Integrated Miniature Fuel Cell – Hydrogen Generator for Portable Power Generation

B. Gurau[1], L. Zhu[2], H.S. Kim[1], R.D. Morgan[1], V. Vilasur Swaminathan[2]
M.A. Shannon[2], R.I. Masel[1]
[1]Chemical & Biomolecular Engineering
[2]Mechanical Science & Engineering
600S. Mathews Ave
University of Illinois, Urbana, IL 61801 USA

The objective of this paper is to describe a miniature hydrogen fuel cell that produces 4 times higher power output than other previously reported miniature hydrogen fuel cells (Table 1) and its integration with a metal hydride based H_2 generator.

MEMS based fuel cells have been proposed to replace batteries in distributed sensor networks, on chip power, and implantable devices. However, MEMS based fuel cells give performance no better than miniature batteries [1-9]. Prior to our work, the best MEMS based hydrogen/air fuel cell only produced 70 mW/cm^2 compared to ca. 280 mW/cm^2 in our device. Yu et al [2] showed 195 mW/cm^2, but running pure oxygen on the cathode. Our device shows the highest power output of those shown previously, operating with a self-breathing cathode.

In this paper, we will describe the fabrication of the miniature fuel cell and we will discuss its advantage as far as size is concerned then focus on its performance. Then the MEMS H_2 generator will be briefly discussed and the results of its integration with the miniature fuel cell will be shown.

The Nafion® membrane is sandwiched between two 25 micron stainless steel sheets with the aid of an adhesive developed at UIUC. To ensure better bonding the SS-Nafion sandwich is hot pressed at ca. 130°C for 5 minutes. Pt based catalyst ink was prepared and applied on top of Nafion® via direct paint method (Fig. 1).

The H_2 generator was produced using conventional microfabrication steps, such as photolithography, ICP-DRIE, etc.

Several experiments were then run to characterize the hydrogen utilization rate as well as the IV performance (table 1 and Fig. 2). The results with the integrated device are shown in Fig. 3. Table 1 also compares our device with other previously published device. Our device shows the highest power output even with stagnant air on the cathode.

Table 1. A comparison of the performance of our device operated on H_2 at RT to those reported previously. We only included references where hydrogen was the fuel and the peak power was more than 10 mW/cm^2

	Open Cell Voltage (V)	**Cell Area mm^2**	**Design**	**Peak Power Density (mW/cm^2)**
Yu *et al.* [2]	0.95	500	Silicon wafers bolted to conventional MEA	195 with pure O_2 flowing on cathode
Modroukas *et al.* [3]	0.85	100	Silicon wafers bonded to conventional MEA	70 with flowing air on cathode
Meyers *et al.* [4]	0.9	Not Given	Silicon wafers bonded to conventional MEA	63 with pure O_2 flowing on cathode
Yeom *et al.*[5]	0.95	100	Silicon wafers bonded to Nafion	35 with stagnant air on cathode
Zhiyong *et al.*[6]	0.96	123	Silicon wafers bonded to Nafion	13.7 with pure O_2 flowing on cathode
Pichonat et al [7]	0.8	7	Nafion filled silicon MEA	18 with pure O_2 flowing on cathode
Our Device	0.95	1	Nafion filled silicon MEA	280 with self breathing cathode

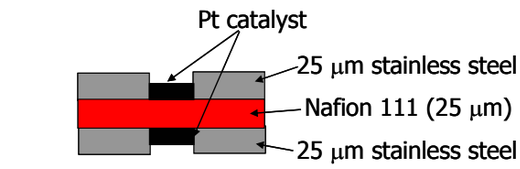

Fig. 1. (Top) Schematic of fuel cell. (Bottom left) Fuel cells of 1 and 4 mm^2. (Bottom right) H_2 generator integrated with the fuel cell.

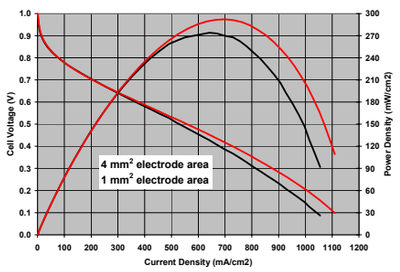

Fig. 2. Polarization curve with H_2 from external source

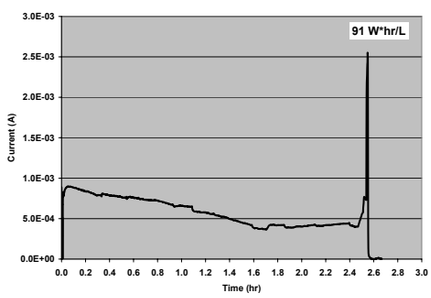

Fig. 3. Chronoamperogram for 1 mm^2 fuel cell with the attached H_2 generator

1. Pichonat, T. and B. Gauthier-Manuel, Microsystem Technologies, 2007. **13**(11): p. 1671-1678.
2. Yu, J., et al,. Journal of Power Sources, 2003. **124**(1): p. 40-46.
3. Modroukas, D., et al., Journal of Micromechanics and Microengineering, 2005, **15(9)** S193.
4. Meyers, J.P. and H.L. Maynard, Journal of Power Sources, 2002. **109**(1): p. 76-88.
5. Yeom, J., et al., Sensors and Actuators B: Chemical, 2005. **107**(2): p. 882-891.
6. Zhiyong, X., et al., Journal of Micromechanics and Microengineering, 2006(10): p. 2014.
7. Pichonat, T. and B. Gauthier-Manuel, Microsystem Technologies, 2006. **12**(4): p. 330-334.
8. Chu, K.L., M.A. Shannon, and R.I. Masel, Journal of the Electrochemical Society, 2006. 153(8): p. A1562-A1567..
9. Chu, K.L., M.A. Shannon, and R.I. Masel, Journal of Micromechanics & Microengineering, 2007. 17(9): p. S243-S249.