

# Reinforcement of polymer electrolyte membranes using tin dioxide particles

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Polymer electrolyte membrane fuel cells are electrochemical energy conversion devices, capable of converting the chemical energy in a fuel into electricity. A fuel such as hydrogen can be produced by electrolysis of water using energy from renewable sources. These devices are interesting considering the concern for anthropological climate influence by emission of green house gasses, the eventual depletion of fossil fuel resources, as well as the desire for independence of fossil fuel resources due to geopolitical reasons.

As the name implies, the polymer electrolyte membrane is integral to this particular type of fuel cell. It acts as a barrier for reactants and electrons, but must facilitate the transport of protons from anode to cathode, i.e. it must be a proton conductor. The requirements to the materials from which the membrane is made are diverse and some of them contradictory.

The commonly used polymer electrolyte membranes are made from a polymer with a hydrophobic Teflon-like backbone with side-chains bearing very hydrophilic acid groups at their ends. Due to this difference in the preference for water, the acid groups tend to aggregate and surround themselves with water, while the hydrophobic parts of the polymer prefer to interact with themselves.

The acid groups are the source of proton conductivity in this material. When enough water is present in the membrane, the protons can leave their acid groups and be transported through the water, which is distributed in the membrane sort of like water in a sponge. The ability of the membrane to conduct protons is determined by the number of acid groups and the ease with which their protons can move through this water filled structure. To obtain a high proton conductivity, a straightforward approach is thus to increase the number of acid groups. However, increasing that number generally comes at the expense of the mechanical properties of the membrane, which are needed to fulfill the other basic task of the membrane, namely the barrier function. One reason is that the many hydrophilic acid groups have such a strong preference for water that the water content in the membrane can become so high that the membrane excessively softens or even dissolves into its molecular constituents. Another reason is that an increasing number of side chains with acid groups at the end can inhibit the interaction between the hydrophobic parts of the polymer, simply by being in the way. This also softens the membrane, since fewer forces are acting to keep the polymer chains together.

Therefore, a compromise must be found between high proton conductivity and sufficient mechanical integrity. This work presents a strategy allowing improvement of the mechanical properties while keeping proton conductivity virtually unchanged. The approach relies on forming chemically interacting particles (namely tin dioxide) inside the membrane in order to reinforce it.

The influence of the particles on membrane hydration, proton conductivity, mechanical properties, reactant permeability as well as the performance of the membrane in a fuel cell is examined. The way the particles interact with the polymer is also studied. Furthermore, investigation of the extent to which the mechanical reinforcement translates into extended mechanical durability of the membrane under fuel cell relevant conditions is attempted.

The particles stiffen the membrane and thereby limit the tendency to take up water. They do so virtually at no cost in terms of proton conductivity at temperatures above 120 °C. Seeing as there are quite a few advantages with operating a fuel cell at such temperatures, the effect of the particles can be useful for improving the properties of polymer electrolyte membranes for fuel cell applications.