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New proton conductive membranes of indazole- and condensed pyrazolebisphosphonic acid-Nafion membranes for PEMFC

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ABSTRACT

In this work, new doped Nafion membranes for PEMFC are prepared by casting with 1 wt% loading of the prepared indazole- and condensed pyrazolebisphosphonic acids (AzBPs). The new membranes were analysed by ATR-FTIR spectroscopy and their morphology was examined by SEM. Membranes were evaluated for water uptake and ion exchange capacity (IEC), and their hydration number was estimated. The proton conduction properties of the modified membranes were evaluated by electrochemical impedance spectroscopy (EIS), at different temperatures (30, 40, 50 and 60 °C) and relative humidity (RH) (40, 60 and 80%). The proton conductivities of all membranes increase with increasing temperature and RH. Also, all new membranes doped with AzBPs exhibited higher proton conductivities than Nafion N-115, used as a reference and tested at the same experimental conditions, with values up to 1.5-fold. Results show that the incorporation of AzBPs dopants on Nafion membranes enhances the proton conduction throughout the modified membranes. The best proton conductivity was observed for membranes with AzBP1 as dopant, with a value of 94 mS cm-^{1}. These results indicate that the Nafion membranes doped with indazole- and condensed pyrazolebisphosphonic acids are a promising approach for new membranes for PEMFC with improved proton conductivity.

1. Introduction

The need of energy for the development of the world is still growing along with the rising of many civilizational problems. The supply of the global demanding energy has its bases on the overuse of traditional energy sources based on fossil fuels, with considerable effects on the environment recognized as a key factor regarding climate change [1–3]. The paradigm for the 21st century society is the transition from traditional energy to cleaner and renewable sources, integrating sustainable energy systems, ensuring that the needed ambitious and well-defined targets and implementation plans, being established by national governments and international institutions, are implemented so that a decarbonized energy system is achieved by 2050 [4–7].

However, renewable energy sources are unstable and low-density sources of production, dependent at all times on the intensity of the source that originates them, such as the sun or wind, and therefore remain intermittent production providers, unable to meet energy needs in certain periods of higher energy consumption. In these periods, it is necessary to compensate the insufficient production of renewable energy using stored energy as an alternative [7]. Energy storage thus attracts a growing interest for a more complete use of intermittent renewable energies, integrating proposals from other vectors, such as hydrogen, in an energy system that is intended to be more flexible, robust, constant, and more sustainable [3,8,9].

In the case of hydrogen, it can be generated by electrolysis of water and renewable electricity, so it can be used as a green fuel. Green hydrogen technology can surpass the drawbacks of many renewable energy systems, but it still remains dependent from several factors, such as, its production and storage. Hydrogen can be used as a green fuel for fuel cells, which are electrochemical devices that can convert its chemical energy to electric energy. The direct and efficient conversion of hydrogen, with formation of water, without formation of intermediates, by-products or toxic gases, makes the hydrogen fuel cells technology a promising renewable and clean energy source [10–12].

Proton exchange membrane fuel cells (PEMFCs) are considered the most promising power sources amongst fuel cells, due to their

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