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Three Dimensional Model of a High Temperature PEMFC. Study of the Flow Field Effect on Performance

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Abstract

A three-dimensional isothermal model of a high temperature polymer membrane fuel cell equipped with polybenzimidazole membrane is described. All major transport phenomena were taken into account except the species crossover through the membrane. The cathode catalyst layer was treated as spherical catalyst agglomerates with porous inter-agglomerate spaces. The inter-agglomerate spaces were filled with a mixture of electrolyte (hot phosphoric acid) and polytetrafluoroethylene (PTFE). This approach proved to be an essential requirement for accurate simulation. In this particular paper, the influence of different flow field designs and dimensions on performance was intensely study. Traditional configurations were tested (straight, serpentine, pin-in, and interdigitated), and new designs were proposed. With these new designs, we tried to maximize performance by providing homogeneous reactants distribution over the active area keeping low-pressure drop and relatively high velocity. The dimension and position of the inlet and outlet manifolds were also analyzed. From the obtained results a massive influence of the manifolds position and dimension on performance was observed. This fact can provide important guidelines for future bipolar plates optimization.

Keywords: 3D PEMFC Model, Flow Field, High Temperature PEM, Modelling, PEMFC, Polybenzimidazole

1 Introduction

During the last decade, fuel cell modelling became an extremely important tool for design and understanding of all chemical and physical phenomena related with this technology. With the increase of computer power, three-dimensional (3D) modelling became a reality; which opened the door to complex modelling procedures using computational fluid dynamics (CFD).

In 2001, Dutta et al. [1] developed one of the first 3D models for polymer electrolyte membrane fuel cells (PEMFCs). They used this model to predict the mass flow between channels in a PEMFC with a serpentine flow path. They found flow directions considerably dependent on the mass consumption pattern, in both anode and cathode. They concluded that density variation effects should be incorporated in fuel cell models, because a significant variation in the gas-mixture density was observed. They also detected a considerable flow through the gas diffusion layer (GDL), which indicated an overall pressure drop lower than that expected in a serpentine channel. One year later, Berning et al. [2] published a non-isothermal 3D model which, with the exception of phase change, accounted for all major transport phenomena. They showed in great detail the 3D distributions of reactant concentrations, current densities, temperature, and water fluxes. They found a significant temperature gradient within the membrane electrode assembly (MEA), and they related the 3D nature of the transport with the current distribution and predicted current density. In 2004, Um and Wang [3] developed a dynamic 3D model for a PEMFC with parallel and interdigitated flow fields. With this model they tried to obtain a basic understanding of the impact on the electrochemical processes in both types of flow field by the 3D flow and transport phenomena in the air cathode. They found that forced convection, induced by the interdigitated flow field, improved oxygen transport and water removal from the catalyst layer. This fact leads, to better performance when compared to that of the parallel flow field.

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