Materials ageing mechanisms in PEM fuel cells

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Abstract

As fuel cell technology matures and time scale to commercialization decreases, the need for a more comprehensive knowledge of materials ageing mechanisms is essential to attain specified lifetime requirements for applications. In this work, the membrane-electrode assembly (MEA) degradation of a 5 cell PEM stack was evaluated, during and after fuel cell ageing in extreme testing conditions. Cross sections of the membrane catalyst layers and gas diffusion layers were examined indicating that cathode thickness is considerably reduced as a result of ageing. Catalyst particles were found to migrate outwards and located on carbon backings. Fluoride release was considered an indicator of membrane degradation, quantified using an ion selective electrode at gases outlet. MEA degradation mechanisms are discussed.

Keywords: *Fuel cells, durability, fluoride loss, scanning electron microscopy*

1 Introduction

At present, lifetime requirements for PEM fuel cells applications can not be guaranteed. A more comprehensive knowledge about materials ageing and degradation mechanisms is needed.

The membrane-electrode assembly (MEA) is considered key component in PEM fuel cells, with significant impact on cell performance [1]. MEA ageing mechanisms are not well understood.

In this work, *in-situ* evaluation of MEA degradation was conducted for a 5 cell PEM low power stack in extreme testing conditions. *Ex-situ* failure analysis was performed after the end of life of the stack.

Electrochemical techniques were used in combination with structural and chemical analysis, in order to correlate the performance of the cell with the material properties of the various MEA components and their ageing.

2 Experimental and Results

Polarization curves were conducted using a purpose built PEM test station and a 5 cell stack. The stack uses own designed flow field graphite plates, integrated in a series configuration. The open cathode allows feeding with air, which is designed to contribute to water removal and stack cooling.

The hydrogen feed gas was used either dry or humidified (forced to pass through a humidity pre-saturation chamber that incorporates temperature control before entering into the cell). Gas pressure and flux were controlled.

Voltage variations associated to pre-set current demand were taken as indicative of cell performance. Results were obtained for the stack in air-breathing conditions using a forced convection provided by a fan powered at optimized voltage. It is observed that mass transfer processes at the cathode dominate the overall performance. When sufficient oxygen is unavailable to feed the stack, current density is observed to drop, drastically [2].

Figure 1 shows typical polarization curves for every single cell in the stack. Results indicated that in the present configuration, the first and the last cell in the stack reflected the voltage loss found in the global polarization curve.

After 500 h cycling, maximum power of the cell was found to be reduced in 60 %.

The ultimate life of PEMFC was found to be primarily related to the chemical stability of the membrane. An ion selective fluoride electrode was

used to evaluate membrane degradation as a function of fluoride release at anode outlet, for the last 1000 hours of the stack life. A striking drop in cell potential was associated to a noticeable increase in fluoride loss and end of MEA life [3].

After cell dismantling, cross sections of MEA samples were observed for morphological and elemental analysis using a Phillips Scanning Electron Microscope, Model XL 30 FEG, coupled to an Energy Dispersive Spectrometer, EDS, allowing elemental mapping.

Figure 2 shows a scanning electron microscope view of the cross section of the fuel cell MEA after end of life.

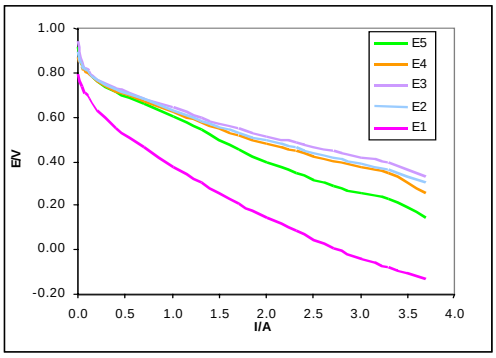

Fig. 1. Polarisation curve for air breathing fuel cell stack showing voltage and power vs. current profile, after load cycles at fixed current of 3 A.

Cathode thickness reduction is striking as well as the reduction of fluoride density in the membrane, on the anode side.

Catalyst particles were found to migrate outwards and located on carbon backings. The mobility of platinum on the carbon-supported electrocatalyst material is also demonstrated. Loss of Pt surface area is observed probably proceeding through electrodissolution/re-deposition and surface migration of Pt atoms.

Changes in the structure, chemistry and distribution of the electrocatalyst over time can lead to an increase in activation losses and therefore a decrease in cell performance. In particular, loss of surface area may occur due to sintering and/or oxidation of electrocatalyst particles.

There is a need to apply a full range of diagnostic techniques in order to understand MEA degradation and contribute to aiding the design and operating strategies in PEM fuel cells.

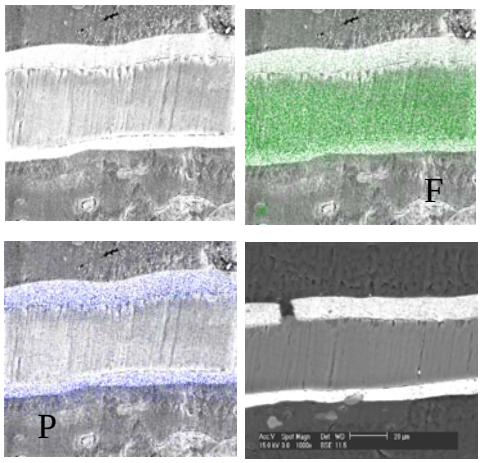

Fig. 2 Cross section SEM view of the MEA displaying results of elemental mapping analysis carried out using EDS for fluoride and platinum. Striking reduction of cathode thickness is observed.

References

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