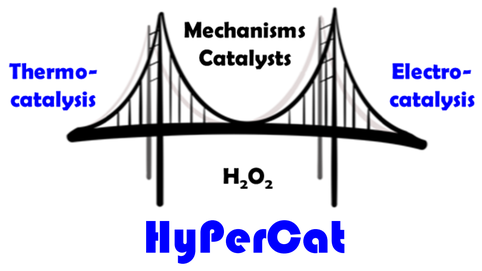
Karlsruhe Institute of Technology

DFG Research Unit FOR 5715
Bridging Concepts in Thermo- and Electro-
Hydrogen **Per**oxide **Cat**alysis



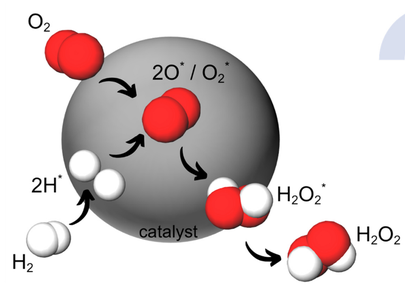
Combining short-circuited thermal catalysis and half-reactions electrolysis in one continuous flow “LEGO-like” reactor for hydrogen peroxide synthesis

<u>Theresa Dick</u>, Roland Dittmeyer, Alexander Navarrete Munoz

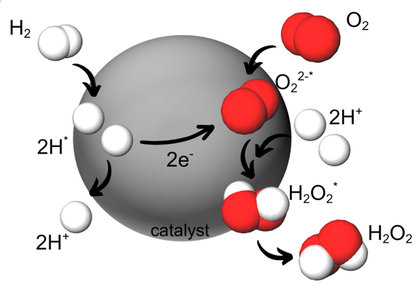
Institute of Micro Process Engineering (IMVT), KIT

Motivation

- Hydrogen peroxide is used in the paper, textile and chemical industries yet the conventional synthesis (Anthraquinone process) is environmentally harmful.
- Alternative production methods of H_2O_2 to the prevalent anthraquinone auto-oxidation process include direct thermocatalytic (t-HP) and electrochemical synthesis (e-HP).
- Due to the similar reaction conditions of t-HP and e-HP (catalyst, pH, solvent etc.), t-HP synthesis is suspected to behave as a “short-circuited” electrochemical cell.
- Nevertheless, comparing both syntheses is challenging: t-HP requires high pressures while e-HP operates at atmospheric pressure. This results in non directly comparable reactor designs.
- To gain a better understanding of the reaction mechanisms, a high-pressure “LEGO-like” reactor is proposed, which can be operated under comparable thermodynamic and fluid dynamic conditions for both t-HP and e-HP.



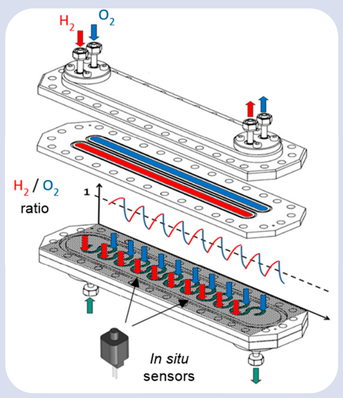
Langmuir mechanism [5]



PET mechanism [5]

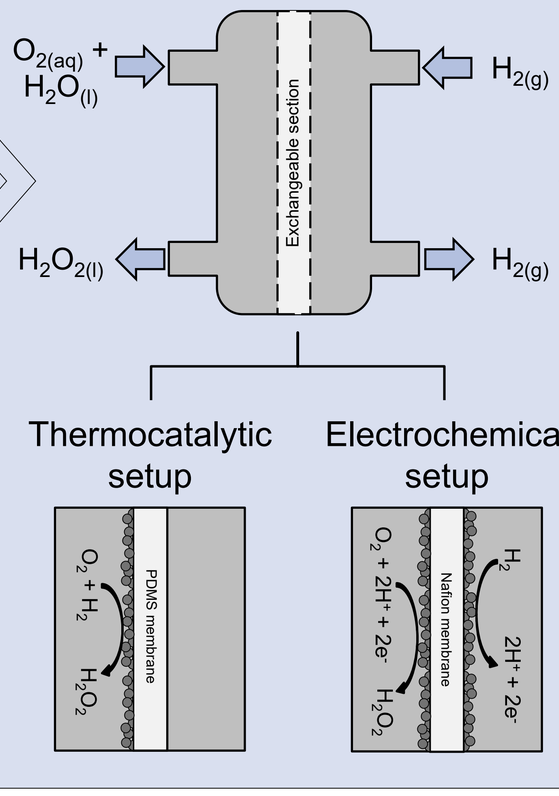
Bridging thermocatalytic and electrochemical reactor in a “LEGO-like” reactor

High-pressure membrane reactor for t-HP [4]

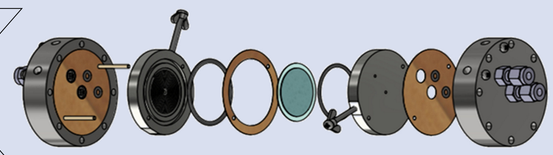


- Direct synthesis of H_2O_2 with alternating O_2 and H_2 dosage
- Operating pressure up to 100 bar
- Exchangeable meander shaped flow field

LEGO reactor concept (up to 100 bar)



High-pressure membrane reactor for electrochemistry [6]



- First electrochemical cell working up to 100 bar for CO_2 conversion
- Revised design and material of flow field plates for high mass transport performance

Approach

- Development of a modular “LEGO” high-pressure reactor
- Flow and design optimization
- Kinetic studies and reaction tests of H_2O_2 synthesis
- Operando spectroscopy for real-time catalyst and reaction insights

Objectives

- Validation of the hypothesis of the catalyst in t-HP acting as a short-circuited electrochemical cell
- Understanding of transport phenomena, kinetics and reaction dynamics in e-HP and t-HP
- Translation of findings into design guidelines

References

[1] G. Centi et al., *Catal. Tod.* **2003**, 79, 139; [2] R. Dittmeyer et al., *Catal. Tod.* **2015**, 248, 149; [3] M. Selinsek et al., *ACS Catal.* **2018**, 8, 2546; [4] M. Selinsek et al., *Catal.* **2018**, 8, 556; [5] B. Deschner et al., *Rev. Sci. Instrum.* **2021**, 92, 124101; [5] G. Fortunato et al., *Nature Communications* **2022**, 13(1), 1973; [6] S. Zhong et al., *Chem. Eng. Journal* **2025**, 161119.