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THE APPLICATION OF A PORTABLE DMFCS STACK WITH FRACTAL CURRENT COLLECTORS USING HILBERT GEOMETRY FOR A CHARGER SYSTEM

Shah-Rong Lee
Technology and Science Institute of Northern Taiwan
Taipei, Taiwan

Yean-Der Kuan
National Chin-Yi University of Technology
Taichung, Taiwan

Min-Feng Sung
Tamkang University
Taipei, Taiwan

Jing-Yi Chang
Tamkang University
Taipei, Taiwan

Shi-Min Lee
Tamkang University
Taipei, Taiwan

ABSTRACT

The study develops a portable charger platform that contains a direct methanol fuel cell (DMFC) consisting of a set of planar DMFCs with current collectors, Fractal Hilbert Geometry and a power balance plant (BOP). The third order Hilbert geometry is used for the 35×35 mm2 current collectors. The system output design is set at 5V controlled by a power balance plant applied to 3C low power products. This paper discusses the Methanol feed rate, air flow rate, bipolar plate thickness and power balance plant layout for DMFC performance. To evaluate the reliability and efficiency of the DMFC power source, a data acquisition (DAQ) system connected to a real time monitor is used to assess the current and voltage output from the DMFC system while running different parameters. The results show the current of the charger system obtain 84 mA and 103 mA under 2V and 3V input voltage converters respectively. The transform efficiency for power balance plant is up to about 84% for 3V input voltage converter.

INTRODUCTION

Due to the severe challenges of petroleum exhaust and aggravating environmental pollution, it is very important to develop renewable, substitute clean energy resources. The fuel cell is one of the most important clean substitute energy converting devices. The main advantages of a fuel cell include higher efficiency, no moving parts, silent, clean and easy independent scaling between power and capacity. The direct methanol fuel cell (DMFC) has the specific advantages of system simplicity, convenient to carry, high energy density and low cost. A DMFC operates at near room temperature and has a short start-up time. Therefore, the DMFC has great potential in portable applications [1-3].

The study of the operating parameter effects could help developers to make proper parameter controls during operation. Narayanan et al. discussed the pressure, temperature and airflow effects with results that showed that cell performance is higher when the temperature is increasing but more methanol crossover occurs. The airflow rate is low at higher temperatures but is obvious at pressures close to ambient [4]. Ge and Liu made systematic experiments to investigate the operating parameter effects on DMFC performance. The parameters included the cell temperature, anode fuel flow rate and cathode airflow rate [5]. In DMFC construction, the bipolar plates/current collector is a major component that contributes to the major stack cost and also significantly affects cell performance [6]. Creating a DMFC current collector design such that the cell displays good cell performance is important for the practical application. The fractal geometry theory was first proposed by Mandelbrot. The main characteristics of a fractal pattern are self-similarity, sub-divisibility and recursive nature [7]. Tüber et al. presented a fractal structure as a flow-field in PEMFCs and DMFCs for portable applications. The results showed that a serpentine flow channel has better cell stability and performance but much more pressure drop across the channel. Both multiple-branched fractal and parallel flow fields could be alternate structures with lower pressure drop with similar performance [8]. Chang et al. presented a DMFC that contained current collectors with Sierpinski carpet fractal holes [9]. The results showed the DMFC with the 2nd order fractal geometry showed better performance than current collectors with standard arranged holes. In addition, a longer total hole perimeter represented better cell performance, while a shorter total perimeter length and free open hole ratio lead to poor cell performance. Therefore, a longer total perimeter length under the same free open ratio is recommended for future current collector/polar plate design. A further study on the current collector with larger total free open ratio and longer total opening perimeter length using the Hilbert curve, a continuous type fractal geometry, was adopted to design the current collectors with the total free open ratio and total opening perimeter length significantly increased. The results showed Current collectors with a more uniform opening distribution and higher total opening perimeter length could reduce the anode flow rate sensitivity in the cell performance. A higher total free open ratio and total opening perimeter length in the current collectors could increase cell performance [10]. The DMFC stack discussed in this paper adopts the 3rd Hilbert curve fractal current collectors.

EXPERIMENTAL SETUP

The study first investigates the performance of a DMFC stack with fractal current collectors using Hilbert Geometry as shown in Fig. 1. The experimental setup is shown in Fig. 2. The system includes (a) data acquisition system, (b) Electro-Load, (c) AC air pump, (d) temperature controller water batch, (e) DMFC Stack (f) Liquid pump. The self-developed data acquisition system program simulates the cell performance for different experimental parameters. The DMFC stack uses 5~15 cc/min. methanol flow rate and 25~55 ^{0}C temperature variation. The designed converter is connected with the DMFC stack. The input voltage is set at 2V/3V, and the rating output is controlled at 5V. Therefore, 5V output for the DMFC system is satisfactory with 3C lower power products. The DC-DC converter is shown in Fig. 3 and the basic circuit theory is presented in Fig. 4.

RESULTS AND DISCUSSION

Figure 5 shows the DMFC stack cell performance for different flow rates. The power density is based on single MEA area (3.5*3.5cm^2). When the methanol fuel flow rate is 10 cc/min. the voltage and power outputs present the best cell performance. The worse cell performance for lower and higher methanol flow rate occur when the methanol flow rate is lower. The cell reactions produce bubbles that are not easily drained and accumulated in the flow path. When the methanol flow rate is higher, the methanol fuel chemical reaction is not complete. Figure 6 shows the DMFC stack cell performance for different temperatures. When the temperature is higher, the cell performance is better. However, as this study is designed for a portable charger system, the cell performance measured data will focus on 250C when the DC-DC converter is connected with the DMFCs stack. Tables 1 and 2 are show the output current and transform efficiency for different converter rating input voltage. When the converter rating input voltage is 3 V, the system output current is 84 mA and the efficiency is up to about 84%. When the rating input voltage is 2 V, the system output current is 103 mA, but the efficiency decays to 50%. Lower converter rating voltage obtains higher current output, but the transformed efficiency is lower.

CONCLUSION

This study successfully developed a DMFC stack with 3rd Hilbert curve current collectors. A DC-DC converter connected to the DMFC was also discussed. When the voltage converted from 3V of the DMFC stack to 5V, the efficiency of the conversion was up to 84%. However, the efficiency of the converter decayed to 50% when the voltage was converted from 2V to 5V. Therefore, it is important that a suitable converter for a DMFC stack shall be obtained in real applications.

ACKNOWLEDGMENTS

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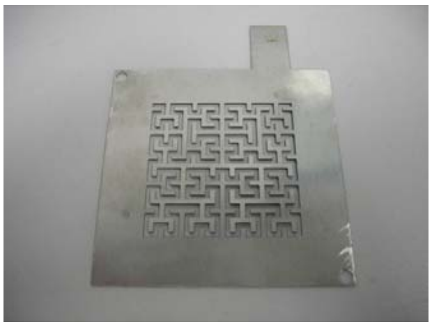
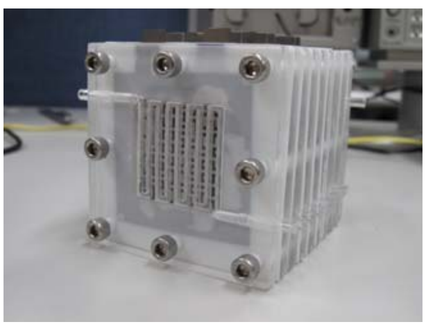


(a) Hilbert curve fractal current collector



(b) DMFC stack

Fig1. The DMFC with current collectors using Fractal Hilbert geometry

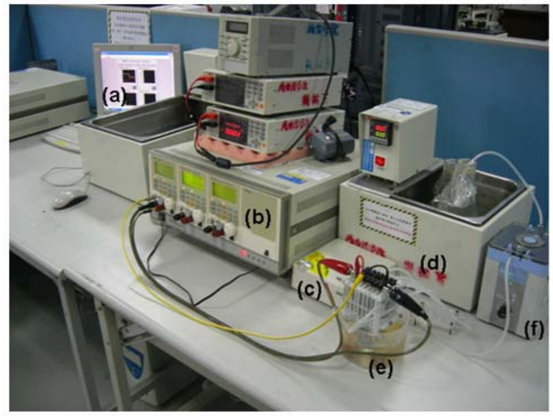


Fig. 2 Experimental setup (a) data acquisition system, (b) Electro-Load, (c) AC air pump, (d) temperature controller water batch, (e) DMFC Stack (f) Liquid pump

Fig3. The DC-DC converter

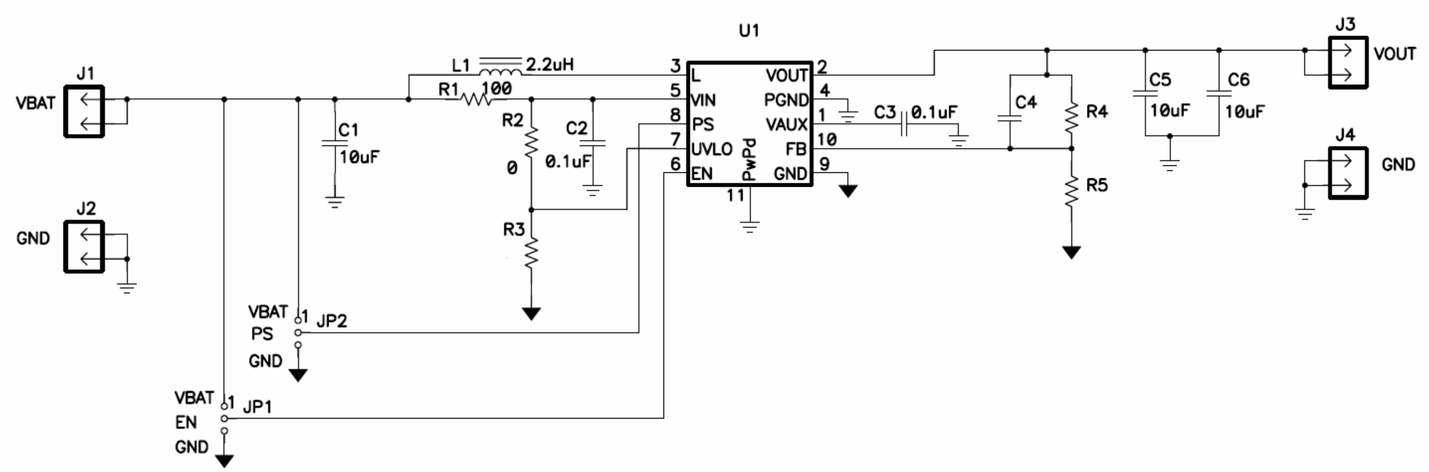


Fig4. The DC-DC converter circuit

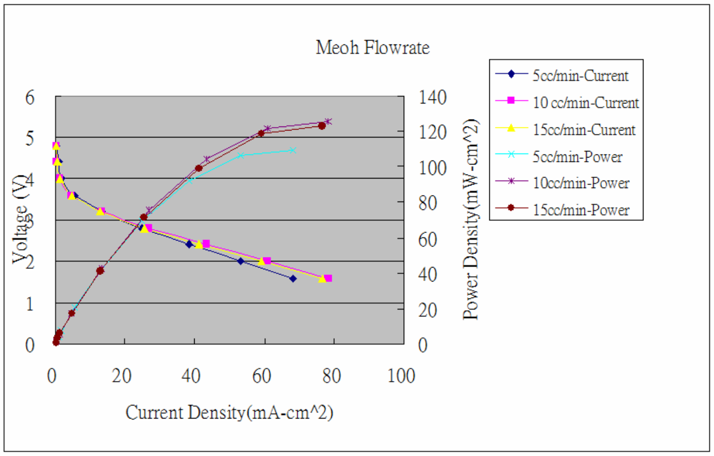


Fig5. The cell performance of DMFCs stack under different flow rates

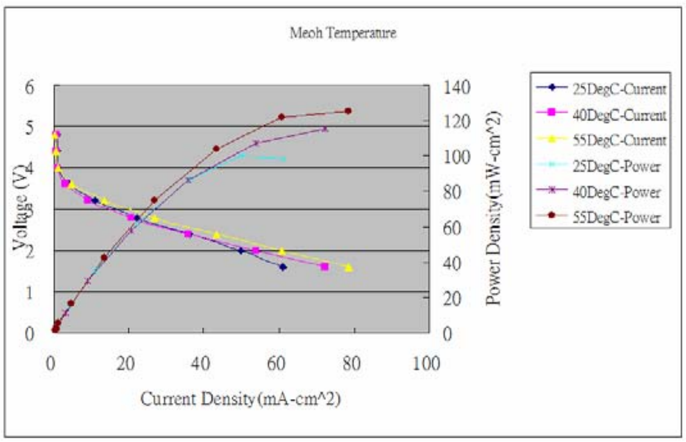


Fig6. The cell performance of DMFCs stack under different temperatures.

Table 1. The output current and efficiency for 3V input voltage converter.

Time(min)	Vin(V)	Ain(mA)	Vout(V)	Aout(mA)	Eff.
5	3	168	5	84	83%
10	3	166	5	84	84%
15	3	167	5	84	84%
20	3	167	5	84	84%

Table 2. The output current and efficiency for 3V input voltage converter.

Time(min)	Vin(V)	Ain(mA)	Vout(V)	Aout(mA)	Eff.
5	2	510	5	112	55%
10	2	520	5	108	52%
15	2	500	5	103	52%
20	2	520	5	103	50%