ABSTRACT:

Optimal Design of Composite Multilayered Metal Membranes for Hydrogen Purification Driven by Complex Non-ideal Permeation

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The permeating flux in multilayer membranes subjected to high pressure is not described by a linear driving force. Dealing with such types of non-ideality for purposes of material design is not straightforward, especially when several layers of different non-ideal materials have to be combined into a single multifunctional membrane [1]. In this lecture, we provide a comprehensive approach to deal with the optimal design of multilayer membranes and thin films in which each layer obeys the following non-linear real-power flux law:$Flux=\pi_i (P_{1,i}^{n_i}-P_{2,i}^{n_i})$ [2]. Specifically, such an approach considers two generic layers of different thicknesses and exponents, for which it is provided a mathematical proof of the existence of a general optimal permeance ratio □1/□2 maximising the flux ratio, which is found to be equal to the inverse of the ratio between the respective maximum theoretical driving forces that can be established in each layer. Such an optimal permeance ratio is also proven to be a global optimum. As an important consequence, to maximise flux, a multilayer membrane/thin film should be fabricated by depositing the layers in cascade according to the ascending or descending exponents, and should be used in a configuration in which the flux flows from the layer with the highest pressure exponent to the layer with the lowest one. Finally, we showed that a virial-type linear combination of polynomial driving forces can be approximated by the empirical flux law investigated. The presented results are valid not only for whatever type of composite membranes and thin films (metallic, ceramic, polymeric and hybrid ones), but also for any sequential system involving a flux of whatever physical entity obeying the aforementioned law, such as heat transfer with radiation, non-linear electrical resistances and possible others.

[1] A. Caravella, D. Martinez-Diaz, G. Prenesti, V. Michienzi, J.A.Calles, R. Sanz, D. Alique D., J. Membr. Sci., 683, 121842 (2023).
[2] A. Caravella, G. Prenesti, D. Martinez-Diaz, D. Alique, S. Hara, J. Membr. Sci., 705, 122877 (2024).