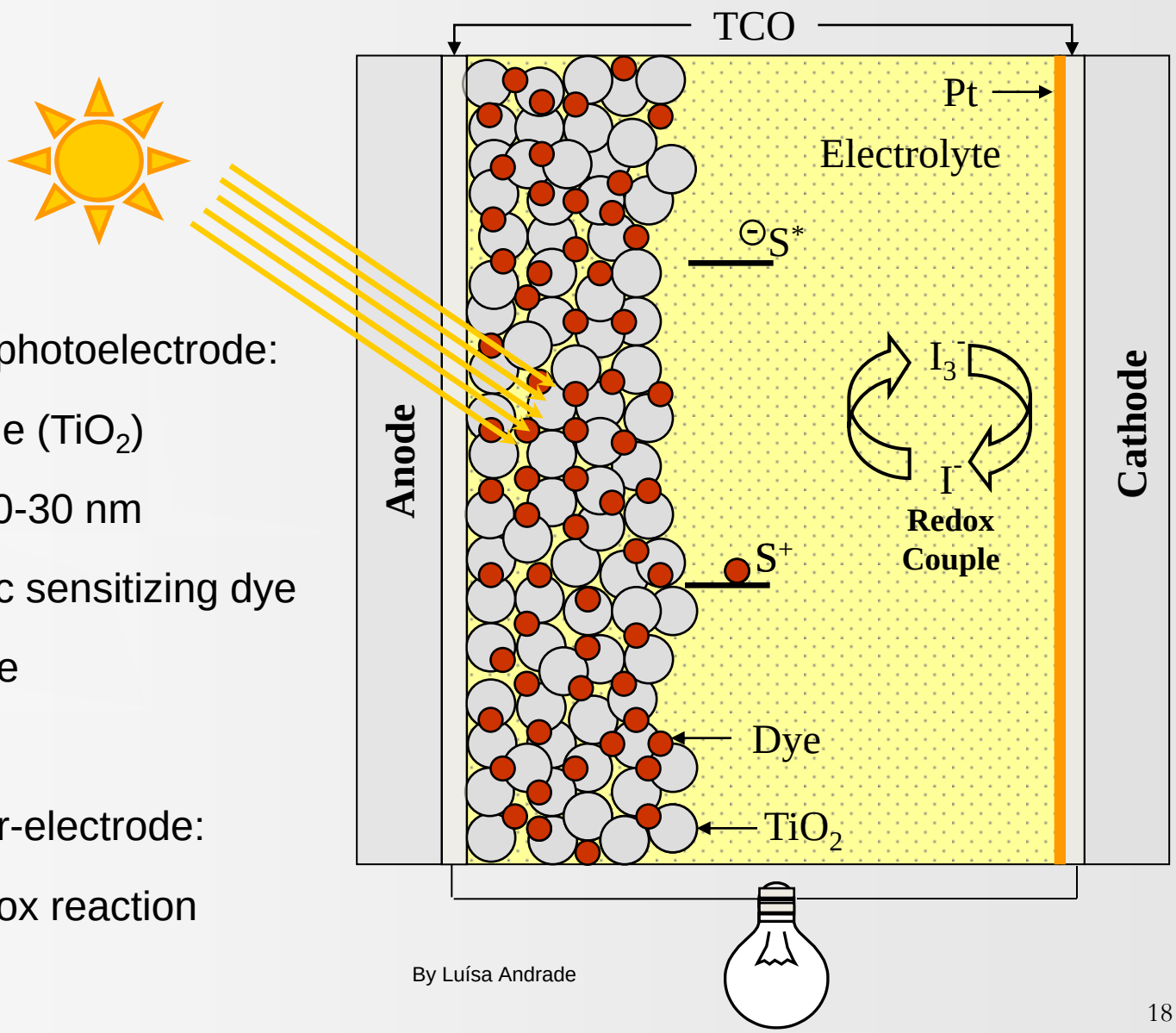
- Nanocrystalline photoelectrode:

  titanium dioxide (TiO_2)

  particle size 10-30 nm
- Ru-metal organic sensitizing dye
- Redox electrolyte

  I^-/I_3^-
- Platinum counter-electrode:

  catalyst of redox reaction



Photovoltaic cells – comparing technologies

Dye sensitized solar cells (DSC) :

- ✓ Considered organic PV type.
- ✓ Maximum energy efficiency: 14.1 %.
- ✓ Practical efficiency: 5-6%.

- \+ Price and high efficiency harvesting diffuse light;
- \+ Very aesthetic for BIPV;
- \+ Uses abundant and no topic materials;
- \+ Possible to make flexible;
- \- Moderate efficiencies;
- \- Not yet commercial.

http://en.wikipedia.org/wiki/Copper_indium_gallium_selenide_solar_cells

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Photovoltaic cells – comparing technologies

Geneva airport, DSCs by G2E:

http://en.wikipedia.org/wiki/Copper_indium_gallium_selenide_solar_cells

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Dye Sensitized solar Cells

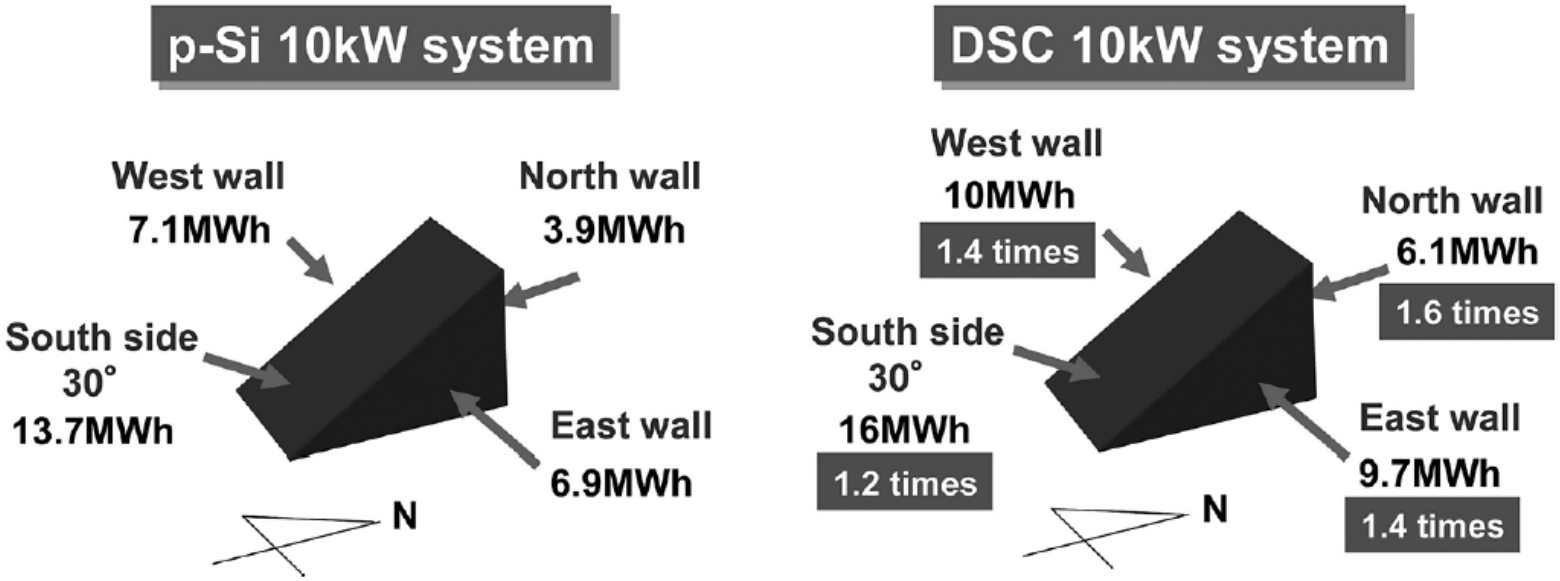


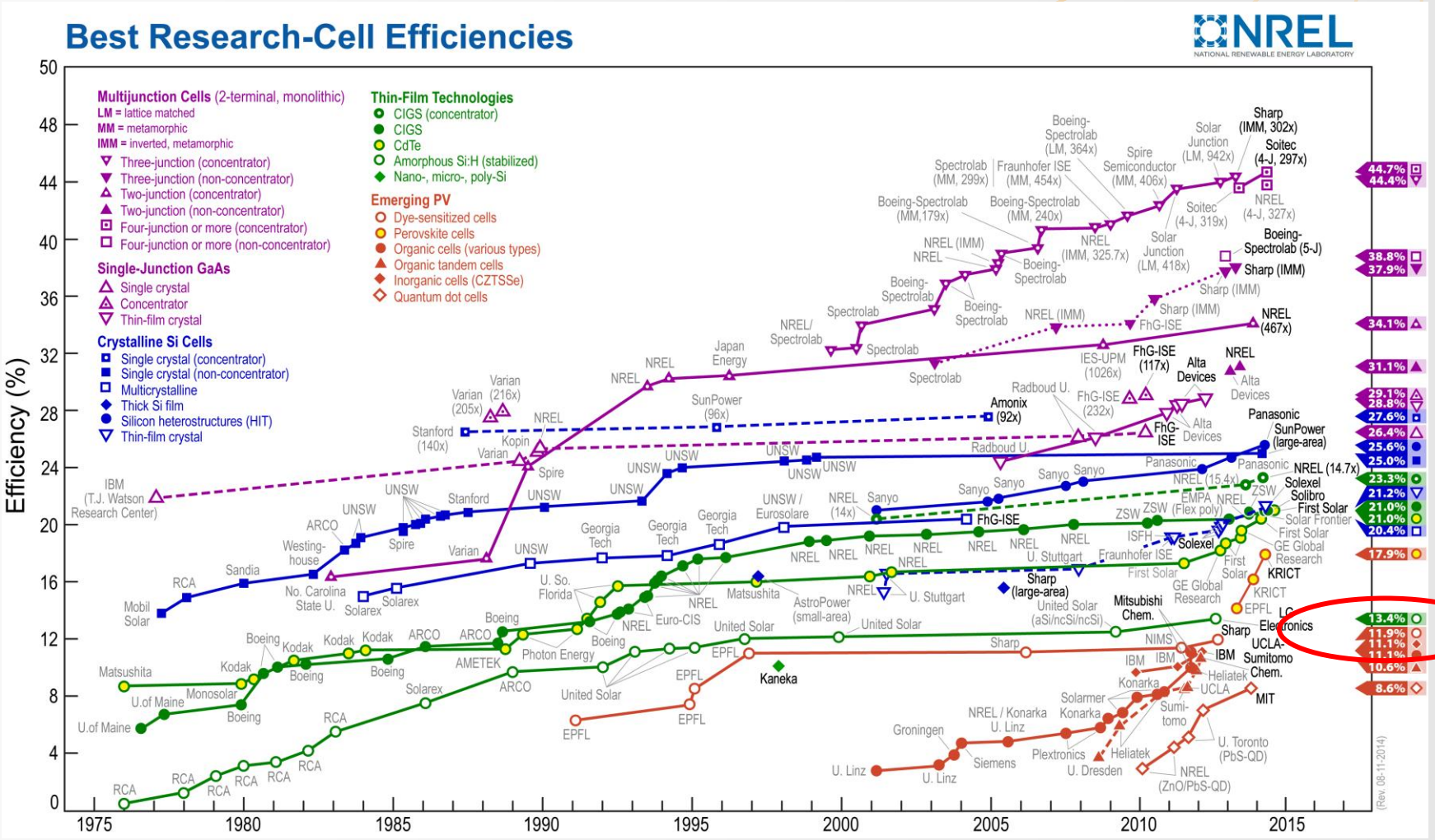
Fig. 1. Field tests done by Fujikura to evaluate the yearly production of two PV plants (DSC and p-Si)

BUDOWNICTWO
CZASOPISMO TECHNICZNE WYDAWNICTWO
TECHNICAL TRANSACTIONS POLITECHNIKI KRAKOWSKIEJ
CIVIL ENGINEERING
2-B/2012
ZESZYT 3
ROK 109
ISSUE 3
YEAR 109

ROSSELLA CORRAO, MARCO MORINI*

INTEGRATION OF DYE-SENSITIZED
SOLAR CELLS WITH GLASSBLOCK

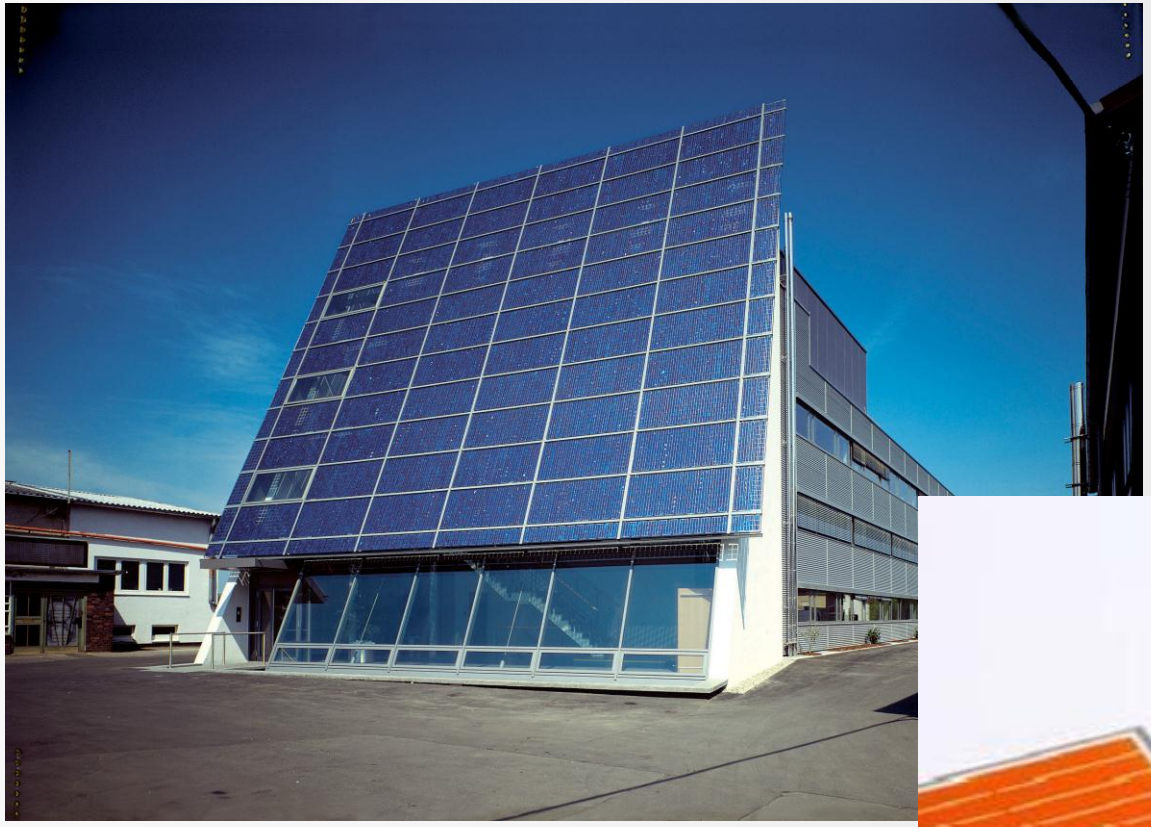
Dye Sensitized solar Cells



US National Center for Photovoltaics website http://www.nrel.gov/ncpv/

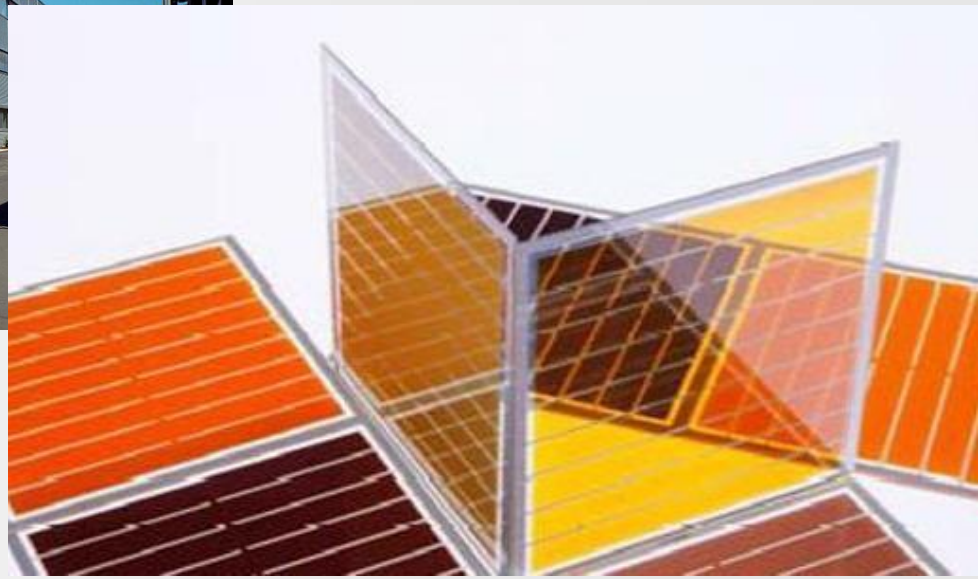
Building Integrated Photovoltaic - BIPV

Dye Sensitized solar Cells



Silicon

…and DSCs



Dye Sensitized solar Cells

Why not?

Our contribution

Sealing

Dye Sensitized solar Cells

What are the challenges?

- ✓ Sealing cells still a challenging issue – normally sealed with polymeric materials such as Surlyn®.
- ✓ Polymer sealed cells last e.g. from Solaronix… 3 month.

Dye Sensitized solar Cells

New approach:

- ✓ Glass sealing assisted by laser

LaserBox

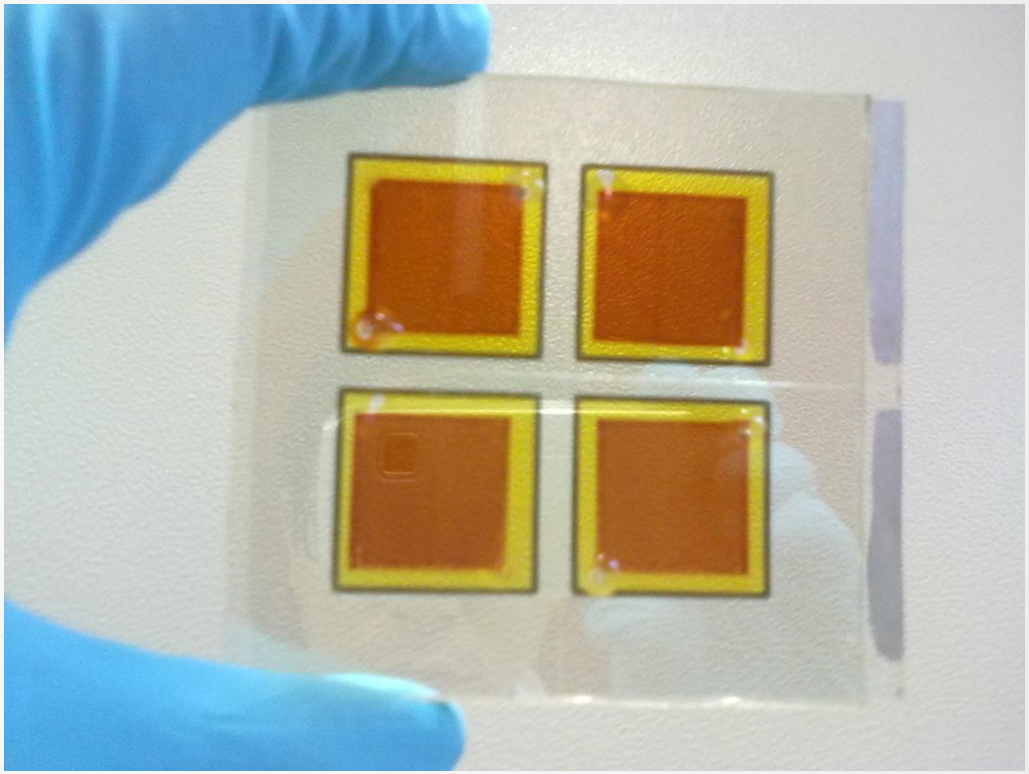
- 2D laser head
- Ytterbium laser

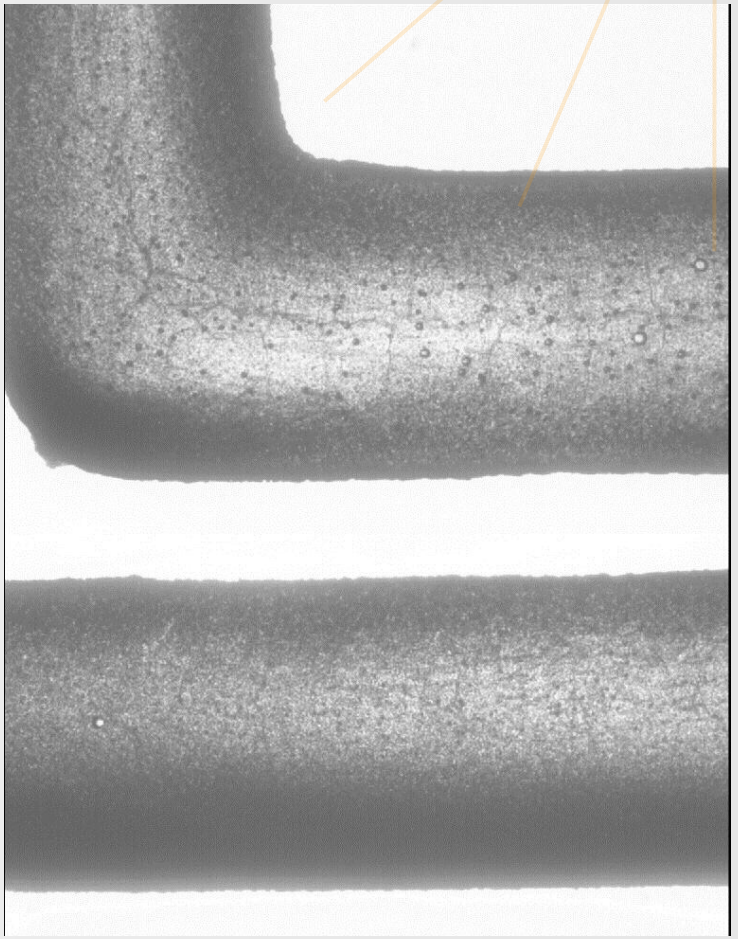
  (λ = 1064 nm, P_{max}= 200 W)
- Sealing temperature: ca. 250 ºC

Dye Sensitized solar Cells

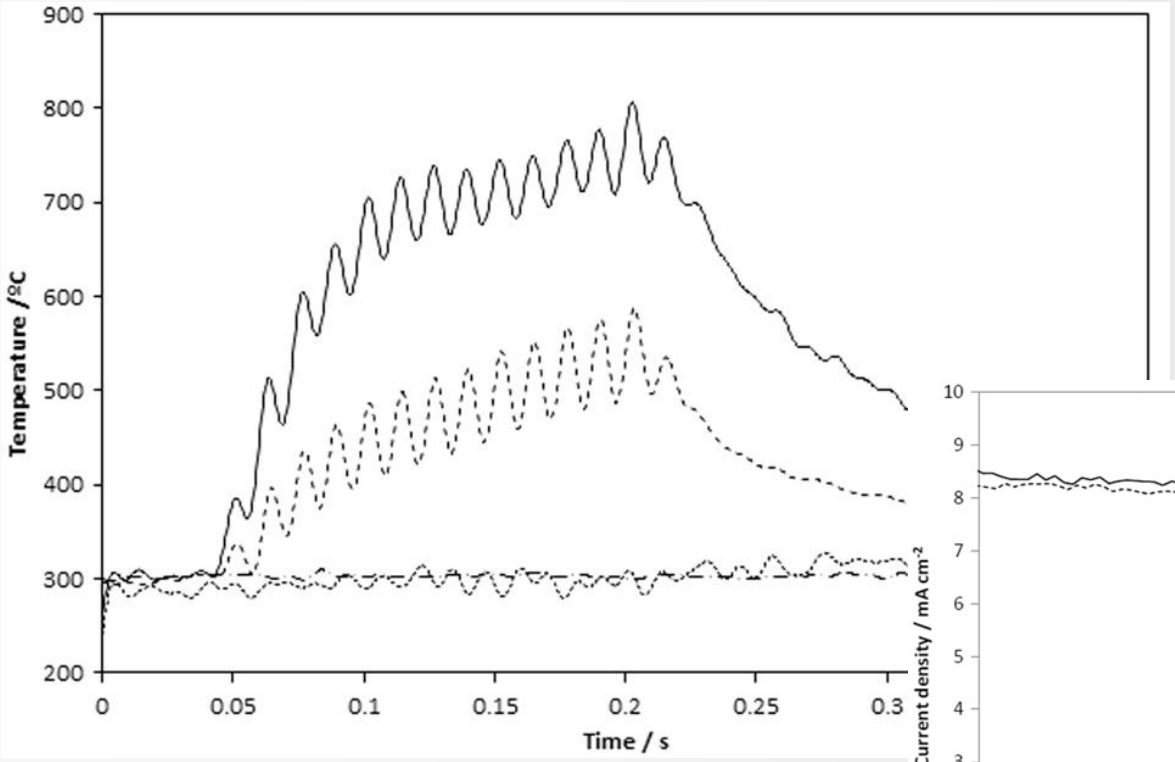
New approach:

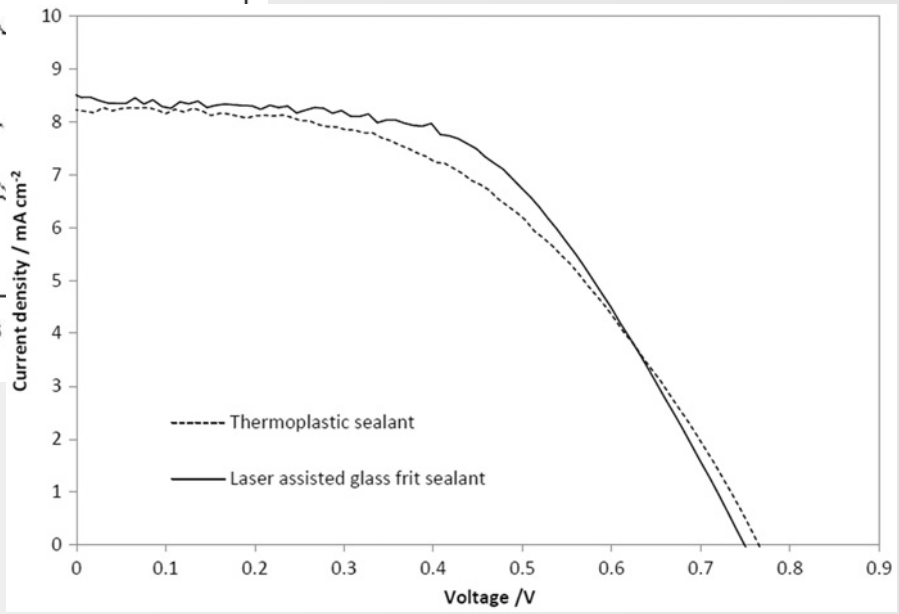
- ✓ Glass sealing assisted by laser





Dye Sensitized solar Cells

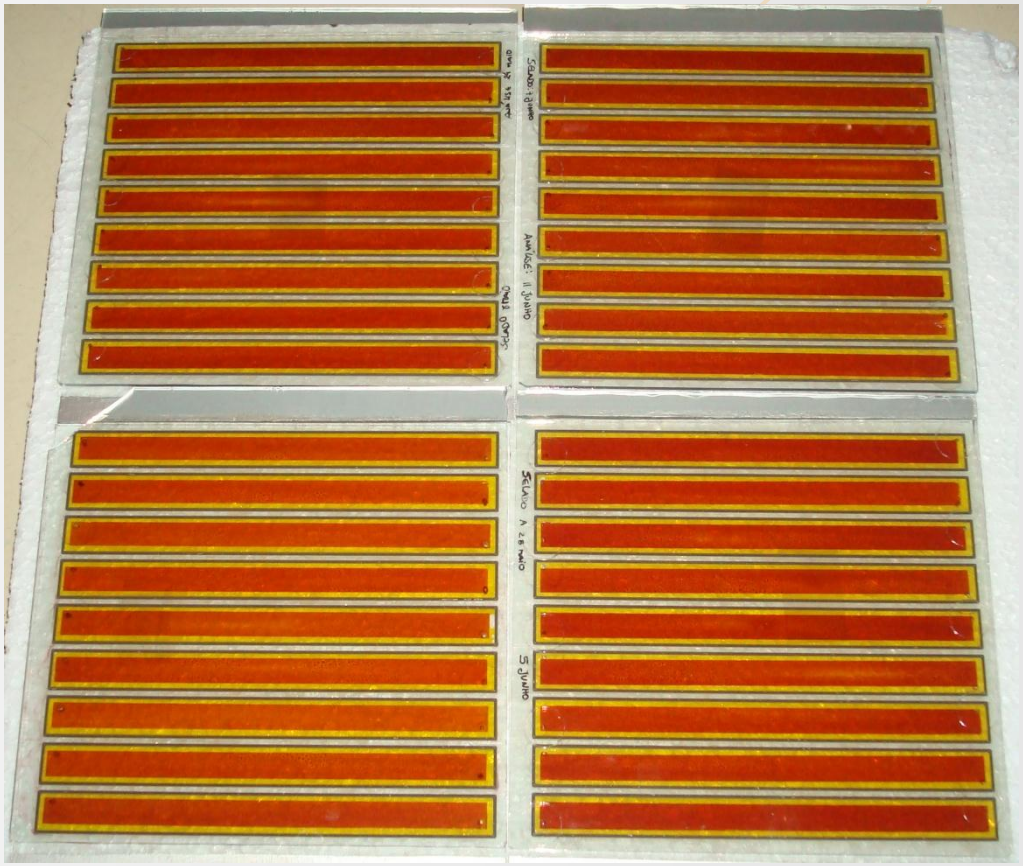




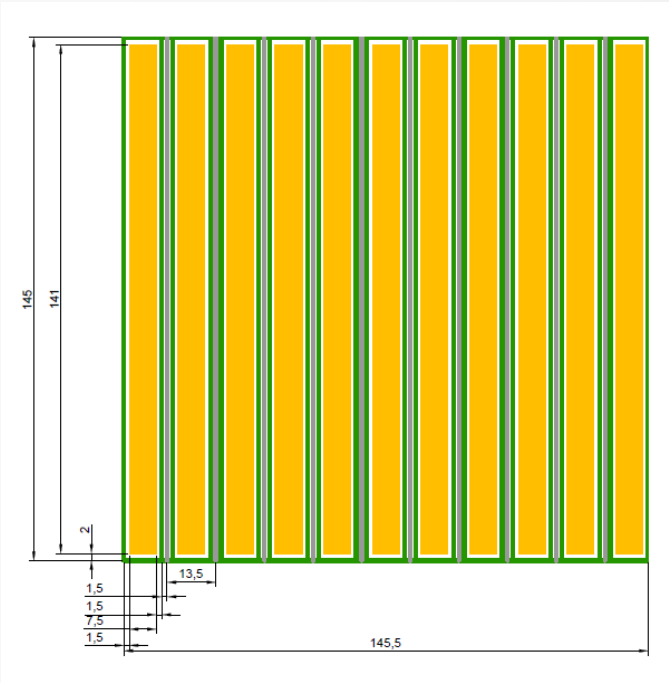
Solar Energy Materials & Solar Cells 96 (2012) 43–49

Dye Sensitized solar Cells

Meanwhile…



4 x 15 x 15 cm² W-configuration module

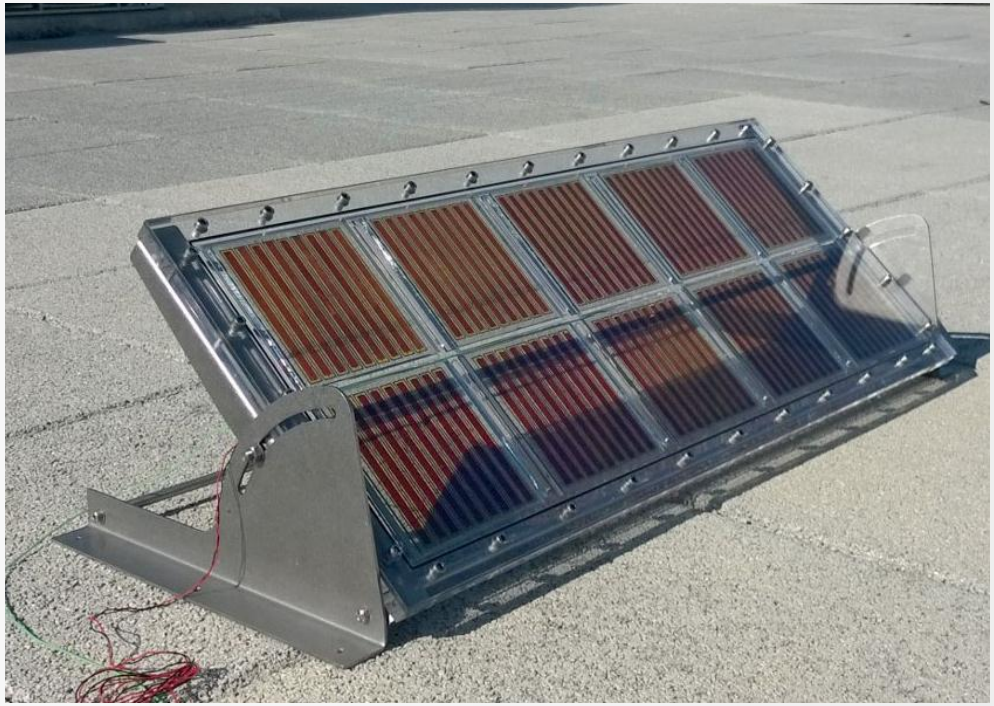


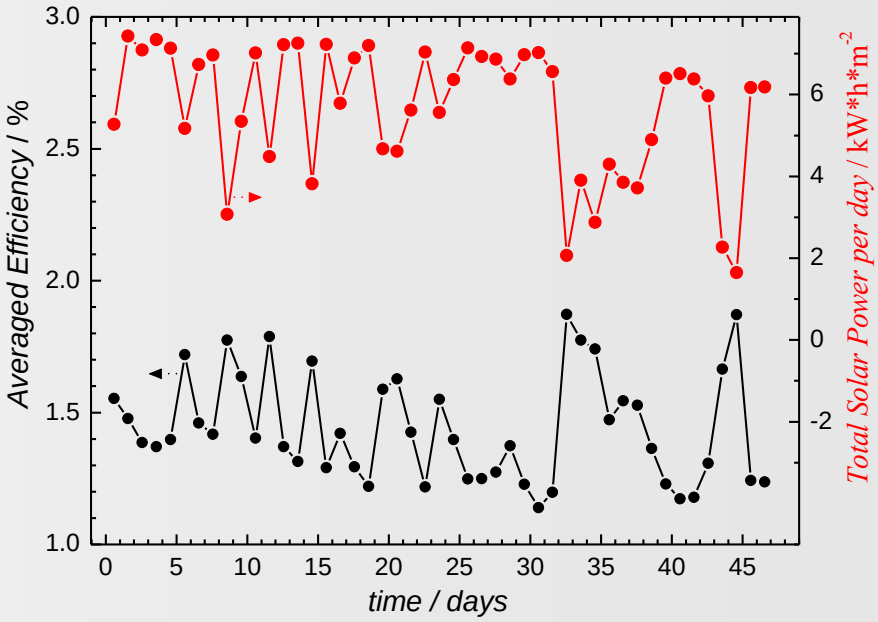
Dye Sensitized solar Cells

REELCOOP

Research Cooperation in Renewable Energy Technologies for Electricity Generation

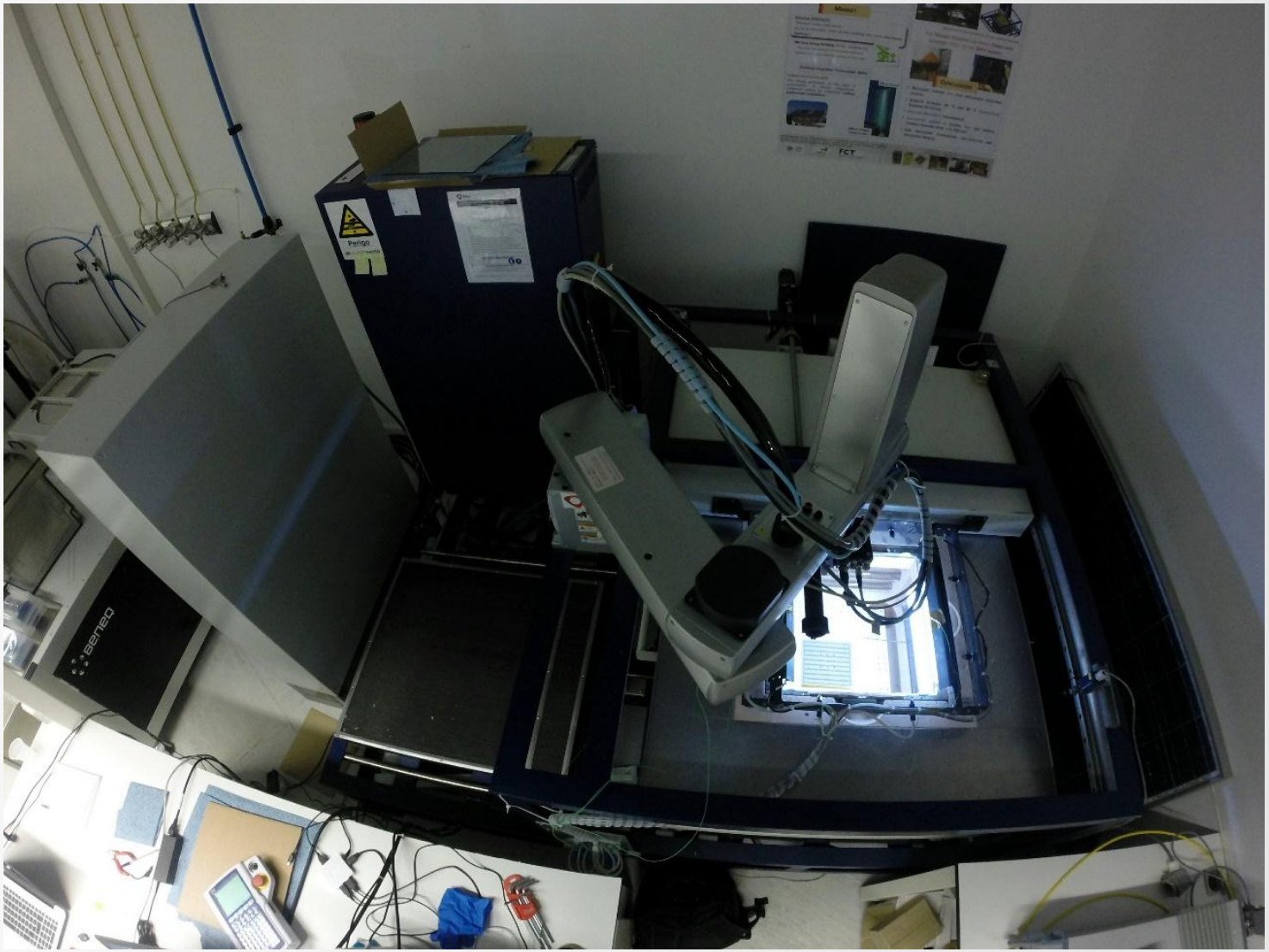
Development, design & construction of prototype 1 (BIPV)





- The Panel performed stable values of main parameters V_{oc}=41±1 V; J_{sc}=60±10 mA, ***FF*** = 0.32±0.4; ***MPP***=0.8±0.1 W and ***Efficiency***=1.2±0.2% during ***1128 h*** of continuous outdoor test.

Dye Sensitized solar Cells



The glass-glass laser assisted glass sealing was developed by UPorto and Efacec and sold to Dyesol for Solar applications

Patent licensing sold by 5 M€

Article | Comments (0) | Print

By **Mark Osborne** - 22 January 2015, 10:38 | In **News**, **Thin Film**, **OPV/DSSC**

Dyesol to pay for novel glass substrate sealing technology

The low temperature, laser-assisted glass sealing technology was first developed by EFACEC and the University of Porto, which will be further developed to specifically meet Dyesol's requirements. Image: Dyesol

Thin-film OPV firm, Dyesol is collaborating with Portuguese electrical engineering firm, EFACEC on a novel laser assisted, glass frit sealing technology for its solid-state DSC solar cells to provide 20-year plus sealing for its planned perovskite-based commercial PV products.

The low temperature, laser-assisted glass sealing technology was first developed by EFACEC and the University of Porto, which will be further developed to specifically meet Dyesol's requirements.

Dyesol said it would pay EFACEC €500,000 over a 15 month period and based on various development milestones. However, a further payment of €1.7 million over 24 months could be made by Dyesol on a successful development of the technology as well as a further €2.8 million payable as a royalty pending the commercialisation of the process in Dyesol's proposed solar panels and modules.

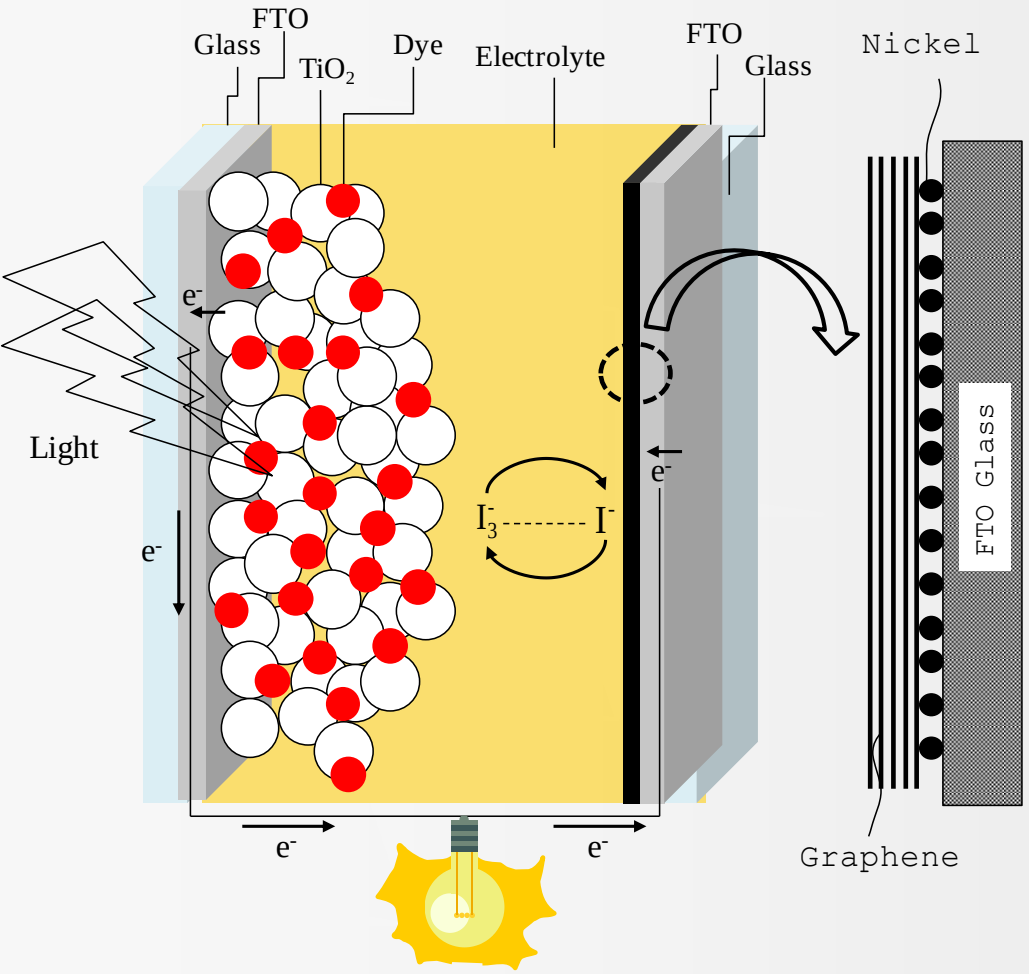
The company reiterated that it was on schedule to produce demonstration prototype modules in 2016, leading to mass production in 2018.

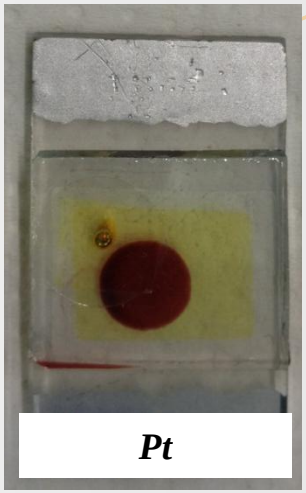
The structured financial transaction could lead to total payout by the company of €5 million after which IP ownership would be transferred to Dyesol.

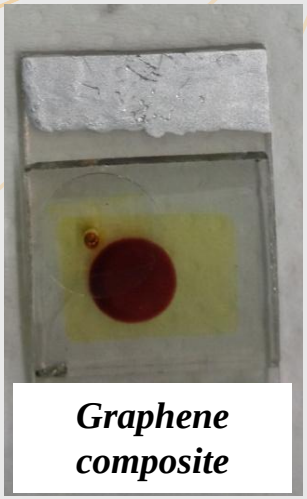
Carbon vs Platinum – The DSC counter-electrode

Dye Sensitized solar Cells

Carbon based counter-electrode – **Graphene composite**





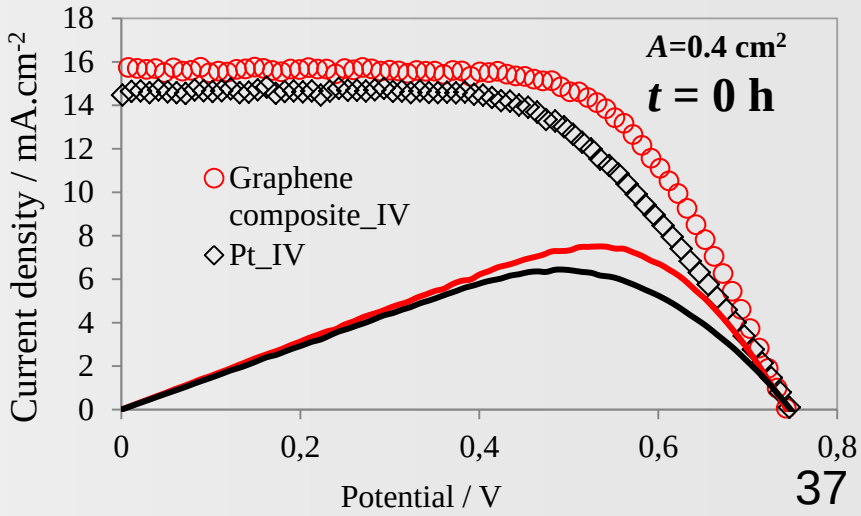


η=7.03 %

T_{550nm} = 92.0 %

η=7.34%

T_{550nm} = 91.8 %

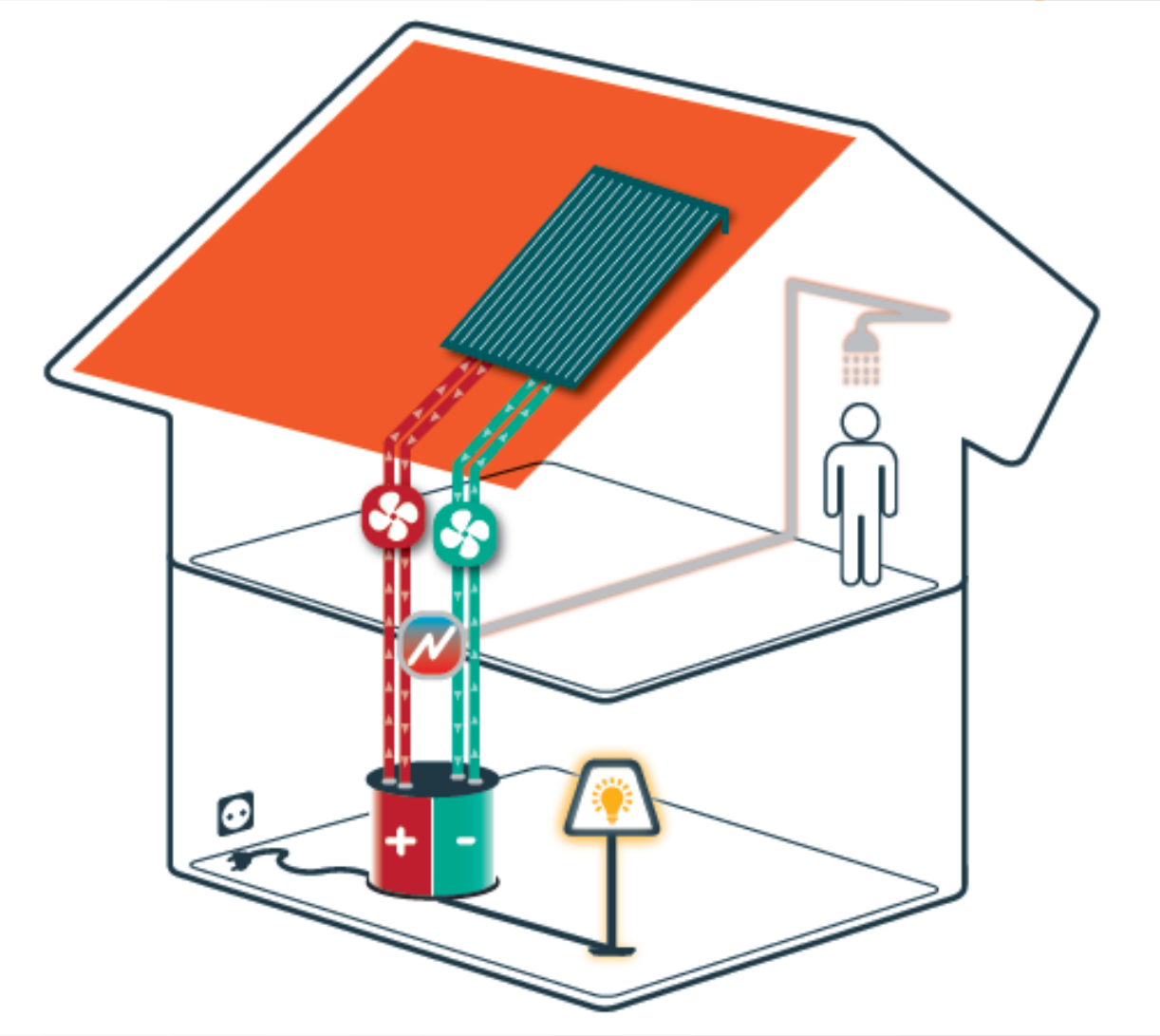


Moving beyond the obvious

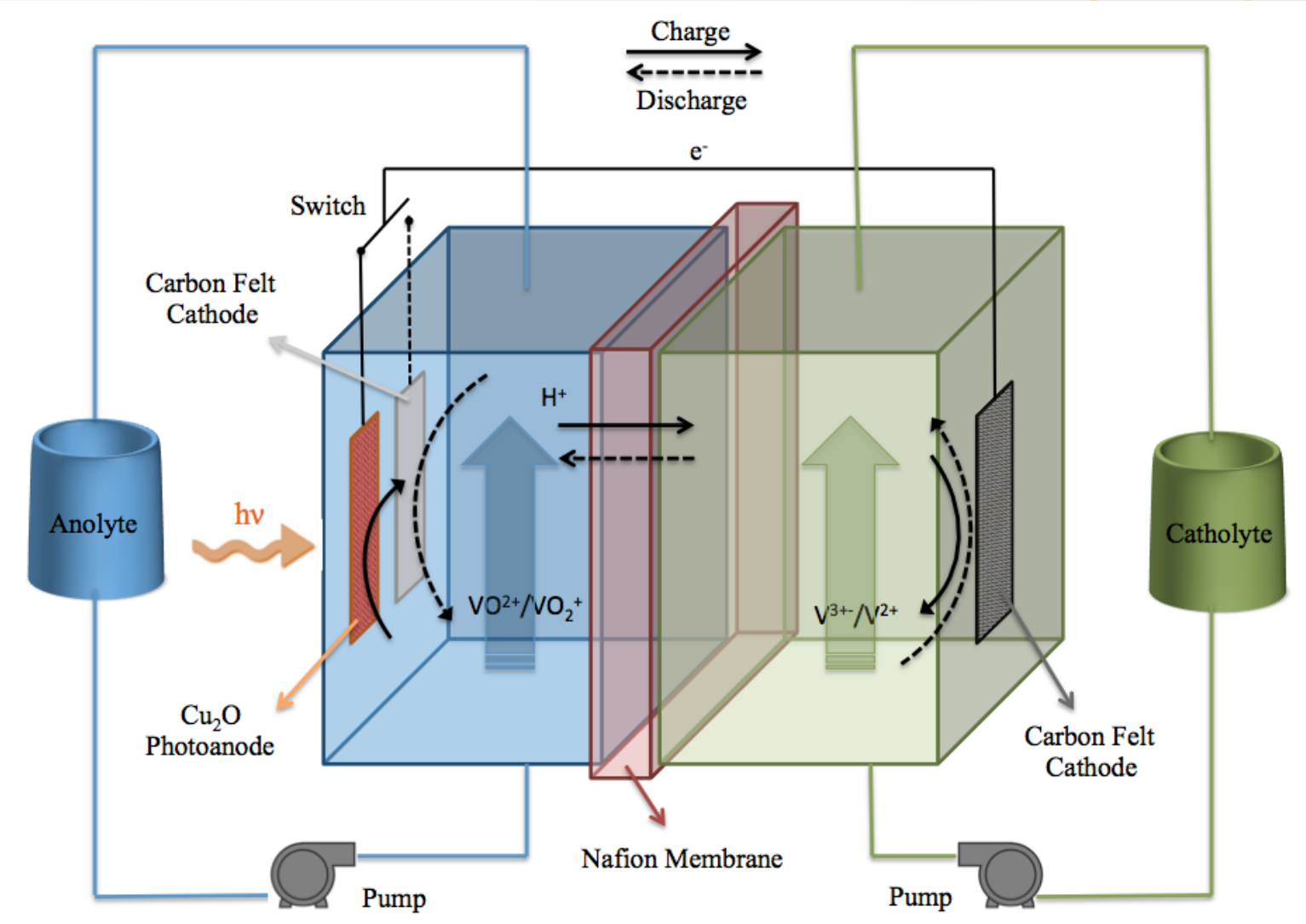
A completely new world:

Solar chargeable redox flow battery

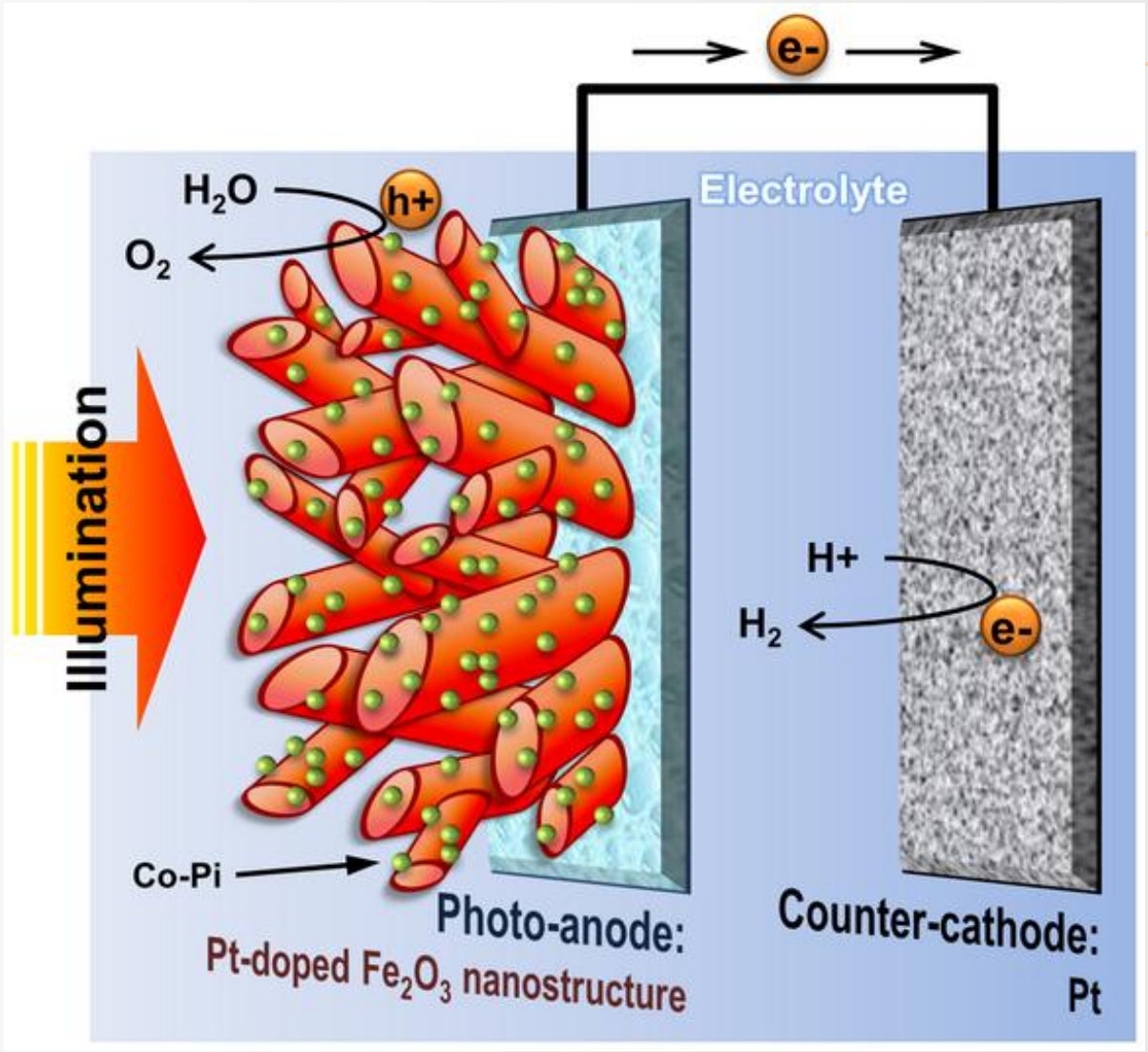
Solar rechargeable redox flow battery



Solar rechargeable redox flow battery



Solar rechargeable redox flow battery



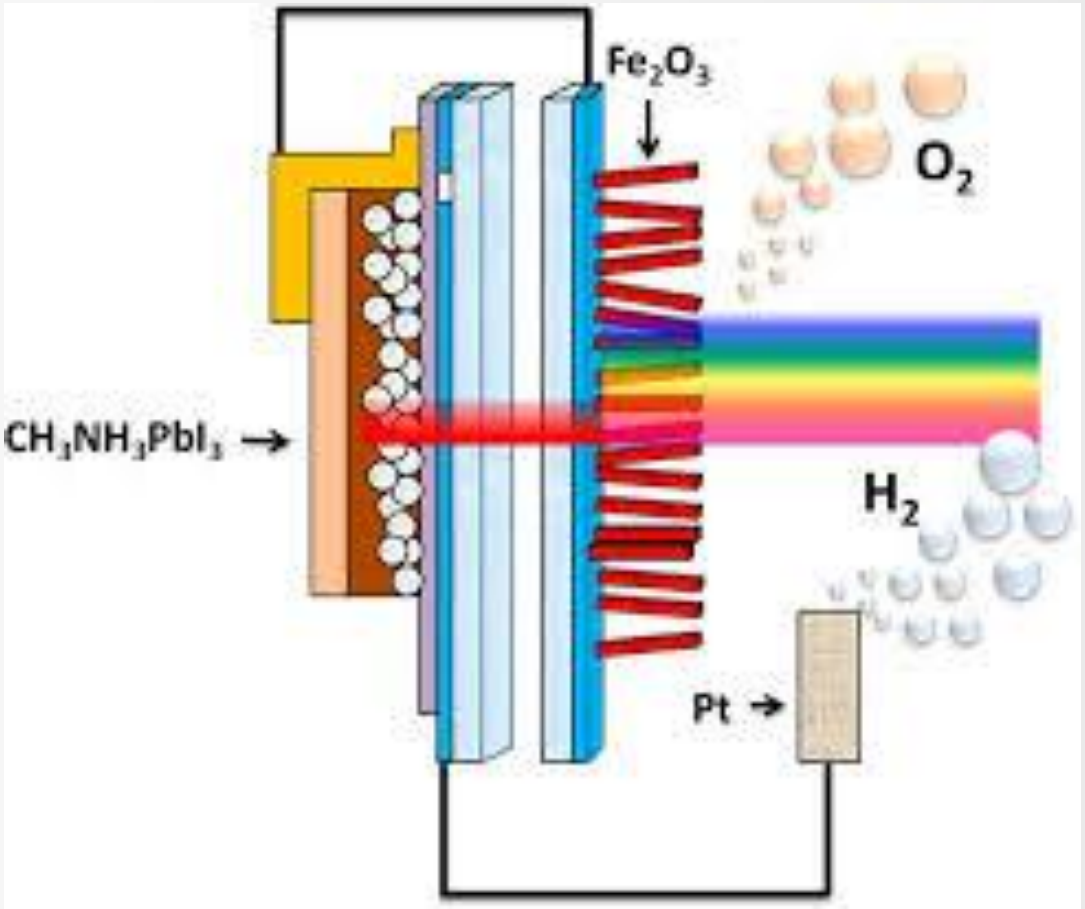
Single hematite photoanode

Article | OPEN

Single-crystalline, wormlike hematite photoanodes for efficient solar water splitting

Jae Young Kim, Ganesan Magesh, Duck Hyun Youn, Ji-Wook Jang, Jun Kubota, Kazunari Domen & Jae Sung Lee

Solar rechargeable redox flow battery



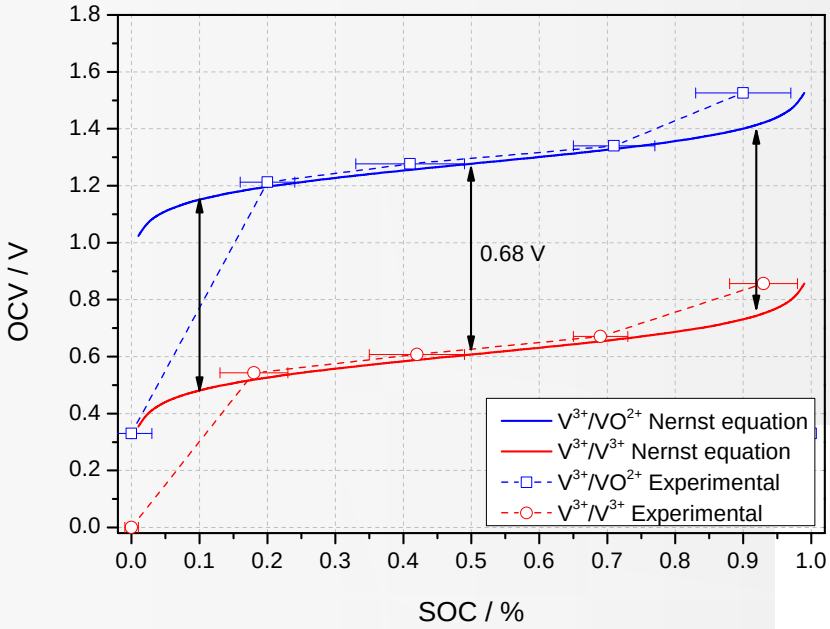
Tandem PSC/Hematite photoelectrode – 1.87 V, η =2.4 %.

Letter
pubs.acs.org/NanoLett
NANO LETTERS

Perovskite–Hematite Tandem Cells for Efficient Overall Solar Driven Water Splitting

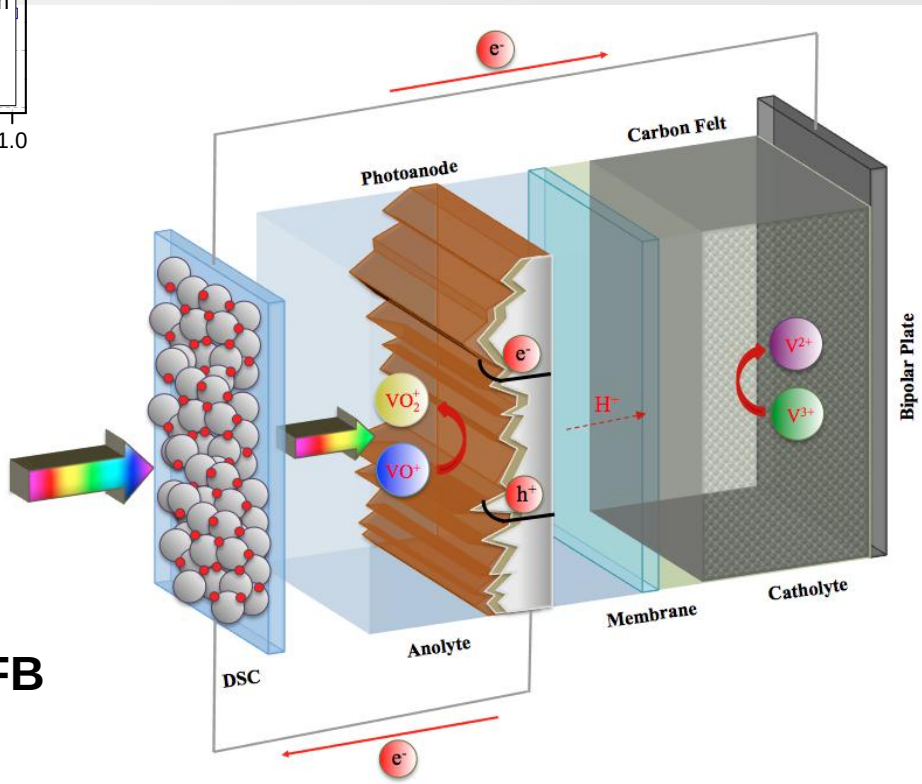
Gurudayal,[†] Dharani Sabba,[‡] Mulmudi Hemant Kumar,[‡] Lydia Helena Wong,[†] James Barber,[†,§] Michael Grätzel,[∥] and Nripan Mathews*[,†,‡]

Solar rechargeable redox flow battery



0.68 V extra to charge a standard all vanadium redox flow battery

Tandem Configuration



Solar charging an All Vanadium RFB

Questions are welcome!