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PII: S0376-7388(18)31365-6
DOI: https://doi.org/10.1016/j.memsci.2018.07.072
Reference: MEMSCI16351

To appear in: *Journal of Membrane Science*

Received date: 19 May 2018
Revised date: 21 July 2018
Accepted date: 25 July 2018

Cite this article as: Sofiatun Anisah, Waravut Puthai, Masakoto Kanezashi, Hiroki Nagasawa and Toshinori Tsuru, Preparation, characterization, and evaluation of TiO_2-ZrO_2 nanofiltration membranes fired at different temperatures, *Journal of Membrane Science,* https://doi.org/10.1016/j.memsci.2018.07.072

Preparation, characterization, and evaluation of TiO_2-ZrO_2 nanofiltration membranes fired at different temperatures

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Abstract

TiO_2-ZrO_2 nanofiltration membranes were successfully prepared using a sol-gel method. Two types of TiO_2-ZrO_2 sols (polymeric and colloidal sols) with molar ratios of 5/5 were coated onto α-Al_2O_3 cylindrical porous supports followed by firing at different temperatures. The structures of the membranes were amorphous up to a firing temperature of 500 °C. Measurements of the N_2 permeance and water permeability revealed that values for average pore size, N_2 permeance, and water permeability (L_p) of the prepared membranes were increased with increases in the firing temperature, and a drastic increase was observed at the temperature of transformation from an amorphous to a crystalline phase. For the membranes fired at 200 - 600 °C, the average pore size and N_2 permeance was 0.5 - 0.8 nm and 0.14-0.54x 10^{-5} mol/(m^2 s Pa), respectively; nanofiltration performance showed molecular weight cut-offs (MWCOs) of 200 - 810 g/mol, and L_p of 2-12x10^{-12} m^3/(m^2 s Pa), respectively. In the present study, values for the structure and separation performance of the membranes were successfully controlled via the use of different sizes of sols and by manipulating the firing temperature.

Keywords

TiO_2-ZrO_2 membrane, nanofiltration, firing temperature, water permeability

1. Introduction

Membrane-based technology has been developed mainly for the processing of aqueous systems such as the purification of drinking water and wastewater treatment [1]. Most commercial membranes consist of polymeric materials, while commercial inorganic membranes consist mostly of ceramic materials, and remain under development [2]. Commercialized ceramic membranes are used mostly for microfiltration (MF) and ultrafiltration (UF), and a very limited number are available for nanofiltration (NF). Hence, extensive investigation has focused on the development of NF ceramic membranes with pore sizes of 0.5-2 nm and a molecular weight cut-off (MWCO) that ranges from 200 and 1000 g/mol [3,4]. These types of membranes have received a great deal of attention because of their superior chemical, thermal, and mechanical stabilities. Therefore, ceramic membranes have shown promise for applications to separation processes under extreme operating conditions for which polymeric membranes are unsuitable such as filtration at high temperatures, in aggressive solvents, and with radioactive or heavily contaminated feeds [3,5,6].

Ceramic NF membranes are prepared via sol-gel processing from a variety of metal oxide materials have reported. ɣ-Al_2O_3, HfO_2, TiO_2, and ZrO_2 membranes are successfully prepared with pore sizes in the NF range [7–10]. The TiO_2 and ZrO_2 membranes show high chemical stability over a wide range of pH [5,11]. Therefore,