Improvement of the Composite Membrane Properties For Fuel Cells: A Review

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As a result of climate change, rapid depletion of fossil fuel reserves and increasing of world's energy demand, fuel cell studies have been accelerated worldwide. The proton exchange membrane fuel cells (PEMFCs) are one of the most promising types of them. They are used in buildings, light-duty vehicles and replacement of rechargeable batteries because of the high energy density, low operational temperature, fast startup time, low to zero emissions depending on the fuel for *net-zero transition.*

Perfluorosulfonic acid-based polymer, known as Nafion, is the most widely used membrane polymer. Despite Nafion being eligible material, dehydration of the membranes causes a drop in proton conductivity at low humidity conditions. So, the Nafion membranes are limited to temperatures below 80^{0}C. In PEMFCs, 150-200^{0}C operating temperature is preferred to enhance catalytic activity in electrodes and reduce the poisoning effect of catalysts from fuel impurities such as carbon monoxide (CO). To obtain a solution, some research has been conducted in the last years.

Nafion membranes generally are modified by using the different chemical stages. For instance, composite membranes were obtained by using zirconium phosphates (ZrP) and ionic liquid (IL) as a solid proton conductor, porous polytetrafluoroethylene (PTFE) as a supporting material, glycerol (GLY) as a dispersing agent in a study. When ZrP-IL based composite materials were evaluated at a high temperature of 200^{0}C and completely anhydrous conditions, high proton conductivity (70% of Nafion) at room temperature was obtained and the reported conductivity at 200^{0}C is equal to at 80^{0}C (60% of Nafion) and at fully hydrated conditions.

The ILs have been used in electrochemical applications as a proton conductor due to their negligible volatiles, high thermal stabilities and high conductivities. ILs have been investigated in fuel cells applications. In a study, composite membranes with different IL

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types and loading amounts were systematically studied and a promising output performance was achieved at a high temperature of 100-250^{0}C in comparison with the non-IL composite membrane.

To minimize or eliminate the improper properties of Nafion membrane, different methods have been developed such as producing Nafion-free membranes by using polybenzimidazole (PBI) and preparing a nonprecious catalyst with low fuel oxidation activity at the cathode. In addition, metal-organic frameworks (MOFs) which are a type of mixed matrix membranes have been used instead of Nafion in low-temperature fuel cells because of the high proton conductivity, chemical and mechanical stabilities and capacity of functionalized with acidic groups. In a study, the application of MOF as a blend with different polymers exhibited promising results in low-temperature fuel cells.

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