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Silica membranes for selective separation of small gasses under hydrothermal conditions

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The hydrothermal stability of microporous ceramic membranes is of high importance for implementation of these membranes in industry, as a lot of industrial processes include steam. Often the hydrothermal stability of these ceramic membranes is only tested for either the mesoporous intermediate membrane layer or the microporous separation layer of the ceramic membrane.

Here, we present the results of a study on the hydrothermal stability of a ceramic membrane system consisting of an intermediate γ-alumina layer and a hybrid, ethylene-bridged, silica separation layer. Also, the influence is investigated of the addition of a monoaluminumphosphate (MAP) coating between the α-alumina support and the γ-alumina layer on the membrane stability. The results show that the hybrid silica on γ-alumina retains its gas separation performance after a hydrothermal treatment albeit with a lower mechanical adhesion between the hybrid silica and the γ-alumina layer, while a bare γ-alumina layer is degraded during a hydrothermal treatment. On the other hand, the hybrid silica on a MAP-modified γ-alumina membrane did not show any signs of delamination after hydrothermal testing. Moreover, a hydrothermal treatment of the hybrid silica on a MAP modified γ-alumina membrane results in a significant increase in the H_2/N_2 (perm)selectivity of a factor 3.

Also by tuning the sol-gel chemistry, the influence of the amount of water on the dip-coating/gelation process was examined. First, membranes were coated on a support with a controlled low water content (RH < 0.5%) and no detectable permeation of N_2 and CH_4 was observed. Second, the system was pretreated at 90% RH while applying the coating, resulting a significantly higher N_2 permeation. The formation of larger pores can be understood by a higher condensation rate and longer drying times when more water is present. This results in a stronger network that better withstands the compressive forces during drying. By limiting both the water and acid contents in the dip sol, a more dense pore structure is obtained that gives the highest H_2/N_2 and CO_2/CH_4 (perm)selectivity's found to date for hybrid silica membranes.

References

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