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Development of a 100W PEM Fuel Cell Stack for Portable Applications

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Abstract

In this work, an air cooled 100W stack was designed, manufactured and tested. The bipolar plates were manufactured by CNC machining of graphite. Membrane electrode assemblies (MEAs) were produced by spraying catalyst ink onto the gas diffusion layer (GDL). A fuel cell stack was assembled with 20 cells each having 12.25 cm^2 active area. The test was carried out with H_2 at anode and air at cathode side both at 100% relative humidity having 1.2 and 2 stoichiometric ratios, respectively. The operating temperature of the stack was kept at 60^oC during the test. The results indicated that the stack has a maximum power of 60W at 12V operation. Cell numbers 1, 2, 3 and 20 always had less potential than the 0.6V average cell voltage. Uniform cell voltage distribution has been achieved by improving thermal management and reactant distribution.

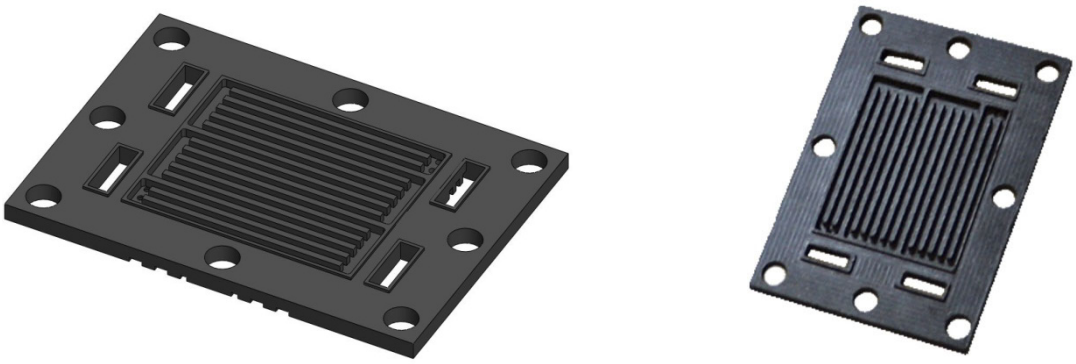
1 Introduction

Fuel cells are electricity generators which are converting chemical energy of hydrogen directly to electricity by means of electrochemical oxidation and reduction reactions. While the operation of them is similar to batteries without any mechanical parts, the electricity generation is continuous as the case in mechanical electricity generators. A single PEM fuel cell can only generate electricity with a potential between 0.5V and 1V. However, one needs more potential in order to utilize the electrical energy generated by fuel cell. The useful potential can be achieved by stacking cells in series to form a PEM fuel cell stack. However, water and heat management play important roles in bipolar stack performance [1]. The aim of this study is to design and manufacture an air/H_2 100 W PEM fuel cell stack for portable applications.

2 Design of the Stack

2.1 Bipolar plates

Figure 1 shows the bipolar plate that was designed and manufactured by means of a CNC router in our lab. The active area of the plate was 12.25cm^2 and machined 300μm above the gasket area. The active area of the plates designed and manufactured having three parallel serpentine flow channels with lands are 1mm wide and 1mm depth.



(a) (b)

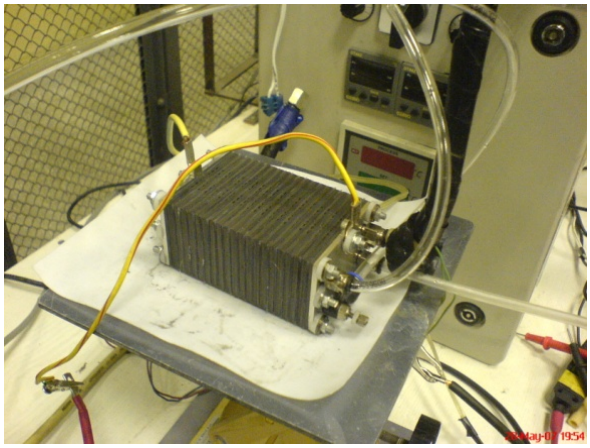
Figure 1: Designed and machined graphite bipolar plate (a) CAD solid model (b) photograph of machined bipolar plate.

2.2 MEAs used for the stack

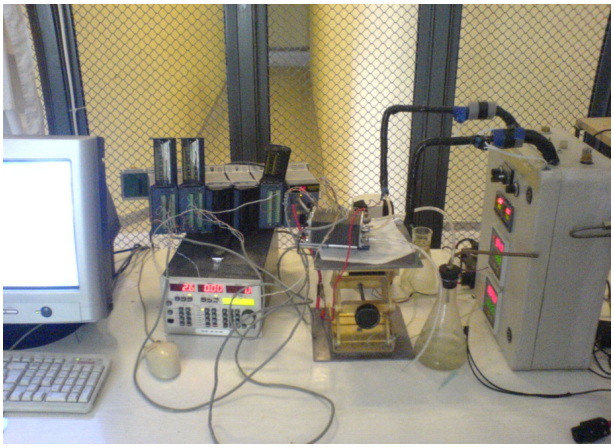
The membrane electrode assembly (MEA) was prepared by spraying catalyst ink onto the gas diffusion layers (GDLs). The gas diffusion layer was GDL 31 BC type (SGL Carbon, Germany). The platinum loading was 0.4 mg Pt/cm^2, whereas Nafion® loading was 1.2 mg Nafion®/cm^2 in catalyst ink. After spraying the catalyst ink onto the gas diffusion layer a five layer MEA was prepared by pressing these GDLs onto the Nafion® 112 membrane (thickness: 50 μm) at 130^{o}C, 250 psi for 3 min [2,3].

2.3 Test station and performance tests

The fuel cell tests were performed in a homemade fuel cell test station which is shown in Figure 2. The test station is capable of testing single PEM fuel cells and small PEM fuel cell stacks. In order to access the required power, reactant gas flow rates were adjusted with mass flow controllers (Aalborg GFC 171). The flow rates for the anode and cathode were adjusted as having 1.2 and 2 stoichiometric ratio, respectively. Prior to entering the fuel cell stack, these gases were humidified to 100% relative humidity (RH) by passing them through the stainless steel humidifiers. The gas lines were heated to prevent the condensation of the water in the lines. The temperature in the humidifiers, the gas lines and the fuel cell were controlled by PID temperature controllers. The exhaust gases pass through water columns. The power of the stack was adjusted by an electronic load (Dynaload RBL488, TDI) that was controlled by a fuel cell testing software (FCPower). Voltage of the cells was monitored and logged by a cell voltage monitor system (Yokogawa MX100).



(a)



(b)

Figure 2: Photograph of (a) PEM fuel cell stack (b) the test station.

3 Results and Discussion

The stack was assembled with 20 cells and the performance tested in the test station (Figure 2). The stack temperature was kept at 60°C during the test. Figure 3 illustrates the cell voltage measured at each cell of the stack at OCV, 13V, and 12V of stack potential. Most of the cells have an open circuit voltage close to 1.1V. Whereas, four cells which are the first, second, third and the last cell have lower OCVs (0.84V – 0.97V) than the other cells. Stack OCV is 21 V. However, voltage drops was observed as expected when the stack is connected to an external load. When the stack voltage is adjusted to 13V, most of the cells have a potential above the average voltage (0.65V). The first, second, third and the last cells have lower voltage (0.45V - 0.56V) than the average voltage. When the stack voltage is adjusted to 12V, most of the cells are above the average cell voltage (0.6V). In parallel to the previous measurements the first, second, third and the last cells have lower voltage (0.36V - 0.48V) than the average voltage.

Figure 4 illustrates the polarization curve for the tested stack. The maximum power of the stack is 60W that is obtained at 11V and at a current 5.5A. The low performance of the first, second, third and twentieth cells decreases the design value (100W).

In Table 1, the results of the present study are compared with the published performance results of 12-220W hydrogen-air PEMFC short stacks and stacks. The power density obtained with short stacks is reported as 550-630mW/cm^2 [4, 5]. In the present study we achieved higher performance (250mW/cm^2) with stacks than the results of Jiang and Chu (2001) [1] (57-150mW/cm^2) and Urbani et al. (2007) [6] (80mW/cm^2).

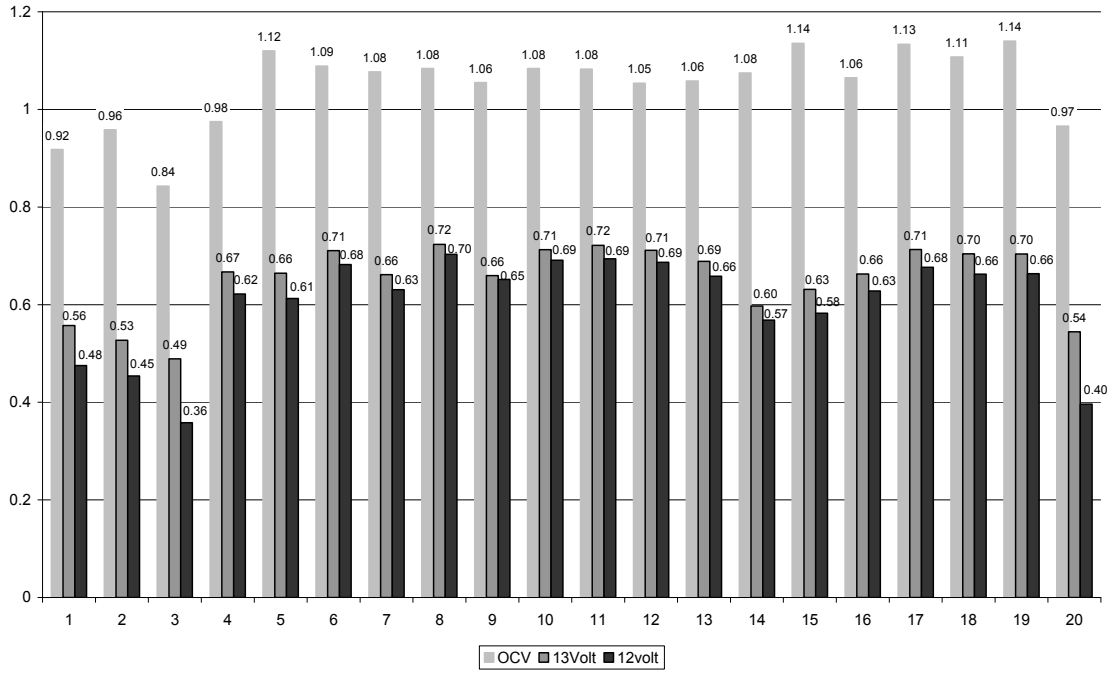


Figure 3: Cell voltage distribution of the stack.

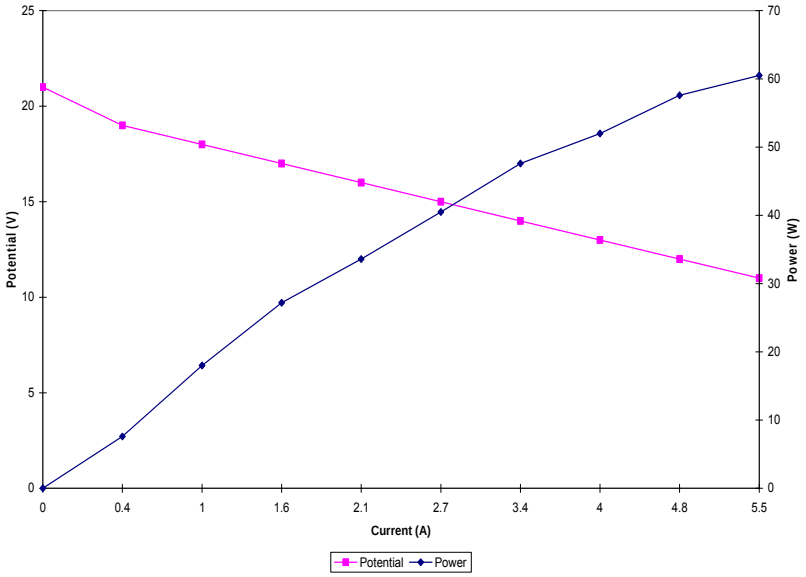


Figure 4: Polarization curve for the tested stack.

Knobbe et al. (2004) [4] achieved a 33% increase in power output of a PEMFC short stack by active gas management (AGM) system integrated by controlling the inlet and outlet of each cell individually. However, that is not applicable for real portable applications.

Weng et al. (2007) [5] developed a 200W short stack with four cells. They reported the maximum power densities of short stacks having 1, 2, or 4 cells as 0.55Wcm^{-2}, 0.48Wcm^{-2} or 0.38Wcm^{-2} respectively. They concluded that as the cell number increases, the uniform

distribution of humidified gases, optimal moisture of membrane and gas diffusion layer to avoid the water flooding become significant.

Table 1: Comparison of the published performance results of the 12-220W hydrogen-air PEMFC short stacks and stacks.

Stack Power (W)	Number of Cells	Active Area (cm^2)	Power density (mW/cm^2)	Reference	Year
12 to 150	6 to 30	19 to 60	57 to 150	Jiang and Chu	2001
50	6	94.3	630	Knobbe et.al.	2004
20	10	25	80	Urbani et.al.	2007
220	4	100	380	Weng et.al.	2007
50	20	12.25	250	Present study	2010

4 Conclusion

Most of the cells operated at a potential higher than the average cell potential of 0.6V. The first three cells at the entrance and the last cell give a potential (0.36V - 0.48V) less than the average potential. The performance loss is most probably due to the thermal and reactant misdistribution. Uniform cell voltage distribution can be achieved by improving thermal management and reactant distribution.

Another reason might be due to differences in the performances of MEAs prepared by hand spraying. Therefore, it is recommended to improve the MEA preparation technique to produce MEAs having uniform thickness with identical catalyst load.

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