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Rare Earth Metal Ion-Doped SiO2 Nanocomposite Membranes for Gas Separation in Steam Atmosphere

Authors : Md. Hasan Zahir

Abstract : Y2O3-doped silica membranes were synthesized with the sol-gel method by using a tetraethyl orthosilicate-derived sol mixed with yttrium nitrate hexahydrate. These solutions were used to fabricate hydrogen separation microporous membranes with a sandwich-type structure on γ-Al2O3 supported by tubular α-Al2O3. Pore size distribution measurements were conducted directly on the membranes before and after hydrothermal treatment with a nano-permporometer. The gas permeance properties of the membranes were measured in the temperature range 100–500°C. The Y-doped SiO2 membrane (Si/Y = 3/1) was found to exhibit asymptotically stable permeances of 2.39×10-7 mol m-2 s -1 Pa-1 for He and 6.19 ×10-10 mol m-2 s -1 Pa-1 for CO2, with a high selectivity of 386 (He/CO2) at 500°C for 20 h in the presence of steam. The Y-doped silica membranes exhibit very high gas permeances for molecules with smaller kinetic diameters. The apparent activation energies of the H2 permeance at 400°C were 24.2±0.2 and 21.3±0.7 kJ mol−1 for SiO2 and Si/Y, respectively. Very high permeances were obtained for N2 and O2, 2.2 and 5 × 10-8 mol m-2 s -1 Pa-1 respectively, which demonstrates that these materials are promising air purification and/or separation systems that block larger impurity molecules by molecular sieving effects. Y-doped SiO2 exhibits greater hydrothermal stability at high temperatures and higher selectivity than SiO2 membranes.

Keywords : ceramic membrane, gas separation, hydrothermal stability, rare earth doped-Silica
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