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Modification of Nafion with silica nanoparticles in supercritical carbon dioxide for electrochemical applications

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Abstract

In this paper a promising approach to implement the hydrolysis/condensation of tetraethoxysilane (TEOS) inside Nafion membrane using supercritical carbon dioxide as a solvent is suggested. Since sc CO_2 is a non-polar fluid, TEOS transport towards the hydrophilic channels of the Nafion should occur mostly through hydrophobic fluorinated domains of the Nafion swollen in CO_2. Therefore, unlike using conventional more polar liquid solvents for TEOS, silica phase growing in the channels does not block the transport of the precursor, which impregnates the polymer matrix uniformly. As a result, silica nanoparticles having size in the range from 2 to 5 nm are formed inside the Nafion membranes. The methanol permeability is decreased from 16×10^{-7} cm^2/s for pristine membranes to about 9×10^{-7} cm^2/s for the modified ones, while the proton conductivity is not affected by the silica incorporation. Thermomechanical analysis revealed that water retention at elevated temperatures is improved by the silica incorporation. Yet, the general water uptake is reduced in comparison to the pristine samples. These results have been interpreted as an evidence for advanced performance of the composite films at high temperatures or at low humidity conditions.

Keywords: Nafion; supercritical carbon dioxide; electrochemical power sources; silica; vanadium redox flow battery.

1. Introduction

Perfluorosulfonated ionomer membranes are commonly used as solid polymer electrolytes in electrochemical power sources, such as fuel cells (FC)[1] or redox flow batteries[2,3,4].