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Synthesis and characterization of new silica membranes using template–sol–gel technology

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Abstract

The sol–gel polymerization process and template technology were used to prepare silica–alumina asymmetric membrane. The FTIR and ^{29}Si-NMR results showed that the silica polymers were formed and the degree of branching depended on the aging time of polymeric sols. Silica membranes were characterized using DTA, TGA, SEM and EDX techniques. Nitrogen physisorption tests revealed that the surface area of the membrane increases significantly around 10-folds when template is used. The average pore size of the silica membrane increases by a factor of 1.5–3 when a template is added. Changing the type and concentration of template, as well as molar ratio of the precursors alter the final characteristics of the membrane. The permeation data on alumina support showed that the gas permeation through the support was controlled by viscous flow model. The H_2 permeance of free surfactant template membrane ($2.09 \times 10^{-6}\,\mathrm{mol/m^2\,s\,Pa}$) was increased approximately 2 times for new templated membrane ($4.2 \times 10^{-6}\,\mathrm{mol/m^2\,s\,Pa}$) at 400 °C. Permselectivities of H_2/CH_4 (149) and H_2/CO_2 (15.5) were obtained for free template membrane and 135 and 35, respectively, for templated membrane at 400 °C.

Keywords: Hydrogen permeation; Sol–gel method; Silica membrane characterization; Nanoporous membrane

1. Introduction

Fuel cell has been nominated as an alternative source of energy for power generation. Hydrogen has also attracted increasing interest as clean energy for fuel cell power generation for various applications such as electrical vehicles. Improvement of hydrogen production technologies is advised for stable hydrogen supply for fuel cells [1–3]. In addition to fuel cells, the ever-increasing demand for hydrogen in oil refining, petrochemicals like methanol, ammonia and other applications such as metallurgy and space transportation have imposed a strong economic incentive to improve the hydrogen production technology. There are many hydrogen production technologies. Nearly 50% of the consumed hydrogen in the world is produced from natural gas [4]. Steam methane reforming (SMR) has been the main process of hydrogen production from natural gas up to now. In the case of hydrogen production by reforming of hydrocarbons (i.e. SMR), carbon dioxide or carbon monoxide are generated unavoidably as byproducts. Also by considering the limitation of equilibrium conversion, some amount of hydrocarbon remains unreacted which must be separated from the products. Therefore, it is necessary to separate such contamination gases from hydrogen flue gas in conventional hydrogen production processes [5]. Recently, great efforts have been dedicated to the study on the applicability of hydrogen separative membranes for the hydrogen production processes, including the membrane reactor in which reforming reaction and hydrogen purification are carried out at the same time. Hydrogen separative membrane has been developed as a new hydrogen production technology. Dense membranes based on palladium alloy give satisfactory results for hydrogen separation. However, the Pd metal is extremely expensive and suffers from embrittlement and chemical poisoning in reforming reaction conditions. Nanoporous membranes are introduced as appropriate alternative to the precious metal-type membranes. They typically contain a separation layer with pores of a few nanometers in diameter. Since the entire hydrocarbon reforming reactions are conducted in the elevated temperatures (> 800 °C),

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