Direct synthesis of hydrogen peroxide with CO₂ as solvent in a double membrane micro reactor

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**Motivation**

H₂O₂ annual global consumption is ca. 3·10^4 t/y
Expected growth (just for the HHPO-Process) is ca. 2·10^5 t/y

H₂O₂ advantages:
- Environmentally harmless
- Higher activity and selectivity than conventional oxygen
- H₂O₂ “bottle-neck”:
  - Expensive – 0.53-0.80 €/kg
  - Industrial synthesis: “Anthraquinone Process” - energy intensive and environmentally unfriendly

**H₂O₂ direct synthesis: an attractive alternative**

**Challenges:**

Safety
Wide explosion range of H₂O₂ mixtures
Activity
Low reactant concentrations due to low solubility of H₂ and O₂ → high pressure; organic solvents; additives
Selectivity
Water is thermodynamically more stable

**Project idea and aims:**

Use of membranes
- enhanced process safety – separate supply of H₂ and O₂
- direct supply and even distribution of H₂ and O₂ along the micro channel

Micro reaction technology
- enhanced heat- and mass-transfer and reduced limitations on reaction kinetics
- improved process safety

CO₂ as medium
- non toxic, non flammable
- easy separable from the products by expansion of the reaction mixture
- enhanced mass transport of the reactants

**Project aims:**

- explore a novel process window

**Double membrane micro reactor**

**Experimental set-up**

Designed with interchangeable reactive part: test micro reactors for catalyst screening experiments built in at first, replaced at a later project stage with the double membrane micro reactor.

- use both liquid and supercritical CO₂ as sol-vent
- P = 60 to 200 bar
- T = -10 to + 50°C
- F(CO₂) = 50 to 350 NL h⁻¹ = 100 to 700 g h⁻¹

**Catalyst coating**

One test micro reactor = one catalyst type
20 Channels (l, w, h): 150 x 0.5 x 0.6 mm
- thickness of one coating layer is 50 – 60 µm
- can be varied through multiple coatings

**Catalyst performance**

**Conclusions**

Experimental set-up: successfully developed and put into operation. Very stable performance was observed with both liquid and supercritical CO₂.

Double membrane reactor: completed manufacturing after the choice of suitable planar metal/ceramic membranes. Extensive characterisation of membrane permeation properties for H₂ and O₂ is planned.

**Catalyst screening:** improved performance of reduced catalysts with productivities comparable to literature data, however, with rather low selectivity. Further optimisation of catalyst performance at different experimental conditions is planned.