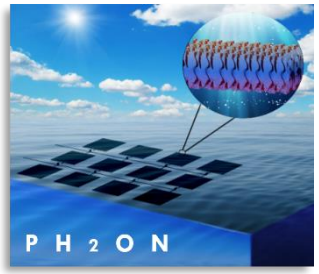
UiO : Department of Chemistry
University of Oslo

Prospects of photoelectrochemical water electrolysis and the production of solar fuels



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Solar Energy

Global power generating capacities of S.E.S.

Energy source	Power (TW)
Wind	4
Hydroelectric	1-2
Tidal and ocean currents	< 2
Geothermal	12
Biomass	10
Nuclear	10
Solar	**> 20**

2011: 15 TW
2050: 30 TW

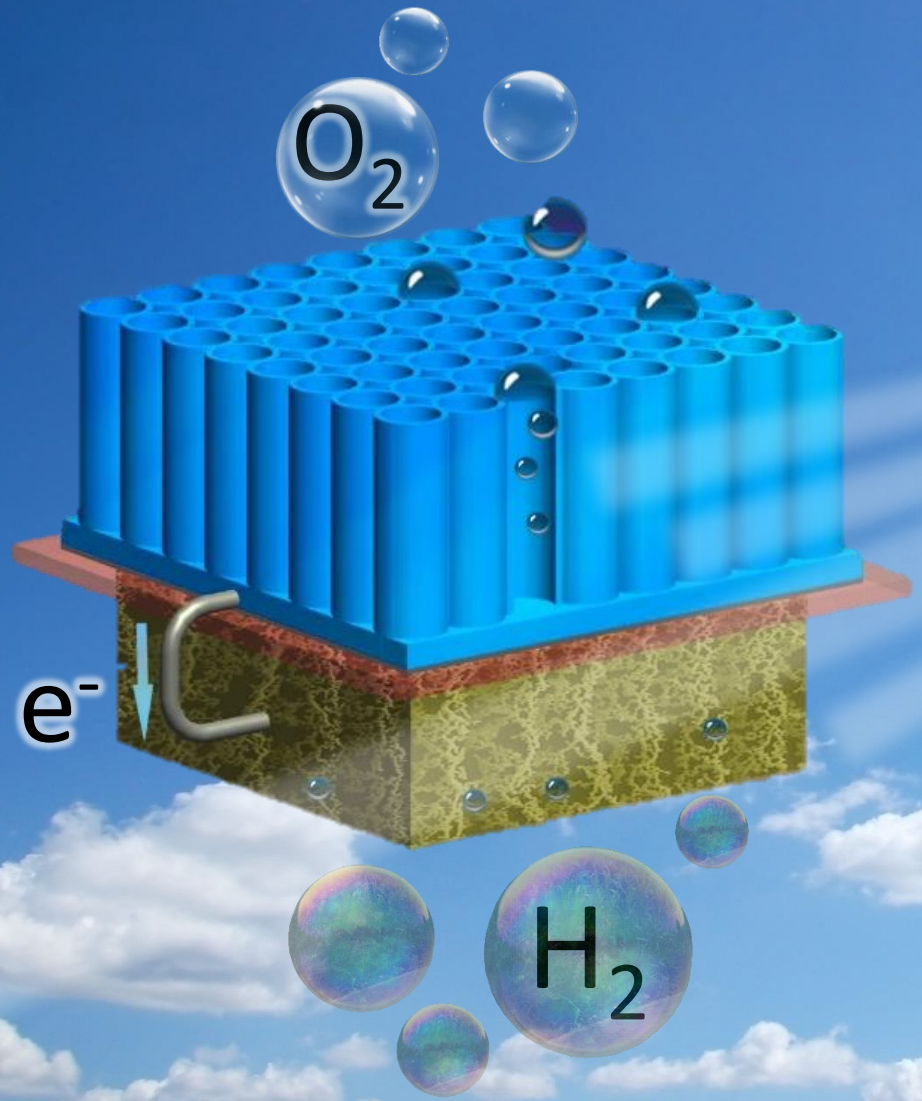
Cover 0.16% of the earth with 10% efficient solar cells we get more than 20 TW

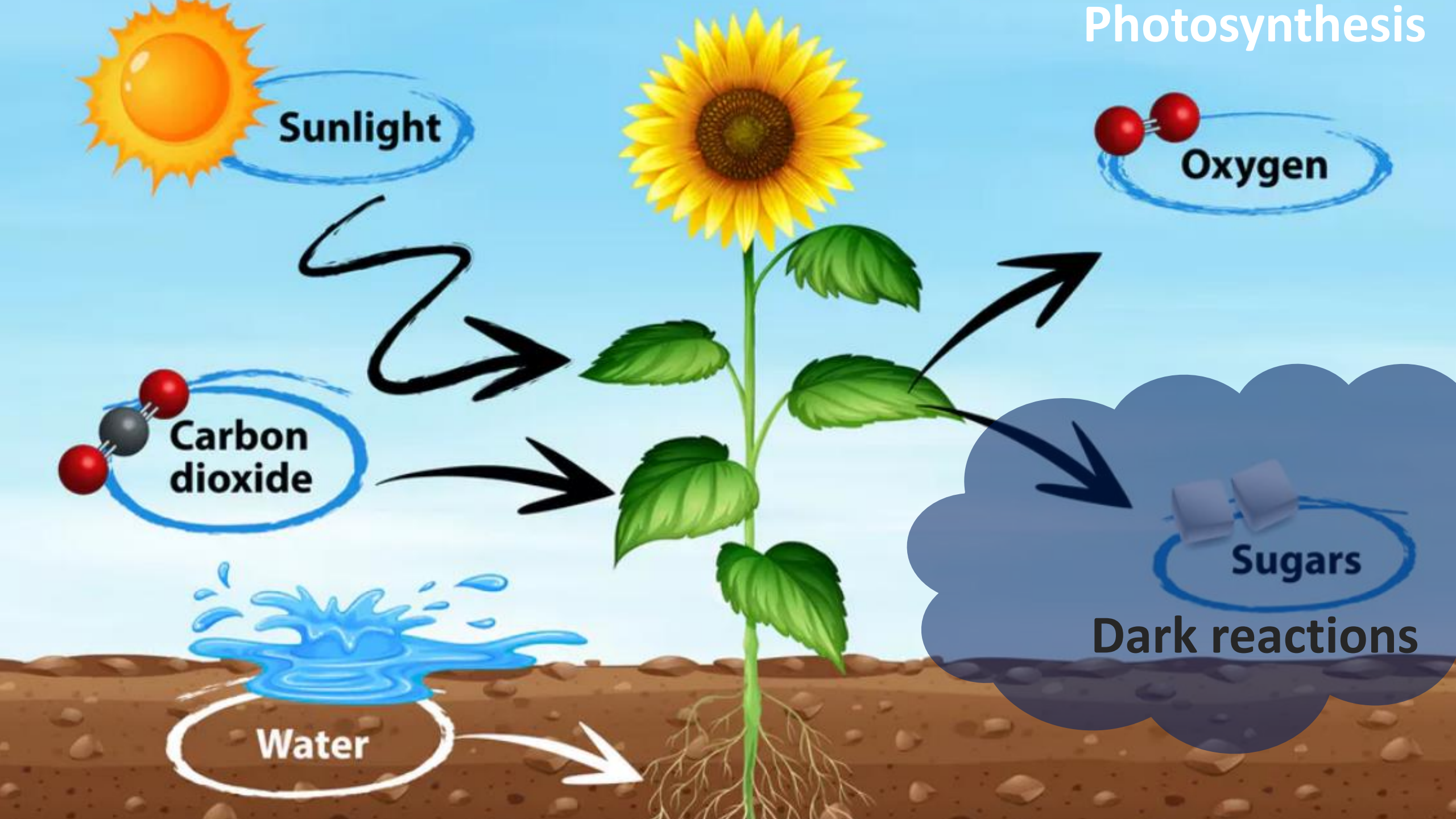
650 m^2 solar cells / second 24/7 for 40 years

M. Grätzel & R. van de Krol, Photoelectrochemical hydrogen production, Springer 2012

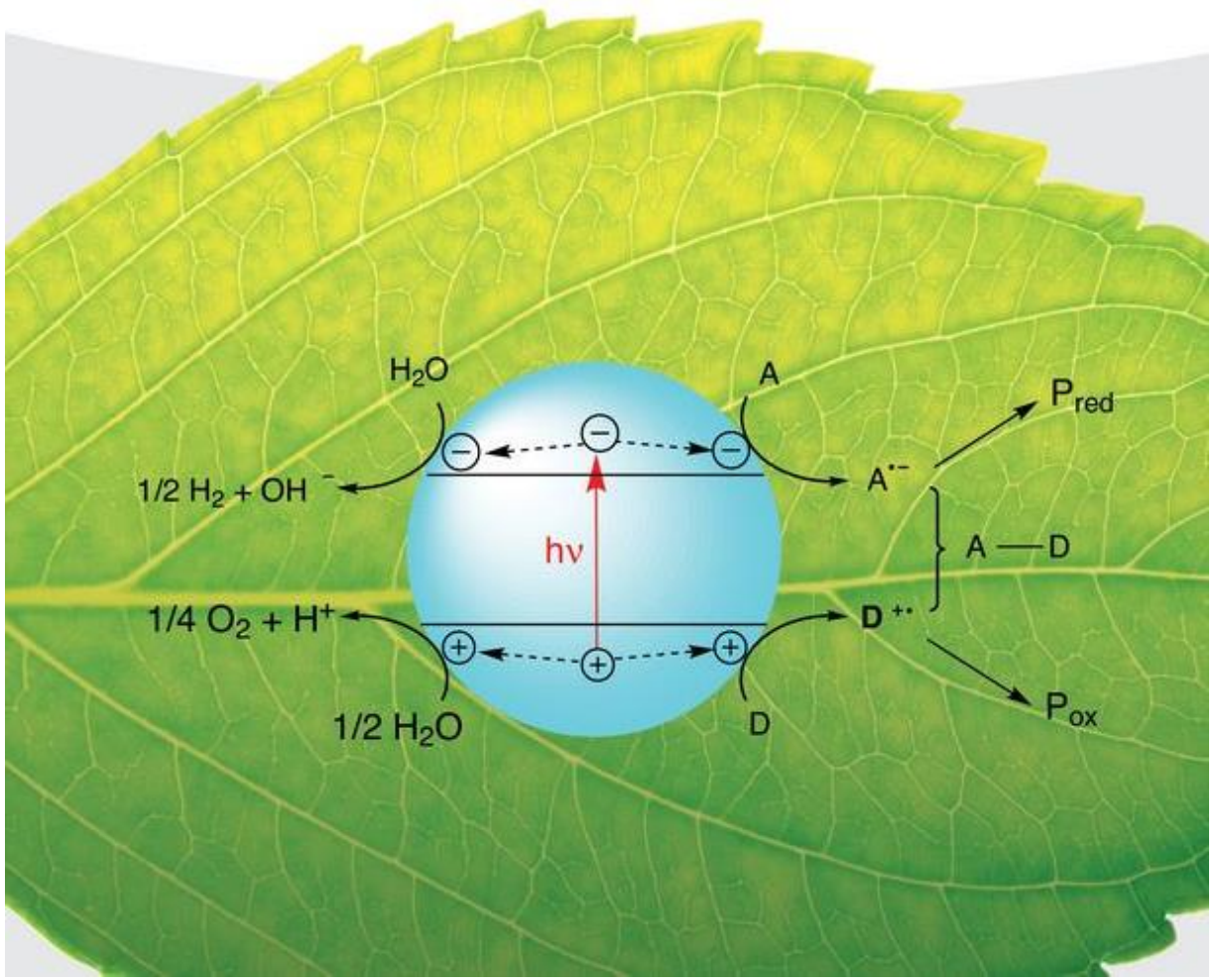
Artificial photosynthesis

Mimicking nature for a sustainable energy future




Photosynthesis
Sunlight
Oxygen
Carbon dioxide
Sugars
Dark reactions
Water

Artificial Photosynthesis (Artificial leaf)

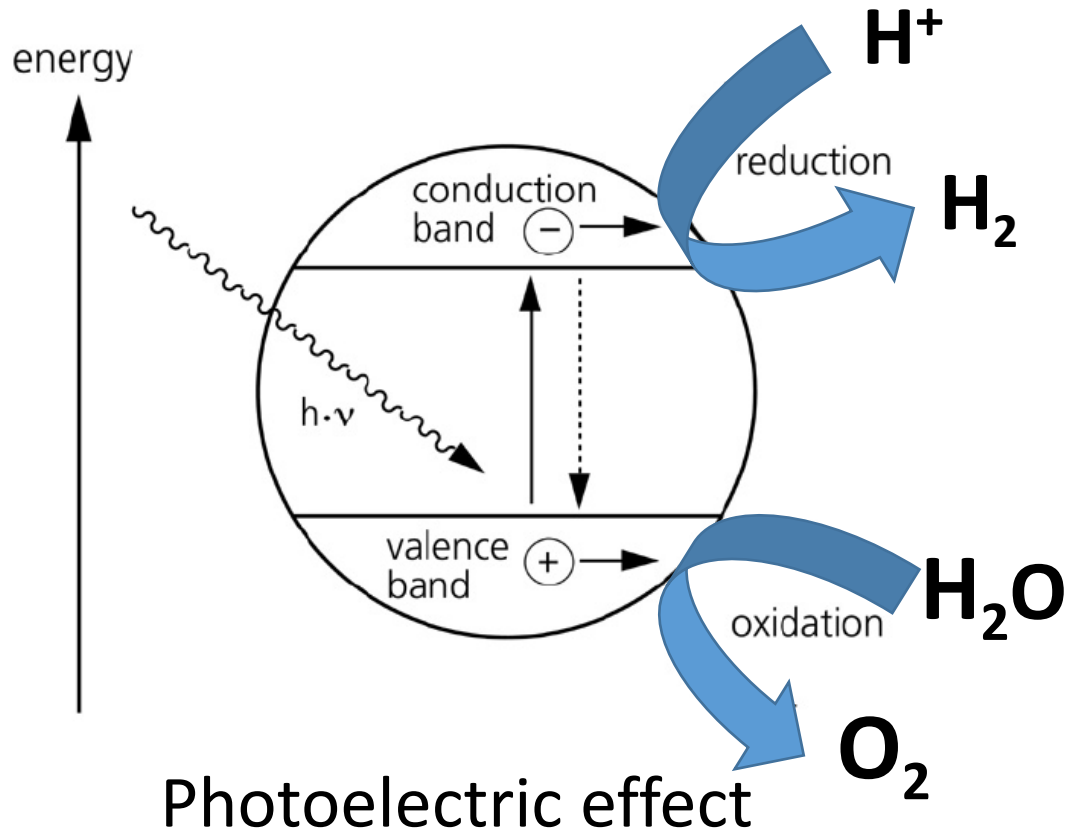


Horst Kisch

Semiconductor Photocatalysis: Principles & Applications

Wiley-VCH

Photo-electrolysis of water



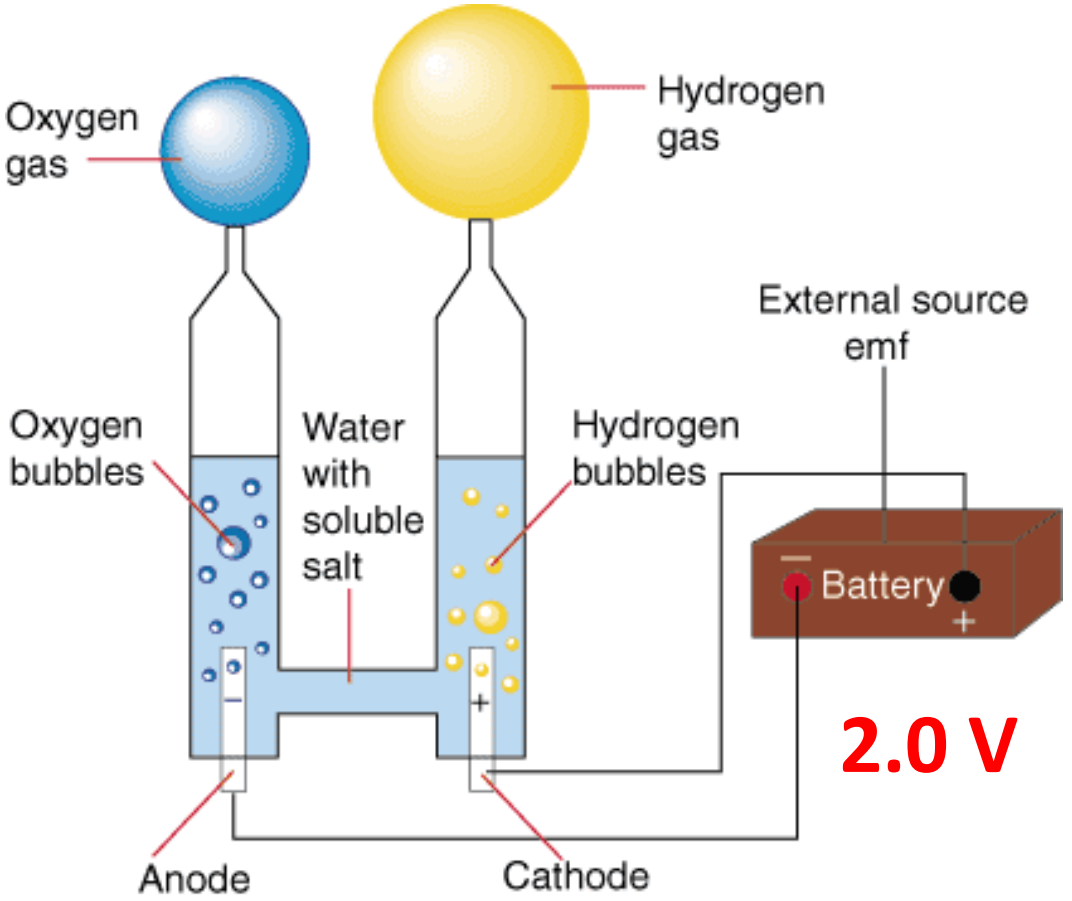
Photoelectric effect

A. Einstein – Nobel prize 1921

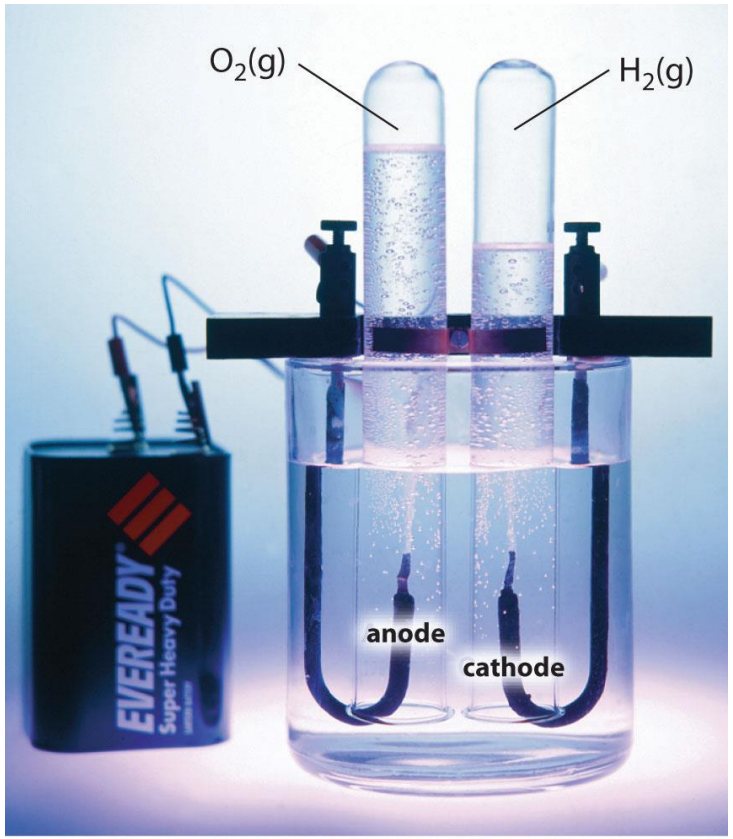
Hydrogen from water electrolysis

In 1 year we need to electrolyze **3.5 10^{13} L**

This corresponds to **0.01%** annual rain fall **0.0000002%** of the amount of water in the oceans[1]



Thermodynamically 1.23 V



anode: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

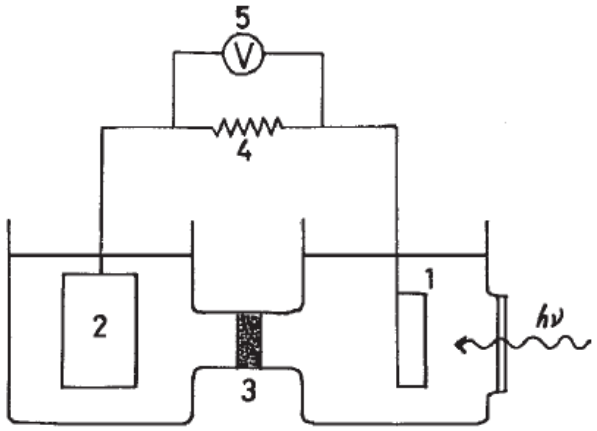
cathode: $2H^+(aq) + 2e^- \rightarrow H_2(g)$

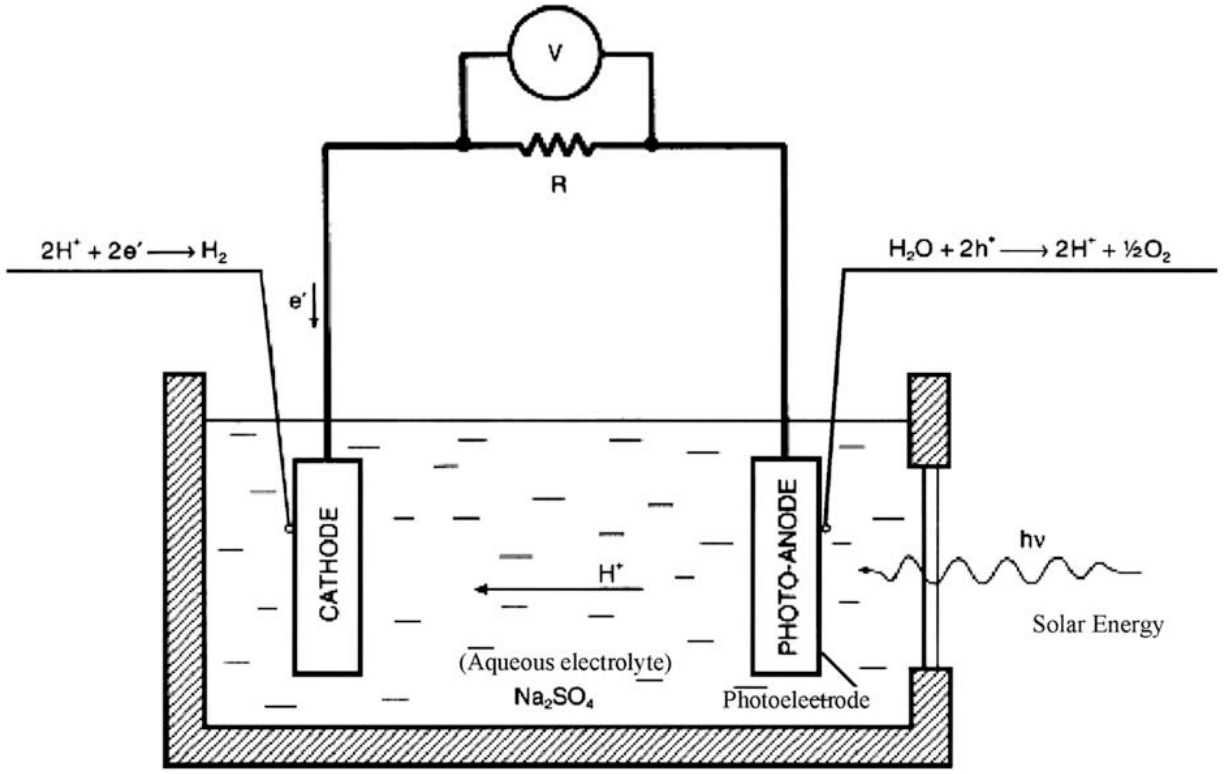
overall: $2H_2O(l) \rightarrow O_2(g) + 2H_2(g)$

[1]M. Grätzel & R. van de Krol, Photoelectrochemical hydrogen production, Springer 2012

Hydrogen from water **photo-**electrolysis

Photoanode: TiO_2
Cathode: Pt
Electrolyte: Na_2SO_4



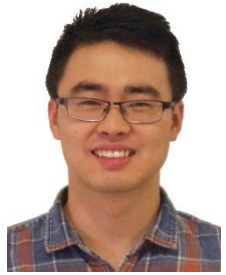


External bias
0.25-0.5V

1.5-1.7 V

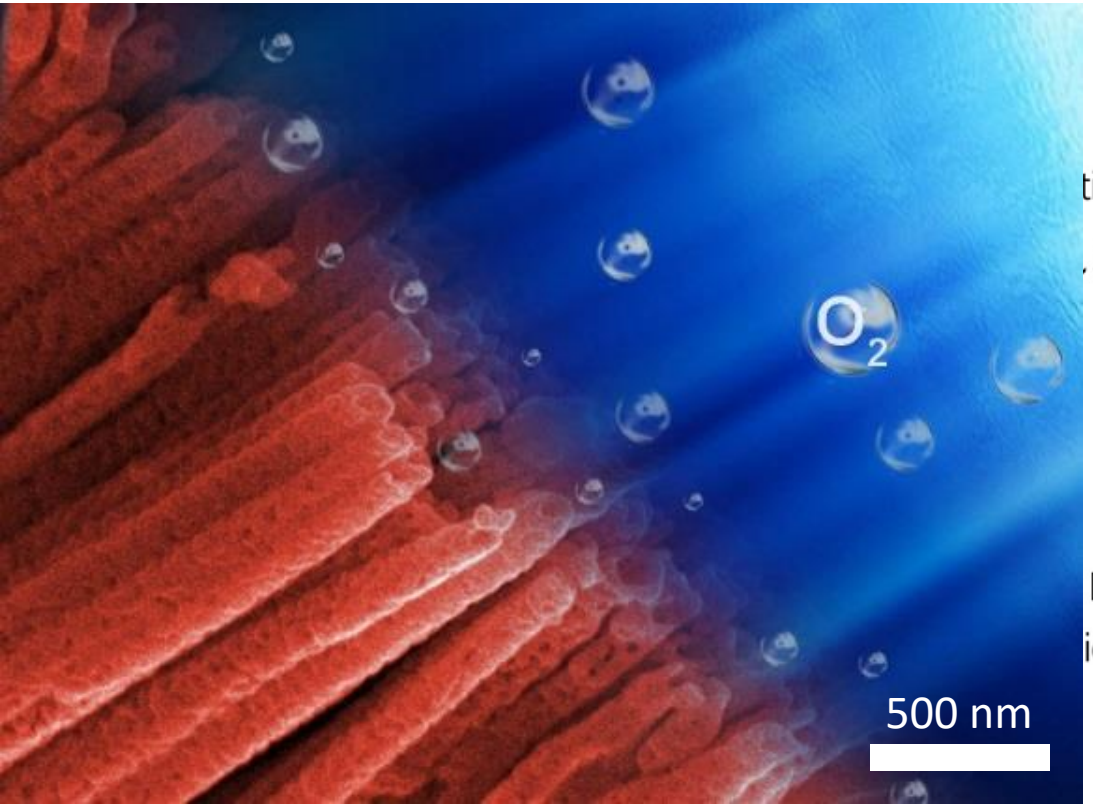
Fujishima, A., Honda, K.. Electrochemical photolysis of water at a semiconductor electrode, Nature (1972), 238, 37–38.

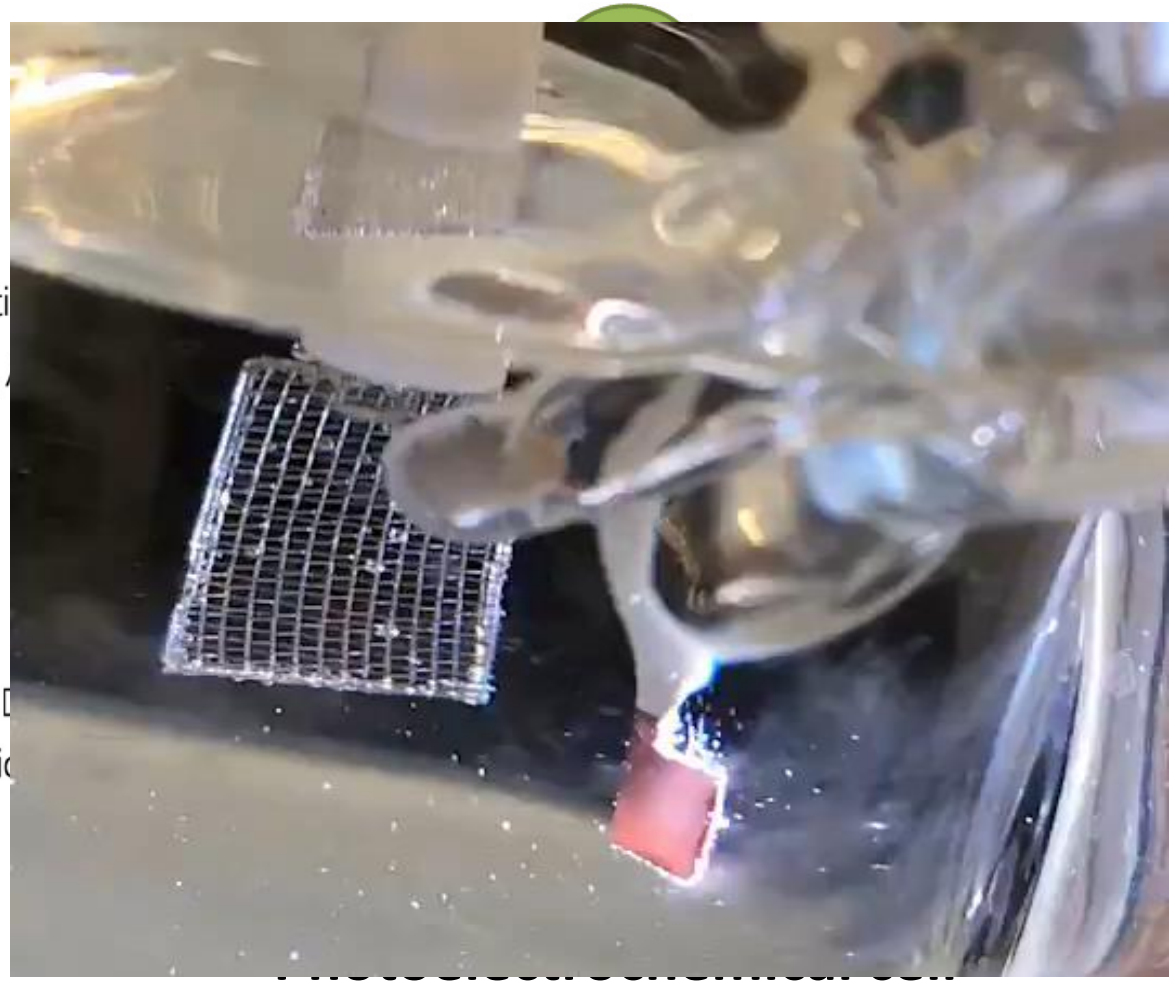
Hydrogen from water **photo-**electrolysis



K. Xu

Photoelectrode: Ta_3N_5 nanotubes





1.1 V

Liao C.H., et al., Catalysts, 2012, 2 (4), 490

Xu K., Chatzitakis A., Norby T. et al., Photochem. Photobiol. Sci., 2019

Benchmarking

To compete with current fossil fuel-based H_2 production and show commercialization potential

8 mA cm^{-2} at 1.23 V (unbiased) yielding a 10% solar to hydrogen (STH), with a 15/year lifetime

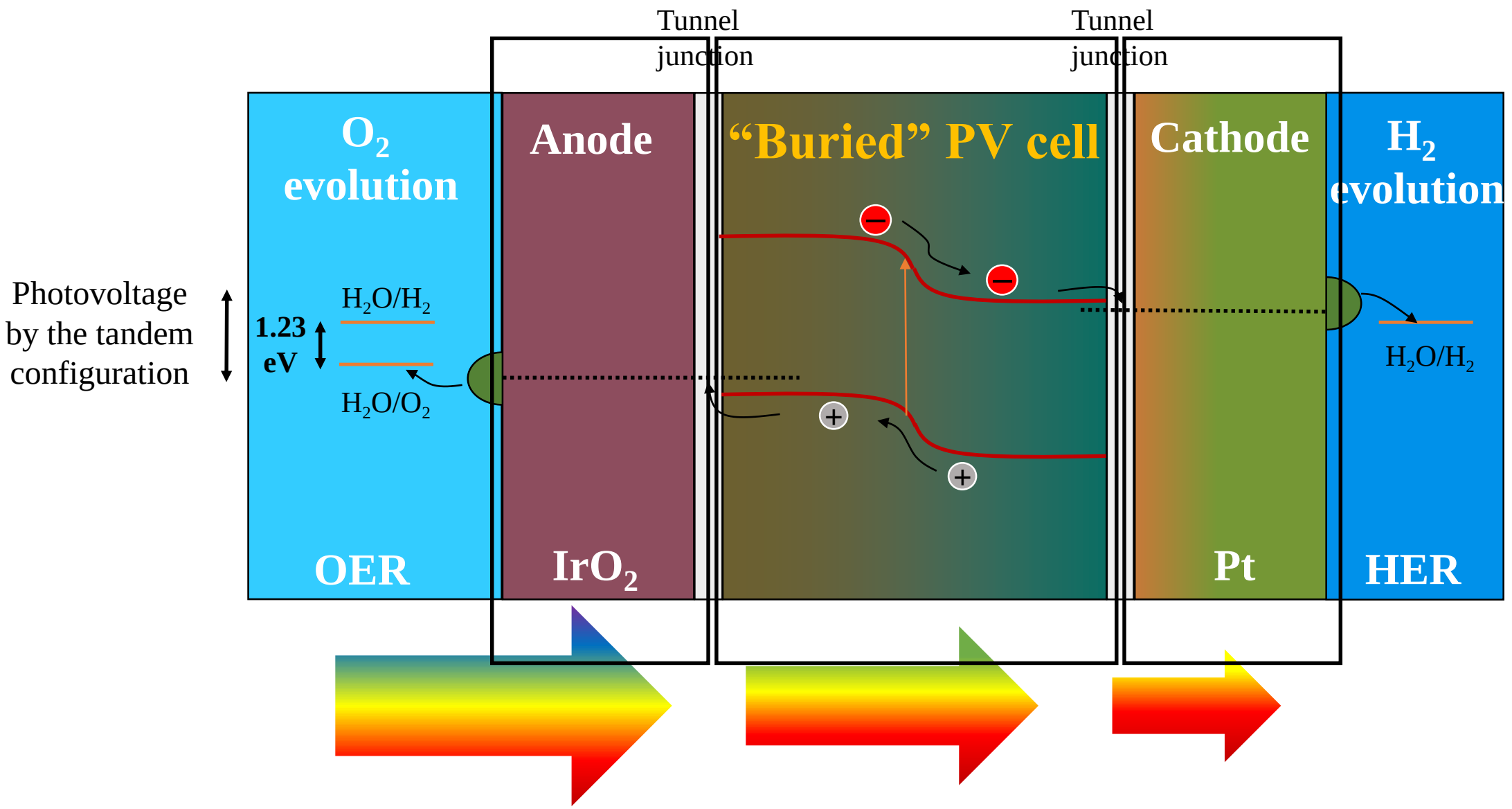
$$\text{Solar-To-Hydrogen \%} = (8\ \text{mA cm}^{-2} \times 1.23\ \text{V}) / (100\ \text{mW cm}^{-2}) \times 100 = 10\%$$

Photocurrent
No degradation
Cheap, earth abundant materials

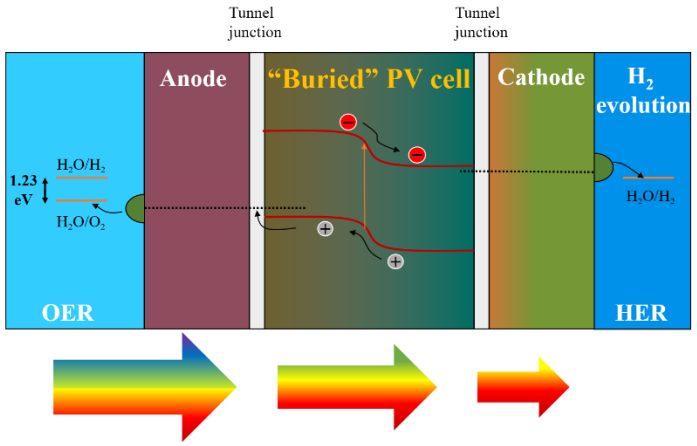
Unbiased
If external bias is provided,
then it should be excluded

1 «Sun» illumination

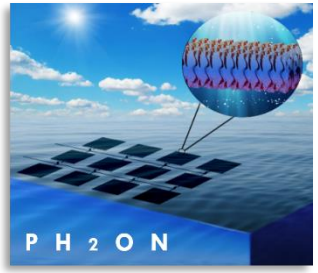
PV-assisted PEC water splitting



PV-assisted PEC water splitting – Bias free operation



[See video of a Bias free water splitting here]



4.2 mA/cm² → STH 5.1%

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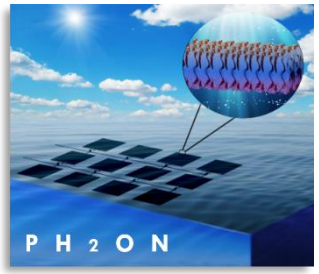
«Water will be the Coal of the Future»

Jules Verne, 1874



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