FUEL CELL TODAY

Opening doors to fuel cell commercialisation

Micro-Fuel Cells: where do the consumers' needs fit?

Sandrine Colson-Inam – April 2003

With a potential WW sales market of about $4.5 billion for rechargeable batteries, environmental issues, and the ever-increasing demand for more power by portable electronic devices (color screens, more functionalities, etc.), Micro-Fuel Cells present nowadays an option that is quite attractive. Indeed, several companies plan commercial availability of micro-fuel cells for some applications (laptops for example) in the next couple of years. However, rechargeable batteries are not going to give up that easily as many new technical improvements are emerging.

The advantages of micro fuel cells

One refers to micro-fuel cells as fuel cells, which can provide power below or around 5 W. Most Consumer Electronics applications are included within that power range: mobile phones, PDAs, cameras, small toys, pagers, audio, small medical devices, some laptops … I may use here portable or micro to define this range of applications.

The fundamental principle between a battery and a fuel cell is the same: one converts the energy of chemicals (chemical reactions) into electrical energy (the power needed for electronic devices to work). However, there is a fundamental limitation for batteries: the volume of the battery limits all the energy available for consumption in an electronic device. Indeed, in a battery, the energy available for electrical power is limited by the amount of active materials (chemicals) present inside the battery. Whatever is in is what comes out.

This is where fuel cells have an advantage. Although the fuel cell has a defined volume, like a battery, the amount of energy/power available for a device to use is, in theory, unlimited. Indeed, the active material (i.e. the fuel) is not included with the mechanical components (the fuel cell core), it is added as needed (by mean of some kind of cartridge). It is like your car, the engine has a certain volume but it is

the gas that determines how long the car runs. Similarly, it is how much fuel (the tank or cartridge's size) you add to the fuel cell's core, which provides the amount of power that a device can feed on. So, like for your car, the power is, in principle, unlimited.

In addition, fuel cells work with air and hydrogen, producing water at the end of the reaction. All critical elements for a fuel cell to work properly are environmentally "clean". Hydrogen, one of the essential components of fuel cells, is certainly environmentally friendly. However, it is how you produce the fuel that can make a difference in defining what can be the most appropriate way to build a micro-fuel cell and how much energy can be delivered. This dependency on fuel is reviewed below

Hydrogen versus Methanol … or else?

Both Hydrogen and Methanol, a type of alcohol, offer more theoretical energy than Li-Ion rechargeable batteries. In principle Hydrogen combined with air can deliver more energy than methanol with air but kinetics play a role as well as convenience: hydrogen is usually in the gas form while methanol is liquid so easier to deal with for transport. Both are regulated by the DOT (Department of Transportation). Kinetics (i.e. how fast the energy can be delivered to the device using it) can prevent methanol or hydrogen to react as fast as one would like for optimum performance. It is by heating the whole or part of the cell that fuel cells using methanol or hydrogen work the most efficiently. This is usually provided through the "balance of plant" part of the fuel cell, i.e. the external connections/controllers that a fuel cell needs to work properly between the fuel cartridge and the fuel cell core. Similarly, rechargeable batteries have internal electronic or mechanical devices, which prevent shorting, excessive gassing or heat generation. Moreover, catalysts (such as platinum or alloys of platinum) are added to the fuel cell electrode(s) to speed the reactions.

One of the advantages of methanol is in a liquid form and easier to transport than Hydrogen in a portable format. The DOT (Department of transportation) has recently allowed one type of methanol fuel cell (sometimes referred as DMFC or Direct Methanol Fuel Cell) to be carried in airplanes so the door is opened for more to come. Similar progresses have been made for the European DMFC manufacturers. However, methanol is flammable and toxic so limited amount or diluted solutions may be prescribed to insure safety.

Although commercial methanol fuel cells are foreseen as early as next year for some applications, not all the technical issues that these micro-fuel cells have to deal with have been resolved. Some intermediate chemical reactions, for example, can impede proper performance to be reached. Most of it comes from the fact that most technical improvements were related to Hydrogen fuel cells. With the commercial focus on methanol fuel cells, technical progresses have already been made but more need to be reached to reach maximum power delivery.

What about Hydrogen for micro-fuel cells? One of the best options on the market is the Hydrogen-on-demand ™ (HOD) system, developed by Millennium Cell, a company from New Jersey. This process uses environmentally friendly raw materials (sodium borohydride and sodium metaborate) to produce in a safe way hydrogen. This technology produces a high quality energy source without the polluting emissions. It is a safe and easily controllable technique where the fuel solution itself is non-flammable, non-explosive, and safe to transport. This HOD fuel option allows fuelling from micro to large power applications and appears to simplify the "balance of plant" needed for the fuel cell to function properly.

Similarly progress is made with metal hydrides (another way to store hydrogen chemically) to improve performance and cost. So Hydrogen can also be a viable solution for fueling micro-fuel cells.

However, the market foresees at this time, methanol as being the first fuel for the initial commercialization of micro-fuel cells.

Research is constant to make sure that performance improves and technical hurdles are resolved in all technologies. New materials are being developed for fuel cells such as carbon nanotubes as provider of hydrogen or new membranes (an essential part of the fuel cell's core) or membranes' replacement option such as porous silicon. Similarly, new materials (lithium phosphates, oxide anodes, new anode metal alloys, etc.) and processes are being researched to improve rechargeable batteries. Which will be the solutions of the future remains in the hand of commercial availability, customer needs, power demand of electronic devices, reliability of performance, safety, and … cost !!

Where is the market today?

The Japanese, Koreans, and Chinese dominate the rechargeable battery market and substantial efforts are also being made to develop micro-fuel cells as well (SONY, Toshiba, Casio, etc.). Similar efforts exist in the US/North America and Europe.

Some of the companies presently planning the commercialization of micro-fuel cells include:

- MTI Micro Fuel Cells: Back up power for cell phone
- Smart fuel cells: fuel cells for cameras and laptops
- Toshiba: a fuel-cell powered PDA
- Casio: a laptop powered by Fuel Cells

Performance up to 10 hrs of laptop power have been claimed. No more worry for that transatlantic flight to London!

The end of rechargeable batteries?

The most performing rechargeable batteries on the market today are Li-ion rechargeable batteries, which include as well Li-polymer batteries here. Present performance is around 450Wh/kg and expected to reach 550Wh/kg within a couple of year or less. Although the performance limit for this type of Li-Ion batteries is around 600 Wh/kg, new materials for the negative or positive electrode, new design, new processes, and more are being developed which may extend the performance of Li-Ion batteries beyond their present performance expectation.

On the other hand, fuel cells have a lot of leverage to improve their performance. Indeed, the fuel cell may not contain the maximum amount of active material (fuel) needed for reaction (methanol solutions contains up to 4% of methanol for example or lower pressurized hydrogen gas is used for safety (up to 4% hydrogen)) so a lot of

the theoretical energy available for fuel cells is not reached in practice. Therefore, providing improvement of the engineering issues for fuel cells, fuel cells have tremendous opportunities to increase their performance.

Additional technical limitations for most power sources include: temperature cycling (cold and hot weathers), aging, storage, … Some battery technologies still thrive to resolve some of these issues (reliability of lead-acid in stationary applications for example). All those issues are being evaluated and quantified for various micro-fuel cell technologies.

Safety was an issue initially raised for Li-Ion rechargeable batteries when first commercialized but found ways of resolution by adding internal devices to prevent shorting, excessive gassing, basically, preventing your battery turns into a small explosive device. Li-Ion polymer rechargeable batteries present an advantage here over standard Li-Ion batteries. In the case of fuel cells, similar issues are being resolved but another hurdle comes in play: "the balance of plant". Depending on the system (pumps, heating, retrieval of end-products), these components can get complex, heavy, create delays in fuel delivery, and add internal resistance (a critical factor for High Power application). So finally, another challenge for fuel cells to overcome is to optimize the "balance of plant" to reach their optimum performances.

What's next? Improved or new rechargeable battery systems or primary (non-rechargeable) battery technology or other power technology could come out as potential threats to micro-fuel cells such as zinc-air, supercapacitors or combination of various technologies (Hybrid solutions). Also different applications have different power needs and cost requirements so there will still be a lot of batteries around for quite sometimes even once fuel cells reach the critical market volumes.

Does anyone really know what are the market needs and do micro-fuel cells fit the consumer needs?

Most consumers see batteries as a commodity. Therefore, although performance can be an issue, the major concern is how beneficial is the ratio of performance over cost. As long as the basic consumer performance needs are fulfilled, cost is the major decision factor in buying a "micro" power source. This is why more recently, consumer battery giants like Duracell decided to lower somewhat their prices as the

well-known branded battery did not sell as well as expected. However, high-end consumers (the rich or enthusiast gadget-amateurs) do not mind as much the high price tag as long as form factor and aesthetic is preserved (paper-thin cell phones for example). The micro-fuel cells presently available are still a little too bulky for my personal aesthetic liking. Look needs to fit the consumer's vision of what's hip. Nevertheless, fuel cell companies are working hand in hand with device manufacturers to accommodate all aspects of the commercial introduction of micro-fuel cells and much improvement has already been made. The way the present electronic device places batteries in their design may be completely revised in the case of micro-fuel cells therefore opening new design concepts for component integration.

How much will this cost? Well, it is the typical chicken and egg issue: demand needs to rise for volume to increase and price to decline. This is a trend that is constantly been seen for Li-Ion rechargeable batteries. Although, one does not know yet how much a micro-fuel cell will cost (Platinum, the typical catalyst in fuel cell is one of the big cost factor in fuel cells but alternative options are being developed), one hopes that similar cost trends will follow for micro-fuel cells once customer acceptance is mastered.

Then comes safety. Consumers do not like anything that may look like it could be dangerous. Even if fuel cells manufacturers are careful about making sure that the overall system - fuel cartridge and fuel cell core - is safe. One cannot predict what a consumer can do to defy the portable power industry's safety standards. This why it is important to be able to short-circuit, shake your micro power source, make it fall, puncture it, swallow it (it really happened to a child with a AAA!) to make sure that, even if it is not recommended by the manufacturer for the consumer to do any of those, the consumer who decides to do it anyway will be safe (children are pretty good to find innovative ways of using a power source such as battery). Fuel Cells need to gain credibility in that area. One of the pioneer in micro-fuel cell recently received CE (European Community) safety certification so positive outcome will result for all micro-fuel cells.

Assuming that all safety issues are acceptable as per the regulations in place and consumer's unpredictable behavior, consumers need to be able to find that fuel cartridge or where to get a fuel cell for my PDA, or more precisely: product

availability. Thus, in addition to developing a safe, performing and reliable micro fuel cell, manufacturers have to also figure out a way to have all the distribution channels covered. It will be nice to go to the next-door convenience store and get a refueling cartridge. Fuel Cells companies are actively involved to develop the right partnerships in this area. This could be an opportunity for Fuel Cell manufacturers to reduce the initial cost by making profit on cartridges.

Who buys battery? Average consumers, who still have trouble distinguishing between an AA and AAA battery, buy most of the batteries. However, most consumers understand that a cell phone should be recharged. Therefore, to add to the cost of product development, consumer education and technology awareness (there the media does a good job as I have seen several articles on this topic) should be added: replace your cartridge when you need similarly to printer or ink pens for example.

On top of all the design, production, and end-user requirements, international, national, federal, and state regulations need to make sure that all comes to a happy ending without compromising market opportunities for fuel cell manufacturers.

Finally

Micro Fuel Cells are emerging on the "micro" electronic device market (first commercial products are expected in 2004). For a smooth transition from a consumer niche market to a viable mass-market option to power portable (or "micro") electronic devices, seamless communication between consumers, manufacturers, device manufacturers, suppliers, and regulators will allow Micro-Fuel Cells to grow into the promising power solution they appear to be. Micro-fuel cells are coming soon … to your friendly neighboring gadget store?