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Development and optimization of a novel PEM fuel cell using printed circuit board technology

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Fuel cells are currently being considered as good alternatives for portable power applications (1-100 W) due to their good energy conversion efficiency, flat geometry, high power and the energy density of their fuel sources, making them highly advantageous over batteries [1]. The increasing importance on compact design of portable devices necessitates miniaturization of fuel cell stack components in order to maximize power density and for easy system integration [1]. Conventional fuel cell stacks that use bipolar plates to connect cells in electrical series are not ideal for this application due to the high cost and bulkiness of the bipolar plates / end plates.

This programme of work aims to develop a planar fuel cell (the Flexi-Planar Stack), which aims to mitigate the issues associated with conventional fuel cell stack designs. The planar design offers a number of practical advantages in addition to the potential for significant cost reduction due to the use of the well-known high capacity manufacturing base of printed circuit board (PCB) technology. The proposed stack design has several advantages over the conventional stack [2]:

- The use of PCBs afford cost-effective prototypes and design flexibility, which can help to reduce the cost of developing fuel cell stacks
- Established bonding techniques for unitization of the cell components, which produces a low-weight, glass-fibre reinforced stack that requires no end plates or expensive seals.
- Any membrane electrode assembly technology can be utilized, which means it will benefit from any new advances and does not have to be redesigned for new technologies.
- Continued operation of the stack (at reduced capacity) even if one of the boards fails as the boards are controlled individually.

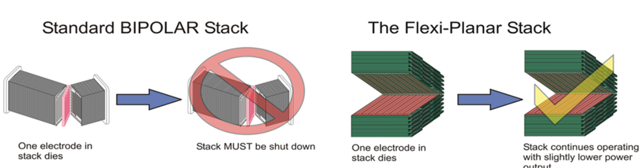

Figure 1: Flexi-Planar Stack concept

The uniqueness of the approach comes from the fact the membrane electrode assembly (MEA) will be enclosed within the PCB by bonding the layers together with prepreg (thin epoxy-impregnated fiberglass sheets), which eliminates the need for mechanical compression and end plates. Gas manifolding is achieved by bonding the back of the PCB current collector to an FR4 board using a prepreg with integrated flow routing, reducing the components required by the system and eliminating the need for expensive seals.

Multiple iterations of the planar fuel cell (single cell and three cell stack) have been developed using different flow field designs and gas routing techniques (with the view of reducing pressure drop, optimizing flow patterns and current collection while minimizing internal resistance) and comparable performance has been achieved with conventional graphitic flow fields (Fig. 2). However, further work is required to optimize design and performance.

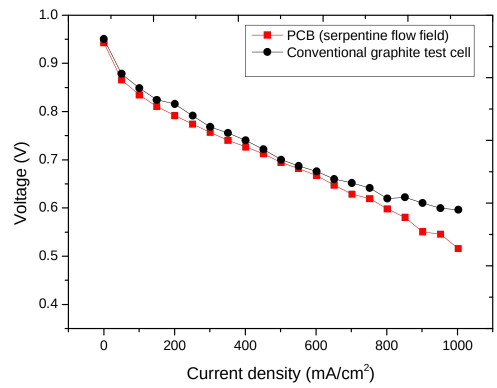

Figure 2: Polarization curve comparison between the use of PCB current collectors and graphite monopolar plates in a standardized test cell.

This paper is centered on optimization of this system by employing advanced diagnostic techniques in order to understand the internal working of PCB fuel cells. This includes the use of a thermal imaging to observe the production and distribution of heat and hotspots at different current densities. Direct visualization of open channels to observe water management and controlled compression experiments to determine the effect of GDL compression on the cell performance. Electrochemical impedance spectroscopy will also be used to study the performance and long-term degradation.

References

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[2] Carbon trust - Application for the Polymer Fuel Cell Challenge, 2011.