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Review

Mechanisms and effects of mechanical compression and dimensional change in polymer electrolyte fuel cells – A review

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HIGHLIGHTS

- Effect of fuel cell component on stack compression reviewed.
- Degradation effects of over-compression.
- Diagnostic techniques used to control and analyse stack compression.
- Review of thermal and water management issues on dimensional change.
- Comprehensive review of techniques used to put stacks into compression.

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ABSTRACT

Conventional polymer electrolyte fuel cells (PEFCs) require a means of placing the series of laminar components that make up cells under mechanical compression so as to ensure effective electrical conduction, mass transport and gas-tight operation. This review describes the effect of mechanical compression and dimensional change on the components of PEFCs and reviews the range of methods used to achieve desired stack compression. The case is made for improved understanding of the mechanisms of fuel cell component compression and greater attention to the development of technological approaches for stack compression.

1. Introduction

Fuel cells generate electricity through direct electrochemical conversion of reactants, and as such show great promise for lowering the demand of hydrocarbon fuels, decreasing pollution and increasing energy conversion efficiency. Operating in the low temperature range (typ. 80 °C), polymer electrolyte fuel cells (PEFC) are particularly suited as a replacement for the combustion engine and batteries in automotive and portable power applications [1]. However, in order to achieve large-scale deployment, further development is required to bring the PEFC to a level where it is competitive with existing technologies in terms of cost, durability and performance. The focus of research thus far has been primarily in the reduction or replacement of expensive catalysts, improving the durability of components, ameliorating water and heat management and improving overall electrical efficiency.

In order to operate at useful voltage outputs, individual cells must be combined and assembled into stacks. This requires a way of mechanically connecting the cells together to ensure effective gas and liquid sealing, current collection and reactant delivery. Each factor plays a vital role in the overall electrical performance of the stack. A typical stack setup can be seen in Fig. 1, the components of which are described in the following section with respect to their role in mechanical compression.

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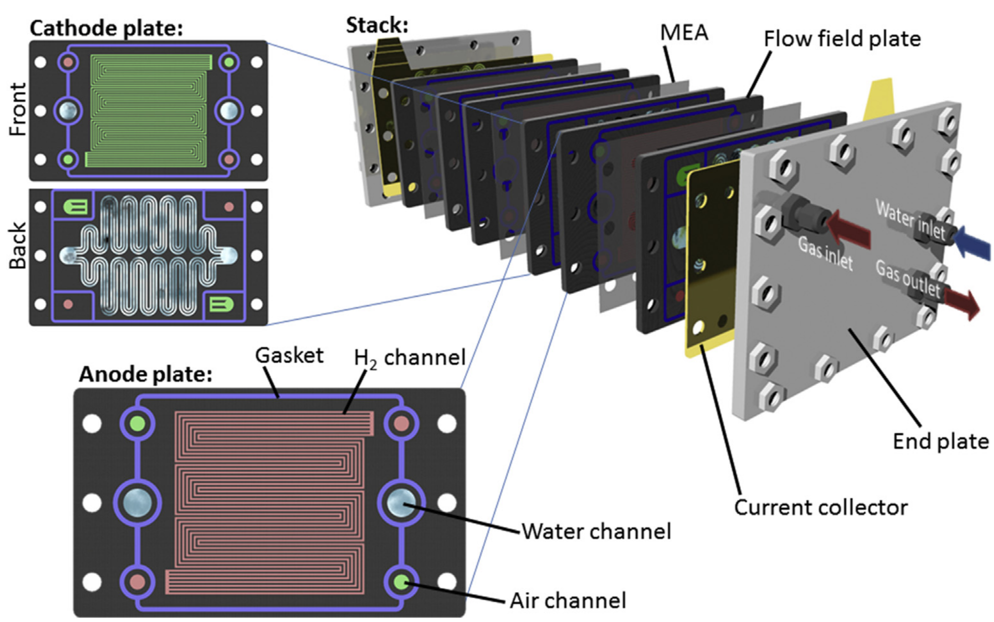

Fig. 1. Stack assembly of PEFC including 'exploded' stack shown in upper right, cathode and anode plates shown on left highlighting gas, water and sealing channels. Bipolar plate design shown is based on that of Pragma Industries, France.

1.1. Membrane electrode assembly

Fig. 2 demonstrates the basic components that make up a single cell. Hydrogen is fed to the anode and air/oxygen to the cathode through flow field plates, which distribute the reactants evenly across the electrodes. The gas diffusion layer (GDL) allows these reactant gases to diffuse under the lands of the flow-field plate (Fig. 3) to the catalyst layer (CL) where reaction occurs. Often, a micro porous layer (MPL) made up of carbon and a hydrophobic agent, is applied to the GDL surface between the CL and the GDL. In order for reaction to take place in the catalyst layer, reactant gas, catalyst particles and ionic conductor (electrolyte) must all meet to create a triple phase boundary (TPB) [2]. Protons generated by the hydrogen oxidation reaction (HOR) migrate through the electrolyte to react at the cathode with oxygen and recombine with the electrons that have travelled through the external circuit, creating useful current and water by-product. Water can travel through the membrane via two different mechanisms; from anode to cathode via electro-osmotic drag arising from the movement of protons through the membrane, and from cathode to anode due to the higher concentration of water at the cathode creating a hydraulic diffusion gradient. The PEFC electrode is made up of the GDL, MPL and CL and when the electrolyte is sandwiched between two electrodes and hot-pressed together, under pressure and heat, they form the membrane electrode assembly (MEA) which can be considered as the essence of the fuel cell.

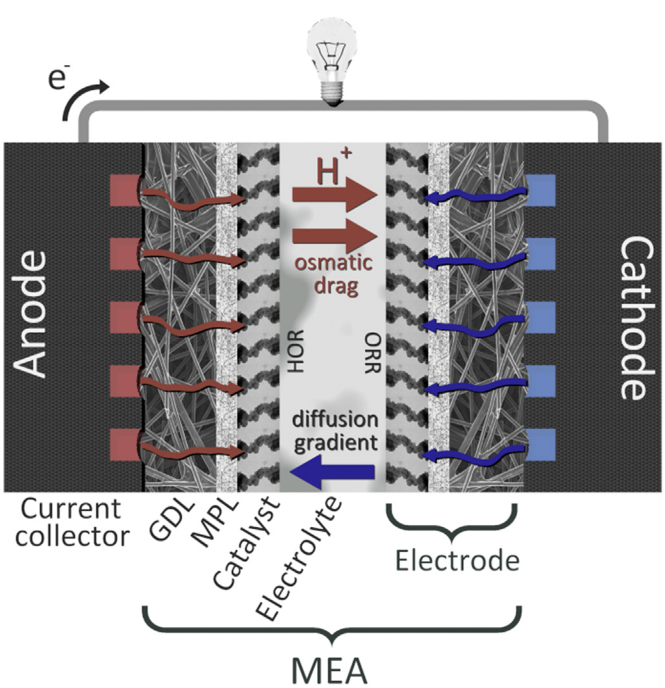

Fig. 2. Schematic of a PEFC showing proton, electron and reactant movement throughout the cell as well as water transport.

1.2. Flow field plates

Flow field plates (FFP) provide the structural integrity to the stack, along with gas distribution and heat dissipation. The flow-field grooves within the plate are referred to as the 'channel'. The plates also act as current collectors allowing for transport of electrons to and from each cell; the term bipolar plate is used when a single plate acts as the current collector for both the cathode of one cell and the anode of another. Electrical connectivity is achieved where the FFP is in contact with the electrode, known as the 'land'. Each end of the stack houses the final current collectors where the electrons are passed onto an external circuit, on the outside of which are the endplates which house the whole stack and introduce the gas reactants and coolant fluid for internal manifold flow plates. The fuel and oxidant manifolds are distributed across each MEA by individual fuel networks.

Flow channels are typically rectangular in cross section, but there are many different channel arrangements available, as shown in Fig. 3.