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Understanding membrane processes on direct liquid fuel cells

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This work intends to develop a theoretical model for the membrane processes on direct liquid fuel cells, particularly the direct borohydride-peroxide fuel cell (DBPFC), as a first step to create a numerical model. The DBPFC is based on the anodic oxidation of sodium borohydride (NaBH4) in alkaline solution with the simultaneous cathodic reduction of hydrogen peroxide (H2O2) in acid media. As the DBPFC uses both fuel and oxidant solutions that are liquid at room temperature, it is a promising device for power generation in space and underwater applications, where O2 gas is not easily available. Crossover through the membrane, specifically in the case of high pH-gradient between the solutions involved, is a crucial point to improve the performance of these fuel cells. Understanding the ion transfer through cation-exchange membranes (CEMs) and anion-exchange membranes (AEMs) will allow the development of pH-gradient-enabled microscale bipolar interfaces (PMBI) [1].

The model is mainly based on the Nernst-Planck equations, where all components of the system are considered to explain the passage of the ions through the membrane used. The latter is split into one section where there is a constant electric field due to the potential difference between the electrodes, and another section without it, but where there is a local difference of electric potential between the two sides of the membrane, i.e., the membrane potential. This effect is created by the different diffusivity of the ions inside the membrane. To keep the electroneutrality in the fuel cell compartments, the system uses a mechanism where the faster ions are slowed down and the slower ions are accelerated, to allow both oppositely charged ions to pass. The passage of the ions is considered individually for each species involved. Each sub-system is considered to work independently based on the different concentrations on each side of the membrane and the specific membrane potential created. The total membrane potential is the overlayed effect of all sub-systems, according to the superposition principle. This model is an upgrade to the generally accepted approach where specific kinds of ions are blocked/hindered by the ion-selective membrane [2]. The obtained experimental data will allow for a better understanding of the processes occurring inside the DBPFC membrane, which has been used until now as a black box, where the initially selected inputs lead to obtaining the polarization and the power density curves as outputs. So far, numerical models for fuel cells have been mainly used for gaseous flows involved, as in the well-studied PEMFC, but a working numerical model for liquid fuel cells is not available in the literature. This study aims to be a starting point to the creation of a corresponding model where liquid solutions are involved, and thus suitable for modeling DBPFCs.

Scientific Area

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