Ceramic supports with highly dense and aligned pores for molten-carbonate based CO2 separation membranes

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Abstract:

Composite molten salt-ceramic membranes are innovative devices for high temperature CO_2 separation with high selectivity. The membrane performance depends on intensive material properties (ionic and electronic conductivity of the phases) and on its geometry (thickness) and microstructure (pore volume, size, connectivity and tortuosity factor). Ceramic production processes that allow controlling pore size, alignment and connectivity are needed for optimum performance.

The microstructural characteristics of directionally solidified fibrilar eutectics are appealing. Selective dissolution of the minority phase provides a ceramic support with a high density of aligned pores, with pore diameter in the micron range and a high specific surface. Here we report on the first gas separation membrane using a porous ceramic matrix obtained from a magnesium-stabilised zirconia (MgSZ) – MgO fibrilar eutectic. The porous matrix consists of highly aligned, ~1 µm diameter pores, with 21% porosity and all pores aligned within 10°. The finished membrane showed a high CO_2 permeability of 1.41×10^{-10} $mol.m^{-1}.s^{-1}.Pa^{-1}$ at 815 °C, among the highest reported for supported molten-carbonate membranes. We suggest that the high permeability is attributable to the excellent pore characteristics resulting from directional solidification.

In a further step, we study eutectics of the systems YSZ – MgO and $Ce_xZr_{1-x}O_2$ – MgO, with a consistently stable fibrilar microstructure. The mixed-valent Ce element also aims to add an electronic contribution to the support conductivity, which is known to enhance the CO_2 and O_2 permeability. Composition, microstructure, structural and ion conducting properties of these families are discussed in relation to their expected performance in CO_2-selective membranes.

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