

Carbon membranes from metal loaded cellulose, and the application of an external field for improved performance

Authors: Jon Arvid Lie, May-Britt Hägg

During the last two decades, microporous carbon membranes have been promising candidates for separation units in selected industrial gas streams, including upgrading of biogas to fuel quality and the application as a CO₂ capture device in a strategy for cutting carbon emissions to the atmosphere. In the petrochemical industry, carbon membranes may become an efficient technique for the separation of an alkane from its corresponding alkene, and recovery of hydrogen. A major obstacle for a breakthrough for carbon membranes has been the loss of permeability when exposed to strongly adsorbing gases. This paper addresses a possible solution to this aging issue. The paper presents the separation performance of cellulosic carbon, both in its pure form and loaded with different metals.

The presence of a metal in the carbon matrix may promote interactions with selected permeating gases. Different metal nitrates, i.a. iron nitrate, were added to disturb the packing of carbon graphene sheets, i.e. to increase the micropore volume, and to increase the electric conductivity of the carbon matrix, for regeneration purposes. The metal nitrate is most likely transferred to a metal oxide during carbonization.

The resulting membranes, obtained from vacuum carbonization, are characterized by permeation of different probe gases, e.g. H₂, He, N₂, O₂, CO₂, CH₄ and C₃H₈. Gas permeation results are visualized in Robeson plots for selected gas pairs. The separation performance of cellulosic carbon is at the same level as carbons derived from specialty polymers like polyimides. The advantage of cellulose is its abundance and low cost. No catalyst is used during the carbonization. When a low voltage direct current is applied to the metal doped carbon during a permeation test, the permeability increases instantaneously and remains stable. The relative permeability increase depends among other factors on the gas type and on the amount of current applied. A great advantage of this regeneration technique is the on-stream operation, avoiding shutdown or switching to an extra set of membranes.

At least three effects may cause enhanced permeability when a direct current is applied: Traditionally, carbon is used as resistors, and ohmic heating of the carbon may increase the desorption rate of the gas through the membrane. If desorption is the rate-limiting step for gas transport, the effect of heating should be pronounced. Since the heat is generated in the inner parts of the carbon, and not by an external fluid (i.e. the direction of heat and mass transfer are the same), this kind of regeneration will be very energy efficient.

Secondly, the magnetic field generated by the electric current may cause orientation of the diffusing polar molecules, and hence less degree of rotation. This entropy reduction *prior to* entering the pores thus increases the chance of overcoming the pore entrance barrier.

Thirdly, when a magnetic field is applied to a ferromagnetic solid like iron oxide, the iron oxide clusters are oriented parallel to the magnetic field, causing a mechanical change in the carbon matrix. This phenomenon is called magnetostriction, and may cause a reduction in tortuosity.