V.0.1 Direct Methanol Fuel Cell Prototype Demonstration for Consumer Electronics Applications

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Methanol Foundation, Arlington, VA

Start Date: August 1, 2004. (Program funding suspended due to DOE funding constraints from January 2006 to March 2007.)
Projected End Date: September 30, 2008

Objectives

- Develop an early pathway for the large scale public introduction to fuel cell benefits.
- Create manufacturing infrastructure for high volume, low cost fuel cell fabrication, benefiting both methanol and hydrogen fuel cell technologies.
- Demonstrate 1,000 hours of continual operation.
- Demonstrate overall energy density equal to or better than 600 Wh/liter.
- Accelerate codes and standards activities that allow shipping and use of methanol and hydrogen in airline passenger cabins.
- Prepare three successive generations of benchmark prototypes to evaluate system integration issues and validate performance.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability
(B) Cost
(C) Performance

Technical Targets

Target metrics for the sub-Watt to 50 W fuel cell system category are shown in Table 1. Some of the targets are not applicable to the sub-Watt systems. These smallest of systems will not have the power density or cost of a larger system in this category. The power and energy density, and cost targets are especially "not applicable" (NA) for the sub-Watt category. There is no energy density to report for 2007 at this time. The project is just coming off of a funding suspension (due to DOE funding issues outside of MTI control), but will have data later in the year as the second round of prototype systems are tested. This project, and subsequent product projects are on track to achieve all the metrics needed to make a direct methanol fuel cell (DMFC) for handheld electronics a commercial success, helping to clear the path for similar hydrogen fuel cell (FC)-powered device introduction.

TABLE 1. Progress Toward Meeting Technical Targets for Sub-Watt to 50 Watt Category

Characteristic	Units	DOE 2006/2010 Targets	2007 MTI Status
Specific Power	W/kg	30/100	NA
Power Density	W/L	30/100	NA
Energy Density	Wh/L	500/1,000	TBA*
Cost	$/W	5/3	NA
Lifetime	Hours	1,000/5,000	>1,000**

* Testing will start shortly to determine current status with round 2 prototypes
** Testing completed on arrays in 2006

Approach

- Develop system designs that reduce complexity, size and number of components.

- Use non-dilute methanol fuel to maximize energy density.
- Passively manage the fuel and water to optimize power, efficiency and size.
- Apply high volume manufacturing technology to array fabrication.
- Work with original equipment manufacturers (OEMs) to develop product introduction strategy, getting them familiar with fuel cell characteristics and advantages.
- Pursue early promulgation of codes and standards to smooth the introduction of fuel cell technology to regulatory bodies, and remove any product introduction roadblocks.
- Develop supply chain, teaching fuel cell technology to suppliers as appropriate.

Accomplishments

- MTI continued to develop the array during the funding suspension period and demonstrated a membrane energy density of 50 mW/cm^2 and a fuel energy density of 1.4 Wh/cc.
- Fabricated and tested a full prototype in 2006 with energy density equivalent to lithium ion batteries.
- Gained International Civil Aviation Organization (ICAO) approval and publication of a passenger exception for methanol fuel cells as carryon for passenger aircraft. (Hydrogen micro fuel cell approval likely to be 2 years later.)

Future Directions

- Evaluate membrane electrode assembly (MEA) components for durability and performance.
- Continue to upgrade the array design and fabrication process to reduce size, optimize performance and reduce cost.
- Investigate manufacturing options and continue to develop infrastructure.
- Test and evaluate system prototypes.
- Complete international standard for consumer use of small fuel cells and attendant fuel; both methanol and hydrogen.

Introduction

The DMFC technology and MTI's passive Mobion® implementation is well suited for handheld portable power applications in consumer electronics such as cell phones, smart phones, PDAs and game systems. It uses liquid methanol fuel directly, instead of hydrogen, so that issues associated with converting the liquid fuel to hydrogen and then managing the hydrogen gas, are avoided. This, along with the lower costs associated with the smaller platform, allows the DMFC technology to proceed at a faster development pace than the related hydrogen fuel cell technology. An early introduction of fuel cells into the consumer environment will assist the development of the necessary manufacturing base for all fuel cell technologies to follow, and will gain a broader public understanding of the fuel cell merits.

Approach

This project is focused on the development of the technology elements and manufacturing base such that low cost fuel cell products can be introduced on an accelerated timeline. While early products have been introduced, the actual manufacturing costs are much too high to ever enter even into niche consumer products. The fuel cell array, which contains many of the same components as a hydrogen fuel cell, must go through a manufacturing volume ramp up and attendant cost reduction. Such components as the membrane, catalyst, diffusion layers, current collectors and humidification membranes must be developed for mass production. This project is working with a broad range of suppliers to develop low cost components to meet performance specifications. These components are then integrated with balance of plant components to produce prototypes to evaluate system integration and to develop OEM interest in the technology. Each design-build-test cycle yields further performance improvements and cost reductions necessary to get into an early market.

Results

The fuel cell array, shown in Figure 1, was just introduced to the public as the funding for this project resumed. This state-of-the-art Mobion® molded "chip" is being designed for high volume mass manufacturing. The chip can be used in orientation-independent systems and in laboratory testing, and has demonstrated power of over 50 mW/cm^2, while producing 1.4 Wh/cc of

FIGURE 1. Fuel Cell Arrays

energy from the fuel. This project will further develop the design and production processes to bring about significant cost reductions. Many of these very same techniques could be carried over to hydrogen fuel cell stack production. The infrastructure developed in these activities will also advance the use of similar processes in the hydrogen projects.

During the funding gap in 2006, the proof of concept prototype (POC), shown in Figure 2, was built and tested through MTI support. This system demonstrated that it had the same energy density as a typical lithium ion battery. This represents the threshold for a product to compete with the batteries now in use for handheld electronics.

FIGURE 2. 2006 Proof of Concept System

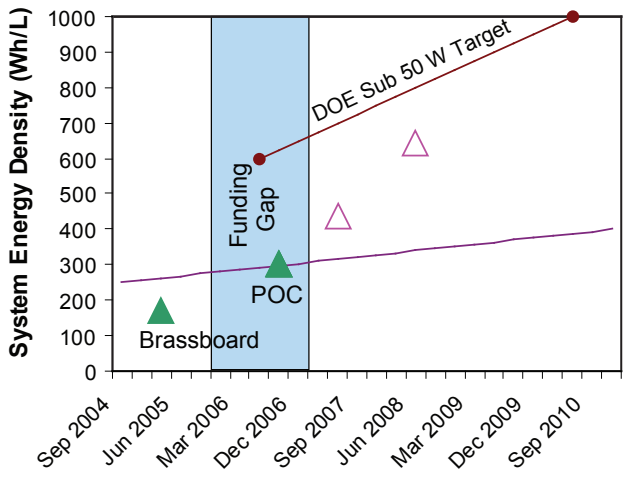

FIGURE 3. System Performance Test Results and Projections

A system energy density projection, shown in Figure 3, was prepared as funding was resumed. This figure reports the original brassboard test results in the first year of the project. It shows the POC results during the funding gap and it provides projections for the units to be tested later this year and next as part of the second and third design-build-test cycles of this project. There is a positive trend toward improved performance in the units tested to date. The projected performance is well above the energy density of the competing battery, approaching the DOE targets. This performance level is more than sufficient to open up markets to small DMFCs.

There is a substantial body of regulations that govern the use and transport of hazardous materials. In order to get fuels and fuel cells of any kind delivered to point of use or carried in commercial transport such as automobiles and airplanes, a large investment is needed to develop the codes and standards for fuel cells and the attendant fuels. This project has concentrated in the past two years on the international regulations for fuel transport and fuel cell use in airline passenger cabins. Teams from MTI and the Methanol Foundation have been deeply involved in wide ranging tasks with multiple international bodies, as shown in Figure 4, driving the standards forward. Many milestones in the process have been achieved toward acceptance of fuel cells in airline passenger cabins. In the process, a number of white papers and presentations have been prepared for the Department of Transportation (DOT) and the Federal Aviation Administration (FAA) to allow them to become familiar with the fuels and fuel cell technology and address their safety concerns. While the international standard establishing a passenger exception for fuel cells and fuel cartridges became effective on January 1, 2007, DOT has yet to promulgate a rulemaking to come into compliance. This will get increased attention over the remainder of this year. This process has also carried the sub-50 W hydrogen fuel cells forward as well. The DMFC forward involvement has potentially trimmed 2

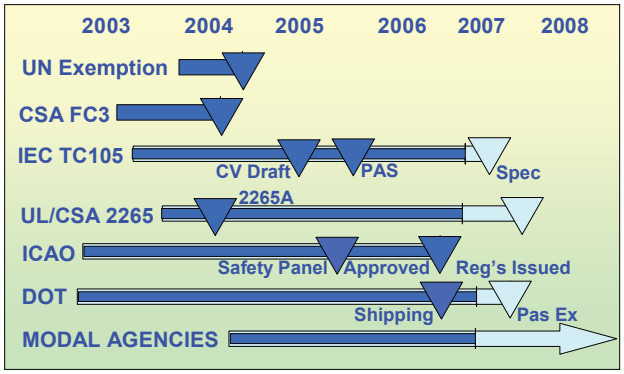

FIGURE 4. Codes and Standards Activities and Timeline

years from the deployment of hydrogen fuel cells in this environment.

Conclusions

- Project performance metrics are on target for sub-Watt devices.
- This project provides key technical progress for the development of the DMFC platform in handheld consumer electronics.
- Regulatory work for sub-Watt DMFCs is on track except for DOT promulgation of airline passenger exception. We will need to concentrate on DOT and FAA issues this year to keep DMFCs and small hydrogen fuel cells on track.
- Manufacturing development is producing infrastructure capabilities that will benefit subsequent hydrogen fuel cell products.