Sulphur Dioxide Depolarized Electrolysis for H_2 production

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Introduction

Sulphur dioxide (SO_2) Depolarized Electrolysis – SDE is the low temperature step of the Hybrid Sulphur Cycle – HyS [1]

Heat ~ 850 °C

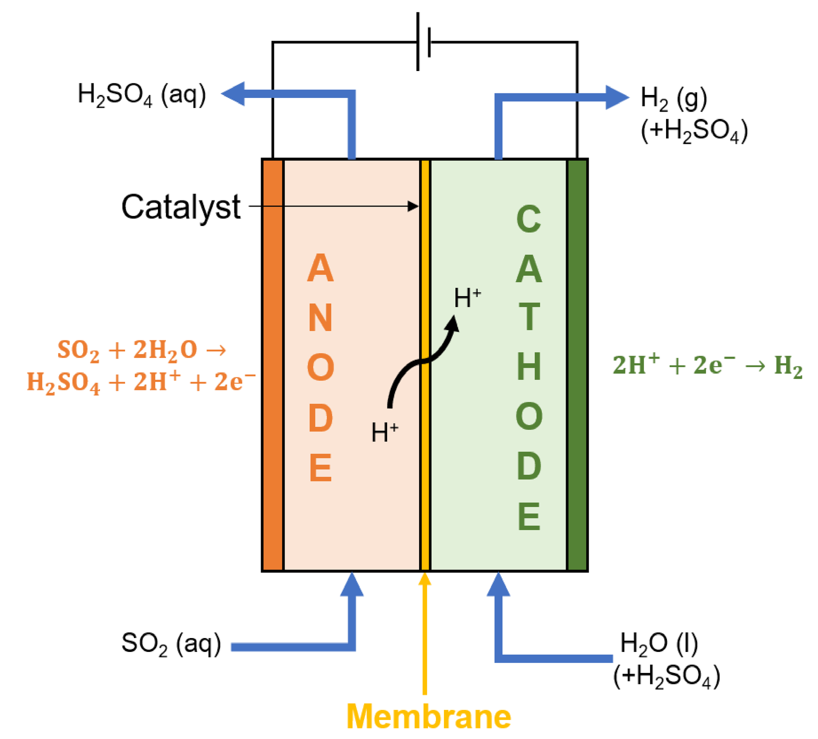
Electrolysis

$E_0 = -0.158\ \mathrm{V}$

$$H_2SO_4 \rightleftharpoons \frac{1}{2}\mathbf{O_2} + H_2O + SO_2 \qquad SO_2 + 2\,H_2O \rightleftharpoons H_2SO_4 + \mathbf{H_2}$$

Thermochemical Step

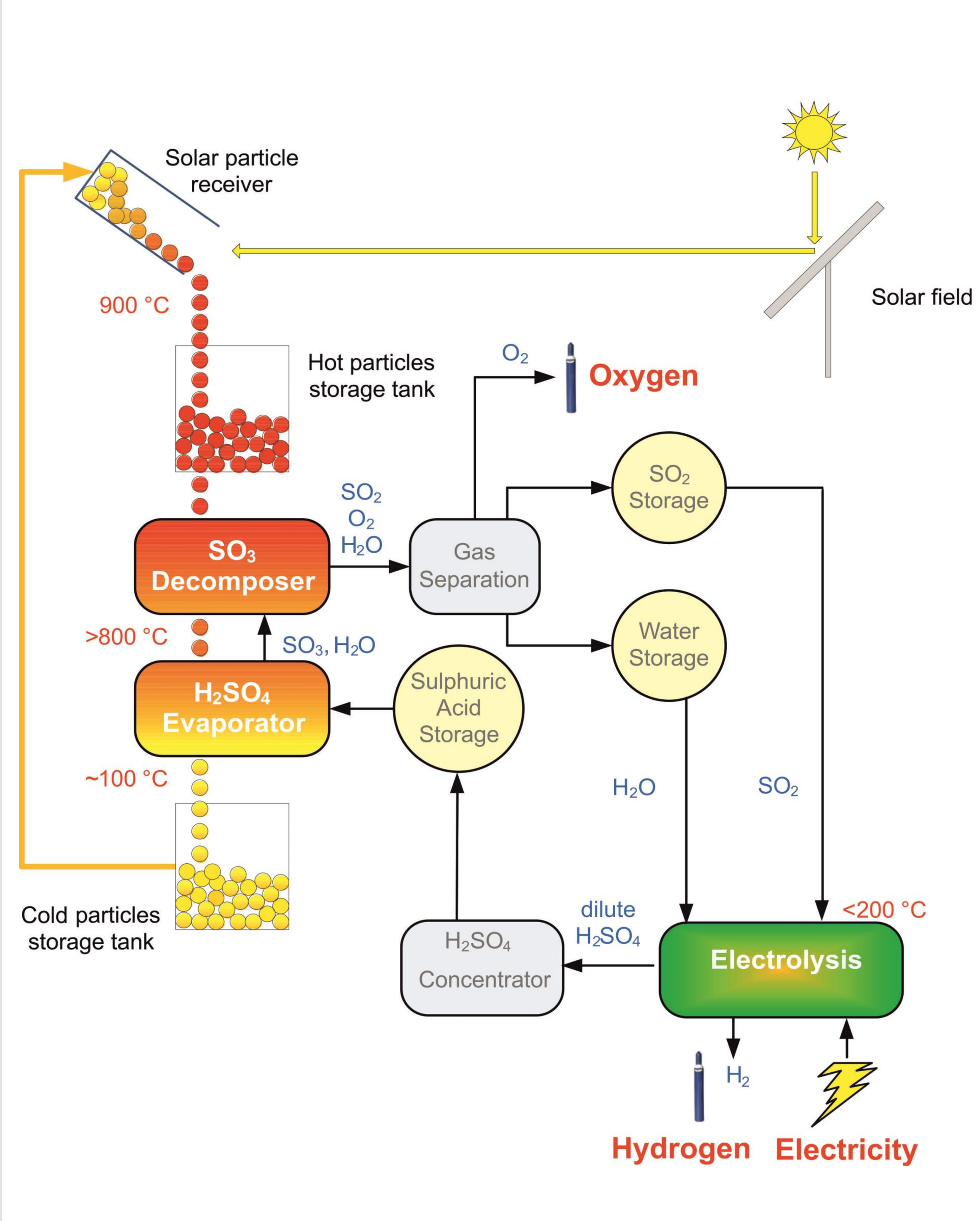
Electrochemical Step (SO_2 Depolarized Electrolysis - SDE)



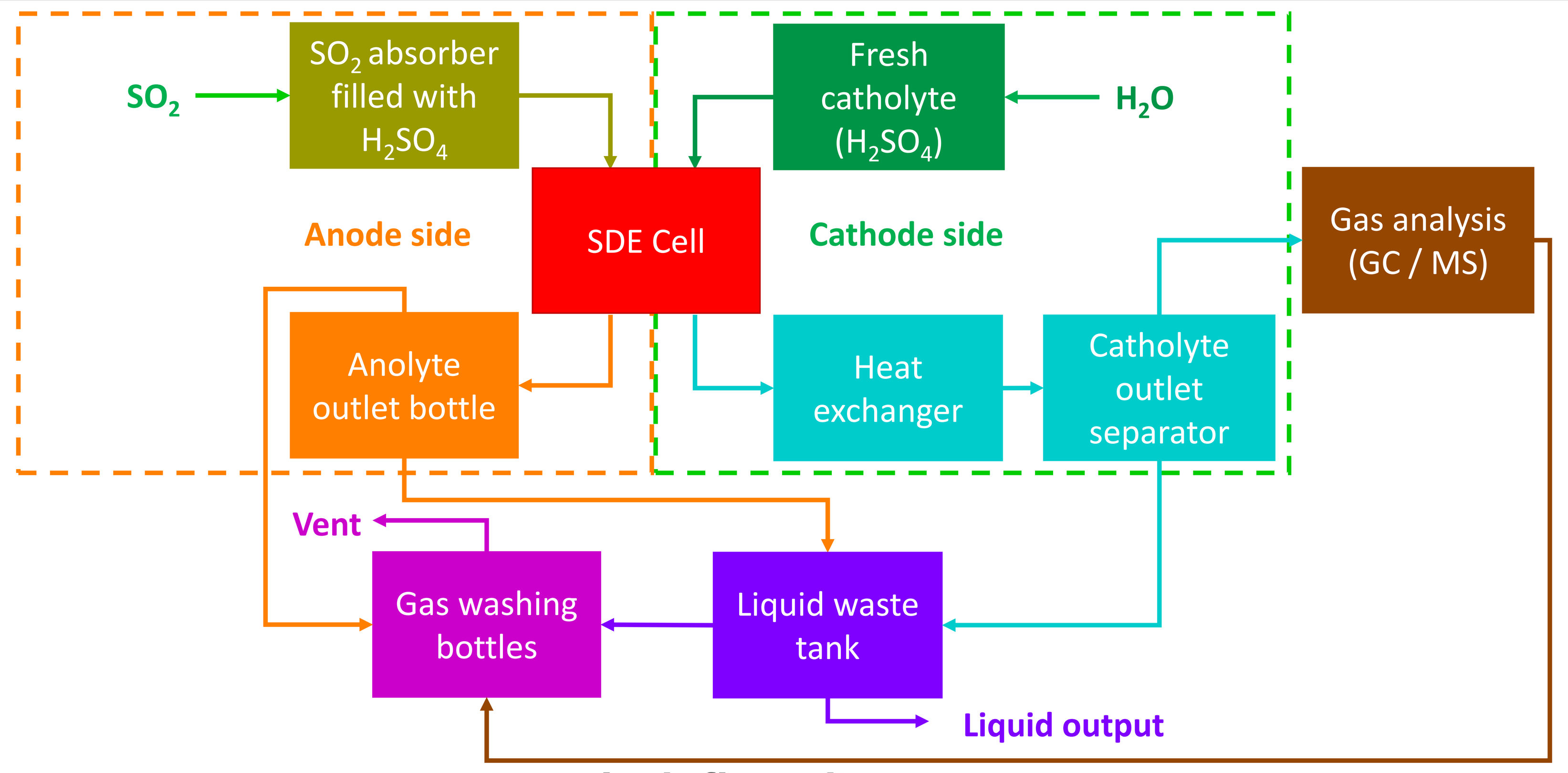
Schematic of the SDE

SDE advantages

- Reversible cell potential (0.158 V)
  - 12.8% of the that for direct electrolysis (1.23 V)
  - The same amount of electricity can produce more H_2
- Promising results with non critical materials
  - PBI instead of Nafion® membranes
  - Au-based and Fe-N-C catalysts
- Effective operation in mild conditions



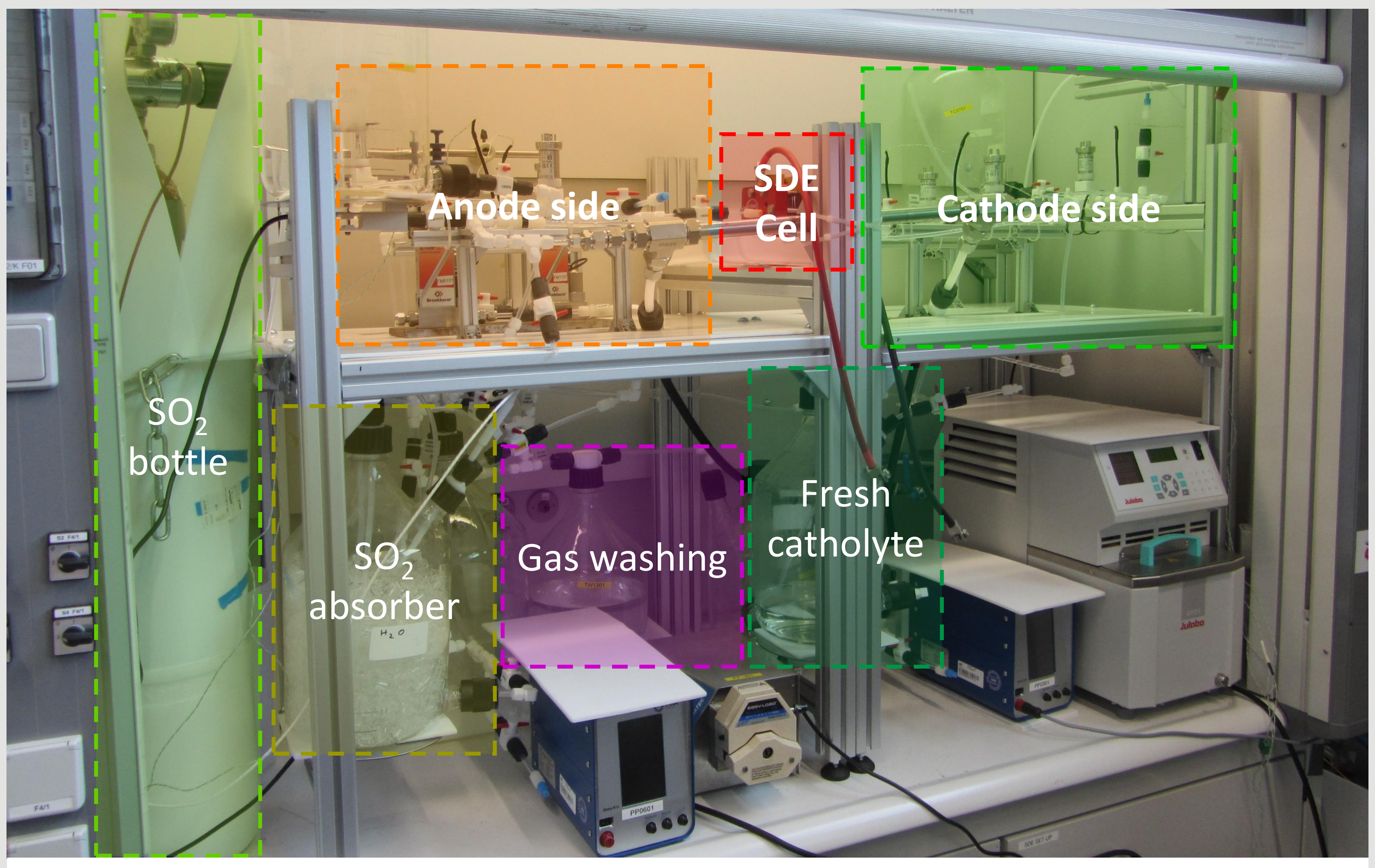
Schematic of the Solar HyS



Block flow diagram

SDE state-of-the-art

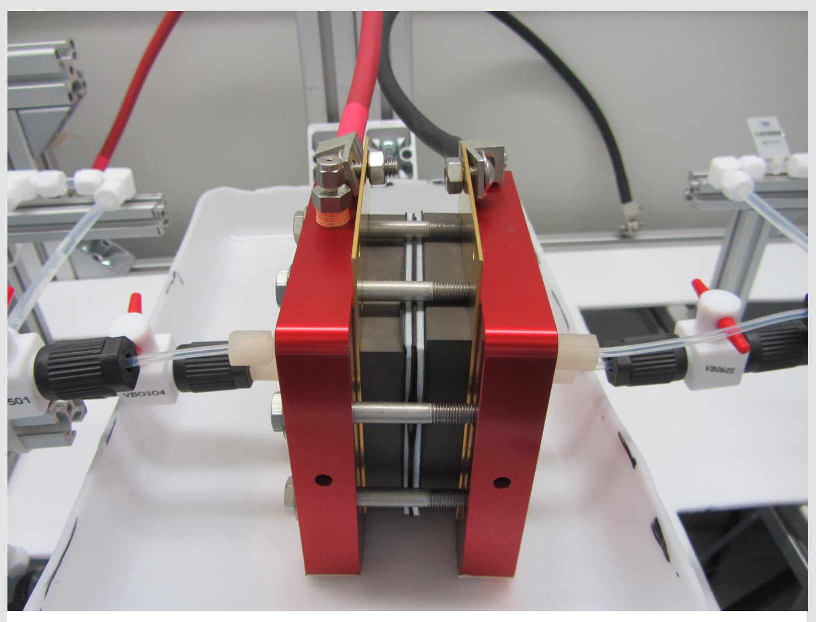
- No standard cell set-up
- Lab scale is investigated [2]
- No standard operation or test protocol
- Based on PEM but corrosion resistant materials necessary
- Applied potentials 0.65 – 0.90 V [3]
- Mainly Pt- and Pd- based catalysts [3]
- Target: 0.5 A/cm² at 0.6 V & H_2SO_4 concentration 65 wt% (for HyS) [4]



Experimental setup in DLR lab

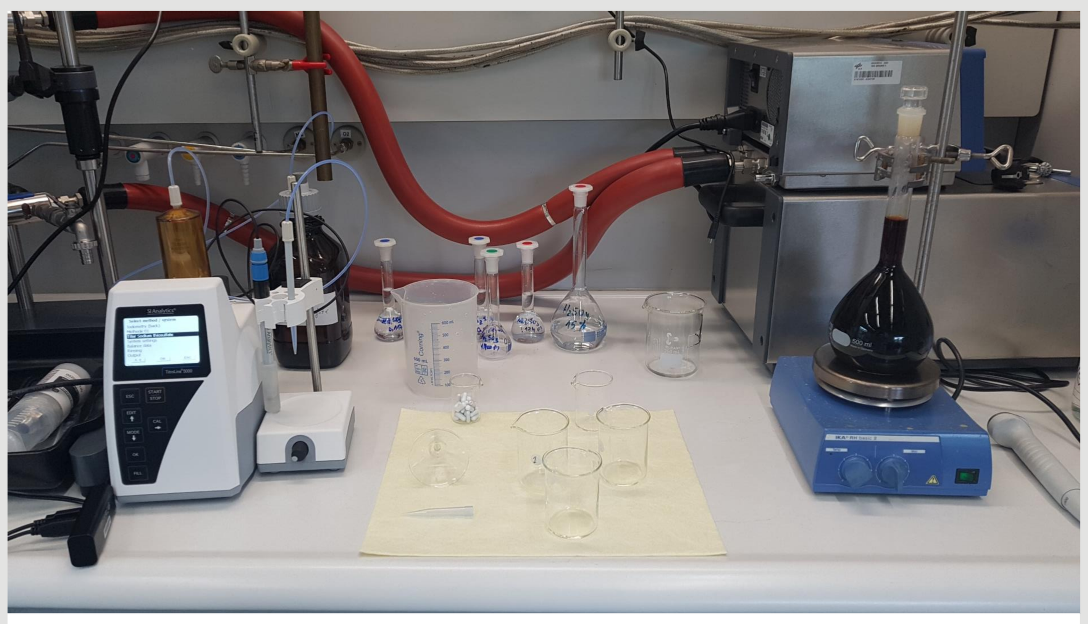
Current state at DLR

- Graphite monopolar plates
- Pt/C catalyst on both electrodes
- Commercial MEAs
- Ambient conditions



SDE cell

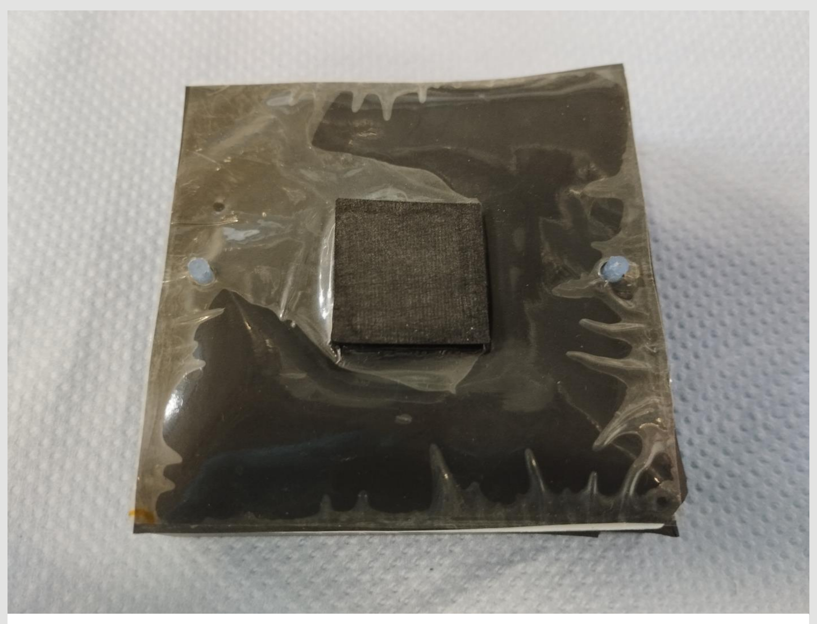
Flow field and GDL



Iodometry setup for the SO_2 determination

Further investigation

- No platinum group catalysts: Au
- Testing of different membranes
- Testing different bipolar plates
  - Au coated stainless steel
- Investigation of SO_2 cross-over
- Purity and energy demand of produced H_2
- Test rig serves as basis for automation
- Long-term operation (50h run)



Membrane electrode assembly

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References

[1] L.E. Brecher, S. Spewock, C.J. Warde, The Westinghouse Sulfur Cycle for the thermochemical decomposition of water, International Journal of Hydrogen Energy, 2 (1977) 7-15.
[2] M.M. Gasik, J. Virtanen, A. Santasalo-Aarnio, Improved operation of SO2 depolarized electrolyser stack for H2 production at ambient conditions, International Journal of Hydrogen Energy, 42 (2017) 13407-13414.
[3] S. Díaz-Abad, M. Millán, M. A. Rodrigo, J. Lobato, Review of Anodic Catalysts for SO2 Depolarized Electrolysis for “Green Hydrogen” Production, Catalysts, 9 (2019) 63.
[4] Gorensek, Maximilian B.; Summers, William A. (2009): Hybrid sulfur flowsheets using PEM electrolysis and a bayonet decomposition reactor. In: International Journal of Hydrogen Energy 34 (9), S. 4097–4114.

Acknowledgements

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