Electrochemical Research Opportunities in PEM Fuel Cells

A Systems Perspective

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Fuel cells in general, and specifically PEM fuel cells, are receiving unprecedented attention. Estimates are that more than $2 billion are invested annually in PEM fuel cells, primarily for automotive applications. At the same time centers of excellence are being formed at many universities. In our opinion, the connection between the universities and research labs and fuel-cell OEM's has not been adequate. As a result, too little of this research is directed at the critical issues. In order for fuel-cell OEM's to deliver stack designs that allow fuel cells to penetrate commercial markets, the designs must be guided by a fundamental understanding of the critical issues. By focusing on this understanding rather than on the demonstration of prototype stacks, research labs and academic institutions can help to ensure that fuel-cell development is properly informed, and allow OEM's to make trades based upon these fundamentals and the constraints of the manufacturing processes and application-specific constraints by which they must abide.

Further, it is the belief of the authors that analysis must start at the system level, whether that system is a vehicle, a stationary power plant, or a portable energy source. The success of any fuel-cell power plant will depend heavily on the integration of the cell stack, where the electrochemical energy conversion occurs, with numerous other components and subsystems.

We will identify key customer/market requirements, and the path from these requirements to requirements for the cell stack and subcomponents such as membrane, catalysts, and gas-diffusion media. Analysis and recommendations are made on the following topics 1) high-temperature membranes, 2) cell-stack endurance and life, 3) effects of contaminants, 4) electrode catalysts, 5) water management and mass-transport losses, and 6) low temperature operation.

High temperature membranes have been identified before as a potentially game-changing advancement in PEM fuel-cell development. Operation at higher temperature would allow greater CO tolerance and higher-grade waste heat, which could increase overall efficiency for stationary applications, and ease the burden of shedding waste heat in transportation or portable applications. In the development of these membranes, one must characterize candidate materials carefully to ensure a path to a membrane that will allow high-temperature operation without compromising other features of the fuel-cell power plant.

Improvements in cell-stack durability are critical for successful deployment of PEM fuel-cell powerplants. Phosphoric acid systems have successfully demonstrated >40,000 hours of operation, but such lifetimes have yet to be demonstrated in PEM fuel cells. In order to lower the cost of ownership for a PEM fuel-cell system, the lifetime must be extended. Fundamental research into decay mechanisms and decay-mitigation strategies is an area that has been neglected at the expense of the more glamorous quest for beginning-of-life performance improvements, but at this stage, it is likely the mitigation of decay that will more greatly benefit the industry at large.

In the area of contamination, the preponderance of the effort has been focused on CO tolerance at the anode, due to the presence of this species as a by-product of the reforming process. While CO must undoubtedly be considered, particularly in systems using reformed fuels, there are other contaminants that will likely impact performance. Understanding the fundamentals of how these contaminants interact with the catalyst and membrane will help cell-stack developers and component suppliers engineer solutions to mitigate these effects.