LA-UR- 9~~3~~6-3233

CONF-961107--1

Title:

STAINLESS STEEL WIRE MESH FLOW-FIELDS FOR POLYMER ELECTROLYTE FUEL CELLS

RECEIVED
OCT 1 1 1996
OSTI

Author(s):

C. Zawodzinski, M. S. Wilson, S. Gottesfeld

Submitted to:

Fuel Cell Seminar
Kissimee, FL
November 1996

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos
NATIONAL LABORATORY

LA-UR- 96-2233

STAINLESS STEEL WIRE MESH FLOW-FIELDS FOR POLYMER ELECTROLYTE FUEL CELLS

Christine Zawodzinski, Mahlon S. Wilson and Shimshon Gottesfeld
Electronic and Electrochemical Materials and Devices Research Group, MS D429
Los Alamos National Laboratory, Los Alamos, N.M. 87545

Introduction

The advantages offered by the PEM fuel cell, efficient power generation with little or no environmental emissions, low operating temperature, and non-liquid/non-corrosive electrolyte, make it attractive as a potential power source for transportation and for portable and stationary power generation applications. Fuel cells have been successfully demonstrated in a number of aerospace, utility and military applications, however, the high cost of fuel cells compared to conventional power generation technologies has delayed their potential widespread use. Stack manufacturers have historically used high-platinum loading membrane/electrode assemblies (MEAs) and intricately machined graphite bipolar plates, which have made the cost too high for most commercial applications. We have thus focused our efforts on decreasing the cost of these components in order to demonstrate an inexpensive, yet high performance PEM fuel cell. Here, we describe the design and demonstration of a 100 cm^2 (active area) cell that utilizes ultra-low platinum loading MEAs and inexpensive, stainless steel wire screen flow-fields.

Membrane/Electrode Assembly

Our efforts in the design of this cell involved adapting ultra-low platinum loading technology developed at Los Alamos [1] to reproducibly fabricate larger-scale, high performance MEAs. This was achieved using a computer-controlled chart-recorder process that has been previously described [2]. A typical MEA consists of a 100 cm^2 active area catalyzed Nafion™ membrane (Nafion 112 from DuPont) and two E-TEK (Natick, MA) carbon cloth backings. The platinum loading is approximately 0.14 mg Pt/cm^2/electrode, which corresponds to a dramatic decrease in total stack platinum content and significantly reduces the cost of the MEA.

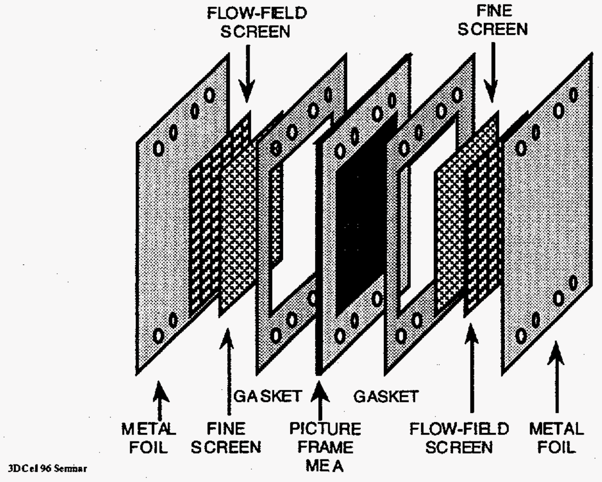

Figure 1. Components of a unit cell utilizing wire-screen flow-fields, metal foil separators, and a Picture Frame MEA.

Wire Screen Flow-Fields and Unit Cell Configuration

More recently, we have focused on replacing machined graphite or machined metal flow-fields with inexpensive, off-the-shelf wire screens and foils [2]. The flow-fields are based on simple woven wire-mesh screens of various stainless steels, which can be sandwiched around a thin metal plate of the same material to create a bipolar plate/flow-field configuration for use in a stack. Major advantages of using stainless steel wire screens include the elimination of expensive raw materials as well as machining and/or other special fabrication costs. Many types of screens are readily available in a variety of thicknesses and mesh sizes. The screens are also relatively light-weight in comparison to thick graphite or solid metal plates. Another advantage of metal screen hardware is that the screens and foils are not brittle, thus very thin unit cells may be possible. The wire screen flow-field consists of a sandwich of two screens, a coarse mesh and a fine mesh, that sit within a compressible gasket "frame" backed by a thin, metal foil (Figure 1). The fine mesh screen, which is situated between the coarse mesh screen and the MEA, allows adequate reactant access to the MEA while protecting the carbon cloth backing from squeezing into the coarser screen. The MEA is encased within a thin metal "picture frame" which simplifies sealing and manifolding and has the added benefits of making the MEA easy to handle and align within the cell during assembly. Cooling plates (not depicted in the figure) can be provided as well by sandwiching two unit cells around a wire-screen flow-field.

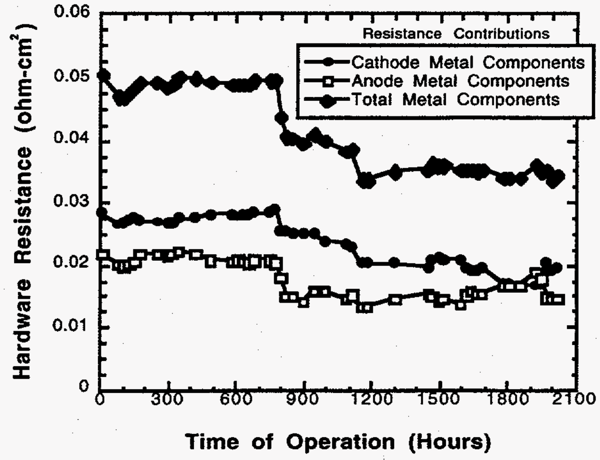

Figure 2. Measured contributions of the 316 SS metal components to the cell resistance on the anode and cathode sides and the total contribution over the life of a cell.

100 cm^2 Single Cells

The first screen flow-fields tested were made of untreated 304 stainless steel (SS), however, it became necessary to acid-etch the screens and foils to remove surface oxide layers that decreased their conductivity. A typical 100 cm^2 single cell utilizing the acid-etched 304 SS flow-fields and operating on humidified, pressurized H_2/air provided about 0.5 W/cm^2 at 0.62 V (50% LHV voltage efficiency). Both the hydrogen and air gas streams were pressurized at 3 atm and flow rates were maintained at approximately 2 and 4 L/min., respectively. These flows are slightly greater than the 1 and 2X the stoichiometric amount of flow required to operate the cell at 1 A/cm^2. Typical pressure drops across the cathode flow-field were about 0.13 atm (2 psi). The high frequency cell resistance (HFR) was close to 0.15 Ω cm^2, which is somewhat high compared to small cells, but not unreasonable considering the numerous components and interfaces involved and the size of the active area. With time, the 304 SS cells demonstrated loss of component conductivity. It was anticipated that the use of 316 SS instead of 304 would improve the stability of the metal structures. Thus, cells were assembled using 316 SS components that were not surface treated beyond a simple cleaning. The latter cells performed as well as the etched 304 SS cells and showed no appreciable performance losses over time.

One such 316 SS single cell was operated for 2000 h at a constant voltage of 0.5 V. The long-term performance of the cell was monitored in a number of ways: by measuring voltage drops across the cell components, measuring the HFR, and by periodically obtaining polarization curves. With the cell set to operate at a fixed current, the voltage drops were measured between the various components, which allows the calculation of the contribution of the metal components to the cell resistance. The 2000 hour life test results are shown in Figure 2.

The anode and cathode metal component contributions in Figure 2 consist of the resistances of all components and interfaces between a fine screen (positioned against the MEA) and its respective current collector plate. Thus, the current traverses 1) the SS fine screen, 2) the SS flow-field screen, 3) an SS foil separator plate, and 4) the current collector plate, a total of four components and three interfaces. Also shown in this figure is the total contribution of the metal hardware, calculated from the measured voltage difference between the fine wire sense leads and the current collector plates at a fixed current. The curves in Figure 2 demonstrate that the contribution of the metal hardware is relatively stable during the 2000 hour test. The exception occurs at about 800 h, whereupon the tie-bolts holding the cell together were re-torqued, which brought the components together more forcefully and substantially improved the conductivities across the interfaces. The improvement in cell performance is demonstrated in Figure 3. From the improvement in the low-current density region of the curves, it is evident that the performance enhancement upon tightening the cell was also due to realizing more effective electrode performance.

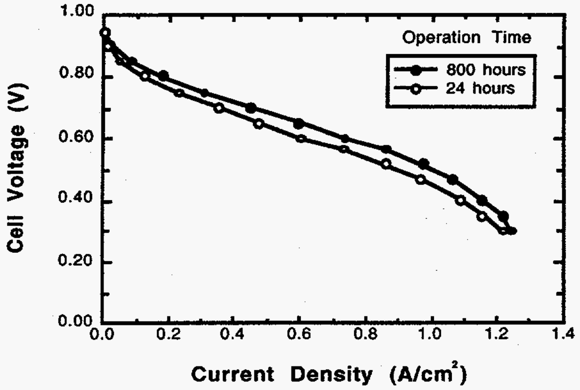

Figure 3. Polarization curves of a cell using 316 SS wire screen and foil components after 24 and 800 h. The improvement is primarily due to re-torqueing of the tie-bolts.

If the stainless steel in the cell was corroding or passivating, the resistance of the metal components would tend to increase over time. This is not observed in Figure 2, which either suggests that corrosion was minimal or that residual corrosion did not cause any appreciable surface passivation. Polyvalent metal ions liberated by residual dissolution of the metal hardware could conceivably enter into the polymer electrolyte membrane and tie up active sites, thus adversely affecting the protonic conductivity of the ionomer. Samples of the MEA were analyzed by EDS (Energy-Dispersive X-Ray Spectroscopy) for the presence of molybdenum, a component unique to 316 SS. No molybdenum was found, though it should be stressed that the detection levels are only in the parts per thousands. Further analyses are underway. In any case, loss of conductivity by ionic inclusion should have been observed by an increase in cell HFR. From Figure 4, the HFR did fluctuate with time, which may only be a reflection of the changes in hydration state of the membrane.

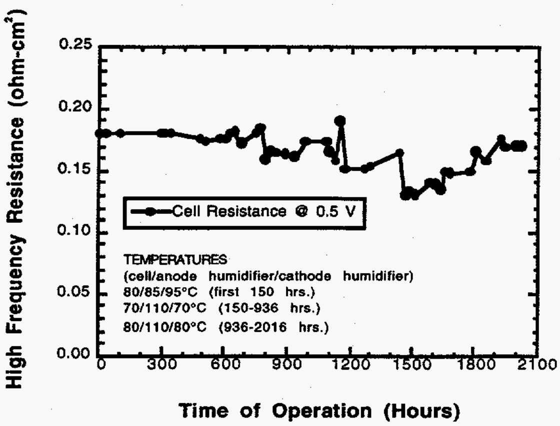

Figure 4. High Frequency Resistance (HFR) of a cell using 316 SS wire screen and foil components over 2000 h.

The 316 SS hardware was clearly superior to the 304 SS in terms of long-term stability. Disassembly after 2000 hours of the 316 SS cell revealed no visible corrosion of the metal components. Perhaps 316L SS could be even more stable than 316 SS because of its lower carbon content and corresponding lower corrosion susceptibility [3].

The long-term performance and stability obtained with the use of untreated metal alloy screens/foils in combination with low platinum loading MEAs are encouraging because these components could provide the basis for a very low-cost PEM fuel cell stack technology.

Acknowledgment

This work was supported by the Hydrogen Program of the Department of Energy, Office of Utility Technologies.

References

1. M. S. Wilson, J. Valerio and S. Gottesfeld, "Low Platinum Loading Electrodes for Polymer Electrolyte Fuel Cells Fabricated Using Thermoplastic Ionomers," Electrochim. Acta, Vol. 40, p. 355, 1995.
2. C. Zawodzinski, M. S. Wilson, and S. Gottesfeld, "PEM Fuel Cell Stack Development Based on Membrane-Electrode Assemblies of Ultra-Low Platinum Loadings," in "Proton Conducting Membrane Fuel Cells I," S. Gottesfeld, G. Halpert, and A. Landgrebe, Eds., The Electrochemical Society Proceedings Series, Vol. 95-23, p. 57, 1995.
3. R. K. A. M. Mallant, F. G. H. Koene, C. W. G. Verhoeve and A. Ruiter, "Solid Polymer Fuel Cell Research at ECN," Program and Abstracts of the Fuel Cell Seminar, p. 503, Nov. 28 - Dec. 1, San Diego, CA, 1994.