Opportunities and Challenges of Membrane Integration into Compact Microstructure Reactors

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Abstract

Partitioning of the fluid flow in chemical reactors in small segments with lateral dimensions in the millimetre or sub-millimetre range through the use of microstructured internals greatly reduces the heat and mass transport resistances as compared to conventional reactor designs. The result is an improved control of the reaction conditions, first of all of temperature, secondly of the concentrations if the reactants are supplied with different process streams to be mixed for the reaction to take place. Accordingly, microstructured reactors often outperform their conventional counterparts in terms of much higher selectivity, yield and productivity, a feature which is nowadays succinctly called “process intensification”. Moreover, due to the high ratio of the wall area versus the fluid volume inside the flow channels typical of microstructured reactors they are basically also well suited for integration of large membrane areas in chemical reactors, which is often a key factor for harvesting the synergy effects expected from the combination of reaction and in situ product separation in membrane reactors.

Two different examples of compact microstructure devices with built-in membranes currently under development at the Institute for Micro Process Engineering will be discussed in this presentation.

The first is hydrogen generation with integrated separation and purification through palladium-based planar metallic membranes. Two systems are in the focus: reforming of natural gas or bio-methane and cycloalkane dehydrogenation. Both reactions are strongly endothermic. Thus the design of the membrane reactor system requires the integration of three functions: the catalyst to effectuate the reaction, the membrane for selective removal of the generated hydrogen, and an additional microchannel system for indirect heating of the endothermic reaction. The expected benefits of the microstructured membrane reactor units will be highlighted in the context of previous results from literature as well as unpublished data from own experiments. Moreover, possible reactor designs will be explained with special emphasis on the requirements of feasible bonding techniques for microstructured metallic sheets.

The second example is a planar membrane contactor based on hydrophobic inorganic porous membranes for gas removal from liquid streams. The separation of carbon dioxide from aqueous methanol solutions used in small-scale direct methanol fuel cells currently is in the focus of this work. System requirements will be explained, potentially attractive membrane types will be reviewed, and a conceptual design of the microstructured membrane contactor will be presented.