

## Scale-up and bipolar arrangements of a Swiss-roll mixed-reactant fuel cell

Amin Aziznia, Colin W. Oloman\*, Elöd L. Gyenge\*  
 Department of Chemical and Biological Engineering &  
 Clean Energy Research Center,  
 The University of British Columbia,  
 2360 East Mall, Vancouver, BC, Canada V6T 1Z3

The conventional design of PEM fuel cell stacks is based on a plate-and-frame in series architecture that evolved from Volta's original concept of the zinc-air battery stack. The performance, durability and cost of the various PEM fuel cell stack components (membrane, electrodes, bipolar flow-field plates) in conjunction with the complex thermal and water management, are some of the major challenges hampering the larger scale adoption of this technology.

Recently, we introduced an innovative Swiss-roll architecture for mixed-reactant fuel cells (MRFCs) both in monopolar and bipolar mode. The Swiss-roll MRFC (SR-MRFC) addresses some of the above-mentioned challenges of fuel cell technology by eliminating the need for ion exchange membranes and bipolar flow-field plates, while providing a lighter, more compact, cylindrical stack architecture [1,2]. As shown in Fig. 1, in the Swiss-roll design, a flexible sandwich of electrodes and separators is rolled around an electronically conductive central axis to give a compact 3D electrode space for the fuel cell reactions. The Swiss-roll MRFC concept is applicable to a variety of alkaline or acid fuel cell systems.

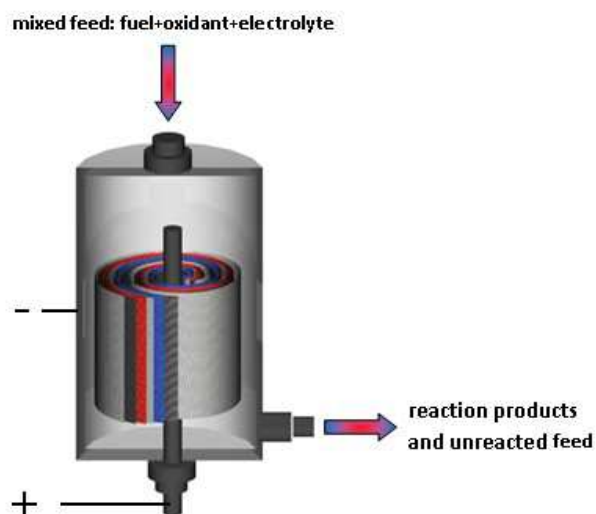


Fig.1: Conceptual view of a Swiss-roll MRFC

In our previous work satisfactory performance of the SR-MRFC was obtained for a direct borohydride fuel cell (DBFC) supplied with a two-phase mixture of aqueous 1 M  $\text{NaBH}_4/2$  M  $\text{NaOH}$  and oxygen gas. There, a  $20 \text{ cm}^2$  geometric surface area SR-MRFC with 2 layers of a hydrophilic microporous separator (Scimat<sup>®</sup> 720/20) and a Pt- $\text{MnO}_2$  anode-cathode pair was operated in monopolar single-cell mode at 323 K, 105 kPa(abs) to give a peak superficial power density of  $640 \text{ Wm}^{-2}$  ( $64 \text{ mWcm}^{-2}$ ) [2]. For bipolar operation of Swiss-roll MRFC, two arrangements are proposed, as shown conceptually in Fig. 2. In the first arrangement, the bipolar plates of a conventional fuel cell are replaced by coarse metal

screens that form the main passages for flow of the two-phase fuel-oxidant mixture through each cell, while providing electronic contact between adjacent cells. The first arrangement for bipolar operation of MRFC composed of two cells in series showed that the cell voltage (both at open circuit (OCV) and under polarization) increased less than two times. For example, the OCV was 1.2 V, while the OCV of a single cell was 0.8 V. The fact that the bipolar cell voltage is not two times that of a single cell can be explained by the establishment of shunt currents, which are a common occurrence in multi-polar electrochemical reactors when there is an ionically conductive pathway between cells [3]. To lower the shunt current between the cells, the effectiveness of the first SR-MRFC design depends on maintaining a high gas to liquid hold up ratio and consequent low effective ionic conductivity in the bipole fluid distributors.

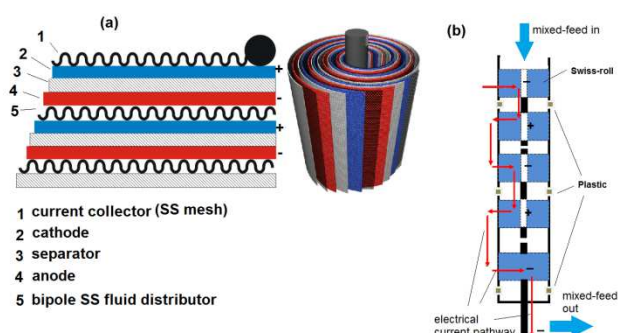


Fig.2: Conceptual view of bipolar arrangements for SR-MRFC (a) first arrangement; example of 2 cells in series (b) second arrangement; example of 5 cells in series

In the second configuration of the multi-polar SR-MRFC (Fig. 2), the segmentation of the electrodes showed promise for minimizing the shunt currents. Hence, the cell voltage scaled proportional to the number of cells connected in series.

To further exploit the Swiss-roll concept, the present work focuses on scale-up and development of bipolar arrangements by suppressing the shunt currents that by-pass the Faradaic processes and compromise the reactor performance.

### References

- [1] C. W. Oloman, UK Patent GB2474202 (B), 2012.
- [2] A. Aziznia, C.W. Oloman, E.L. Gyenge, "A Swiss-roll liquid gas mixed-reactant fuel cell", *Journal of Power Sources*, 212 (2012) 154–160.
- [3] A.T. Kuhn, J.S. Booth, *J. Appl. Electrochem* 10 (1980) 233-237.

\* Corresponding authors: [coloman@intergate.ca](mailto:coloman@intergate.ca) and [egyenge@chbe.ubc.ca](mailto:egyenge@chbe.ubc.ca)