METAL HYDRIDE FUEL CELLS FOR UPS AND EMERGENCY POWER APPLICATIONS

Stanford R. Ovshinsky
Chairman & CEO

Kevin Fok
Manager of Marketing

Srinivasan Venkatesan
Vice President of R&D

Dennis Corrigan
President & COO

Ovonic Fuel Cell Company LLC, Rochester Hills, MI

ABSTRACT

A new type of fuel cell with metal hydride materials in the anode has intrinsic energy storage functionality and characteristics of a battery as well as a fuel cell, resulting in features such as instant start on the order of microseconds, improved ability to handle power transients, and good performance at ambient and low temperatures. These characteristics are particularly useful for UPS and emergency power applications. This new fuel cell uses no noble metal catalysts, no expensive membranes, and no expensive graphite conducting plates. Relatively inexpensive materials and a simple and highly manufacturable design make this practical solution also an affordable one for extended runtime UPS and emergency power applications. It is a scalable technology particularly well-suited for power levels between 100 W and 200 kW.

INTRODUCTION

In the UPS and telecommunications industries, there has been significant dissatisfaction with existing battery backup power solutions due to issues such as reliability, life, maintenance, safety, and cost [1-3]. Recent natural disasters, unprecedented acts of terrorism, and power outages from the failure of aging power grids have reinforced the need for reliable back up power. Prolonged outages have emphasized a need for extended run times, especially for critical operations. Run time extensions to more than a few hours are not as practical for traditional battery solutions due to size, safety, and cost issues. Other options including generator sets have their own disadvantages including noise and exhaust emissions problems.

Recently, there has been a consideration and selected introduction of evolving hydrogen and fuel cell technologies. While operational success with PEM fuel cells has been demonstrated [4-7], the high cost of fuel cells is still a barrier to large-scale commercial introduction [8]. Other disadvantages include poor low temperature performance and the need to still include a separate battery for start-up and transient issues. Here, we discuss a new technology option for the UPS/emergency application, a new type of fuel cell that also can function as a battery with inherently lower materials costs than the PEM fuel cells that are predominant in the fuel cell industry today.

METAL HYDRIDE MATERIALS

The technological basis for metal hydride fuel cells is the metal hydride materials developed for battery and other applications. Novel concepts of compositional and structural disorder developed by S.R. Ovshinsky at our parent company Energy Conversion Devices, Inc. (ECD Ovonics, see www.ovonic.com) were fundamental to the development of metal hydride materials [9] and their subsequent commercialization into Nickel Metal-Hydride (NiMH) batteries [10] and solid state hydrogen storage devices [11]. NiMH consumer batteries are now a billion dollar a year business with billions of cells manufactured and sold annually under ECD licenses. For the emerging electric and hybrid vehicle industries, the chosen technology is NiMH batteries provided by ECD licensees and joint ventures. Our recent fuel cell advances also have origins in a corporate vision and commitment to the evolving hydrogen economy dating back to the formation of ECD in 1960.

METAL HYDRIDE FUEL CELLS

The Ovonic Metal Hydride Fuel Cell is a patented technology [12-13] that incorporates metal hydrides into the fuel cell hydrogen electrode, where it serves both as an anodic catalyst for the oxidation of hydrogen and as a hydrogen storage medium. The metal hydride imparts a charge storage or battery functionality to the hydrogen fuel cell electrode providing this fuel cell with a unique intrinsic energy storage capability.

The metal hydride fuel cell is simple in design as shown in Fig. 1. The anode contains metal hydride as the anodic catalyst together with carbon and PTFE materials with a nickel screen current collector. The cathode contains metal oxides as the cathodic catalysts with carbon and graphite materials again with a nickel screen current collector. The electrolyte is potassium hydroxide with compositions similar to those in alkaline rechargeable batteries. The separator is an inexpensive polypropylene screen. The simple design and inexpensive materials provide for a manufacturable and cost-effective product.

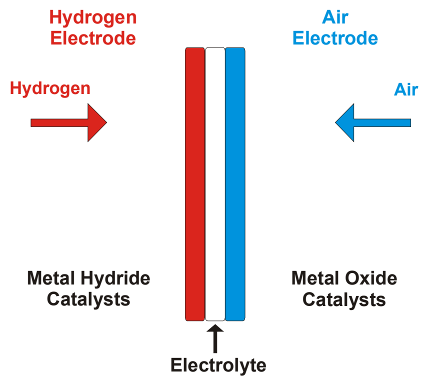

Figure 1: Schematic diagram of metal hydride fuel cell

Instant Start

Conventional fuel cells require rather long start-up times. High temperature fuel cell systems typically require several hours. Ambient temperature systems such as conventional PEM fuel cells require many minutes to reach temperatures needed to achieve rated power performance. At least a few seconds may be required for hydrogen to reach the fuel cell stack once the hydrogen is turned on. For many UPS and emergency power applications, fast start-up times on the order of microseconds are often required, something conventional fuel cells cannot provide. A solution for this problem is supplemental batteries or supercapacitors paralleled at the systems level. While providing for instant start, batteries add cost, weight, and complexity and additionally the traditional battery maintenance and reliability issues. Supercapacitors are even more costly and provide less energy per unit weight and volume.

By contrast metal hydride fuel cells with inherent battery functionality provide instant start in the fuel cell stack itself on the order of microseconds. This is illustrated in Fig. 2 showing power generation in a few microseconds. Instant power generation is provided even at low temperatures down to -20^{o}C.

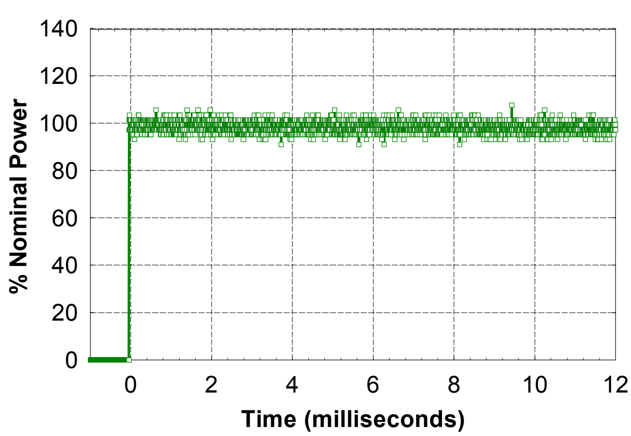

Figure 2: Instant start operation

The instant start feature illustrated in Fig. 2 has a robust fail-safe nature in that power can be provided even in the absence of hydrogen fuel flowing to the fuel cell. The hydrogen stored in the metal hydride anodes can provide power for several minutes at peak power levels, even if the fuel cell is not supplied with hydrogen gas fuel. This unique feature is illustrated in Fig. 3. The intrinsic energy storage capability is thus significant, on the order of 10 Wh/kg with current prototype designs. The 10 Wh/kg intrinsic energy storage density, which already exceeds the level of supercapacitor energy storage devices, can be substantially increased by designs with higher metal hydride contents. Of course, the total system energy density utilizing the fuel cell in combination with hydrogen sources is typically much higher than the intrinsic energy storage density. Total system energy densities on the order of 200-1000 Wh/kg or more are possible.

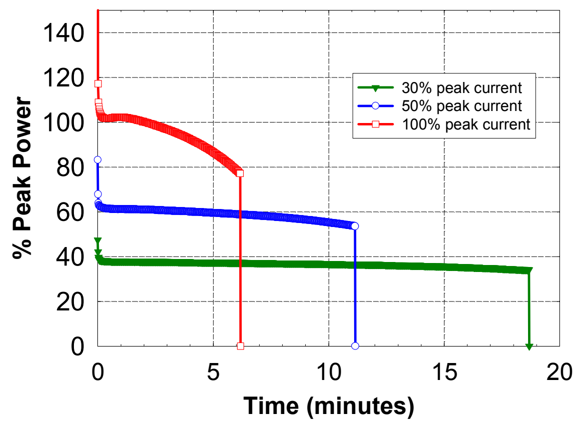

Figure 3: Instant start operation without hydrogen gas input

Power Performance and Temperature Ranges

The power performance as a function of current density for a prototype metal hydride fuel cell is shown in Fig. 4. Peak current densities exceeding 250 mA/cm^2 have been demonstrated, which is an excellent result for a fuel cell without noble metal catalysts. Prototype devices have been built and tested demonstrating a specific power of around 100 W/kg and a power density of around 100 W/L. We are currently engineering new prototypes aimed at around 200 W/kg and 200 W/L which will be more than sufficient to build suitable systems for UPS and emergency power applications.

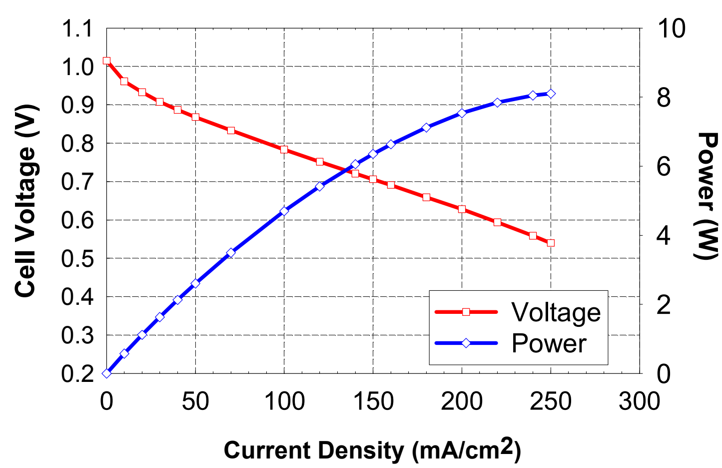

Figure 4: Fuel cell power performance in recent prototype

A significant advantage to this new technology is the operational and storage temperature range. The storage temperature extends to about -40 °C, below which the electrolyte freezes. The operational temperature ranges from -20°C to 80 °C. The dependence of power on temperature is less than that of conventional fuel cells leading to superior power performance at low temperatures as shown in Fig. 5. Over 75% of the peak rated power is available at room temperature and about 50% is available at 0 °C.

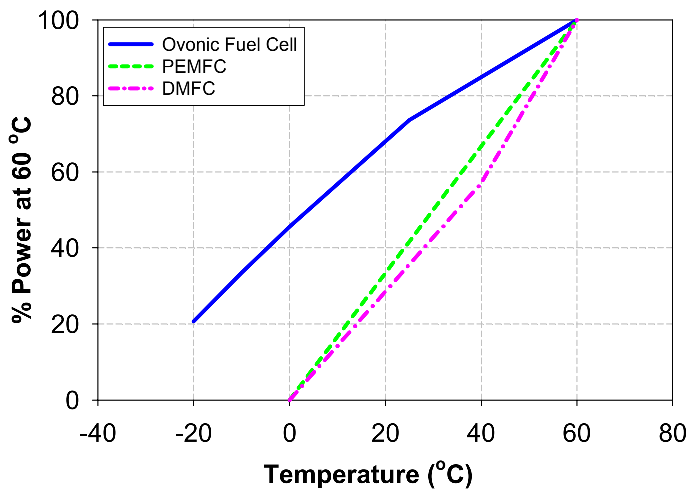

Figure 5: Effect of temperature on power performance

Operational and Calendar Life

In life testing of early prototypes, over 1000 hours of operation near peak power have been demonstrated with multi-cell stacks. Up to 5000 hours have been demonstrated in single cell tests of electrodes. The operational life can be extended by the use of carbon dioxide scrubbers at the air inlet to mitigate carbonate formation. There are now a variety of conventional and regenerative carbon dioxide scrubber technologies available. However, the liquid electrolyte design of the metal hydride fuel cell is much more tolerant to carbon dioxide than the traditional immobilized matrix electrolyte design (starved electrolyte type) of alkaline fuel cells used for space applications. Even totally without scrubbers, an operational life of several hundred hours has been demonstrated, more than adequate for UPS and emergency power applications. The calendar life is under study. We expect it to be comparable to that of the 10+ year calendar life of nickel metal hydride batteries.

Manufacturability and Cost

A major advantage of the metal hydride fuel cell is the utilization of lower cost materials. Conventional ambient temperature fuel cells such as PEM fuel cells utilize noble metal catalysts and other expensive components. For example, PEM fuel cells use platinum catalysts as well as expensive proton exchange membranes that typically comprise even a larger fraction of the fuel cell cost than the platinum. A comparable fraction is also typically allotted to bipolar conductive plates between cells that are comprised of special graphite materials that require special techniques to machine or form. PEM fuel cells are now in production by major fuel cell companies such as Ballard. However, high costs mandate pricing in the range of $5000/kW or more.

The metal hydride fuel cell, by contrast, is made from relatively inexpensive materials. The active materials are metal hydrides, composed of common transition metal components, and also non-noble metal oxides. Other electrode components include conductive graphite powders, PTFE materials, and a conductive nickel screen and tab. The most expensive component is the nickel metal screen and tab. Production processing and assembly are also expected to be simpler and less expensive than for PEM fuel cells. Bill of materials estimates yield materials costs an order of magnitude or so lower than for PEM fuel cells.

SUMMARY

Metal hydride fuel cells offer useful new features for UPS/emergency power applications including instant start on the order of microseconds and excellent low temperature performance. Low cost materials and a simple design provide for a lower cost and highly manufacturable fuel cell solution for extended run time applications.

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