Dye sensitized solar cells - a successful research

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Portugal & Porto
Faculty of Engineering

Chemical Engineering Department

New research laboratory space (1800 m²)
Research team
Scientific areas:

- Electrochemistry
- Photoelectrochemistry
- Reactions engineering
- Separation processes – adsorption and membranes
- Catalysts and catalysis
On-going international funded projects with industry
Main collaborations 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.
Main collaborations with industry

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

97 000 TW
The sun
The sun

Levelled cost of electricity from photovoltaics

LCOE from PV.

Difference between the grip and the PV prices.

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 2 of 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”.

Nearly zero-energy buildings
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 (TiO₂)
  - particle size 10-30 nm
- Ru-metal organic sensitizing dye
- Redox electrolyte
  - I⁻/I₃⁻
- Platinum counter-electrode: catalyst of redox reaction

By Luísa Andrade
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
Photovoltaic cells – comparing technologies

Geneva airport, DSCs by G2E:

http://en.wikipedia.org/wiki/Copper_indium_gallium_selenide_solar_cells
Dye Sensitized solar Cells

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

Best Research-Cell Efficiencies

US National Center for Photovoltaics website http://www.nrel.gov/ncpv/
Building Integrated Photovoltaic - BIPV
Dye Sensitized solar Cells

...and DSCs

Silicon
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
  \( \lambda = 1064 \text{ nm}, \ P_{\text{max}} = 200 \text{ W} \)
• Sealing temperature: ca. 250 °C
Dye Sensitized solar Cells

New approach:

✓ Glass sealing assisted by laser
**Dye Sensitized solar Cells**

![Graph showing temperature and current density over time and voltage](image)

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 $V_{oc}=41 \pm 1$ V; $J_{sc}=60 \pm 10$ mA; $FF=0.32 \pm 0.4$; $MPP=0.8 \pm 0.1$ 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.
Carbon vs Platinum – The DSC counter-electrode
Dye Sensitized solar Cells

Carbon based counter-electrode – *Graphene composite*

\[ \eta = 7.03\% \quad T_{550\text{nm}} = 92.0\% \]

\[ \eta = 7.34\% \quad T_{550\text{nm}} = 91.8\% \]

\[ A = 0.4\text{ cm}^2 \quad t = 0\text{ h} \]
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

Single-crystalline, wormlike hematite photoanodes for efficient solar water splitting
Solar rechargeable redox flow battery

Tandem PSC/Hematite photoelectrode – 1.87 V, $\eta = 2.4\%$. 
Solar rechargeable redox flow battery

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

Solar charging an All Vanadium RFB
Questions are welcome!