

## **Steam removal using membrane micro reactors for the concentration of sugar solutions**

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The combination of process steps has long been a goal of chemical engineering. Micro structured reactors exhibit excellent heat and mass transfer properties. The use of micro structured reactors for separation seems also to be a logical approach, however not many successful attempts are known.

Evaporation should benefit from the use of equipment with high heat transfer rates. However, the formation of bubbles in the flowing fluid presents some problems<sup>1</sup>:

- Formation of an accelerating force on the liquid in the direction of the flow
- Generation of flow inhomogeneities in the flow distribution in multichannel systems

The removal of steam via a membrane as a wall of the microchannels in the micro structured reactor may mitigate these effects. However, the use of membranes for steam removal with the final aim of concentrating sugar solutions presents several challenges:

- Selection of suitable membrane materials. The concentration of the sugar solution should be rapid as to avoid unwanted caramelization. Micro structured devices offer the possibility to provide the needed heating rates as well as a precise residence time control. Beyond 150°C, many of the common materials used for membrane separation are excluded. This leads to the consideration of metallic membranes.
- Surface properties. The flow of the sugar solution through the membrane has to be avoided. Hence, the surface properties should be thus that the liquid is prevented from entering the pores. Metallic membranes exhibit high surface energy (hydrophilic behaviour) which allows the wetting of the pores even for low pressure differences between the feed and permeate side. By means of

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<sup>1</sup> Maikowske, S. et al. "Efficient Heat Transfer by Phase Transition in Microstructured Devices". *Proceedings of the ASME/JSME 2011 8<sup>th</sup> Thermal Engineering Joint Conference*. Honolulu, Hawaii, USA. March 13-17, 2011. T10214. ASME <https://doi.org/10.1115/AJTEC2011-44116>

specific hydrophobic coatings based on Plasma Enhanced Chemical Vapour Deposition (PE-CVD), the liquid wetting of the metal surface can be avoided. Within this context, some results of hydrophobization experiments together with characterization measurements of thermal stability will be presented.

- Fouling. The sugar solution is highly temperature dependent: the variation of the operating conditions could lead to the precipitation of the solution and therefore the obstruction of the micro channels and membrane pores in the micro-structured reactor. The micro structured reactor needs to exhibit a well-defined flow field, which avoids the formation of precipitation. Measures for the creation of such a flow field with flow guiding elements<sup>2</sup> fabricated with 3D printing are presented.

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<sup>2</sup> Hansjosten, E. et al. "Custom-designed 3D-printed metallic fluid guiding elements for enhanced heat transfer at low pressure drop", *Chemical Engineering and Processing - Process Intensification*. 130 (2018) 119-126