17th International Conference on Inorganic Membranes
New Frontiers for Inorganic Membranes
July 1 - 5, 2024
Oceania Convention Center - Florianópolis - Brasil

Model-supported analysis of gas transport in oxygen permeation experiments considering asymmetric membrane structures and 3D-test cell geometry.

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Oxygen transport membranes (OTM) can be used in the fields of the separation of pure oxygen for e.g. oxy-combustion, or in membrane reactors for the synthesis of chemical energy carriers or commodity chemicals. The advantages of membranes are their higher energy efficiency compared to conventional processes as well as their modularity. Advanced membranes are designed in an asymmetric way, i.e., a thin dense membrane layer on a porous support providing sufficient mechanical stability. This structure, however, leads to a very complex combination of several transport mechanisms.

As illustrated in Fig. 1 the transport through the structure can be described as a series of six resistors which are the transport in the gas phase on both sides, the transport through the dense membrane including surface exchange and the porous support. Each of these steps can be rate determining [1] depending on the combination of up to 11 individual material, microstructural, or operational parameters, Fig. 2.

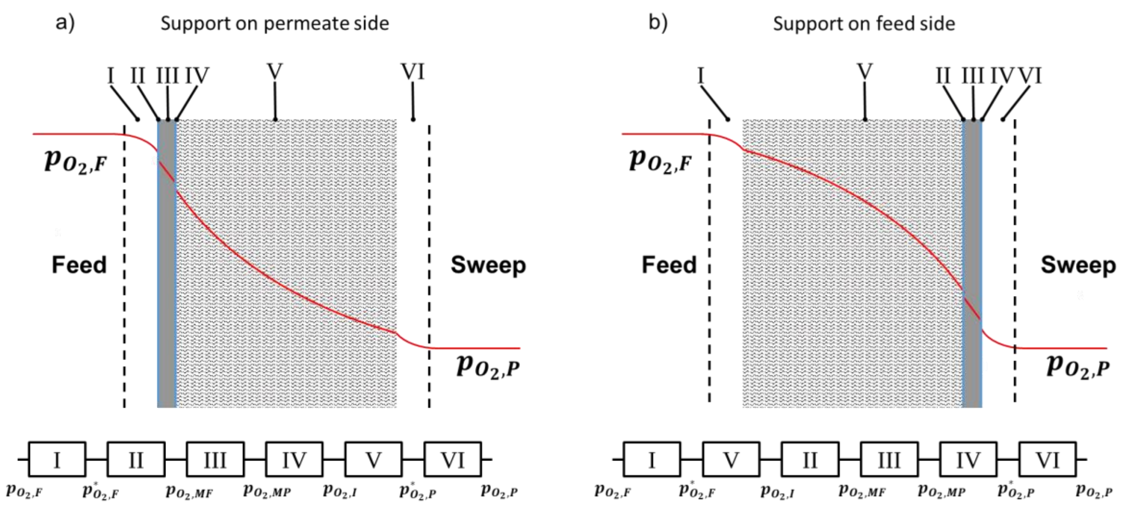

Fig. 1: The transport steps of gas transport from bulk gas phase on feed side to bulk gas phase on permeate side

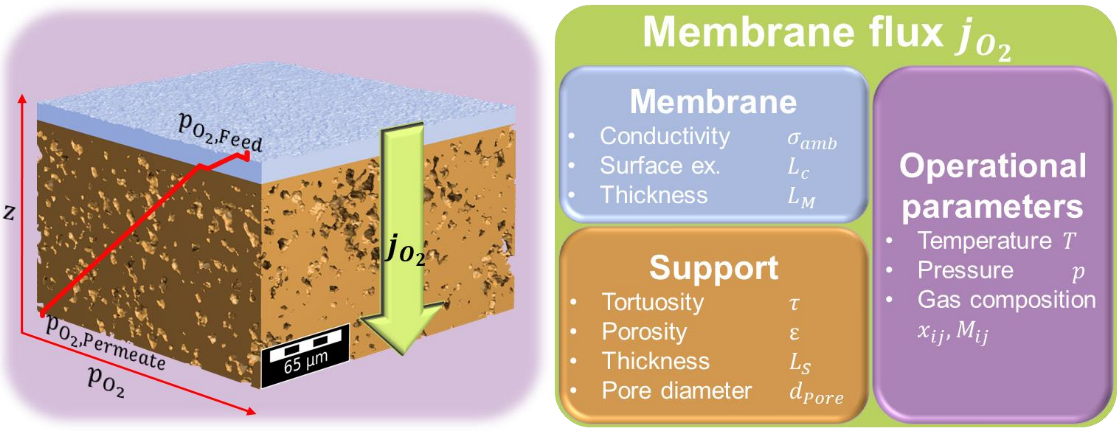

Fig. 2: parameters considered for modelling the transport thorough the asymmetric membrane

In order to describe the transport through the membrane itself, i.e. steps II to V of the asymmetric OTM (cf Fig. 1), a 1D transport model consisting of extended Wagner equation and a simplified version of the binary friction model is applied [2–4]. The model includes surface exchange, ionic and electronic transport as well as binary diffusion, Knudsen diffusion and viscous flux inside the support pores.

Results from the 1D transport model help to identify the most performance-sensitive parameters of the asymmetric membrane system. Therefore, it is well suited guiding experimentalists in the targeted development of high performance gas separation membranes for any kind of application [5].

For the consideration of the concentration polarization in the adjacent gas phases (steps I and VI in Fig. 1), a 3D CFD simulation software with the geometry of the permeation experiment (membrane test cell) is applied. The simulation includes the 1D transport model for membrane and porous support within a user defined function. This validates the model and adds additional value to the experimental data at the same time. In case of deviations between simulation and experiment, this approach helps to improve the model and the experimental setup, respectively.

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