Fuel 222 (2018) 465–474

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

The effect of different gas diffusion layer porosity on proton exchange membrane fuel cells

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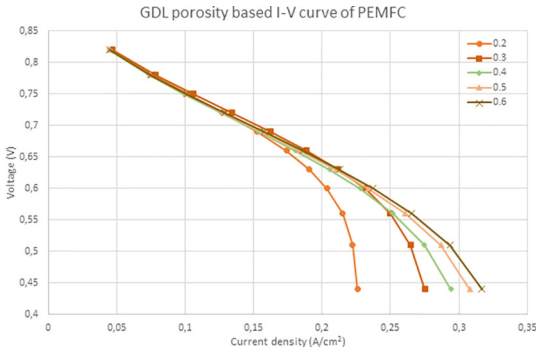
GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
PEMFC
Gas diffusion layer
Porosity

ABSTRACT

In this study, the effect of cathode side gas diffusion layers' porosity on Proton Exchange Membrane Fuel Cells (PEMFC) was modelled. In the model prepared, all the geometric parameters and material characteristics were kept fixed except gas diffusion layer. GDL porosity was between 0.2 and 0.6, and a parametric work was conducted with modifications in the rate of 0.1 per modification. It is understood from the obtained current-voltage graphics that porosity change has different effects on low and high voltage fuel cells. Limit value was 0.63 V, and the highest current levels were obtained when the porosity was 0.3, however, performance of the fuel cell using gas diffusion layer with higher porosities (especially 0.6) increased. The results of the study conducted were shaped based on an experiment study in the literature and the model was verified.

1. Introduction

Fuel cell (FC) is one of the best ways to decrease fossil fuel consumption and is considered as a promising device to decrease emissions of polluting gases such as carbon dioxide and sulphur dioxide. This electro-chemical device converts the chemical energy in the fuel, or in other words, chemical compounds that have hydrogen as their structural element to electrical energy and water. Conversion performance is quite high when compared with other type of energy systems [1], e.g. combustion engines and turbines, especially in terms of small-scale power plants.

There are different types of FCs and these are classified according to the electrolyte used, operating temperature or applicability. Two widely researched FCs are proton exchange membranes (PEMFC) and solid oxide fuel cells.

PEMFC has low operating temperature and rapid commissioning characteristic, however, it requires pure hydrogen as fuel. On the other hand, solid oxide fuel cells may operate with various fuel due to

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https://doi.org/10.1016/j.fuel.2018.02.058
Received 11 September 2017; Received in revised form 23 November 2017; Accepted 8 February 2018
Available online 23 March 2018

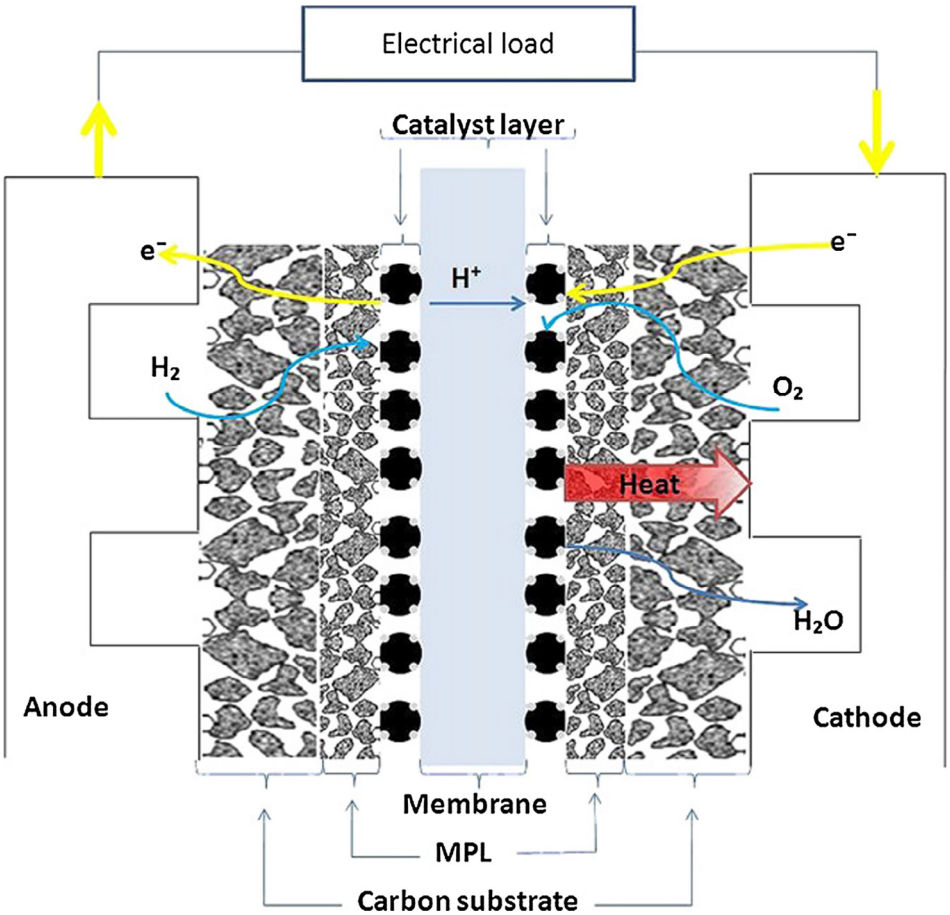

Fig. 1. GDL structure and MEA sub-components in a PEM fuel cell [23].

operating on high temperatures [2].

Polymer electrolyte membrane (PEM) fuel cells are considered as the new alternative, integrable, innovative green energy technology systems in transportation, fixed power systems and portable devices [3].

PEM fuel cells are designed to operate with 600 mW/cm^2 or even higher [4,5] power density and high current densities up to 1.5 A/cm^2 to increase performance compared to conventional power supplies. Additionally, high current densities may lead to increase in losses due to mass transport. Thus, different parameters of the system such as transport coefficient should be scrutinised [5].

Use of PEMFCs for portable applications due to characteristics mentioned before is more appropriate in comparison with other types of fuel cells. Subjects of future focus in FCs in order to provide part of energy needs and to compete with conventional energy resources are about reducing the costs and increasing the performance in general. When analysed in detailed, behaviour of the liquids in PEMFC (hydrogen, oxygen and water) allow improvement of functional components. This type of components in electrodes, e.g. gas diffusion layer (GDL) and catalyst layer are often porous media [6] and allow fluids and charge transport for energy conversion.

There are various works available on the effects of gas diffusion layers on thermal hydraulic characteristics and behaviour of PEMFCs [7,8].

Gas diffusion layer (GDL) is a vital component of PEM fuel cells. GDL is typically a porous material as carbon paper. One of the most important functions of GDL is to equally distribute reaction agents to reaction areas and to provide a path to alienate the water. GDL also provides mechanical support to membrane and conducts heat and electricity to it [9].

Various mathematical models were developed in order to define transport phenomenon of GDL thoroughly and to estimate cell performance. In these models, it is usually considered that GDL is a homogenous material and has fixed porosity [10,11].

Experimental measurements and analytical works were also conducted about GDL structures and performance [12–14]. Additionally, there are some ongoing studies analysing behavioural characteristics of the liquid in GDLs considering characteristics which can be observed in micro-scale environments such as porosity, gas phase frizziness and planar permeability in particular.

GDL's functional requirements are highly dependant on morphological, thermal, electrical and mechanical characteristics such as porosity, thermal and electrical conductivity and chemical and physical resistance. [15].

Application of compression pressure to ensure impermeability in the assembly of fuel cell changes the morphology of diffusion layer. Thickness and porosity of soft and flexible material of GDL layer changes under compression pressure. Liquid water in GDL is another reason of porosity change and was first observed through a one-dimension semi cell model developed by Gurau et al. [16].

Majority of experimental studies assessed the effects of porosity change on fuel cell performance as a function of compression pressure [17–19].

High operation costs makes the conduction of fuel cell experiments harder. That is why numerical modelling became an effective alternative to these experiments in academic research. A comprehensive analysis regarding the development of this type of models is provided in [20–22].

GDL plays an key role in reaction initiation process of reagents of Hydrogen Oxidation Reaction (HOR) and Oxygen Reduction Reaction