Photo-electrochemical reactors for hydrogen sulfide splitting

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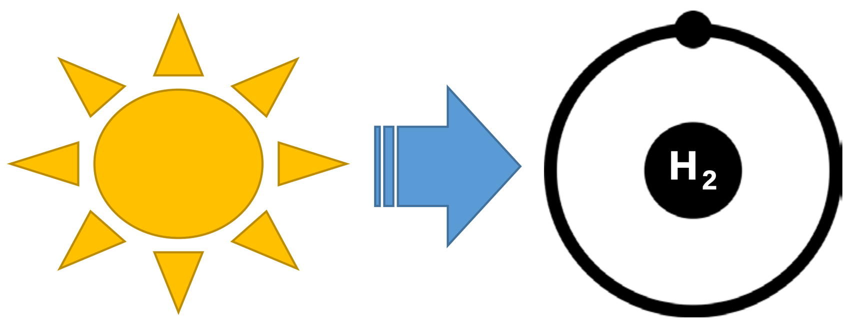
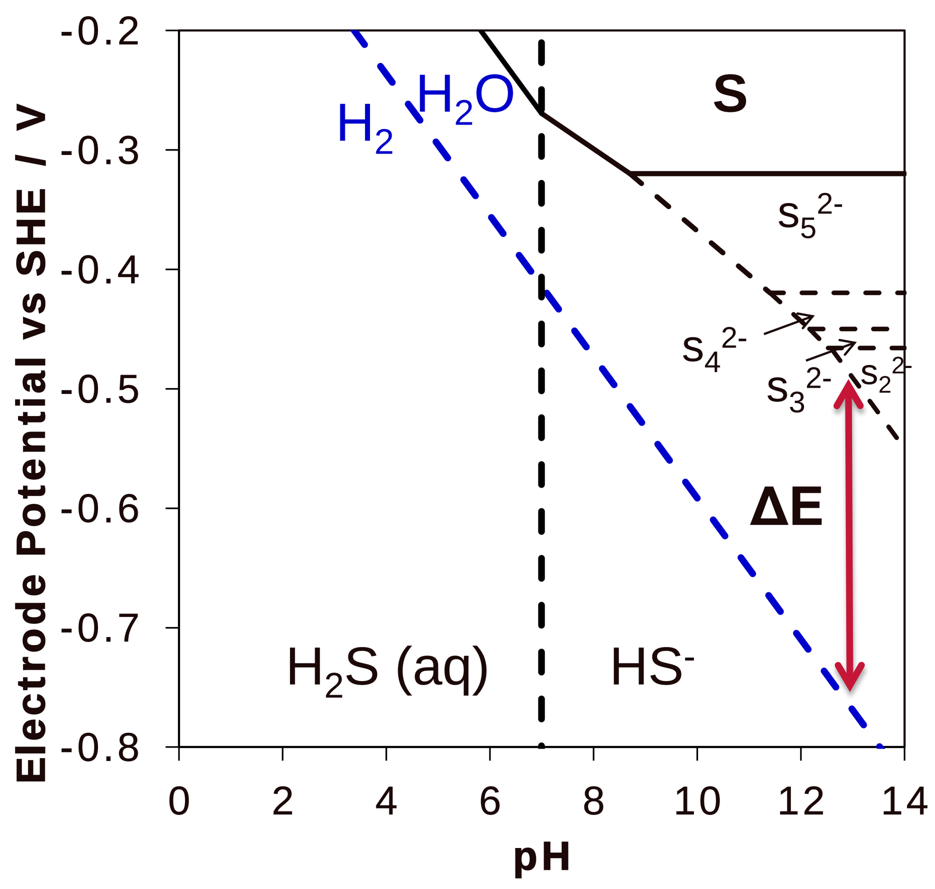
Why are we doing this?

Hydrogen sulfide or H_2S is produced in large quantities in waste water treatment plants and refineries after hydrodesulfurization processes to remove sulfur from oil. 64 million tonnes are processed as sulphur every year in the world. H_2S is a toxic, corrosive and smelly gas.

Solar energy suffers from intermittency and low yields. Energy storage is an issue that needs to be solved in order to consider the sun as an effective source of energy. **Hydrogen** is considered as a promising alternative for chemical energy storage.



H_2 is the fuel of the future

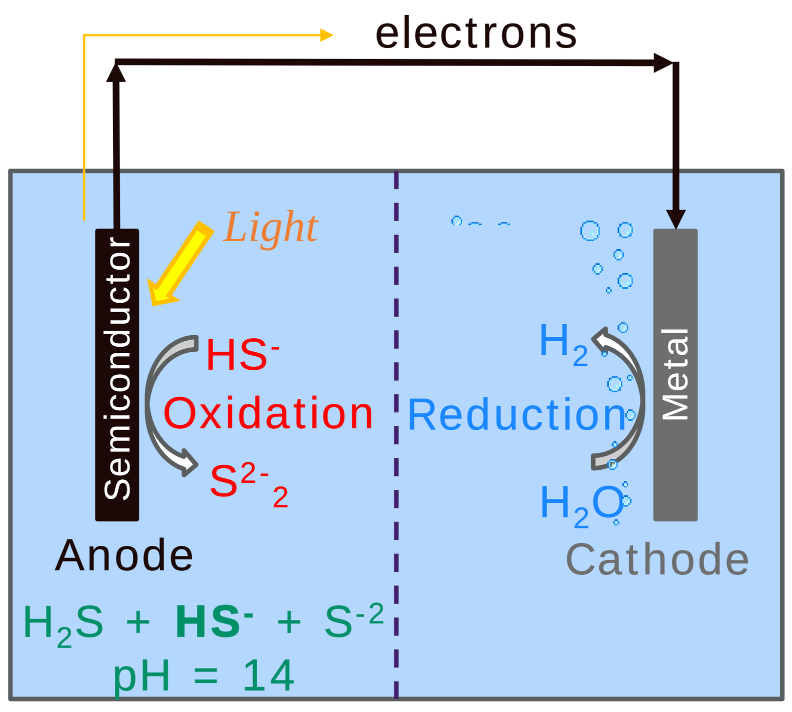


Water splitting to produce hydrogen and oxygen using solar energy is the most studied process. However, in order to produce H_2 from water at least 1.23 V should be provided to the system. We propose to split something less energy intensive such as H_2S, which requires only 0.27 V to produce hydrogen and polysulfides.

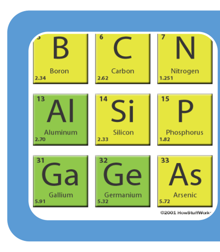
$$2H_2O + 4h\nu \rightarrow O_2 + 2H_2$$
$$\Delta E = 1.23\ V$$

$$2H_2S + h\nu \rightarrow 2H_2 + S_2^{2-}$$
$$\Delta E = 0.27\ V$$

How do we do it?

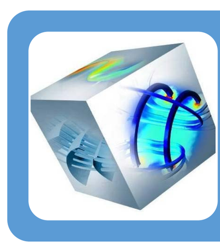


Photoelectrochemical Reactor (PER)



Semiconductor selection
- Stability
- Efficiency
- Band edges

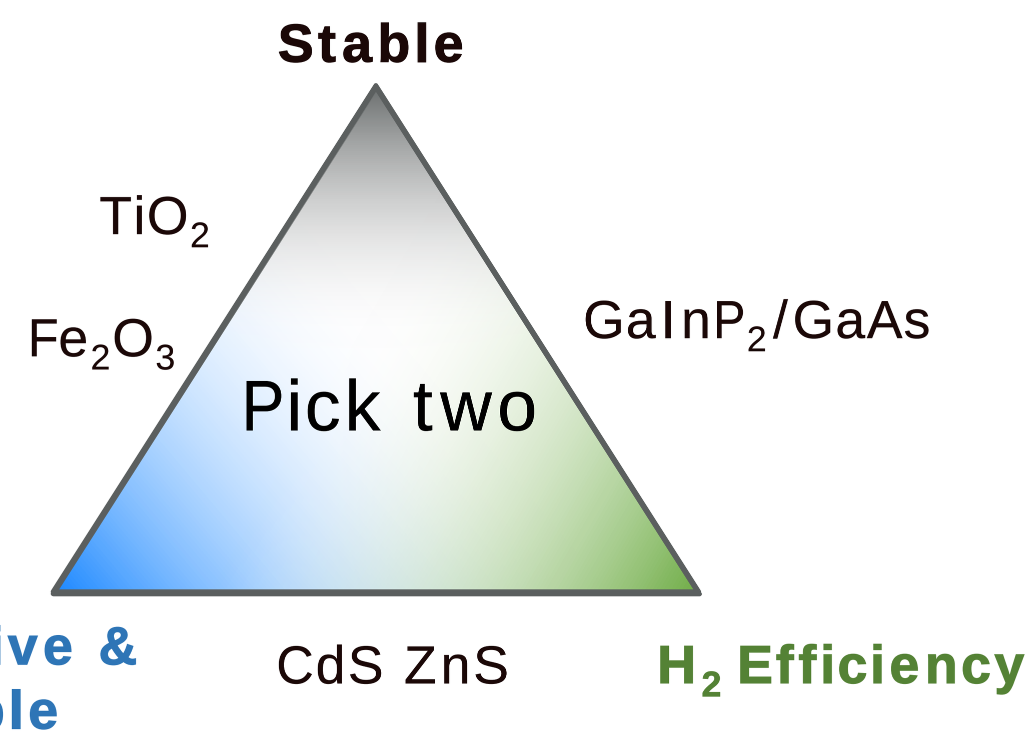
Characterization
- Flat band potential
- Recombination efficiency
- Band gap



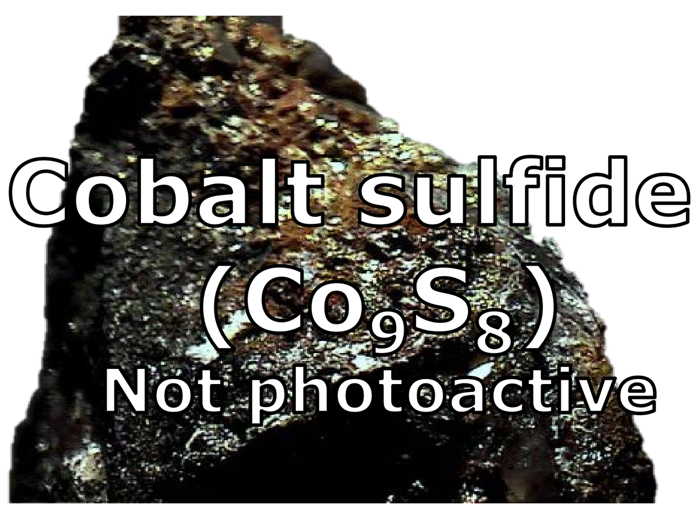
Modelling
- Development of kinetic model
- Medium scale reactor (0.01 m²)
- Large scale reactor (1 m²)

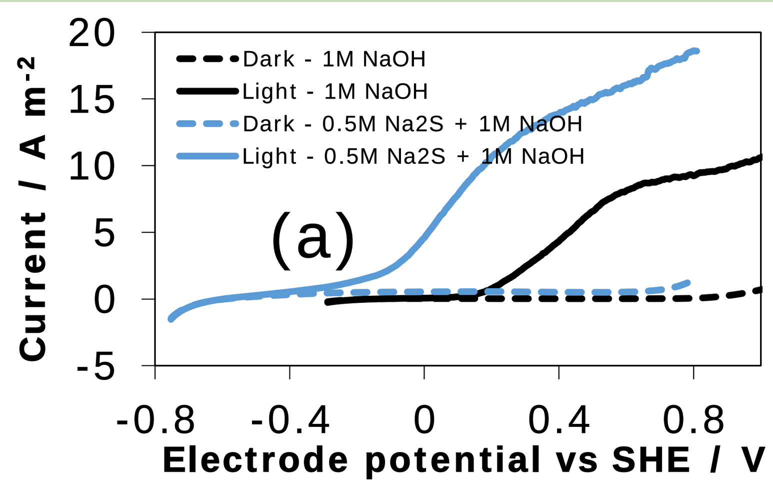
Where is the catch?

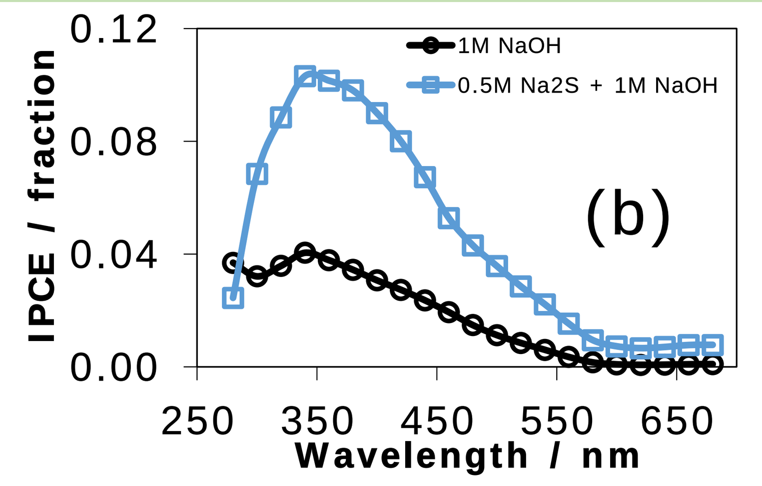
It is very challenging to find an inexpensive **semiconductor**, able to split hydrogen sulfide efficiently without decomposing. Also, it is recommended to be environmentally benign. Heavy metals such as cadmium and lead should be avoided.



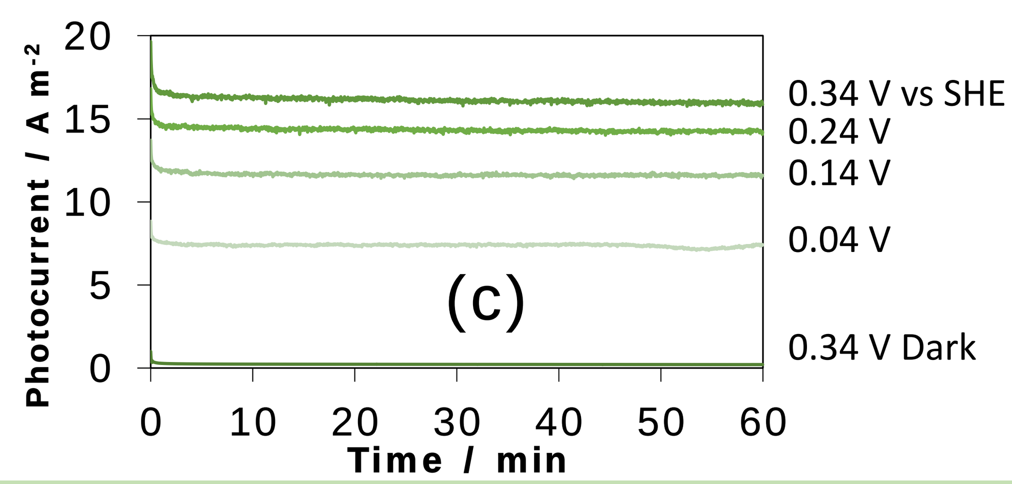
Which materials have been tested?







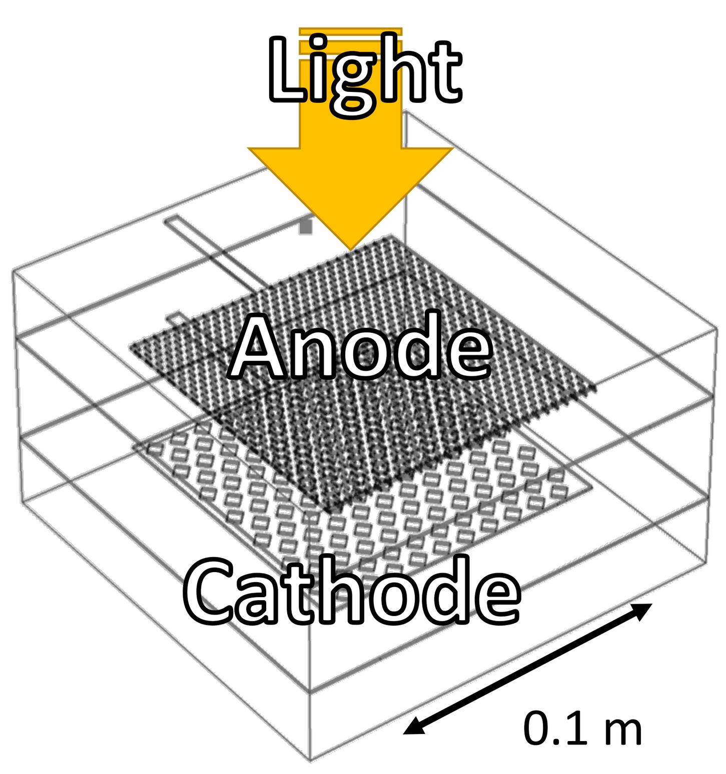
Hematite is thermodynamically unstable in sulfide solution, but its kinetics of decomposition are very slow. (a) Higher current densities and (b) efficiencies were achieved compared to conventional water splitting. Also, (c) photocurrent with time is stable at moderate potentials.

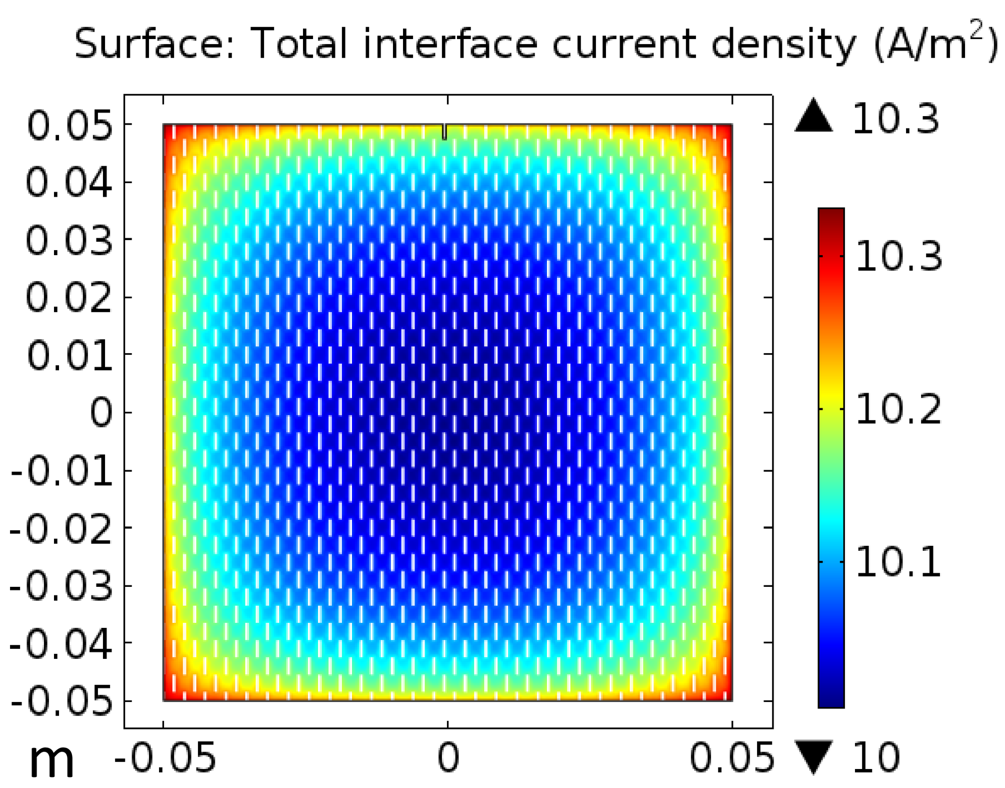


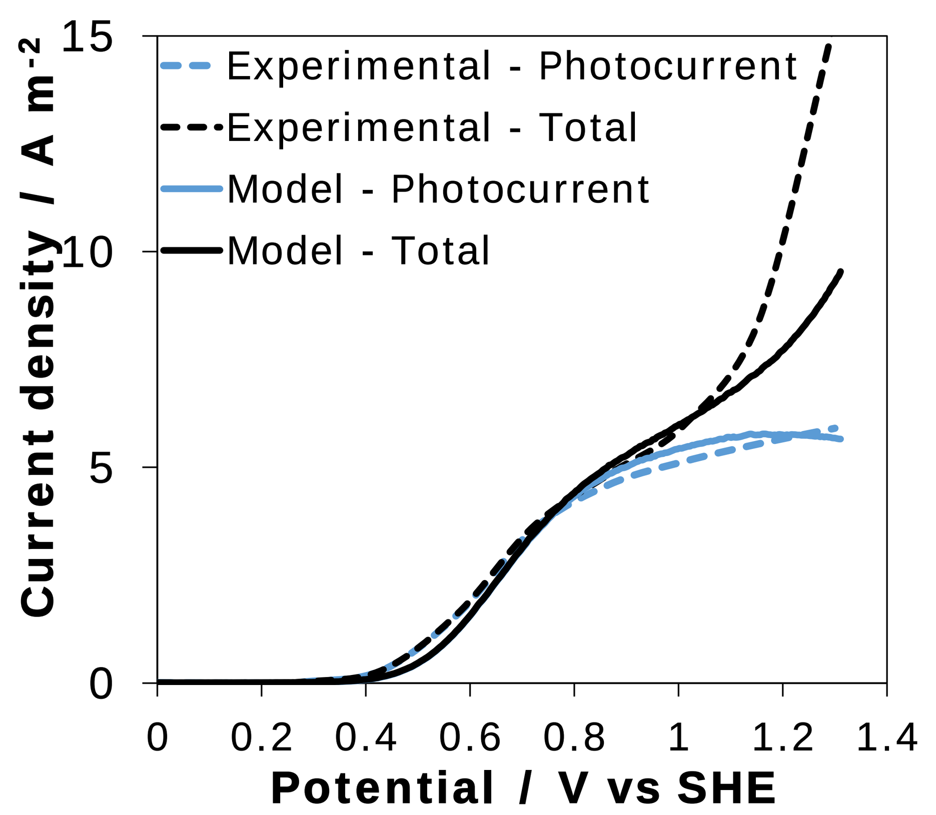
Reactor modelling

Experimental data was compared with finite element model predictions (**Comsol Multiphysics**) of spatial distributions of potential and photocurrent densities.

The main aim is to optimize geometrical parameters such as distance and size of perforations in the anode in order to **reduce ohmic drops and recombination losses**. Also, this will help to see how this affects hydrogen yields, which is related to the achieved photocurrent.







Conclusions

- Hydrogen sulfide splitting is a feasible process and less energy intensive if a suitable semiconductor is found.
- Hematite performed better than most of mineral sulfides. However, an electrical bias must be applied because of mismatching of band edges.
- Current densities are homogeneous for medium scale reactors (0.01m²). However, that is not the case when its size exceeds 0.3 m.
- Model predictions and experimental results agreed.

References

- KAWADE, U. V., et al. *RSC Advances*, 4, 49295-49302, 2014.
- BAK, T. et al. International Journal of Hydrogen Energy, 27, 991-1022, 2012.
- Ager, J. et al. Energy & Environmental Science. 1-3, 2015.