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Short communication

Synthesis and characterization of proton-conducting sol–gel membranes produced from 1,4-bis(triethoxysilyl)benzene and (3-glycidoxypropyl)trimethoxysilane

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Abstract

Hybrid membranes using 1,4-bis(triethoxysilyl)benzene and (3-glycidoxypropyl)trimethoxysilane have been synthesised by polymerization of epoxy groups and inorganic condensation of silanol groups. Sulfonation processes of aromatic rings to produce attached SO_3H groups are applied to provide proton conductivity. Thermal analysis shows a high water adsorption capacity combining $SO_3{}^-$ and silanol groups. The measurement of conductivity shows a general increase with temperature, and stabilization at temperatures above 100 °C. This behaviour suggests the presence of two competing trends, one enhancing (thermal activation) and the other reducing (dehydration) conductivity. The water retention properties provided by $SO_3{}^-$ and silanol groups lead to relatively high proton conductivity (maximum values around 8.5×10^{-4} S cm^{-1}) at 100–150 °C.

Keywords: PEMFC; Hybrid conductor; Sulfonation; Sol–gel; Proton conductivity; Fuel cells

1. Introduction

There is a great interest in proton-exchange membrane fuel cells (PEMFC) for different applications, especially for transportation. Compared to internal combustion engines, PEMFC in transportation operate with zero emissions of environmental pollutants [1,2]. Limitations of actual PEMFCs, that use Nafion™ membranes, are their poor water retention above 80 °C, CO poisoning of Pt anode electrocatalysts and problems associated with the use of hydrogen as fuel (fabrication, storage and safety). Also, these membranes remain expensive and have several limiting factors, such as low conductivity at low relative humidity, high methanol permeability and a low glass transition temperature (T_g), which restrict their application to below 100 °C [1,2]. If the membranes were capable of operation at temperatures above 100 °C without substantial humidification, the CO poisoning would be reduced, given that the absolute free energy of adsorption of CO on Pt has a larger positive temperature dependence than that of H_2, meaning that the CO tolerance level increases [3]. Moreover, the increase of PEMFC operation temperature would allow increased fuel cell reaction kinetics and lower consumption of platinum catalyst, and direct use of low-temperature fuels, such as methanol [3–5].

Nano-structured materials consisting of organic and inorganic components are an interesting alternative to polymeric membranes in order to reach higher PEMFC operation temperature. The inorganic component allows the thermal stability to be increased and combines it with the mechanical and proton conductivity properties of the organic component. Similarly, the inorganic phase can improve chemical stability and high temperature proton conductivity of the membranes by the increase of water retention up to higher temperatures, although a greater fragility is usually associated with high inorganic content [6,7]. A compromise between all these properties has to be achieved to produce adequate proton-conducting membranes with application in PEMFC.

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