PowerDisc's eFlow® reduces fuel cell commercialisation cost

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The successful commercialisation of any new technology is inherently dependent on its ability to compete head-to-head with incumbent product. In pursuit of price parity, the fuel cell industry has historically focused on reducing unit cost, increasing durability and longevity, and volume production. While these are all important, many fuel cell developers have yet to address the exorbitant costs and time-consuming processes required to develop new applications which ultimately encumber profitability, sway allocation decisions, and influence which markets to pursue. This article outlines a radical approach that can dramatically lower the total cost burden of product development, as well as reduce fuel cell unit cost and improve longevity and durability, enabling a more economical path to fuel cell product commercialisation.

Introduction

Fuel cells have benefited from more than two decades of research & development activities by industry, government, and educational and research institutions. During this time, there have been impressive improvements in power densities and lifetimes, yet commercial fuel cell products have been limited to niche markets such as materials handling, backup power, and cogeneration where adopters are willing to pay high costs for their power, have issues with their current energy storage system (i.e. batteries), or where government incentives are in place.

While the current state of the technology continues to advance, it is clear that fuel cell manufacturers continue to be plagued by an assortment of cost issues related to market entry and expansion, including:

- *Material costs:* Until the fuel cell sector's volumes kick in to enable supply chain cost reductions, material costs will remain high.
- *Product development costs:* Developing new products incurs sizeable and irretrievable investments in research & development, engineering, and manufacturing development costs.
- *Market acceptance:* Aligning market applications with realistic adoption timelines continues to have a great deal of uncertainty.

Figure 1. PowerDisc's fuel cell stack.

Given the above, cash constraints felt by fuel cell manufacturers continue to be so high that developing new products for emerging market applications will remain difficult, resulting in commercial fuel cell companies that merely flirt with profitability.

In the absence of a strong economic position, how can fuel cell manufacturers make a compelling business case, without high volumes, and without incurring a sizeable and irretrievable investment?

Some might suggest that a new injection of capital would solve the problem, but that is not a solution, as fuel cell unit cost will still be encumbered by research & development (the time and cost of material down-selection), engineering (balance of plant and packaging work), and manufacturing (unique tooling and setup for different products).

In 2012, Kerry-Ann Adamson projected that the fuel cell industry is sitting on a precipice, in need of (i) realistic business plans, (ii) solid management teams, and (iii) a clear understanding of the level of investment in order to bring the venture capital (VC) community back to the market.[1] Without realistic business plans, there is no business for a management team to rally around and entice the VC community to invest. Therefore, the fuel cell community needs to reduce costs and compete head-to-head in 'beachhead' markets that will provide sufficient volume to open up second- and third-generation applications.

As Adamson warned in 2012, now is the time to act to build volume in the community. With several publicly traded fuel cell companies recently demonstrating renewed optimism and impressive market capitalisation gains throughout 2013, clearly the resurgence has started, but the sector still needs to show a viable business model for the industry to grow and prosper.

PowerDisc offers a different approach. PowerDisc's eFlow® technology enables the freedom to change a unit cell count for peak power, efficiency, or a balance of the two, to deliver the best total cost of ownership (TCO). While in the past a fuel cell firm would need to launch a fully dedicated effort of R&D, engineering, and manufacturing to deliver a new product, PowerDisc can deliver a new product with only minor balance of plant and engineering modifications (**Figure 1**).

So how does PowerDisc change the financial, personnel, and calendar costs of development? The company's patented eFlow technology eliminates mass transport losses, and provides uniform distributed current density through 'design', not material development.

eFlow® technology: How it works

In a standard flow channel, based on a constant cross-sectional area, the mass flow rate reduces proportionate to the consumption rate of reactants, and therefore the flow velocity also reduces. This leads to uneven flow distribution, resulting in stack performances which are more variable compared to single cell measurements.

PowerDisc's eFlow technology differentiates from the standard types of flow-fields, as it provides a cross-sectional area which converges down the length of the channel in a proportionate fashion to compensate for the reduction in mass flow rate due to reactant consumption (**Figure 2**). Simply put, reactant availability throughout the entire flow channel is levelised.

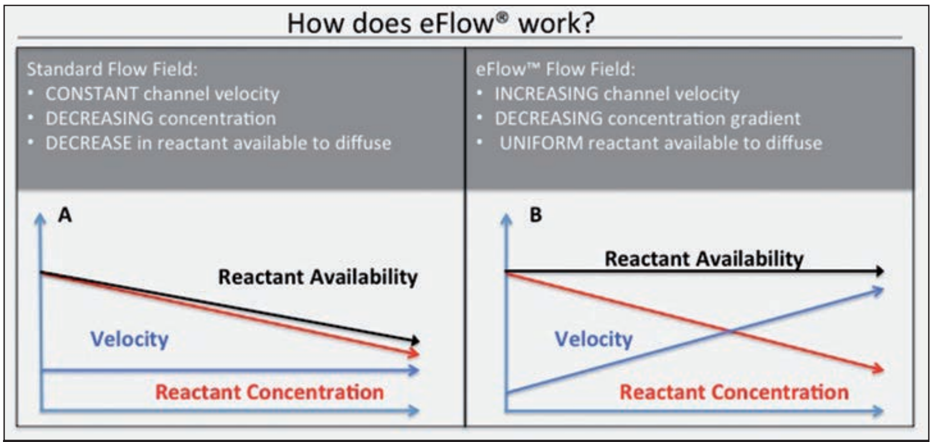

Figure 2. Comparison of eFlow™ and straight-channel designs: (a) standard designs with reducing reactant availability, and (b) eFlow design providing uniform reactant availability.

Improved performance, no mass transport losses

The advantage that eFlow provides is rooted in the uniform availability of reactants down the channel. PowerDisc has observed a striking phenomenon – no mass transport losses – even out to high current densities. There are no boundary conditions that limit design choices through an upper-bound current density due to mass transport losses in the stack voltage.

Figure 3 shows that eFlow high current density operation compared to traditional straight-channel flow-fields is dramatic. When using eFlow-based flow-fields with commercially available membrane-electrode assembly (MEA) technologies, PowerDisc has measured dramatic increases in peak power. The high current density operation, under ambient backpressure, is the most impressive demonstration of what eFlow technology offers the fuel cell industry – a predictable ohmic polarisation curve that provides a limitless design space.

Whether picking an operating point for peak power, constant power, efficiency or packaging constraints, eFlow designs allow one material set to be designed and sized to meet any application requirements. There is no need to develop special components for different operating conditions. This means the volume is cumulative across a family of products.

Reduced cost of goods

PowerDisc's eFlow technology provides higher stack performance, enabling a lower cost of goods. Whether using off-the-shelf or advanced MEA technologies, fuel cell stacks incorporating eFlow flow-fields will result in incremental performance gains and reduced cost of goods compared to non-eFlow fuel cells.

Depending on the application, eFlow-based fuel cells can provide (i) reduced cost of goods with greater power density, (ii) better fuel efficiency under the same power per unit area, or (iii) a balance of reduced cost and improved efficiency (**Figure 4**). The design space expands significantly because there are no mass transport issues, which is an important advantage when sizing stacks for product requirements such as cost and power density.

- *Case 1:* When choosing a peak power design point for motive applications, there are many factors that need to be evaluated. In this comparison, a baseline polarisation curve was used in contrast to PowerDisc's eFlow polarisation curve as shown in Figure 2. When sizing for peak power, the PowerDisc stack can generate 58% more power at a 28% lower cost of goods, because it can operate at a much higher current density. The peak power condition evolves from the overall efficiency targets, demonstrating the limitless design space afforded to eFlow-based fuel cells.
- *Case 2:* For materials handling applications that do not require extreme peak power but must have a minimum demonstrated stack efficiency, PowerDisc's eFlow stacks can provide 50% more power for the same stack active area, which results in a 26% lower system cost.
- *Case 3:* In stationary applications where efficiency is paramount, the following case provides a comparison of eFlow at the same power output. This case would represent an application driven by operational costs, where a 13% higher efficiency could provide a tremendous reduction in total cost of ownership over the application lifetime.

Reduced product development costs

Once a product concept has been validated, each product must go through a series of product development stages, with associated costs for each: research & development; product engineering; and process development. All these processes must be followed until the product meets the requirement and is officially accepted.

As PowerDisc's eFlow technology provides uniform current density and eliminates mass

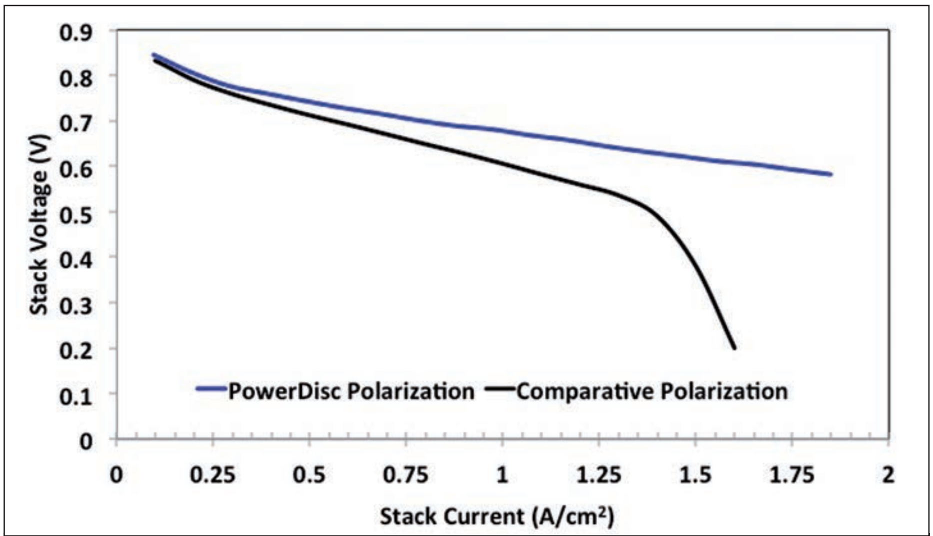

Figure 3. Polarisation comparison between PowerDisc and a comparative baseline.

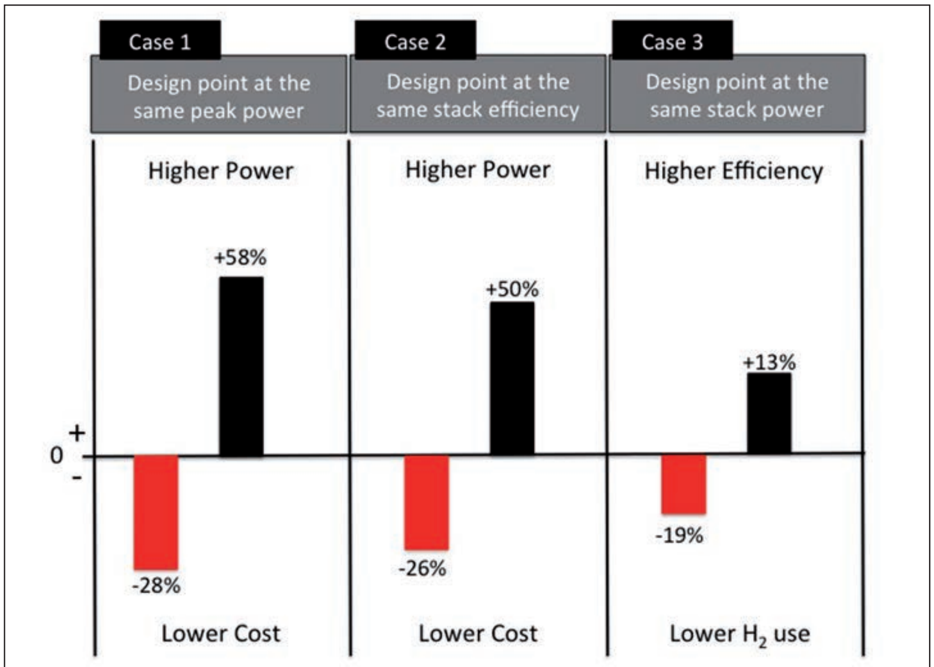

Figure 4. Comparison of various design cases dependent on the application. Case 1: peak power, Case 2: same stack efficiency, Case 3: same stack power.

transport losses, its application can dramatically reduce development costs through each of these stages as well as the total time to market-entry.

Research and development

R&D costs are constituent of labour and expenses required for readiness of technologies and materials for a subsequent product development phase. The higher power densities provided by PowerDisc's eFlow designs, over and above conventional bipolar plate flow-fields, can lower technology targets required for next-generation components. For example, platinum (or other exotic) cathode catalyst mass activity targets can be lowered by enabling earlier achievement of commercialisation cost targets, thereby reducing overall R&D costs.

Product engineering

Costs borne out in the engineering phase of product development stem from customer demonstrations, design and test iterations, and process development. By eliminating mass transport losses in a conventional bipolar plate, the result is a far more versatile plate that addresses high efficiency and peak power end-use customer needs.

For example, initial engagements with potential customers often require bespoke designs for each demonstration. Since stacks containing PowerDisc's eFlow flow-fields are more flexible, they can be used in varied applications as compared to stacks containing traditional flow-fields. This enables a much faster response time in providing product demonstrations for customers by utilising existing designs, thereby avoiding the need for a costly self-funded design phase before a demonstration can commence. It is easy to see how months or years can be eliminated from a project timeline, giving these stacks an advantage over competitors.

Process development

During the product development lifecycle, process development takes place where, for example, it is necessary to minimise mass transport losses in the cathode catalyst layer of the catalyst-coated membrane (CCM). However, with the elimination of mass transport losses, PowerDisc's eFlow flow-fields do not require most of the mass transport reduction optimisation designed into traditional flow-fields. With the scope reduction of this process development activity, development budgets can be reduced and development phases shortened.

When the cost and duration of a complete product development programme are considered, stack development programmes utilising PowerDisc's eFlow technology can be realised for significantly less cost and time than stack development programmes utilising conventional flow-fields.

While the use of a single stack or bipolar plate in a company's product strategy is not new, it has not been realised to date. Many companies require three or more stack architectures to service their product space.

By integrating PowerDisc eFlow technology into a company's product strategy, it may be possible to reduce the number of bipolar plate architectures to two or one, and enjoy the resulting development cost savings and time reductions it brings.

Conclusions

PowerDisc has developed a game-changing technology that is clearly significant at the stack level, but an equally important contribution is the transformational effect it can have on how an organisation funds, staffs, and manufactures new products.

Where the industry is right now, the cost of delivering demonstration units to prove out a business case is prohibitive, especially if the current product portfolio requires design iteration.

PowerDisc's eFlow technology enables the ability to lower the total cost burden and compete head-to-head with incumbent products in new markets with a much lower threshold cost.

Reference

1. Kerry-Ann Adamson: Fuel cell industry faces a precipice, *Forbes Magazine*, 25 October 2012. Available at: www.forbes.com/sites/pikeresearch/2012/10/25/fuel-cell-industry-faces-a-precipice/

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