INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 38 (2013) 7684–7696

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

International Journal of HYDROGEN ENERGY

Assessing cell polarity reversal degradation phenomena in PEM fuel cells by electrochemical impedance spectroscopy

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ARTICLE INFO

Article history:
Received 15 April 2012
Received in revised form
23 December 2012
Accepted 18 January 2013
Available online 26 February 2013

Keywords:
PEM fuel cells
Degradation mechanisms
Fuel starvation
Catalyst loss
Electrochemical impedance spectroscopy
Distribution of relaxation times

ABSTRACT

Electrochemical impedance spectroscopy (EIS) is identified as one of the most promising in-situ diagnostics tools available for assessing fuel cell ageing and degradation. In this work, the degradation phenomena caused by cell polarity reversal due to fuel starvation of an open cathode 16 membrane electrode assembly (MEA) – low power (PEM) fuel cell (15 W nominal power) – is reported using EIS as a base technique. Measuring the potential of individual cells, while the fuel cell is on load, was found instrumental in assessing the "state of health" of cells at fixed current. Location of affected cells, those farthest away from hydrogen entry in the stack, was revealed by very low or even negative potential values. EIS spectra were taken at selected break-in periods during fuel cell functioning. The analysis of impedance data was made using an *a priori* equivalent circuit describing the transfer function of the system in question – equivalent circuit elements were evaluated by a complex non-linear least square (CNLS) fitting algorithm, and by calculating and analyzing the corresponding distribution of relaxation times (DRT). Results and interpretation of cell polarity reversal due to hydrogen starvation were complemented with ex-situ MEA cross section analysis, using scanning electron microscopy. Electrode thickness reduction and delamination of catalyst layers were observed as a result of reactions taking place during hydrogen starvation. Carbon corrosion and membrane degradation by fluoride depletion are discussed.

1. Introduction

Fuel cells are prone to chemical, mechanical and thermal degradation modes that lead to a voltage/performance decline and lifetime reduction. Durability criteria for fuel cells require a minimum lifetime of 40000 h for stationary applications and 5000 h for automotive applications, making materials degradation a critical issue and creating the need for a more comprehensive knowledge about the mechanisms which are, at the present, not well understood. Normal degradation targets accepted for most applications [1,2], require less than 20% loss in the efficiency of the fuel cell system by end of life and a degradation rate of 2–10 μVh^{-1}.

Proton exchange membrane (PEM) fuel cells lifetime can be reduced by chemical degradation of the membrane electrode assembly (MEA) which is related to the stability of both

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0360-3199/$ – see front matter
http://dx.doi.org/10.1016/j.ijhydene.2013.01.132