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Novel Ternary Polymer Blend Membranes Doped with SO_4/PO_4-TiO_2 for Low Temperature Fuel Cells

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Extended Abstract

Low temperature fuel cells, namely direct borohydride fuel cells (DBFCs), have high energy density and good performance at room temperature, allow the use of non-noble metal catalysts, and present low levels of toxicity [1]. However, three main issues concerning their development exist: (i) BH_4^- hydrolysis; (ii) BH_4^- crossover; (iii) the cost of materials (membrane and electrodes) related to the DBFC [2]. Regarding membrane separators, there is an idea to drive the research on a more sustainable approach, by choosing economic, available and environmentally friendly polymers, such as poly(vinyl alcohol) (PVA), poly(ethylene oxide) (PEO) and poly(vinyl pyrrolidone) (PVP). Herein, these polymers were crosslinked covalently with glutaraldehyde (GA) and ionically with 4-sulfophthalic acid (SPA), a sulfonating agent [3]. This compatible crosslinked blend was prepared based on simple chemistry, which is advantageous from the industrial point of view.

In an attempt of improving the physicochemical properties of the membrane, titanium phosphate (TP) and sulfated titania nanotubes (STN) were synthesized by impregnation-calcination method, where phosphate and sulfate groups were introduced on the titania surface using phosphoric and sulfuric acid respectively, then incorporated equally into the ternary blend matrix with concentrations of 1, 2.5, and 5 wt.%. The nanocomposite membranes were characterized by evaluating their ion-exchange capacity (IEC), water uptake, thermal stability, chemical stability, sodium ion conductivity and borohydride crossover as a function of TP and STN loading. The membranes' physicochemical properties (i.e., chemical stability, thermal stability, tensile strength, IEC, ionic conductivity) are improved by increasing the filler loading as a result of the good compatibility by hydrogen bonds formed between the oxygen-containing functional groups [4] of TP and STN and the functional groups of the polymers. These hydrogen bonds avoid excess of water uptake, compact the membrane structure, and reduce the swelling degree. When increasing the filler concentration, the swelling degree and water uptake were gradually reduced to below 20% while IEC was 3.5x higher. The introduction of TP and STN in the membrane with 5 wt % doping also lowers the permeability to borohydride (5.4×10^{-6} cm^2 s^{-1}) and increases the ionic conductivity by increasing the number of ion conducting sites on TP and STN surfaces. Peak power density of DBFC using TP and STN-doped membrane with 5 wt.% doping (72 mW cm^{-2}) is close to that of Nafion®117 (81 mW cm^{-2}) under the same testing conditions.

In conclusion, this research relies on preparing a different (ternary) polymer matrix from available and biodegradable polymers, taking advantage of their chemical compatibility, by using a simple and green process in which water is the main solvent. Incorporation of TP and STN in the blended polymers generates a new reinforced nanocomposite membrane with enhanced properties and performance. The general features and simple processing of these novel nanocomposite membranes enable the development of environmentally sustainable and cost-effective DBFCs.

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