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# Progress in the use of ionic liquids as electrolyte membranes in fuel cells

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ABSTRACT

This work provides a critical review of the progress in the use of Room Temperature Ionic Liquids (RTILs) as Proton Exchange Membrane (PEM) electrolytes in Fuel Cells (FCs). It is well-known that for an efficient early commercialisation of this technology it is necessary to develop a proton exchange membrane with high proton conductivity without water dependency capable of working at temperatures above 100 °C. The use of ionic liquids as electrolytes in electrochemical devices is an emerging field due to their high conductivity, as well as their thermal, chemical and electrochemical stability under anhydrous conditions. This paper attempts to give a general overview of the state-of-the-art, identifies the key factors for future research and summarises the recent progress in the use of ionic liquids as an innovative type of PEMs.



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## 1. Introduction

The need to reduce our dependence on fossil fuels and the generation of pollutants has led to the development of proton exchange membrane fuel cells (PEMFCs) as promising alternatives for clean power generation, particularly due to their high efficiency and low emissions. This technology facilitates the adequate performance and durability needed to compete with conventional technologies and it will likely be commercialised in the medium term for transportation and portable applications. The number of publications (Fig. 1) describing fuel cells in the last decade shows the increasing interest in this technology.

Fuel cells are electrochemical devices able to convert chemical energy directly into electrical energy. They can be classified based on their operating temperature and electrolyte: alkaline fuel cells (AFCs), proton exchange membrane fuel cells (PEMFCs), phosphoric acid fuel cells (PAFCs), molten carbonate fuel cells (MCFCs) and solid oxide fuel cells (SOFCs). PEMFCs, which can be fed with hydrogen or methanol (Direct Methanol Fuel Cells, DMFCs), are generally used for portable applications and transportation

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because they hold several advantages over conventional technologies, such as their high electrical efficiency, silence, low pollutant emissions, ease of installation and rapid start-up.

A PEMFC is composed of different fundamental elements: bipolar plates, diffusion layers, electrodes (anode and cathode) and the electrolyte. A schematic of a PEMFC is shown in Fig. 2. The core of a PEMFC is called the membrane electrode assembly (MEA), and it is composed of the proton exchange membrane (PEM) placed between two electrodes. Proton exchange membranes have different functions, such as separating the gaseous reactants, conducting protons from the anode to the cathode, electrically insulating the electrons and supporting the catalyst [1]. Membranes should meet the following requirements to be applied in PEMFCs [2]:

- High proton conductivity in both dry and wet states.
- Outstanding mechanical strength and dimensional stability.
- Chemical, electrochemical and thermal stability under the operating conditions.
- Low fuel and oxygen crossover.
- Easy conformation to form a membrane electrode assembly.
- Competitive cost.

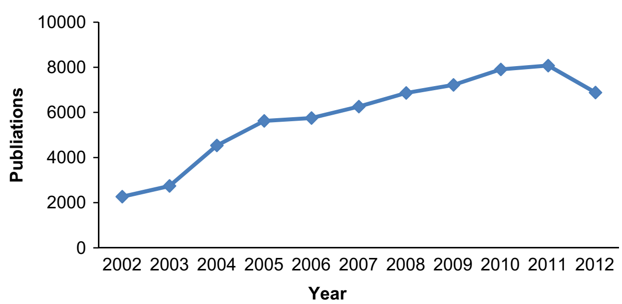


**Fig. 1.** Number of publications describing fuel cells (Database: Scopus. Search Keywords: Fuel Cells and Fuel Cell).

Perfluorosulfonic acid ionomer, being Nafion the most representative ionomer of this category (Fig. 3), is the most widely used membrane in PEMFC devices because of its excellent chemical stability, high ionic conductivity and good mechanical strength [3,4]. However, the conductivity of Nafion drops at temperatures above 100 °C due to the evaporation of water which is critical for proton conduction. Higher temperatures are desirable because tolerance of the catalyst to contaminants is improved and hydrogen with less purity can be used. Moreover, an increase in temperature enhances the electrode reaction rates [5]. Table 1 compares the five different types of membranes frequently used in PEMFCs [1,2].

During the last few years, significant progress in cost, durability and performance of fuel cells has been made, but the remaining technical and economic issues must be solved before this technology can be commercialised. Several authors have focused on the optimisation of the stack design and the fuel cell configuration. Other aspects that require improvement include the structure and composition of the catalyst layer. For the electrolyte, many efforts have been made to develop a PEM with high conductivity at low relative humidity to reduce the cost and complexity of the system. Besides, the development of non-volatile and non-flammable electrolytes is important in order to improve the safety and durability of fuel cells. Consequently, several studies have incorporated ionic liquids as electrolytes in PEMFCs under anhydrous

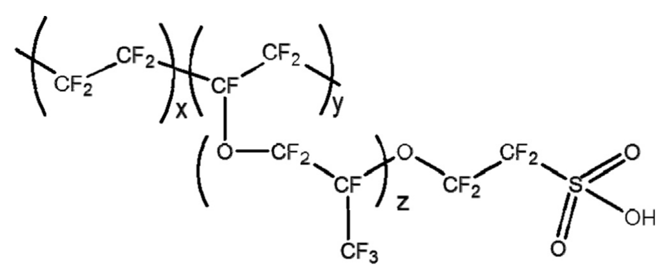

**Fig. 3.** Chemical structure of Nafion.

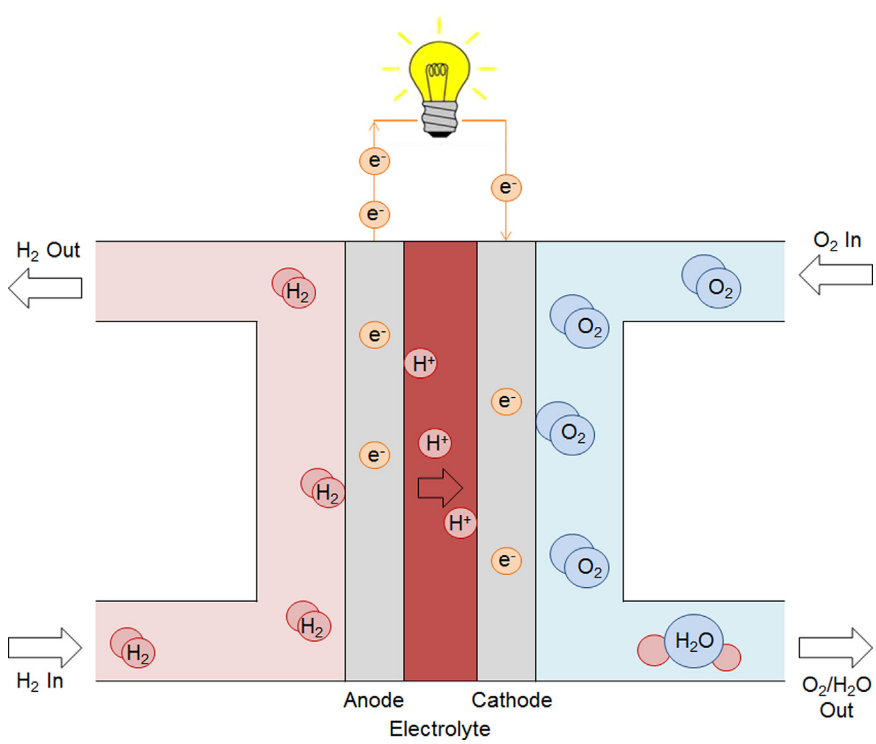


**Fig. 2.** Schematic of a PEMFC.