Reactor Optimization by Membrane Enhanced Operation:
Process intensification with membrane reactors (ROMEO)

A. Weiß[a], P. Wolf[a], M. Haumann[a] and P. Wasserscheid[a]
[a] Lehrstuhl für Chemische Reaktionstechnik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Egerlandstraße 3, 91058 Erlangen, Germany

What is ROMEO?

- Research and Innovation project within the **European Union's Horizon 2020** research and innovation program
- Focus on new reactor concept :
  - Reduction of **energy consumption by 80%** and **emissions by up to 90%** in industrial catalytic gas-phase reactions
- **9 partners** team up for **4 years** to demonstrate the technical feasibility of this reactor concept
- Started in **September 2015** with an EU budget of **6 million euros**

- Combination of **different building blocks** (membrane, support, catalyst) into **single reactor module**

$$\text{Olefin} \xrightarrow[\text{Cat.}]{\text{CO / H}_2} \text{Aldehyde}$$
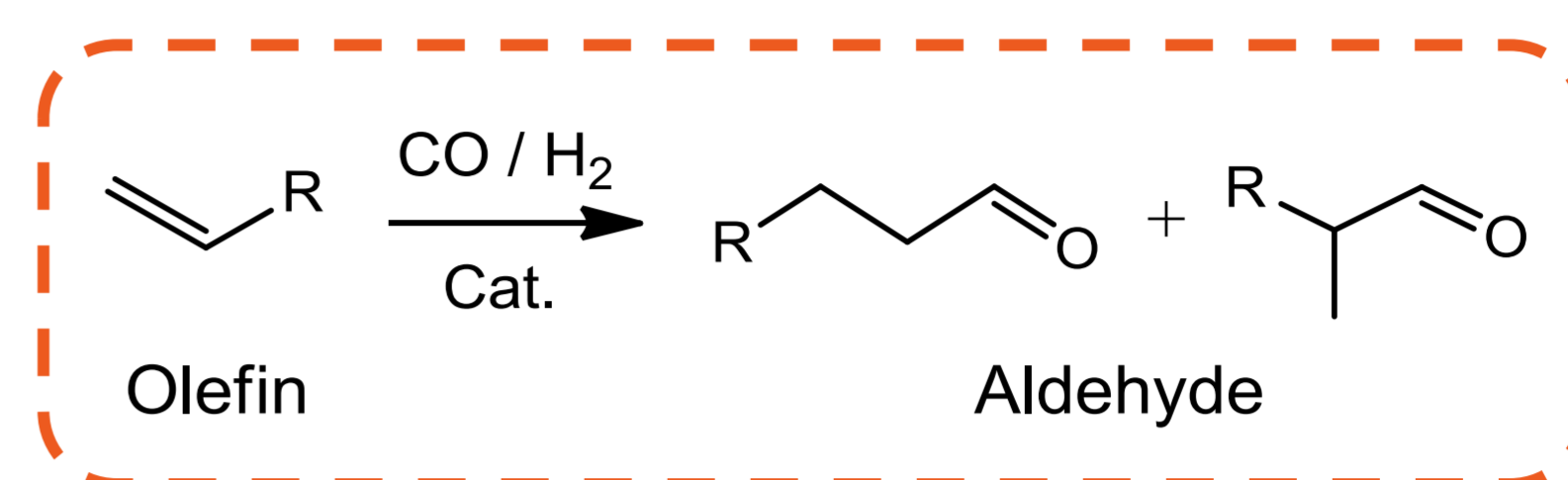
- Gas phase **hydroformylation** reaction as case study
 - Side product difficulty

Using the SILP Concept for ROMEO

Supported Ionic Liquid Phase (SILP) Catalysts:

- Innovative immobilization concept for gas phase applications
- Heterogenization of homogeneous catalysts
  - Free flowing powder
  - Homogeneous catalyst phase (Ionic liquid + precursor + ligand) impregnated into pores of support material

powder → particle → pore
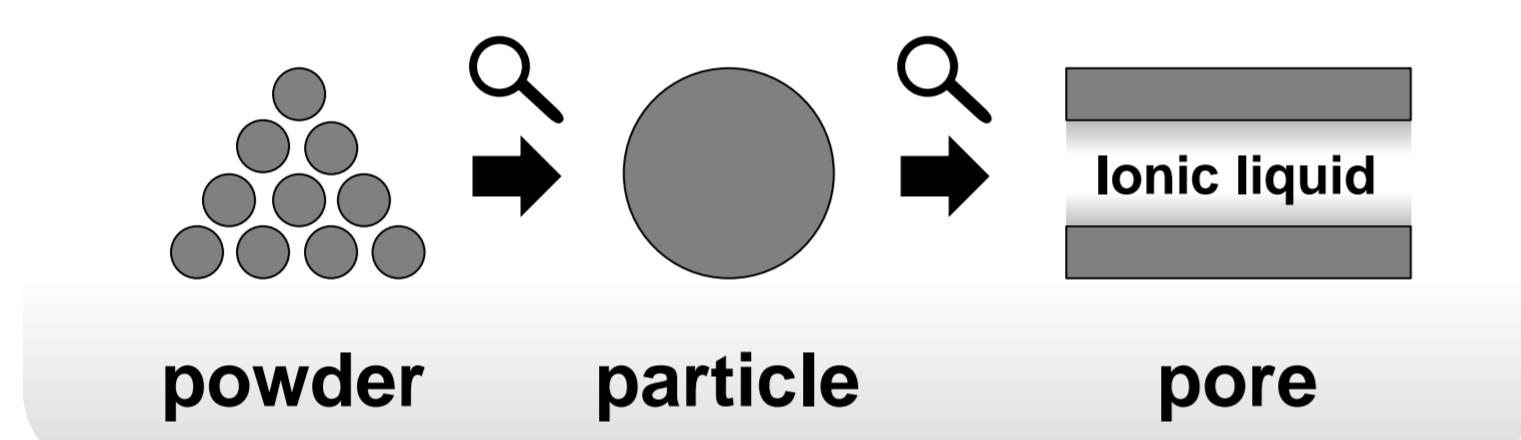
Homogeneous Catalysis
- (+) Selectivity
- (+) Reaction rate
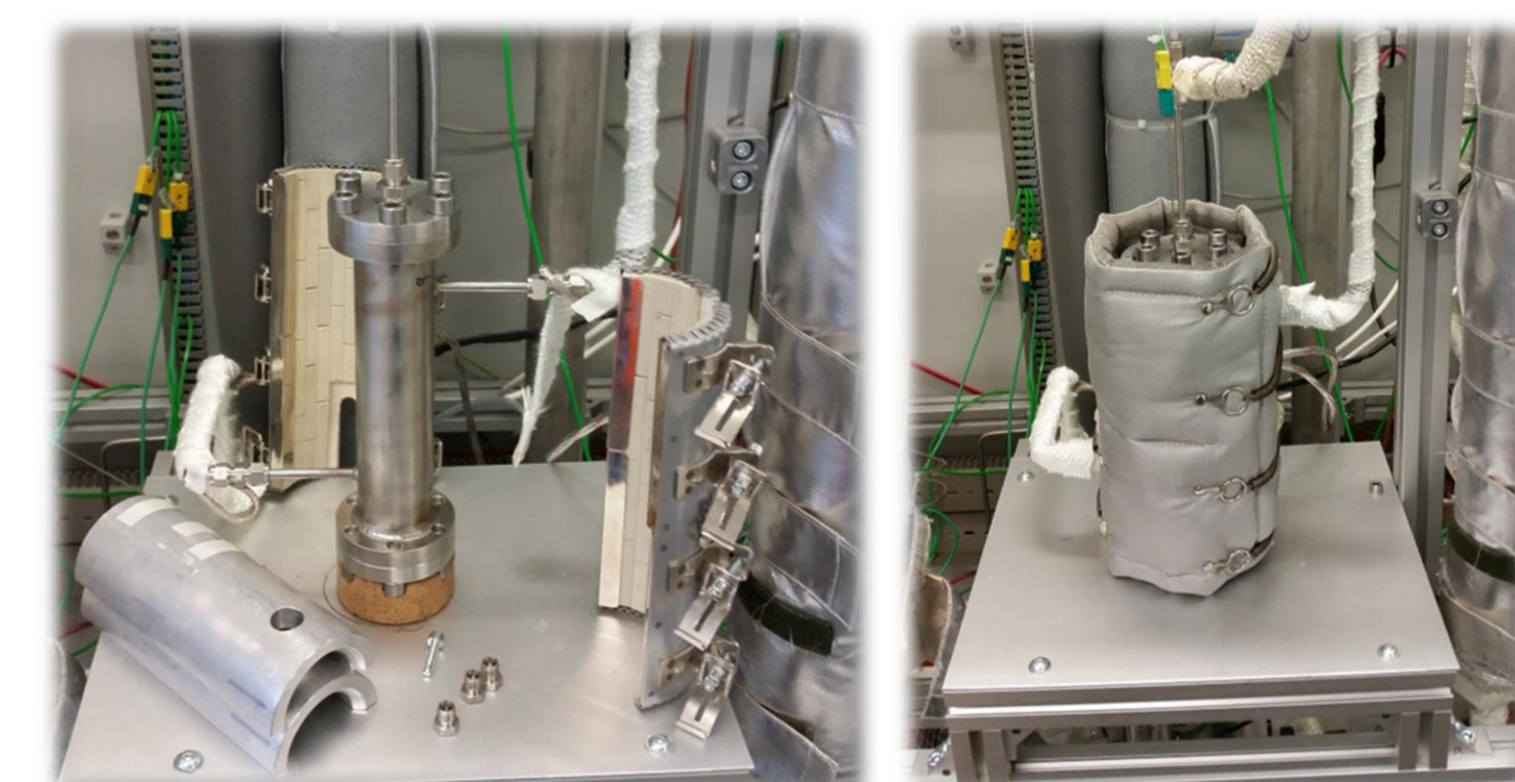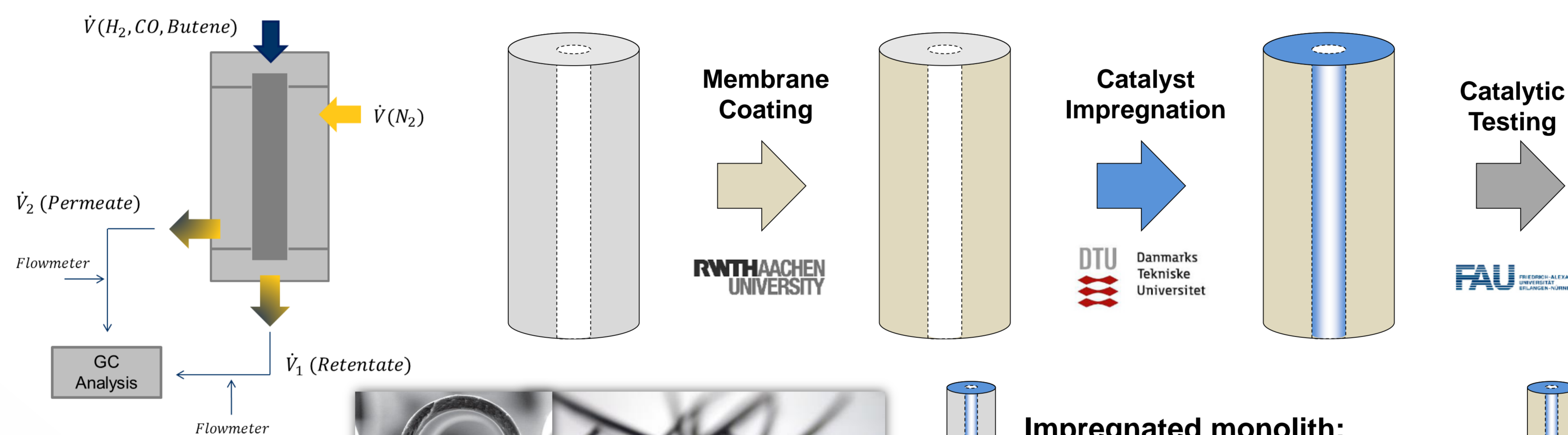- (−) Catalyst recovery
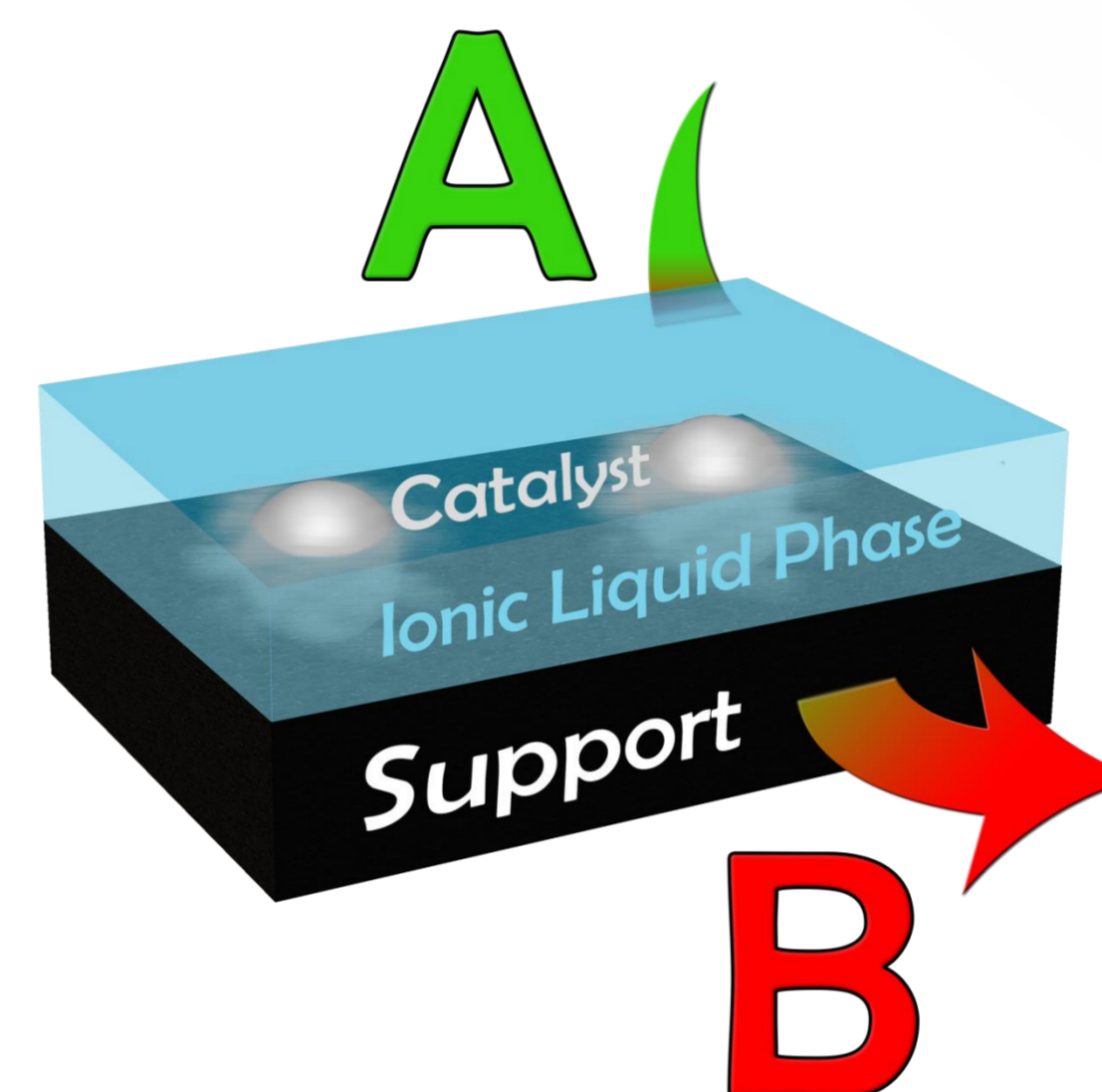
Heterogeneous Catalysis
- (+) Catalyst recovery
- (+) Simple systems
- (−) Selectivity

First Catalytic Results
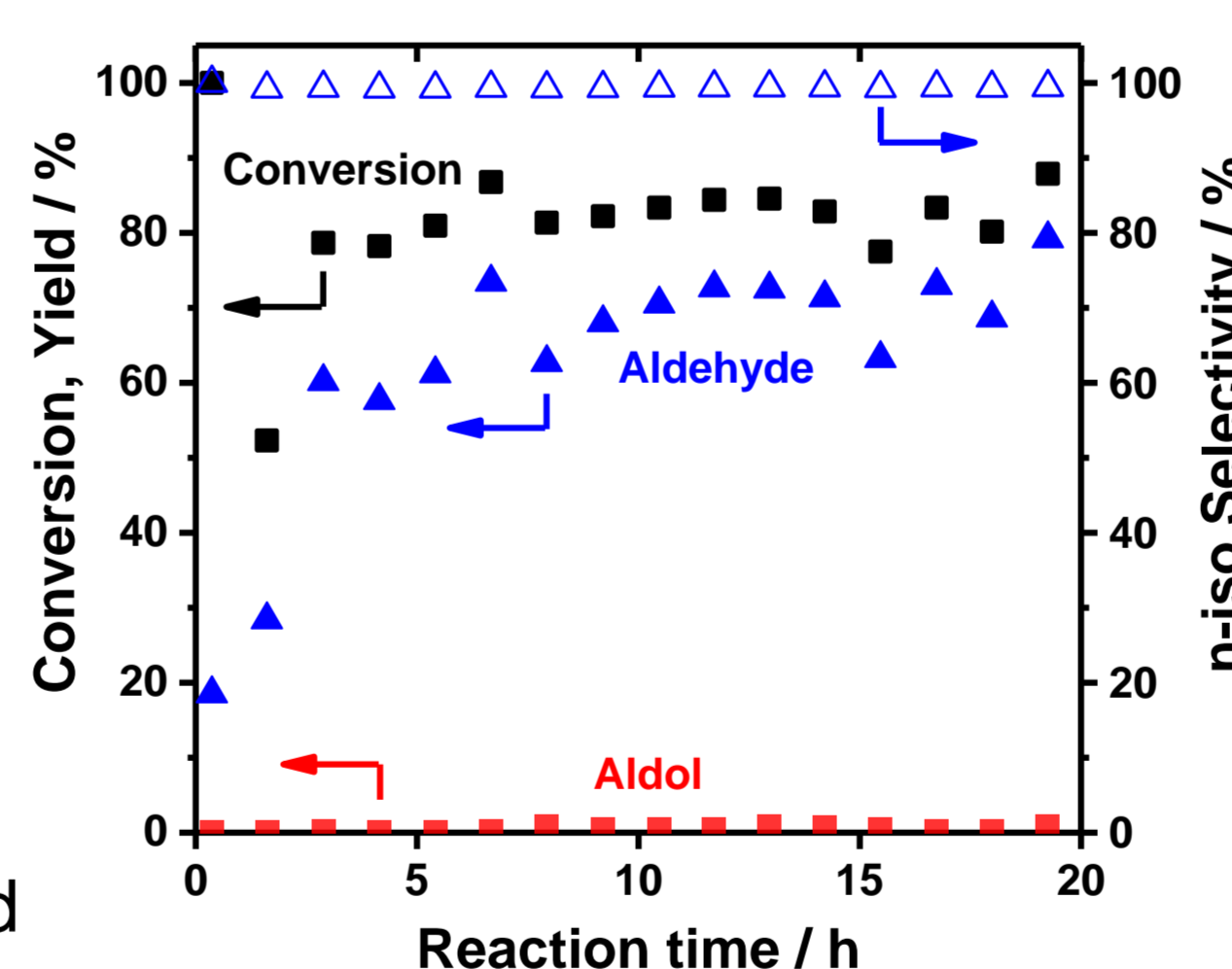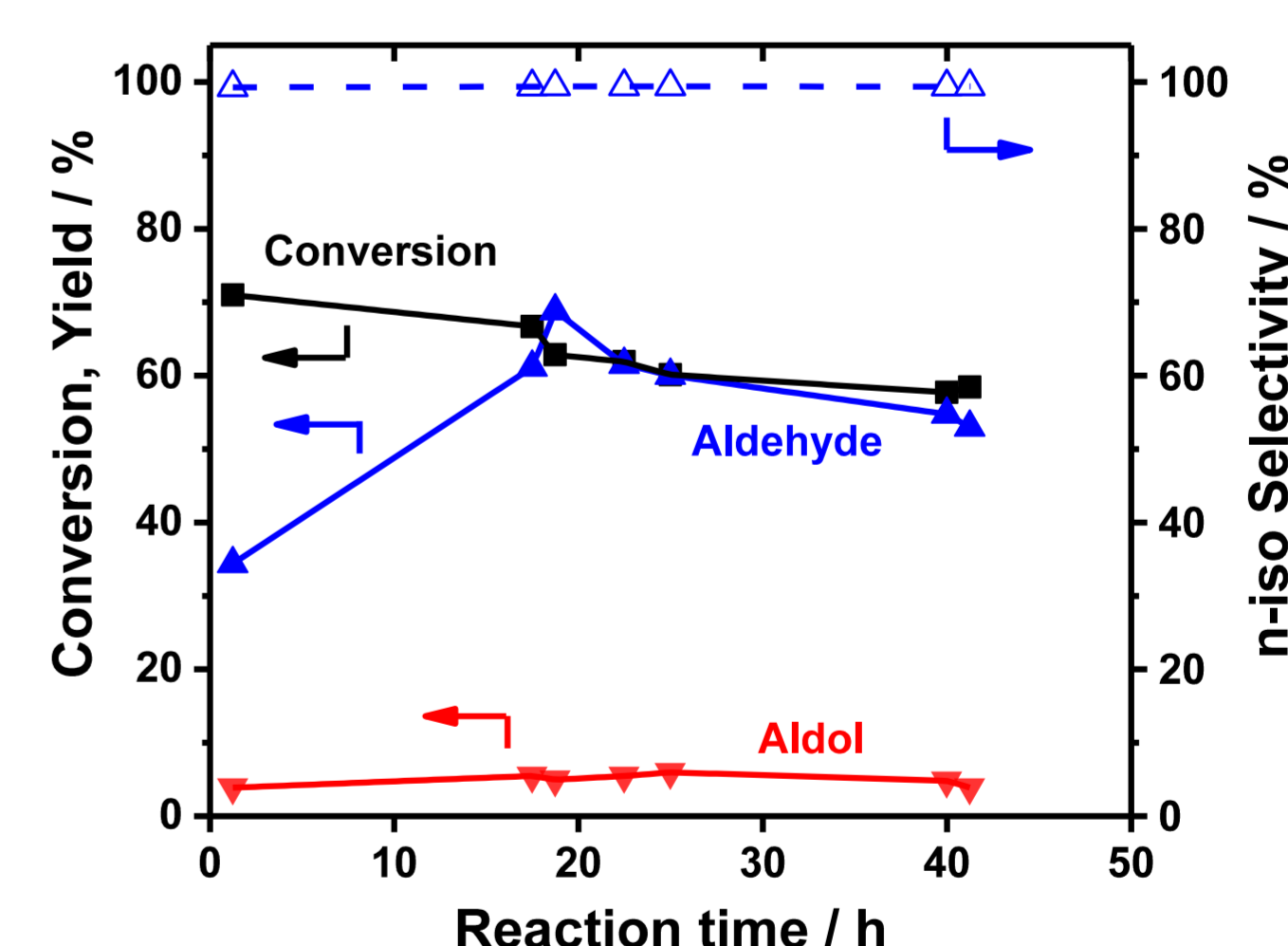
Reactor set-up & preparation procedure:

$\dot{V}(H_2, CO, Butene)$ — $\dot{V}(N_2)$ — $\dot{V}_2$ (Permeate) — Flowmeter — GC Analysis — $\dot{V}_1$ (Retentate) — Flowmeter

Membrane Coating → Catalyst Impregnation → Catalytic Testing

Support screening:

Normalized Activity / - ; Selectivity / %
Ceramic Supports — CNT's
Aldehyde; Aldol; CNT's; Ceramic Supports
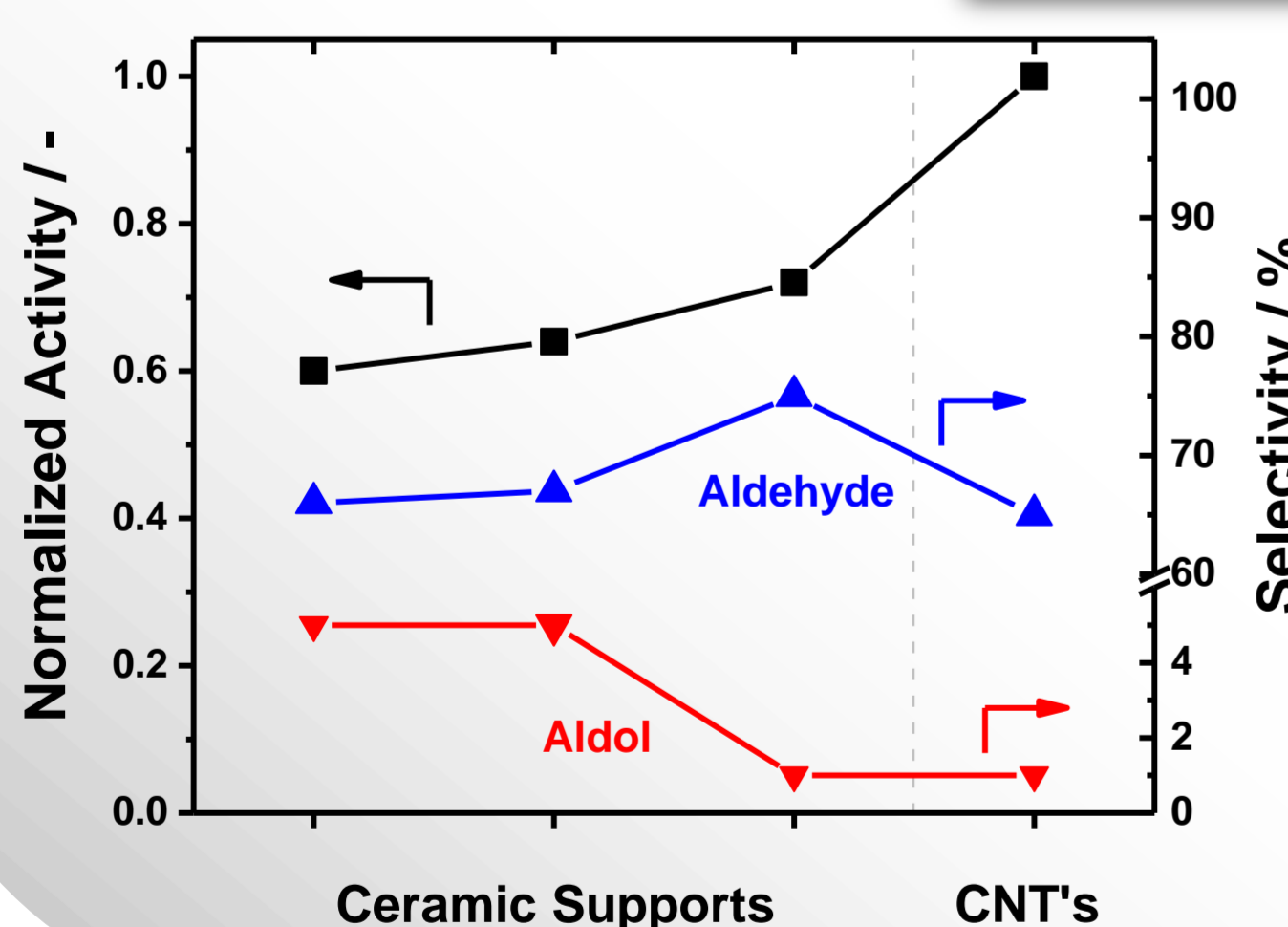
- Promising results for ceramic and CNT's as novel SILP supports

Impregnated monolith:

Conversion, Yield / % vs Reaction time / h ; n-iso Selectivity / %
Conversion; Aldehyde; Aldol

Impregnated & membrane coated monolith:

Conversion, Yield / % vs Reaction time / h ; n-iso Selectivity / %
Conversion; Aldehyde; Aldol

- **First successful application** of Supported Ionic Liquid Membrane (SILM) module

Summary

- Investigation of novel membrane reactor concept
- Combination of already studied building blocks into a single membrane reactor module
  - Novel support materials
  - Membrane functionality
  - SILP catalyst
- Teamwork of different partners on support fabrication, membrane coating & SILP impregnation

- Successful screening of suitable support materials
- Establishment of membrane reactor set-up
- Successful application of monolith supported SILP catalysts
- First investigation of SILM module:
  - Successful preparation process at different partner sites
  - First catalytic active membrane module

Lehrstuhl für Chemische Reaktionstechnik
Vorstand Prof. Dr. P. Wasserscheid
Egerlandstr. 3
91058 Erlangen
Germany
www.crt.cbi.uni-erlangen.de