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SCIENCE DIRECT®
Journal of Power Sources 151 (2005) 25–31
JOURNAL OF POWER SOURCES
www.elsevier.com/locate/jpowsour

Symmetrical electrode mode for PEMFC characterisation using impedance spectroscopy

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Accepted 24 February 2005
Available online 2 June 2005

Abstract

This paper investigates a single complete proton exchange membrane fuel cell (PEMFC) as a whole, modelling it by an electrical equivalent circuit (EC) using the electrochemical impedance spectroscopy (EIS) technique. The cell tested was a PEM single cell with a Nafion 117 membrane. The measurements were carried out with the fuel cell working in an electrode "symmetrical mode" (SM), that is, with the same gas injected in both electrodes, with different gases supplied to anode/cathode compartments (O_2/O_2 and H_2/H_2). The working temperature of the cell was (40–70 °C), and the humidification conditions of reactant gases were 45 ± 5 and 100% relative humidity (RH).

This study obtains the structure of the EC and its parameters values, and offers a physical interpretation relating these parameters to several processes occurring in the system. The relations of properties, such as membrane conductivity or the resistance to the charge transfer process as a function of the working parameters of the fuel cell, such as temperature, reactant gases injected and their humidification conditions are also studied.

The efficiency of EIS for the modelling and characterisation of PEMFC working in SM is also discussed.
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Keywords: PEMFC; Impedance spectroscopy; Equivalent circuit; Membrane conductivity; Charge transport; Mass transport

1. Introduction

Among the different types of fuel cells, the PEMFC has been attracting much interest as an energy source for residential applications and electric vehicles. It is capable of achieving high-power densities working at low temperatures, e.g. 60 °C.

PEMFC EIS electrode symmetrical mode characterisation achieves a double objective:

- it gives a deeper quantitative/qualitative understanding of the fuel cell system that permits improvement in the design and operation of the fuel cell; and
- it leads to a better understanding of the performance of these systems which depend on a complex group of structural and functional characteristics, which interact internally to provide the optimum situation for the entire process.

Modelling electrochemical systems by an EC is a procedure used in the EIS technique that offers an explanation of the macroscopic or microscopic properties of the electrochemical system analysed. EIS is a method to characterise the electrochemical properties of materials and their interfaces with electronically conducting electrodes [1]. Due to the complexity of the electrode behaviour inside a fuel cell, and the influence of several factors, such as electrical conductivity and interface structures, EIS has been demonstrated to be a useful and powerful technique to study the different processes that occur in the fuel cell. It also allows us to evaluate the electro-

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0378-7753/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.jpowsour.2005.02.081