Journal of Membrane Science & Technology
ISSN: 2155-9589

Parnian, J Membr Sci Technol 2018, 8:3
DOI: 10.4172/2155-9589.1000e125

Editorial Open Access

# Proton Exchange Membranes for PEM Fuel Cells Applications

**Mohammad Javad Parnian***

*Department of Chemistry, University of Calgary, Calgary, Canada*

***Corresponding author:** Mohammad Javad Parnian, Department of Chemistry, University of Calgary, Calgary, Canada; E-mail: mohammadjavad.parnia@ucalgary.ca

**Received date:** October 15, 2018; **Accepted date:** October 22, 2018; **Published date:** October 29, 2018



## Editorial

Electrochemical energy conversion and storage systems are promising technologies for environmental contamination and energy shortcoming concerns that are potential alternatives for conventional internal combustion engines and fossil fuels. One of these systems is Proton Exchange Membrane Fuel Cells (PEMFCs) that convert the chemical energy to electricity in different operating conditions and have high energy conversion, quiet performance, and approximately zero pollution. PEMFCs are the promising technology for the stationary power generation and automotive systems because of their lower operating temperature and smaller size in comparison with other fuel cell types. Different efforts have been done to fully commercialization of this technology and to reach the requirements of international protocols based on the cost, performance and durability issues [1-3].

A single cell of PEMFC has some different parts including the current collector plates, flow fields, and the Membrane Electrode Assembly (MEA). MEA is the heart of fuel cells that all reactions, transportation and energy production occurred inside that and consists of proton exchange membrane, gas diffusion layers, and anode and cathode catalyst layers [4]. Hydrogen gas separates into its protons and electrons on the anode electrode. The protons are conducted through the membrane electrolyte (from the anode side to cathode side), whereas the produced free electrons at the anode move through an external circuit to the cathode. Oxygen gas combines with the electrons and protons at the cathode electrode. Therefore, the electric power, water, and heat are produced in a cell. Many research works have been focused on the improvement of cathode and anode electrocatalysts, ionomer type and content, membrane, and other sections [5-8].

The key component of MEAs is the Proton Exchange Membranes (PEMs) that used as the separator of reactant gases and carrier for proton transport from the anode to cathode side and electrons barrier and the desired properties for a PEM are consist of good electrochemical stability, appropriate chemical and mechanical properties, appropriate thermal and hydrolytic stability, high proton conduction properties, compatible with electrodes, high durability, and low cost. Thus, the main goals for PEMs improvement are reducing the cost, increasing the performance, and improvement the durability. Based on these criteria, different researches have been focused on the improvement of different properties of PEMs [9,10].

Different types of polymeric membranes used as proton exchange membranes such as Perflourosulfonic Acid (PFSA) membranes (Nafion®, Flemion®, and etc.) and non-fluorinated membranes (sulfonated hydrocarbon membranes, and etc.). In the current applications, the PFSA membranes (especially Nafion® (DuPont) membranes) are the most commonly used PEMs and they have high mechanical and chemical stability and excellent electrochemical performance but there are some drawbacks such as the high cost and low performance at high temperatures and different researches have been focused on improving different properties of PFSA membranes [11]. On the other hand, different research works have been focused on replacing the expensive PFSA with new inexpensive PEMs (non-fluorinated membranes) such as sulfonated hydrocarbon membranes that exhibit higher thermal stability and lower reactant gas crossover [12]; sulfonated polybenzimidazole [13], sulfonated poly (ether ether ketone) [14], sulfonated polysulfone [15], Sulfonated Polyimides (SPIs) [15], sulfonated polyphosphazene [16].

In addition, some membranes have been developed for the high temperature PEMFC (higher than 120°C) that Polybenzimidazole (PBI)-based membranes and other aromatic amines activated with Phosphoric Acid (PA) are in this category [17,18].

Different research works have focused on improving the membrane performance by blending of different polymers, introducing new polymer structures, using ion liquids, using organic additives, and preparation of nanocomposite membranes approaches. The incorporation of hygroscopic nanoparticles such as metal oxides including $SiO_2$, $TiO_2$, and $ZrO_2$ into different membranes can improve the properties of different membranes [19-23].

Besides the cost and performance issues, the durability of membranes is also very important. Mechanical, chemical, and thermal degradations of the membranes occurred during the fuel cell operations and these degradations are significant barriers to PEMFC commercialization. During fuel cell operation, mechanical stresses cause life failure due to existing perforations, cracks, tears, and pinholes in the membranes, and dimensional changes in the different humidity levels [23]. Thermal degradation is being increased in the application of membranes in the higher temperatures. In addition, the formation of free radicals (hydroperoxy and peroxy) and their subsequent reactions with the PEM are the main drivers of PEM chemical degradation [24]. In fact, a combination of different degradations (thermal, mechanical, and chemical degradations) leads to polymer damage, loss in the membrane integrity, and decrease the fuel cell performance and durability and consequently the membrane failure. To improve the durability of membranes different research works have been done, for example one strategy for chemical durability improvements of different membranes is the use of different inorganic additives to catalyze the decomposition of hydrogen peroxide and free radicals during fuel cell operation [25,26].

In conclusion, the cost, performance and durability should be considered for the proposed membranes for proton exchange membrane for fuel cell applications. To reduce the cost of membranes as mentioned the replacing of expensive PFSA with inexpensive hydrocarbon membranes has been studied. PEMs should have appropriate water uptake, without defect structure, high proton conductivity, appropriate dimensional stability, high thermal stability, appropriate mechanical properties, and high chemical durability. To improve the performance different approaches such as blending of different polymers and incorporation of nanoparticles or other additives have been investigated. Besides these issues, the durability of membranes is also very important and in recent years different researches have been focused on the durability.

## References


1. Wilberforce T, Alaswad A, Palumbo A, Dassisti M, Olabi A (2016) Advances in stationary and portable fuel cell applications. Int J Hydrog Energy 41: 16509-16522.
2. Sharaf OZ, Orhan MF (2014) An overview of fuel cell technology: Fundamentals and applications. Renew Sust Energ Rev 32: 810-853.
3. Lucia U (2014) Overview on fuel cells. Renew Sust Energ Rev 30: 164-169.
4. Thepkaew J, Therdthianwong A, Therdthianwong S (2008) Key parameters of active layers affecting proton exchange membrane (PEM) fuel cell performance. Energy 33: 1794-1800.
5. Xie J, Xu F, Wood DL III, More KL, Zawodzinski TA, et al. (2010) Influence of ionomer content on the structure and performance of PEFC membrane electrode assemblies. Electrochimica Acta 55: 7404-7412.
6. Rivera LM, García G, Pastor E (2018) Novel graphene materials for the oxygen reduction reaction. Current Opinion in Electrochemistry 9: 233-239.
7. Rahnavard A, Rowshanzamir S, Parnian MJ, Amirkhanlou GR (2015) The effect of sulfonated poly (ether ether ketone) as the electrode ionomer for self-humidifying nanocomposite proton exchange membrane fuel cells. Energy 82: 746-757.
8. Ghanbarlou H, Rowshanzamir S, Kazeminasab B, Parnian MJ (2015) Non-precious metal nanoparticles supported on nitrogen-doped graphene as a promising catalyst for oxygen reduction reaction: synthesis, characterization and electrocatalytic performance. J Power Sources 273: 981-989.
9. Huang ZM, Su A, Liu YC (2014) Development and testing of a hybrid system with a sub-kW open-cathode type PEM (proton exchange membrane) fuel cell stack. Energy 72: 547-553.
10. Zhang L, Chae SR, Hendren Z, Park JS, Wiesner MR (2012) Recent advances in proton exchange membranes for fuel cell applications. Chem Eng Sci 204: 87-97.
11. Shen L, Sun Z, Chu Y, Zou J, Deshusses MA (2015) Novel sulfonated Nafion®-based composite membranes with pillararene as selective artificial proton channels for application in direct methanol fuel cells. Int J Hydrog Energy 40: 13071-13079.
12. Higashihara T, Matsumoto K, Ueda M (2009) Sulfonated aromatic hydrocarbon polymers as proton exchange membranes for fuel cells. Polymer 50: 5341-5357.
13. Wang G, Xiao G, Yan D (2011) Synthesis and properties of soluble sulfonated polybenzimidazoles derived from asymmetric dicarboxylic acid monomers with sulfonate group as proton exchange membrane. J Membrane Sci 369: 388-396.
14. Parnian MJ, Rowshanzamir S, Gashoul F (2017) Comprehensive investigation of physicochemical and electrochemical properties of sulfonated poly (ether ether ketone) membranes with different degrees of sulfonation for proton exchange membrane fuel cell applications. Energy 125: 614-628.
15. Mabrouk W, Ogier L, Vidal S, Sollogoub C, Matoussi F, et al. (2014) Ion exchange membranes based upon crosslinked sulfonated polyethersulfone for electrochemical applications. J Membrane Sci 452: 263-270.
16. Luo T, Zhang Y, Xu H, Zhang Z, Fu F, et al. (2016) Highly conductive proton exchange membranes from sulfonated polyphosphazene-graft-copolystyrenes doped with sulfonated single-walled carbon nanotubes. J Membrane Sci 514: 527-536.
17. Haque MA, Sulong AB, Loh KS, Majlan EH, Husaini T, et al. (2017) Acid doped polybenzimidazoles based membrane electrode assembly for high temperature proton exchange membrane fuel cell. Int J Hydrog Energy 42: 9156-9179.
18. Authayanun S, Im-Orb K, Arpornwichanop A (2015) A review of the development of high temperature proton exchange membrane fuel cells. Chinese J Catal 36: 473-483.
19. Bakangura E, Wu L, Ge L, Yang Z, Xu T (2016) Mixed matrix proton exchange membranes for fuel cells: state of the art and perspectives. Prog Polym Sci 57: 103-152.
20. Parnian MJ, Rowshanzamir S, Moghaddam JA (2018) Investigation of physicochemical and electrochemical properties of recast Nafion nanocomposite membranes using different loading of zirconia nanoparticles for proton exchange membrane fuel cell applications. Materials Science for Energy Technologies 1: 146-154.
21. Song JM, Woo HS, Sohn JY, Shin J (2016) 12HPW/meso-SiO2 nanocomposite CSPEEK membranes for proton exchange membrane fuel cells. J Ind Eng Chem 36: 132-138.
22. Gashoul F, Parnian MJ, Rowshanzamir S (2017) A new study on improving the physicochemical and electrochemical properties of SPEEK nanocomposite membranes for medium temperature proton exchange membrane fuel cells using different loading of zirconium oxide nanoparticles. Int J Hydrog Energy 42: 590-602.
23. Amirinejad M, Madaeni S, Navarra M, Rafiee E, Scrosati B (2011) Preparation and characterization of phosphotungstic acid-derived salt/ Nafion nanocomposite membranes for proton exchange membrane fuel cells. J Power Sources 196: 988-998.
24. Pozio A, Silva R, De Francesco M, Giorgi L (2003) Nafion degradation in PEFCs from end plate iron contamination. Electrochimica Acta 48: 1543-1549.
25. Xiao S, Zhang H, Bi C, Zhang Y, Ma Y, et al. (2010) Membrane degradation mitigation using zirconia as a hydrogen peroxide decomposition catalyst. J Power Sources 195: 8000-8005.
26. Parnian MJ, Rowshanzamir S, Prasad AK, Advani SG (2018) Effect of ceria loading on performance and durability of sulfonated poly (ether ether ketone) nanocomposite membranes for proton exchange membrane fuel cell applications. J Membrane Sci 565: 342-357.