Ovonic Fuel Cell Company

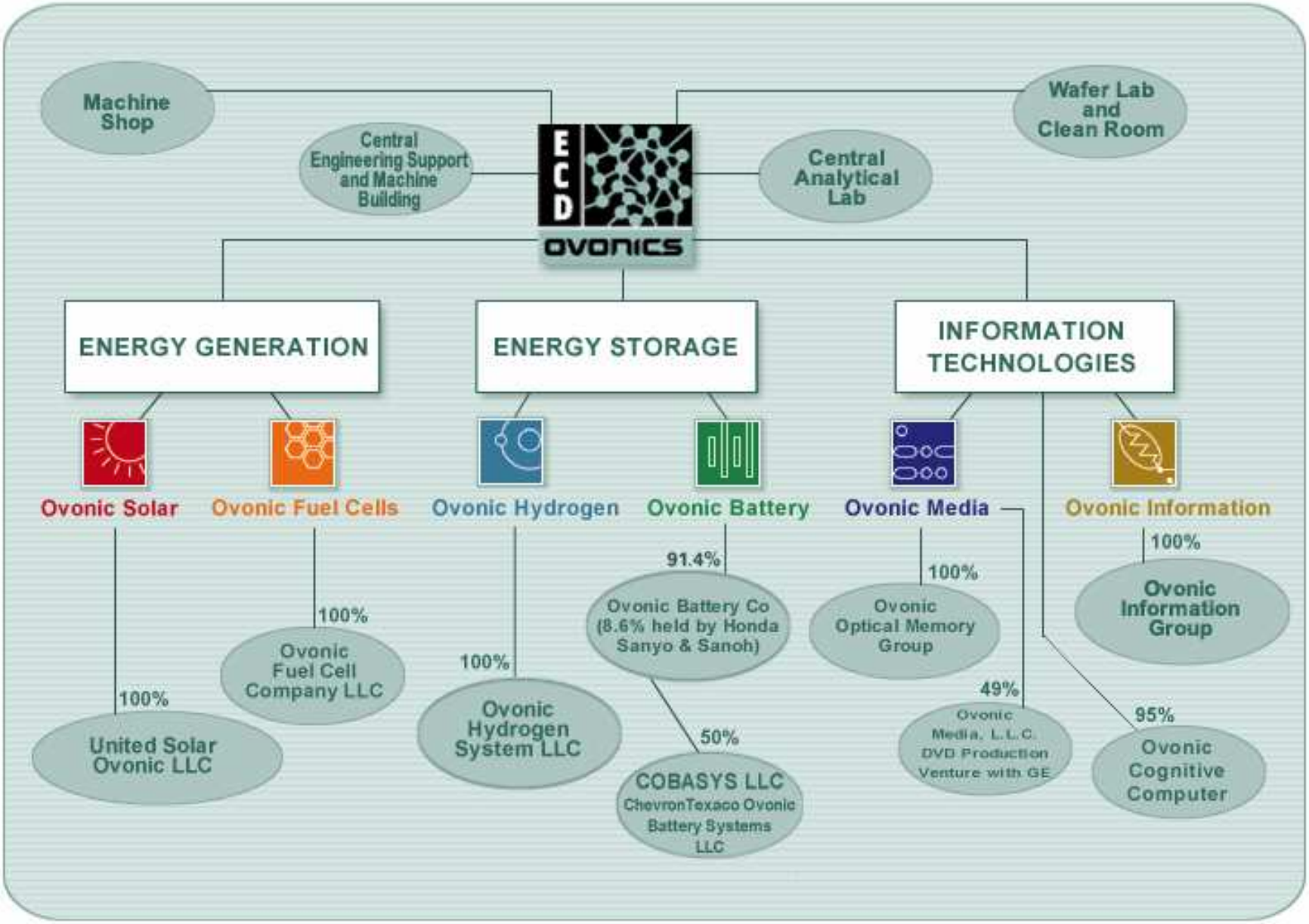
The Ovonic® Regenerative Fuel Cell:
A revolutionary patented hybrid energy device that provides the combined benefits of a fuel cell and rechargeable battery



…Paving the way to practical power solutions

January 31, 2005

CORE BUSINESSES & STRATEGIC ALLIANCES



Ovonic Metal Hydride Technology

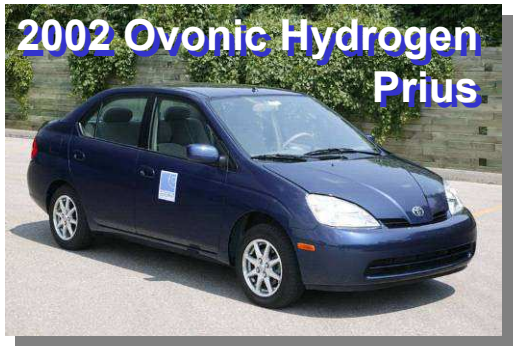




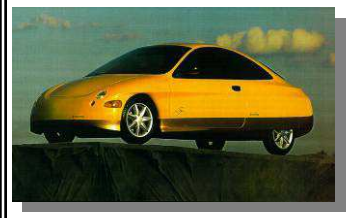




Consumer NiMH Batteries



Ovonic Hydrogen Systems, LLC

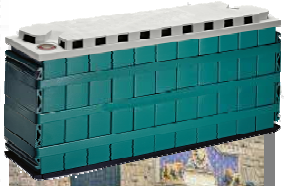




NiMHax™

ovonics@work







COBASYS

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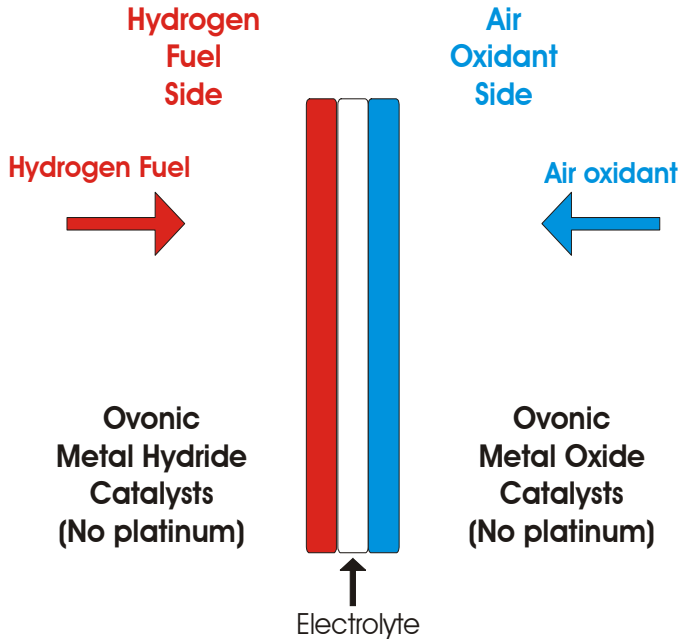
Ovonic Fuel Cell Company

- **ECD Ovonics subsidiary founded in 2000 to commercialize game-changing technology:**
- **The Ovonic Regenerative Fuel Cell utilizing hydrogen storage material in anode active material.**

Ovonic Regenerative Fuel Cell

- **Uses Ovonic metal hydride materials in anode:**
  - **Stores hydrogen in stack**
  - **Rechargeable chemically and/or electrically**
- **Uses alkaline electrolyte**
  - **Commonly used in inexpensive batteries**
- **Uses Ovonic metal oxide materials in cathode**
  - **Rechargeable chemically and/or electrically**
- **Ovonic concepts and patents can be applied to all fuel cell types**



Ovonic Benefits Over PEMFCs

Ovonic Regenerative Fuel Cell Feature	Benefits to the Customer	PEMFC Status
➢ Regenerative Operation	➢ Ability to store regenerative braking energy ➢ Tolerance to power transients ➢ No buffer battery needed	➢ Buffer battery needed ➢ No intrinsic energy storage
➢ Instant Start Capability	➢ Microsecond start times ➢ No starter battery needed ➢ Some operation without hydrogen gas	➢ Startup battery needed for instant start ➢ No operation without hydrogen gas fuel
➢ Excellent Low Temperature Power	➢ Intrinsic low temperature operation ➢ Operation to below -20 ˚C	➢ Limited low temperature operation ➢ Stack freezes at 0 ˚C
➢ Lifetime	➢ Excellent life opportunities	➢ Life limited by membrane degradation
➢ Low Cost Components	➢ Significant low cost opportunity ➢ Stack materials cost < ½ PEMFC	➢ High cost noble metal catalysts ➢ High cost membrane ➢ High cost graphite bipolar plates

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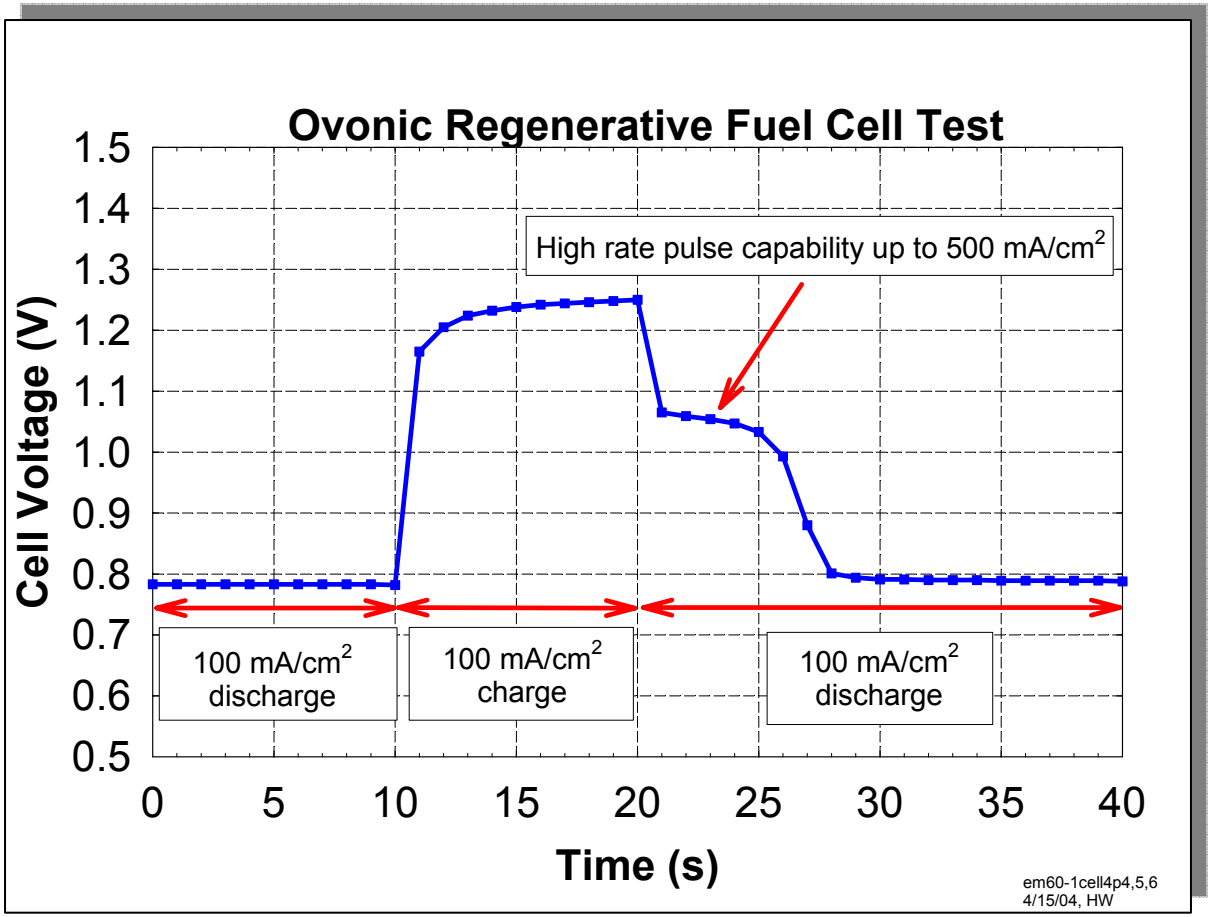
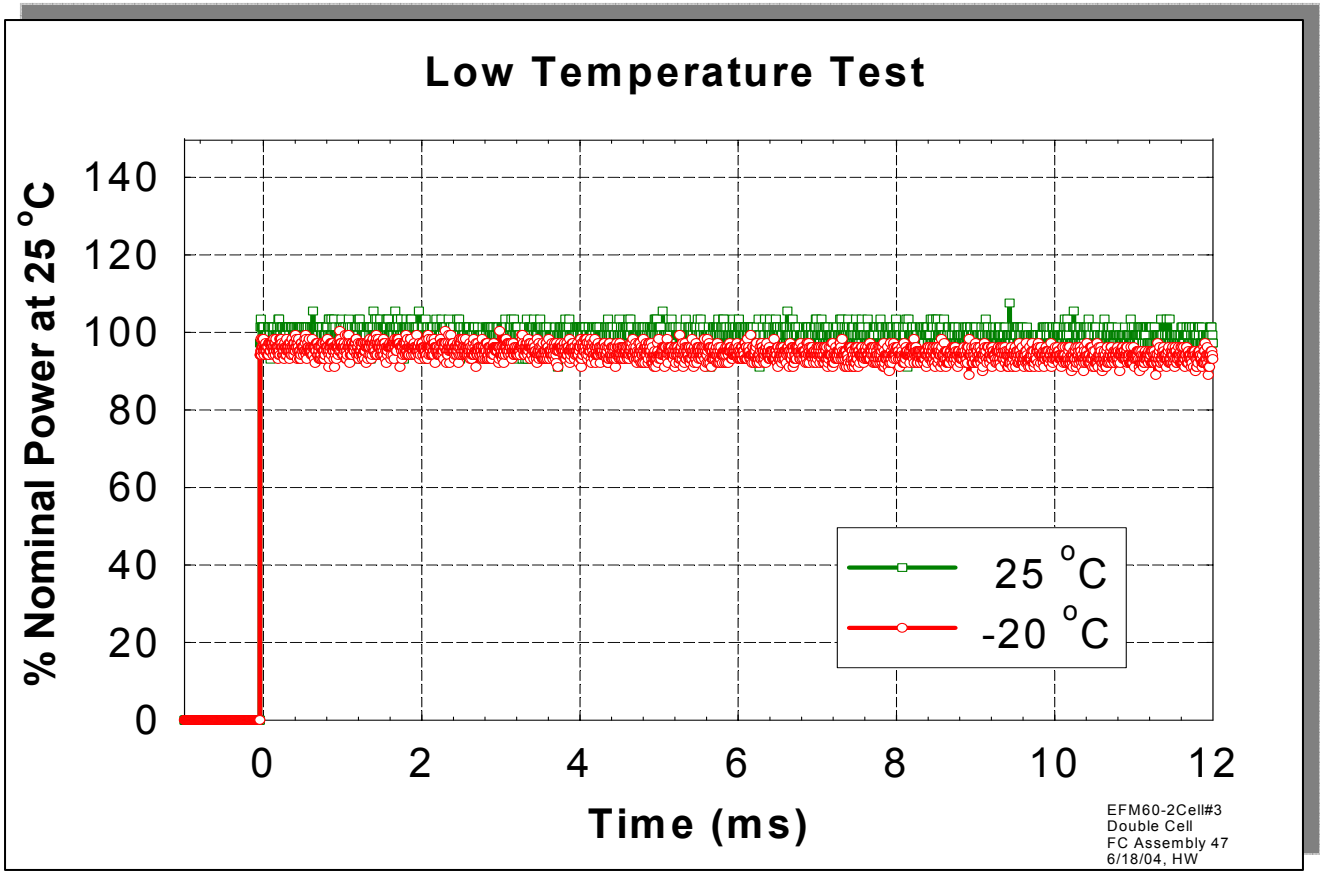
Energy Storage Functionality: Regenerative Operation

- The Ovonic Regenerative Fuel Cell can store energy
- 80% energy efficiency at 50% of full power
- Unique capability
- Game-changing technology!

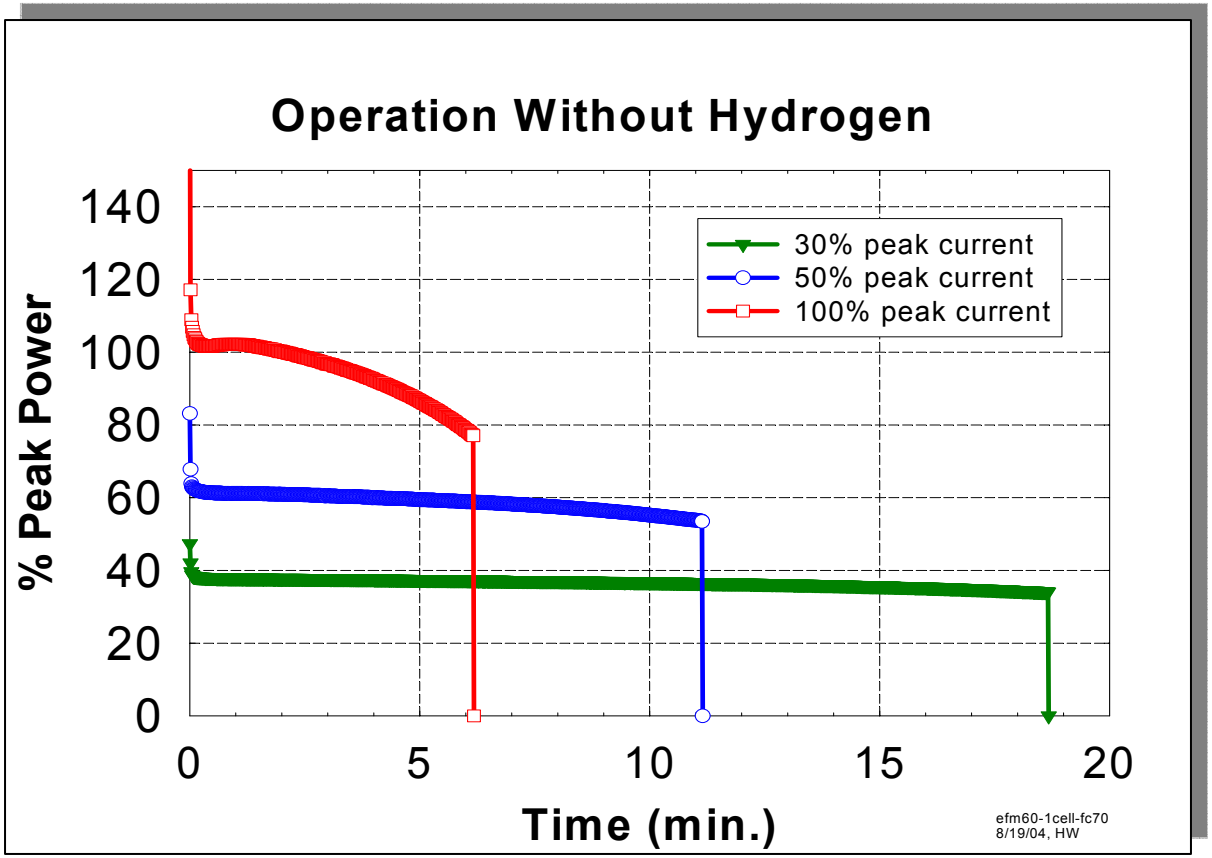


Instant Start Operation

- Instant start even at -20°C

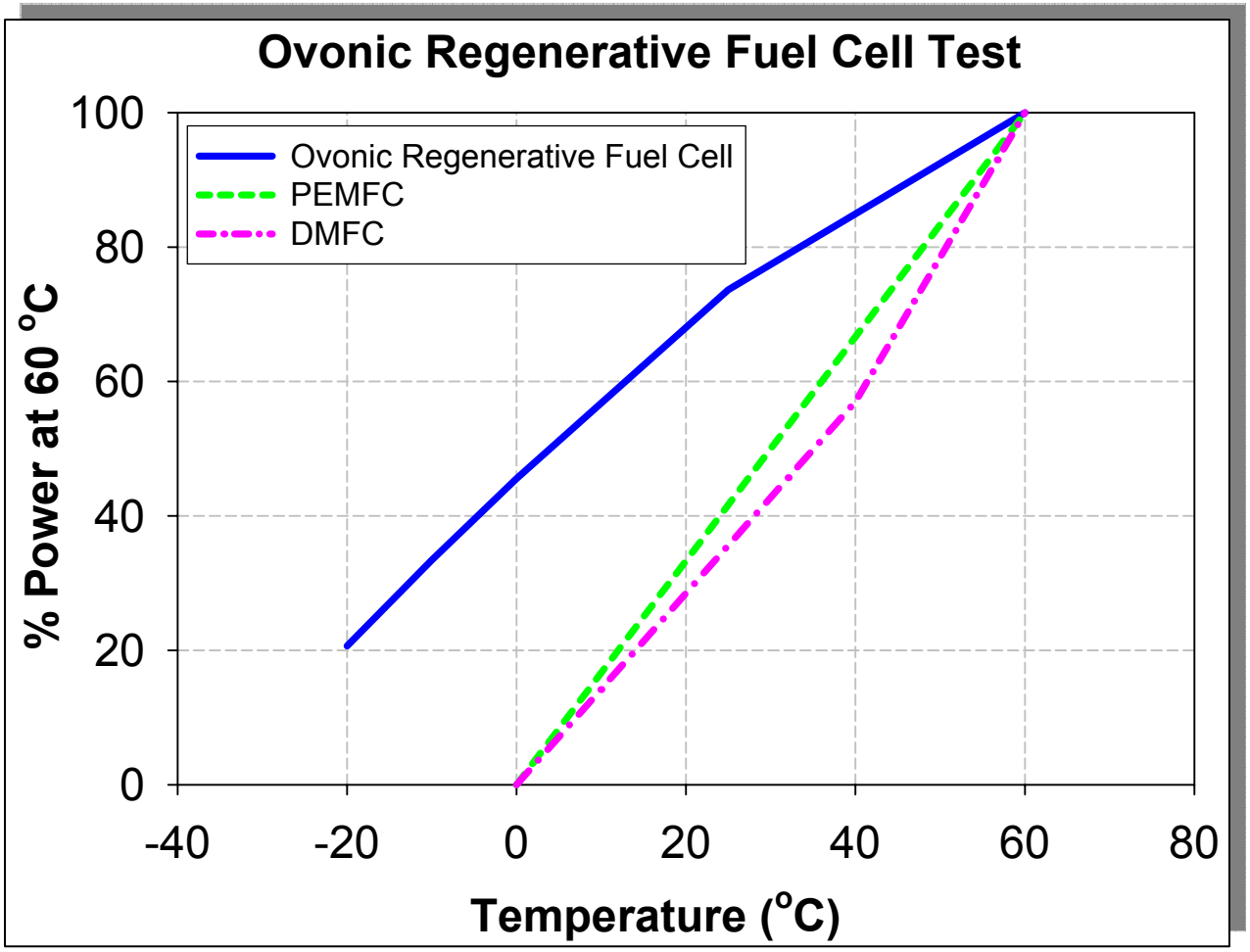


Instant Start Operation



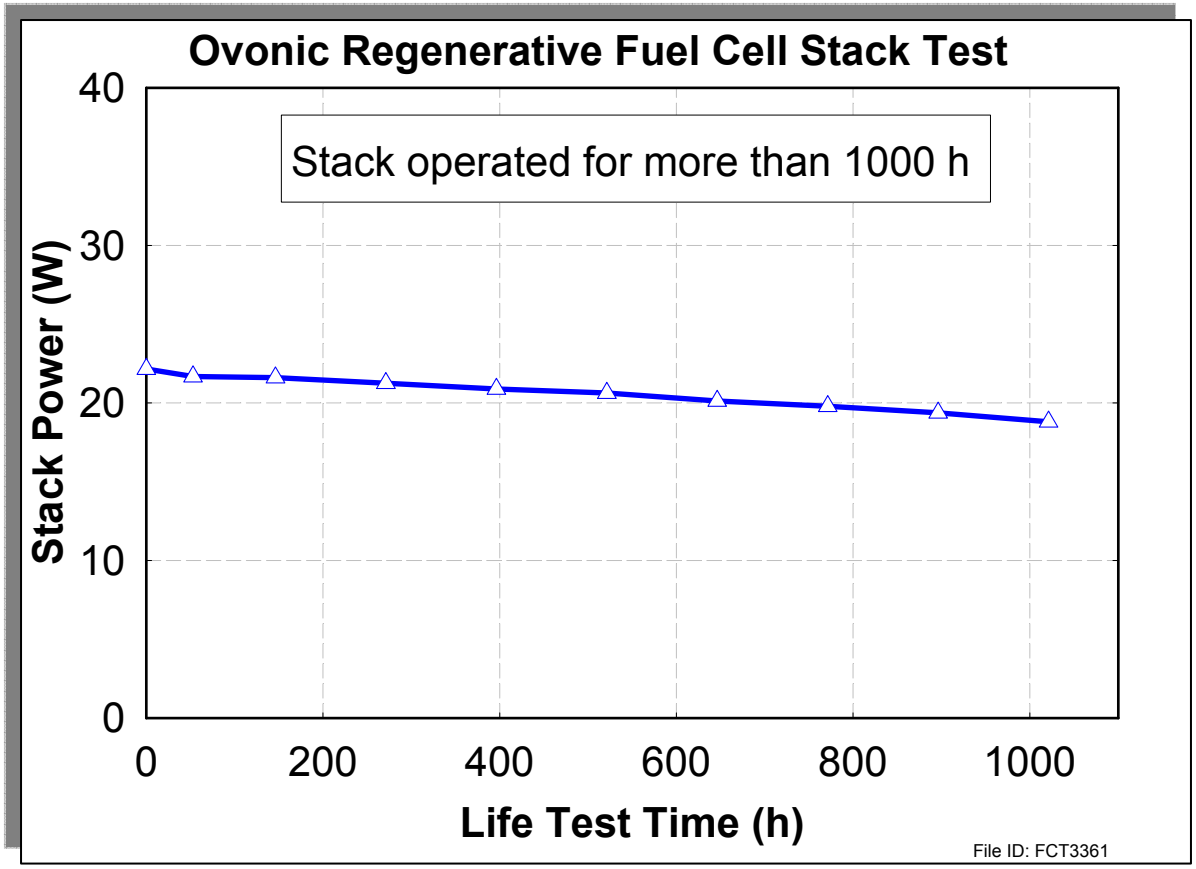
- **The Ovonic Regenerative Fuel Cell can start up <u>without hydrogen</u> and operate for several minutes**

Low Temperature Operation



- **The Ovonic Regenerative Fuel Cell stack can operate below -20 °C**

Prototype Life



- **Multicell stacks demonstrated to last over 1,000 hours**
- **Electrode life tests exceed 5,000 hours**

Low Cost Fuel Cell Opportunity

- **Component costs as a percentage of total materials cost projected for volume production (~50,000 units/year @ 10 kW/stack)**

Component	Ovonic Fuel Cell	PEM Fuel Cell*
Catalyst	9%	40%
Electrolyte	1%	31%
Cell Interconnects	2%	12%
Misc. Hardware	88%	17%

Inherent high raw materials costs!

Hardware cost reduction opportunities!

*** Source:**
TIAX, LLC., 2003 Hydrogen and Fuel Cells Merit Review Meeting, Berkeley, CA, May 19-22, 2003

- **Initial Ovonic FC materials cost estimates 50% reduction from PEMFC with significant future cost reduction opportunities**

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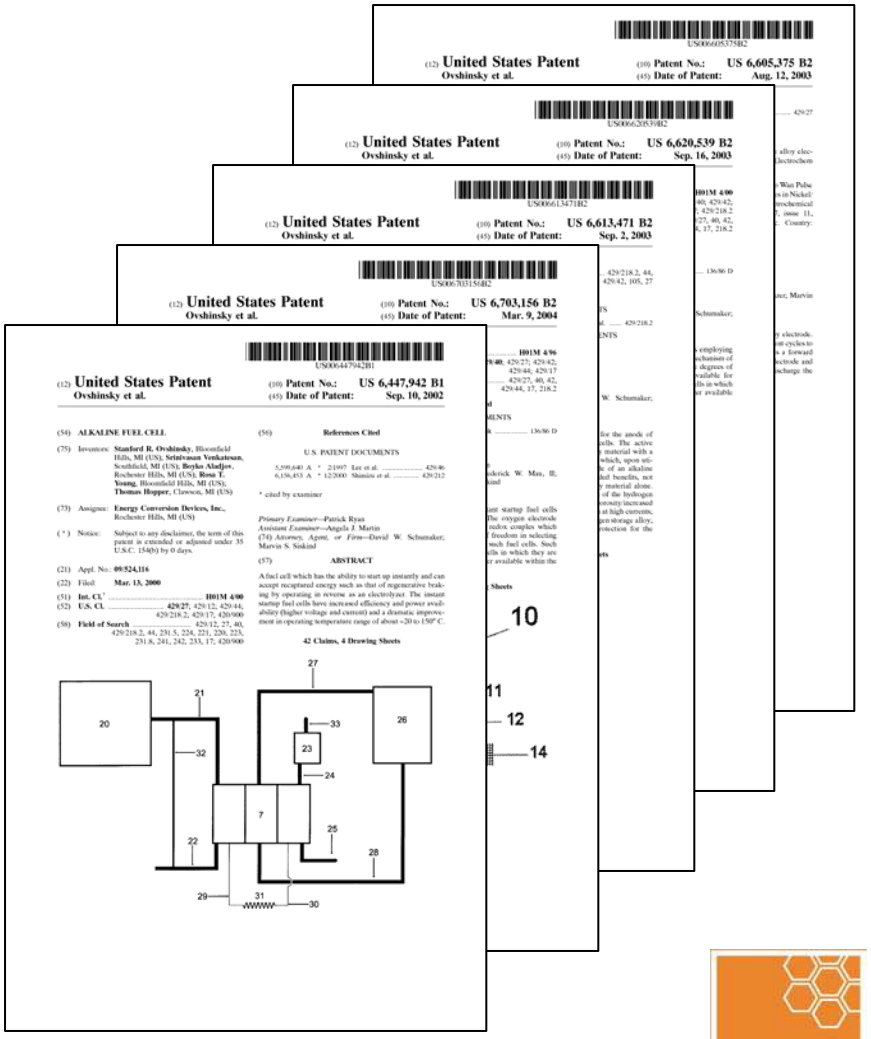
Electrolyte CO_2 Absorption

- **Practical engineering solutions available**
- **Flexible solutions tailored for applications**
  - **Cartridge replacement for small, portable systems**
  - **Regenerative CO_2 removal for large systems**

Solution	Small, Portable, Cost Sensitive Systems	Small, Portable, Long Life Systems	Large, Long Life Systems
No removal	✓		
Electrolyte exchange	✓	✓	
Soda lime canister		✓	
Pressure swing adsorption			✓
Amine-based regenerative scrubbers			✓
Carbon fiber composite molecular sieve (CFCMS)			✓

Intellectual Property

- **Ovonic Regenerative Fuel Cell IP**
  - **11 U.S. Patents**
    - **Key patent granted 2002**
  - **U.S. Patent Applications**
    - **>25 published**
    - **More pending**



Infrastructure and Facilities



Electrode Fabrication Lab



22,000 ft² Building



Fuel Cell Test Stations



Fuel Cell Assembly Lab



Rapid Prototyping Machine



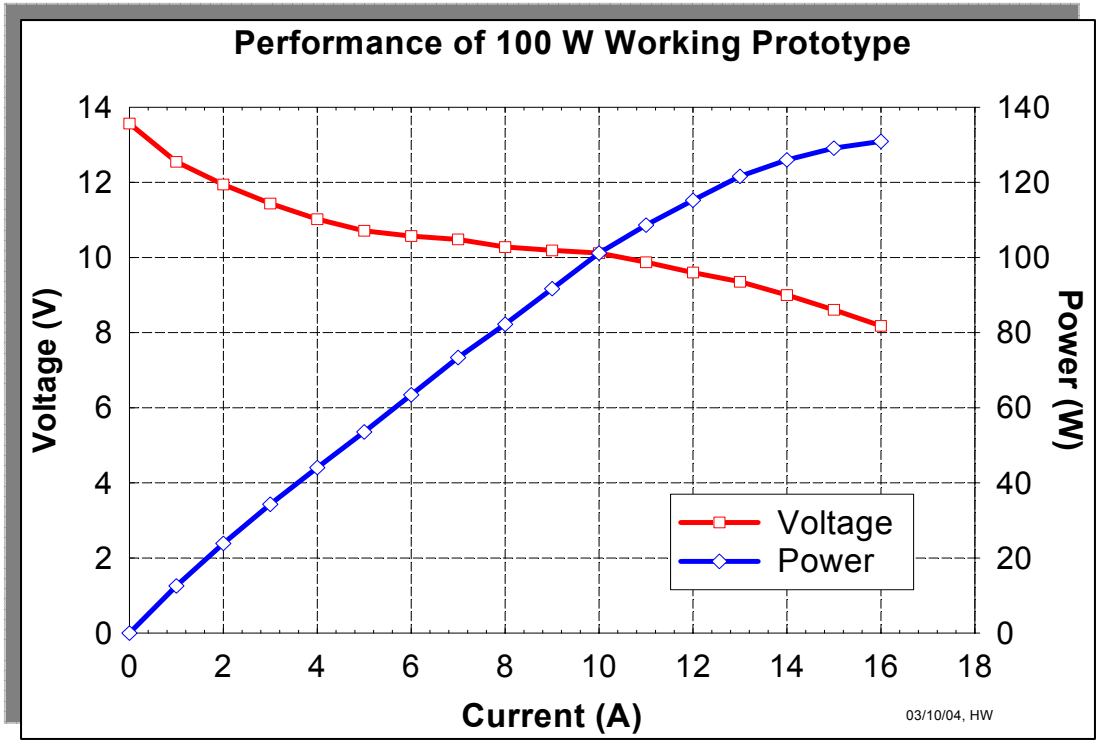
Analysis Equipment



Prototype Product Development



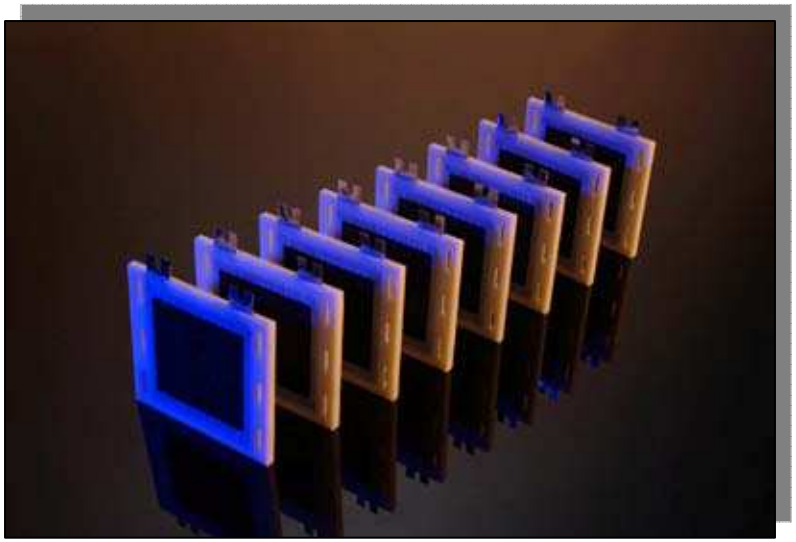
Early 100 W Working Prototype

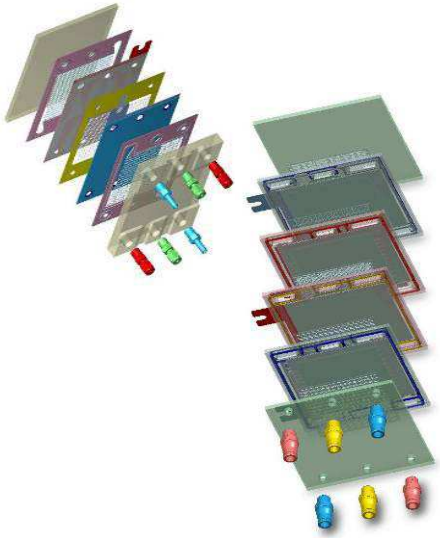


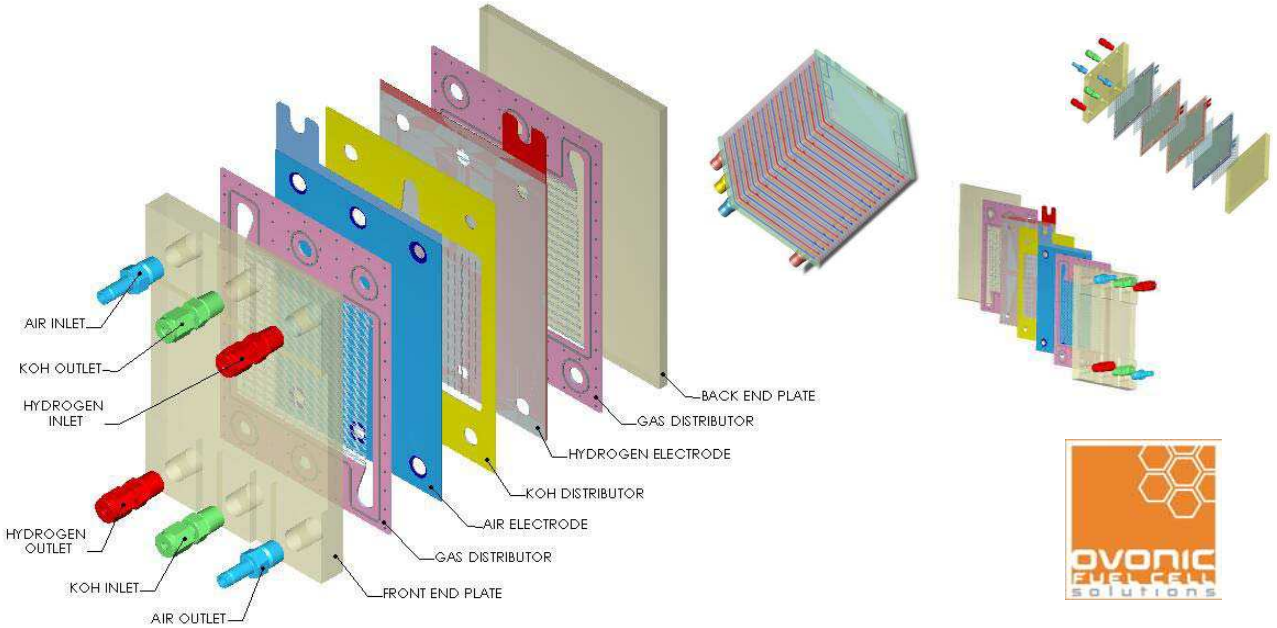
- **Early prototypes at 150 mA/cm^2 peak**
- **New results up to 200$^+$ mA/cm^2 continuous**
- **Pulse capability exceeds 500 mA/cm^2**

Practical Design Approach

- Low-cost
- Modular
- Scalable
- Easy to manufacture







Designed for Manufacturability

- Can use roll-to-roll processes for electrode fabrication
- Bulk processing for non-noble metal catalyst deposition
- Readily available and robust materials and hardware



Cobasys Roll-To-Roll Processes



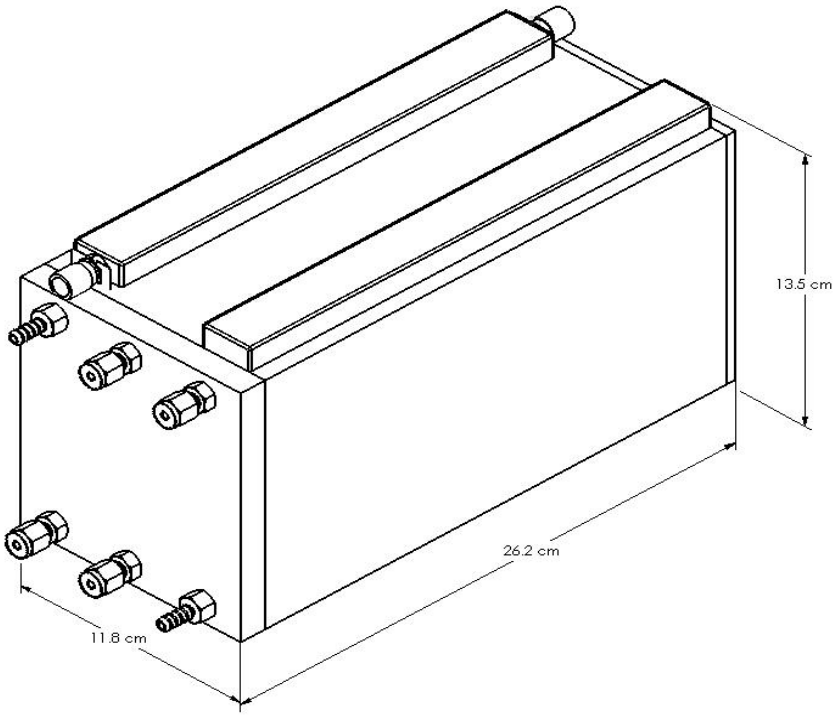


Ovonic Fuel Cell Company
Electrode Roll Mills

OV-60 Prototype Products

OVONIC 40-OV-60 FUEL CELL STACK

Configuration:	40	cells in series
Electrode Surface Area:	60	cm^2
Module Dimensions:		
Width	11.8	cm
Length	26.2	cm
Height	13.5	cm
Volume	4.2	L
Module Weight:	3.9	kg
Nominal Performance:		
Power	260	W
Voltage	26	V
Current	10	A
Specific Power	67	W/kg
Power Density	62	W/L
Temperature	60	^oC

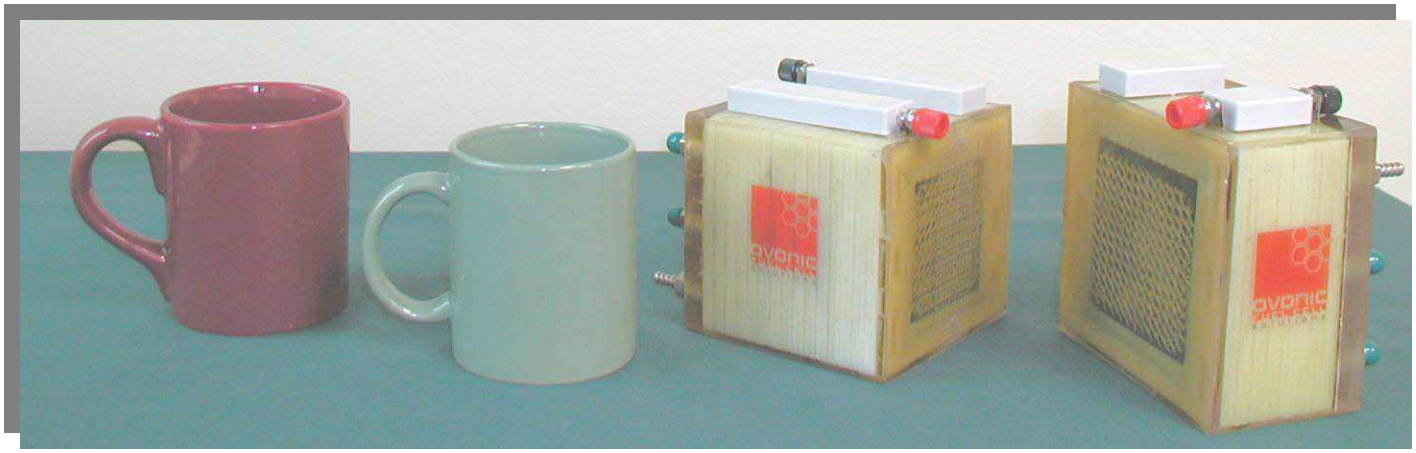


Ovonic Fuel Cell Demonstration System



Market Opportunities

- Military Applications
- Emergency Power/UPS
- Stationary Applications
- Scooters and Motive Power
- Automotive Fuel Cell Market



Management/Senior Staff

- **Stanford R. Ovshinsky, Chairman**
  - Pioneered science of amorphous and disordered materials
  - Commercialized revolutionary products through licenses and business alliances with large corporations
- **Dennis Corrigan, PhD, President & CEO**
  - Developed prototype electric & battery vehicle systems delivered to major automakers worldwide
  - Successfully managed several multimillion dollar development contracts for US DOE and auto manufacturers
- **Frank C. Ingriselli, Exec. VP & CFO**
  - 25 years of international energy commercial experience; former President of Texaco Technology Ventures
- **Srinivasan Venkatesan, PhD, VP R&D**
  - 30 years of electrochemical R&D experience, coinventor of NiMH battery and ORFC
- **Kevin Fok, Manager of Marketing**
  - BS in Chemical Engineering and MBA degrees, 10 years experience at ECD Ovonics
- **Richard Bendert, Manager Systems Engineering**
  - BS in Chemistry, 25 years advanced battery systems experience
- **Konstantin Petrov, PhD, Senior Scientist**
  - 20 years R&D specific experience in fuel cells
- **Hong Wang, PhD, Senior Scientist**
  - 20 years R&D specific experience in fuel cells

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Summary

- Revolutionary low cost fuel cell technology with unique performance advantages
- Exceptional patent coverage
- Excellent facilities and experienced staff
- Prototype products aimed at near-term military, UPS/emergency power markets
- Significant intermediate upside potential
  - Stationary power
  - Forklifts/motive power
- Game-changer technology for massive automotive fuel cell market in longer term

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