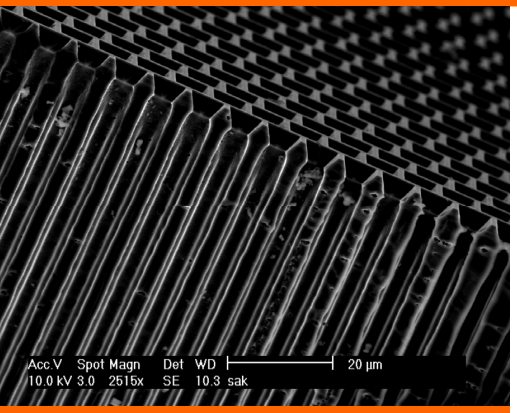
Silicon-Based Micro Fuel Cells for Mobile Electronic Applications



NEAH™ power systems

Longer-lasting power for mobile electronics

Leroy Ohlsen
Chief Technology Officer & Founder

Micro Nano Breakthrough Conference
Portland, Oregon

Wednesday, July 28, 2004
www.neahpower.com

Neah Power Systems

- **Micro fuel cell development company founded in 1999 in Seattle, WA, USA**
  - Formed to solve problems with fuel cells in mobile products
- **Pursuing an innovative silicon-based design to solve key technical limitations of fuel cell commercialization**
  - Higher power density
  - Fully sealed system
- **Venture capital funded**

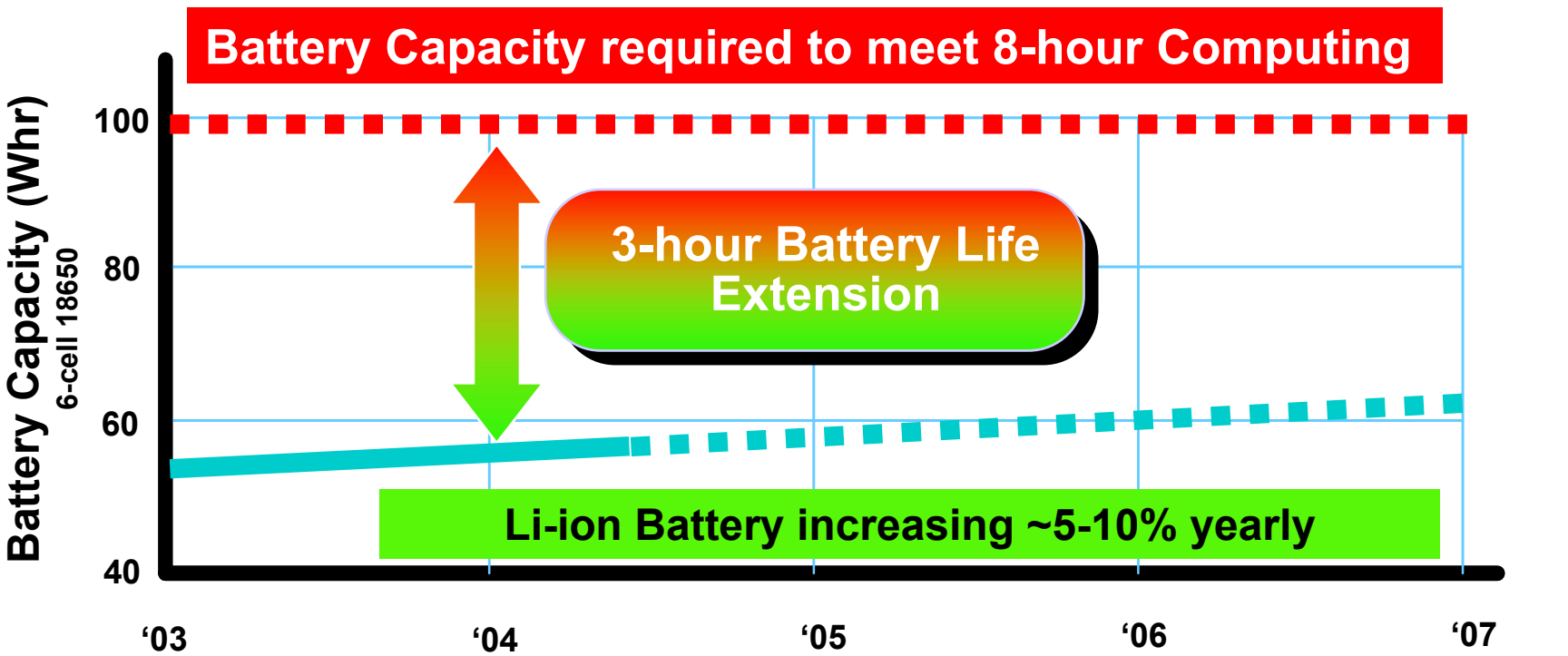
FRAZIER TECHNOLOGY VENTURES Alta Partners intel

- **2004: Design fuel cell for OEM product(s)**
- **2005: Complete designs and ship qualification units to OEMs**
- **2006: Scale-up production, initiate product shipments, expand OEM customer base**

Agenda

- What are the technical challenges for micro fuel cell commercialization?
- Neah Power technical approach
- What are the business challenges?
- How does a company and the industry address these challenges?

"All Day" 8 Hour Battery Requires 100Whr
Large Gap for Li-ion Battery to Overcome



Source: Intel/MPG study

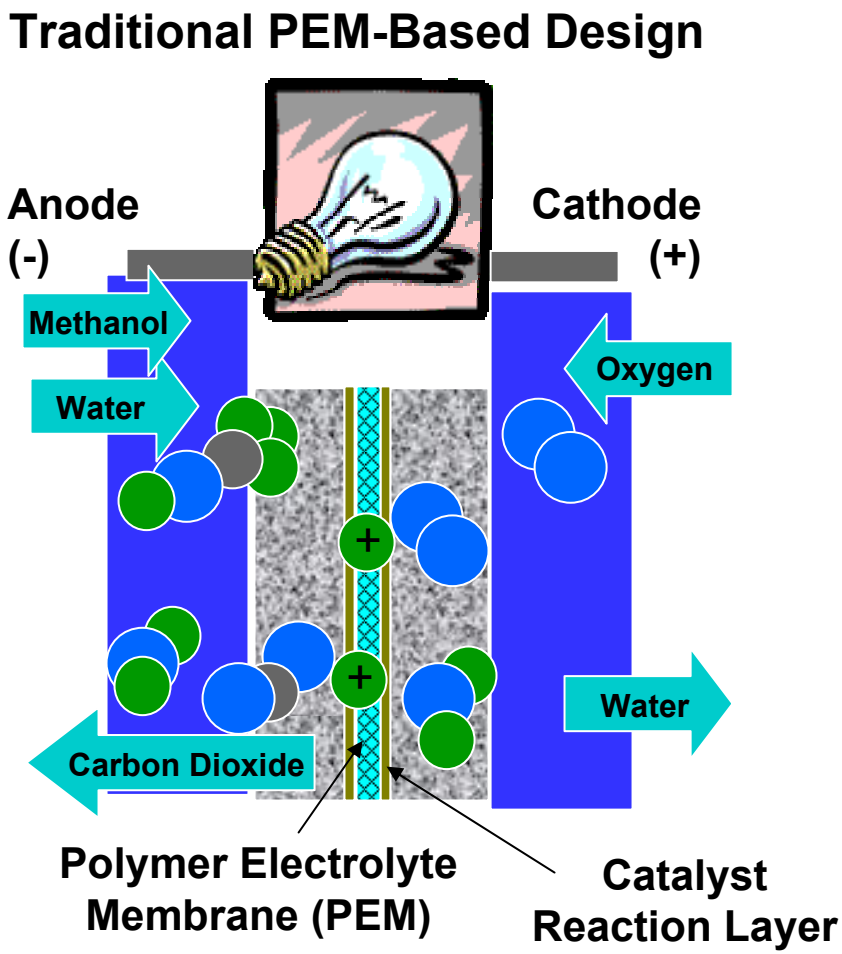
Longer battery life is the 2nd-most requested notebook improvement, from nearly 40% of survey respondents. Source: CMR, May 2002

Fuel Cells Can Be The Next-Generation Power Source For Mobile Products

- **Combine fuel (Methanol) with oxidant in a chemical reaction to generate electricity**
- **Generate electricity continuously when fuel and oxygen are supplied**
  - Analogous to automobile engine
  - Buy the engine once
- **"Refueled" instantly by replacing the fuel cartridge**
  - Analogous to disposable alkaline batteries
  - Methanol is available and inexpensive
- **Enable long run-time with spare cartridges, not extra batteries**
  - Market potential driven by device power needs and increasing user mobility
  - Wireless networks lead to "Opt Out, Not In" behavior
  - Convenience of use prevails with consumers

Design Limitations Have Hindered Application of Direct Methanol Fuel Cells Up to Now

- **Low Power Density, 20-50mW/cm^2**
  - Catalyst utilization
  - Catalytic surface area
  - Methanol crossover
- **Miniaturization**
  - Low power density
  - Requires "clunky" big cells
  - Managing by-products
- **Cost**
  - Precious metal catalysts
  - "Teflon" based polymers
  - Large size and low efficiency
- **Environment Interaction Complications**
  - Released water is problematic given proximity to electronics
  - Catalyst susceptible to contamination



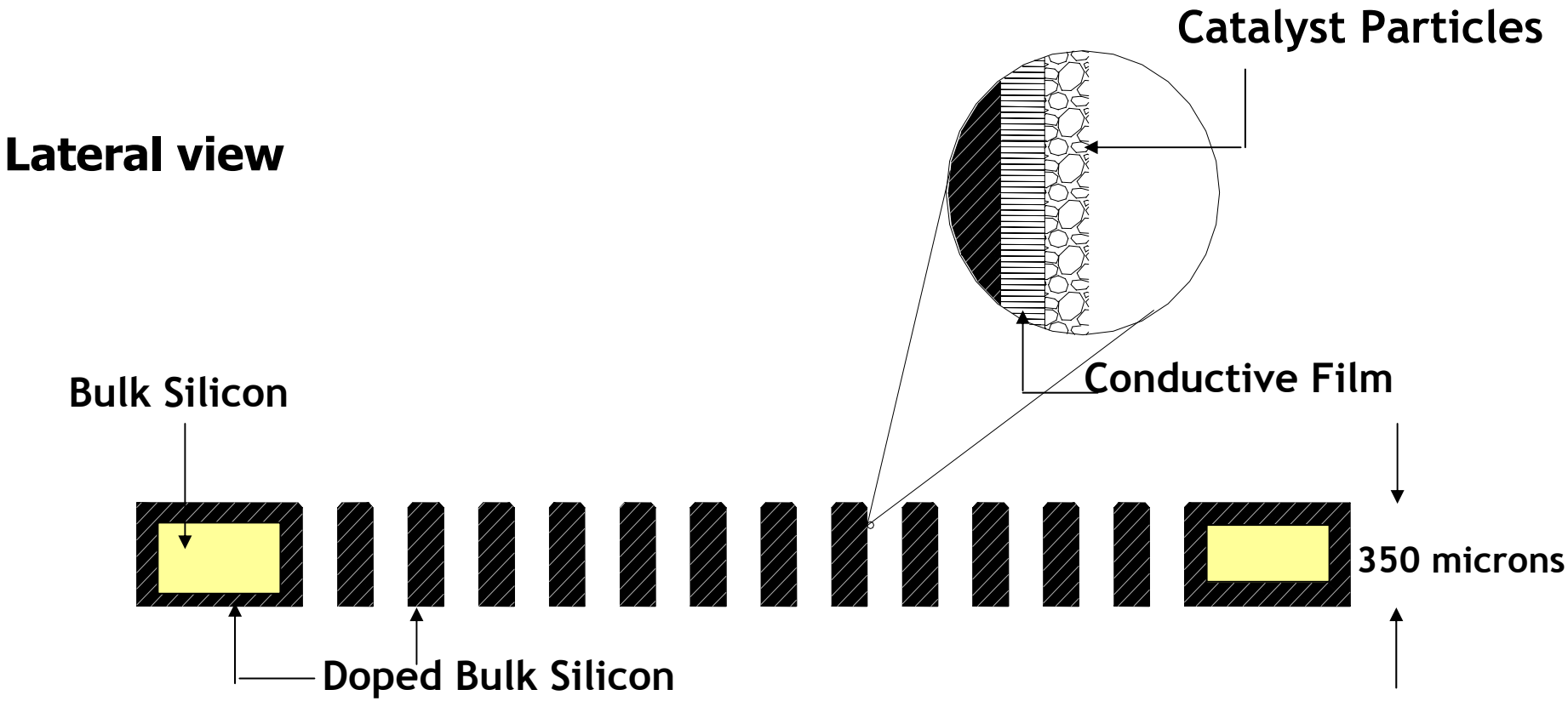
Result: PEM Fuel Cells Are Over-sized and Under-Powered

Fuel Cell Charger for Notebook PC (prototype)

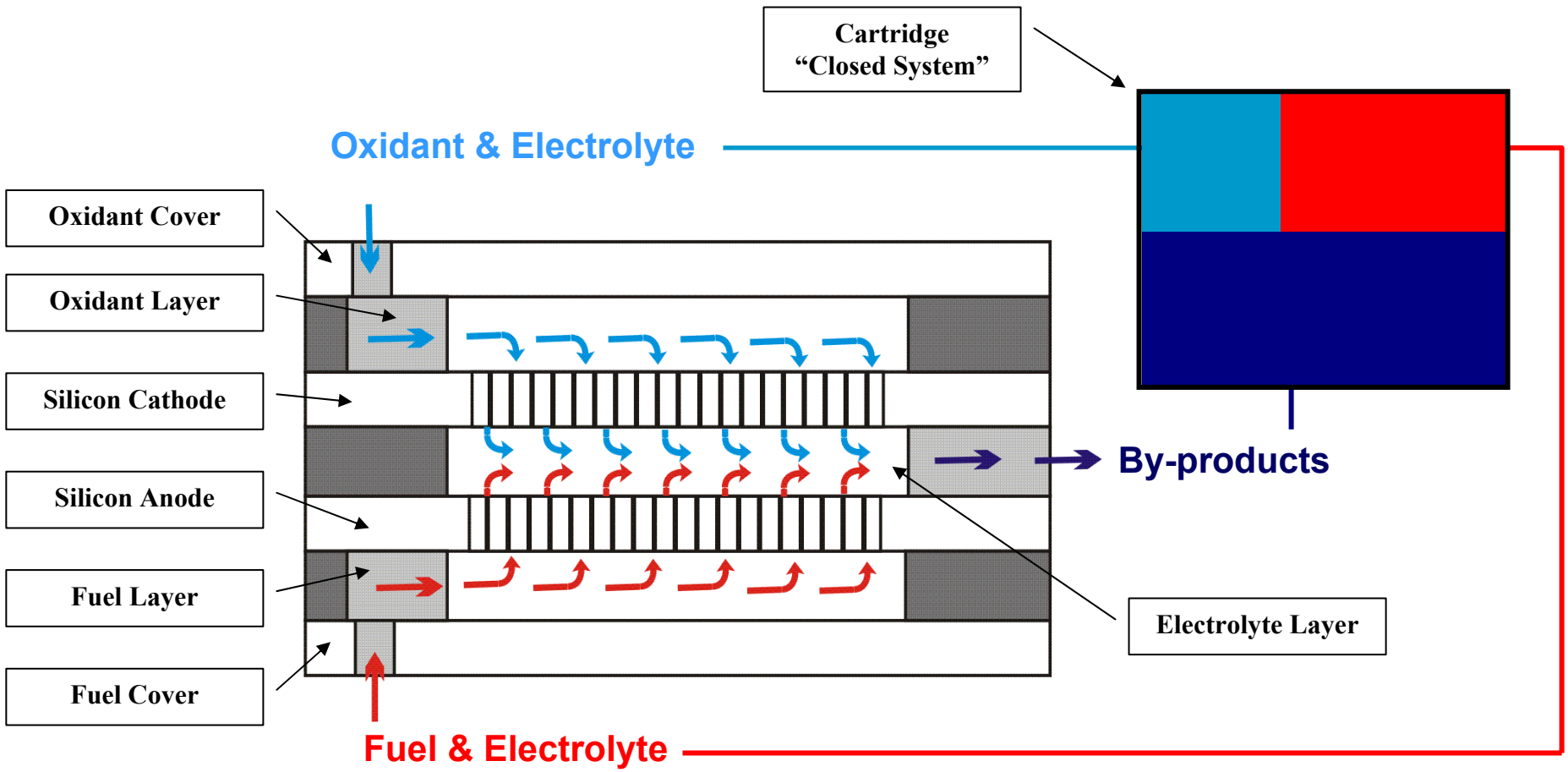
Fuel Cell for PDA (prototype)

Fuel cell for Notebook PC (prototype)

Porous Silicon Membrane Enables Unique Electrode Design



Reactants Pumped Through Electrode and By-Products Collected in Cartridge



Note: This is a simple schematic for illustrative purposes only. There are more advanced fluidic/electrolyte recirculation circuits not shown.

Example of Average Performance from a Single Neah Fuel Cell

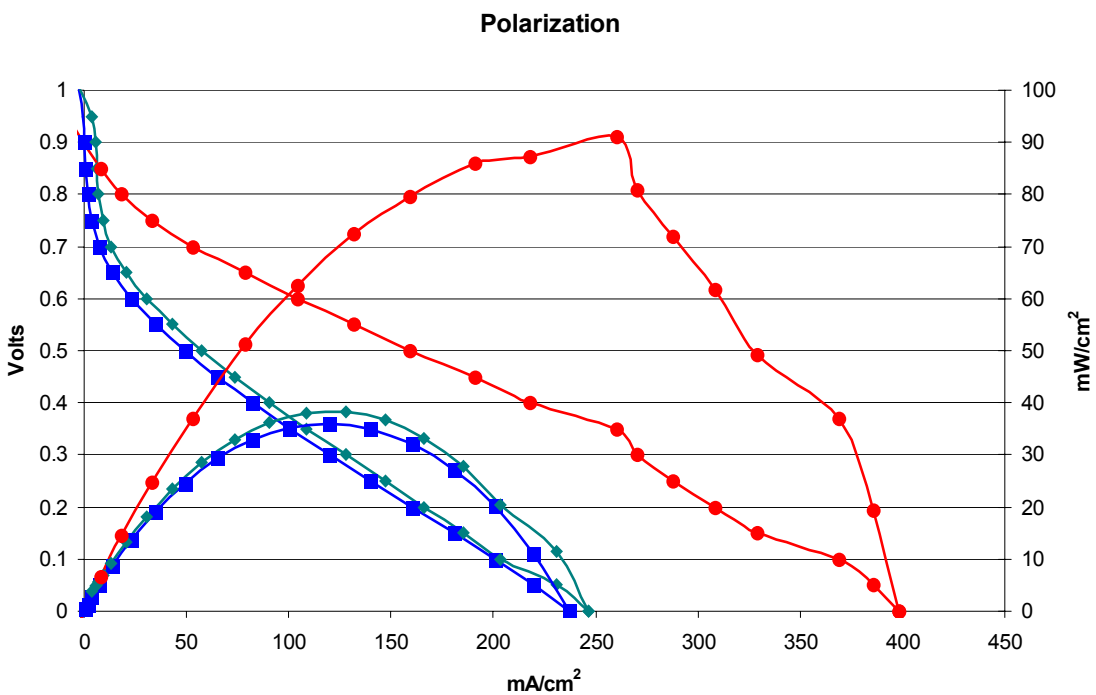
Anode (Pt:Ru): $CH_3OH + H_2O \rightarrow 6H^+ + 6e^- + CO_2$

Cathode (Pt): $2\,HNO_3 + 6H^+ + 6e^- \rightarrow 2NO + 4H_2O$

Cell: $CH_3OH + 2HNO_3 \rightarrow 2NO + 3H_2O + CO_2$ $E=1.15V$

(1) **Nitric Oxide converted to Nitric with Water and Oxygen**

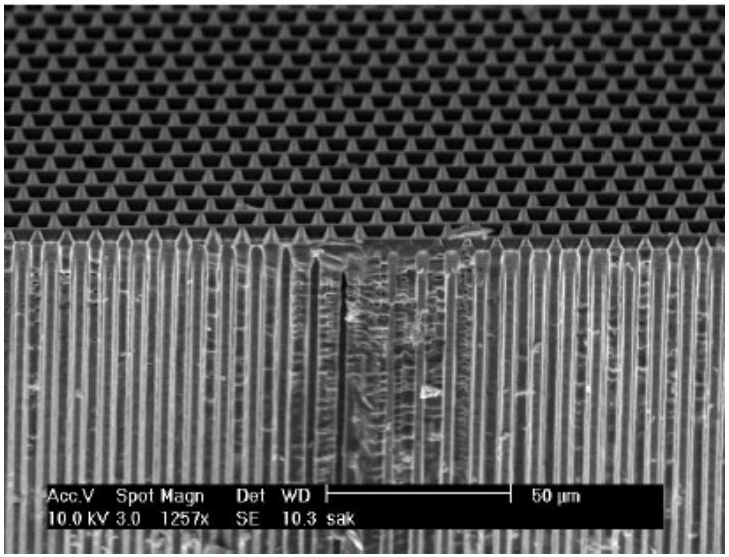
(2) **Small Quantity is Required.**



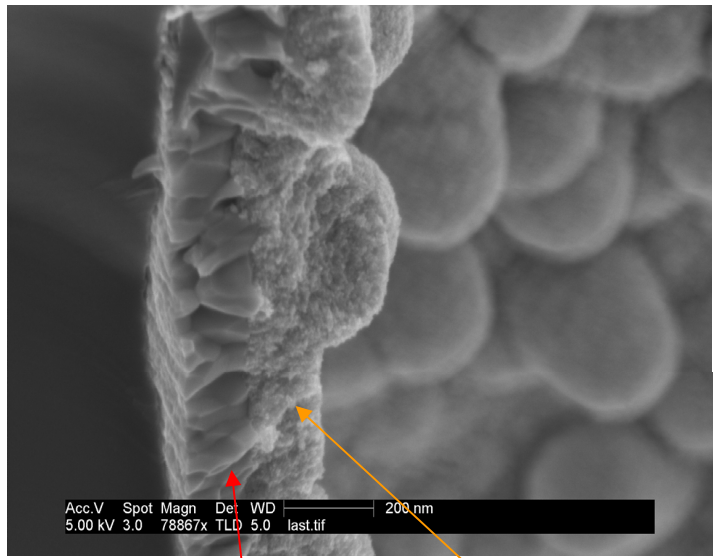
Test Sequence:

- Run 1: 20°C.
- Run 2: 20°C.
- Run 3: 60°C

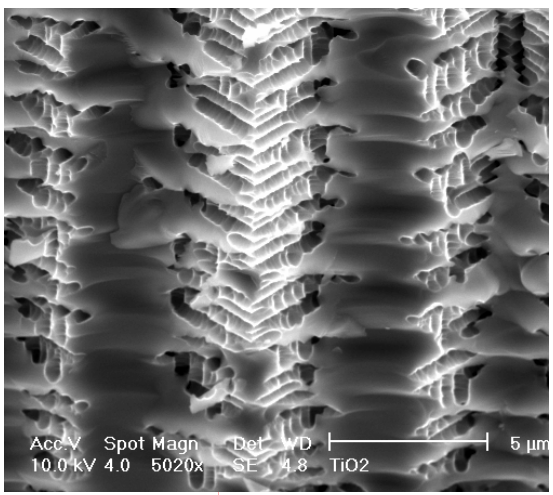
A Neah Has Developed Early Stage Capability to Produce Silicon Fuel Cell Electrodes



"Honeycomb" structure with 5um diameter on 8um pitch pores



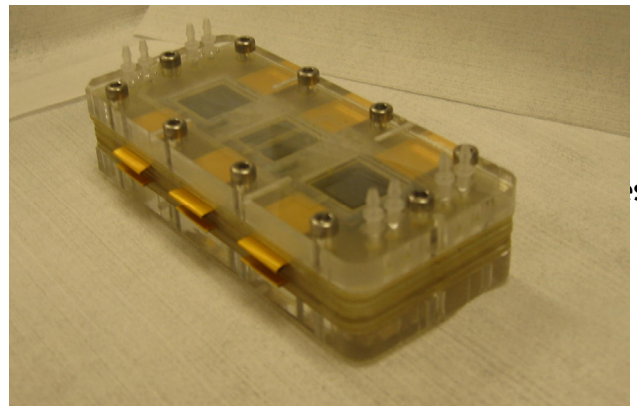
Metal conductor & catalyst coated pore walls.

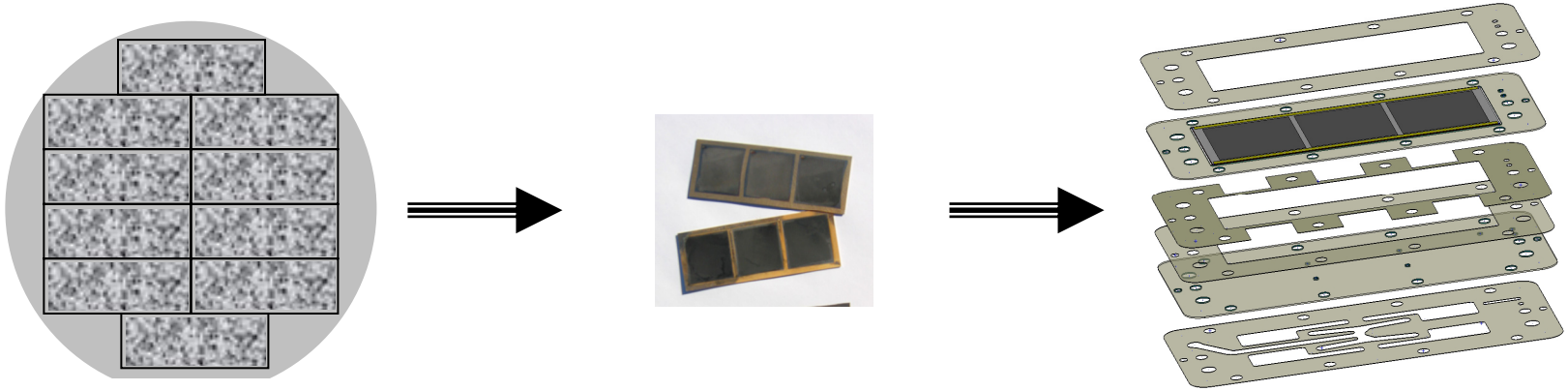


Goal is to achieve >200mW/cm^2. Still much more room for improvements, *i.e.*, structures providing higher surface area are feasible.

“Scalability” of Silicon Yields Low Cost By Producing Multiple Fuel Cells From One Wafer

- Etch and catalyze 200mm wafer
- Dice wafer into multiple electrodes
- Bond electrodes into fuel cell stacks
- Stack size defined by power density and device power needs
- Process can “scale” to yield multiple fuel cells from one 200mm wafer





Neah Approach to Solve Technical Challenges

- **Construct a "3D" reaction zone to increase power density**
  - Reduces size, material usage and cost
- **Utilize Powerful Chemistry**
  - Methanol Fuel & Regenerated Nitric Acid from Oxygen (Open System Embodiment) or Peroxide (Closed System Embodiment)
- **Create fully sealed system**
  - Collect by-products in fuel cartridge
  - Disposable

Agenda

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- ☑ Neah Power technical approach
- ❑ What are the business challenges?
- ❑ How does a company and the industry address these challenges?

Electronic Product Markets Provide Huge Volume Opportunity for Fuel Cells

Worldwide Annual Unit Volume (millions)

	2003	2009	Δ%
Notebook PCs	41	85	+107%
Tablet PCs	0.6	4.1	+592%
Military	0.3	0.6	+79%
PDAs	15	29	+93%
"Smart" Phones	14	78	+446%
Camcorders	20	41	+101%
Digital Cameras	31	76	+146%
Music Players	12	44	+266%
All Other	9.6	29	+201%
Total (14 markets)	144	387	+168%

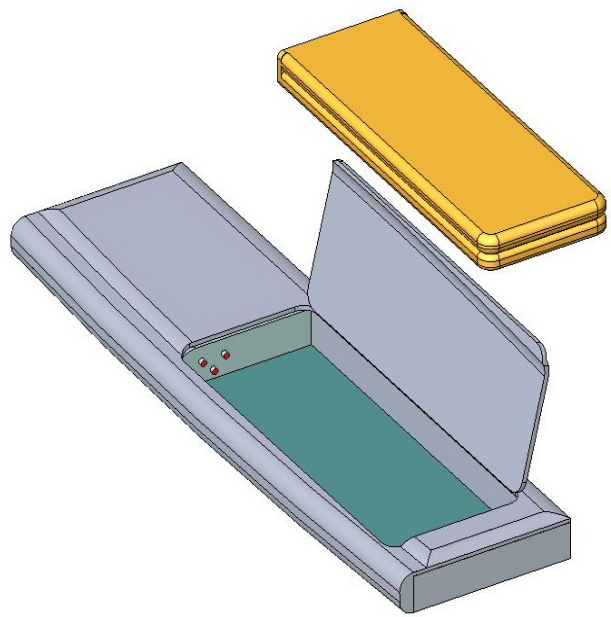
Sources: IDC, Bear Stearns, Morgan Stanley, ABI, CEA, etc.

Business Challenges

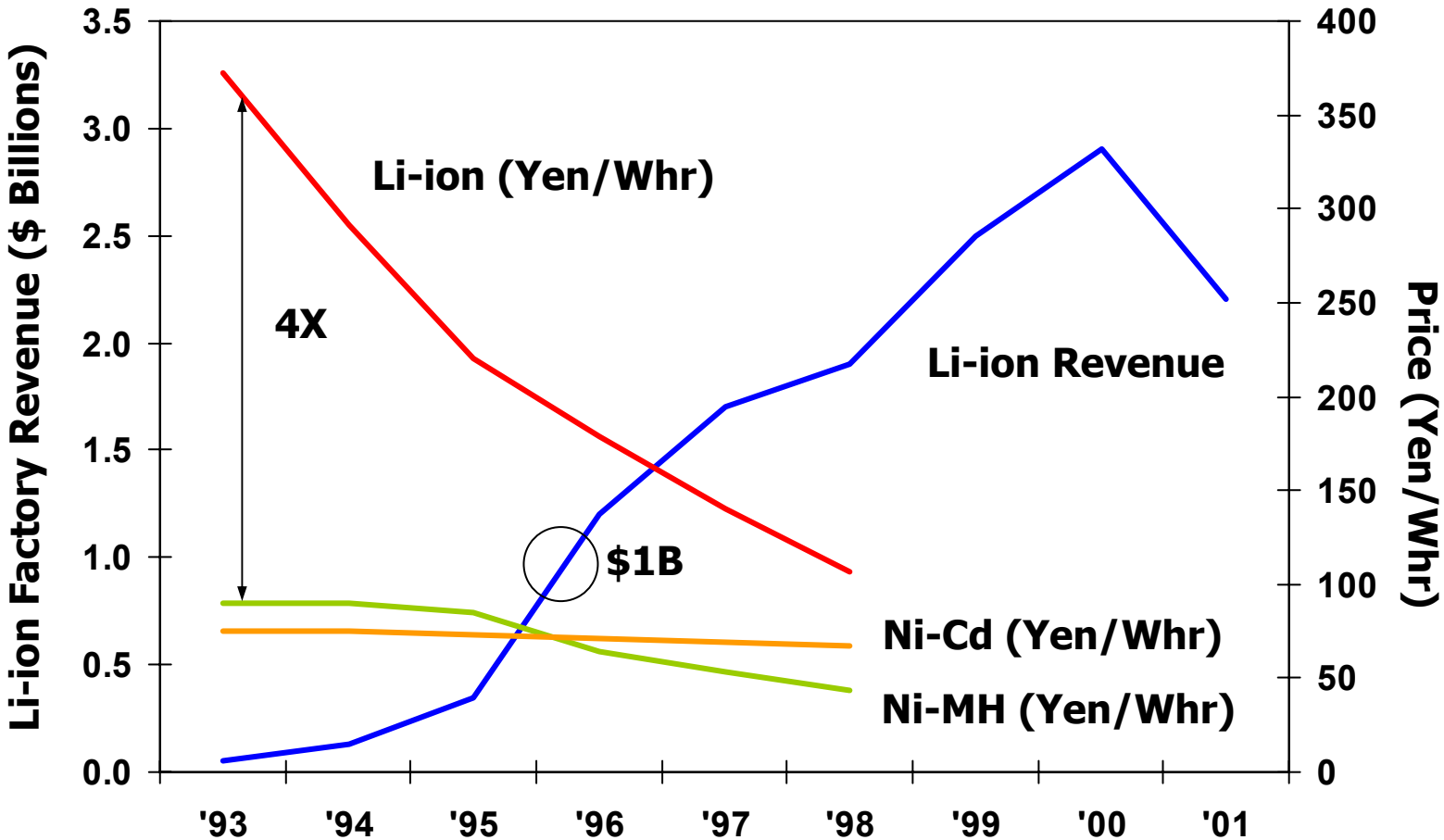
- User behavior - will users pay for power?
- OEM adoption
- Fuel cartridge distribution
- Regulatory & standards

Paying for Power Must be Considered in Context with User Benefits

- **By carrying spare cartridges, not extra batteries, user benefits include:**
  - Operating freedom
    - Run your device anywhere, for as long as desired
  - Productivity
    - Get work done during down times without having to worry about power issues
  - Convenience
    - Less bulk and weight to carry, no need to search for “plug” power
    - Vending machine premium
  - Peace of Mind
    - Reduce anxiety by knowing you will not run out of power at critical moments



Rapid Growth of Li-ion Suggests Users Willing to Pay for Performance



Source: Nomura Research Institute, Advanced Rechargeable Battery Industry Report, '97/'98; Takeshita, Institute of Information Technology, 9/2000

Targeted Segmentation Focuses on Markets with Greatest Needs for Mobility

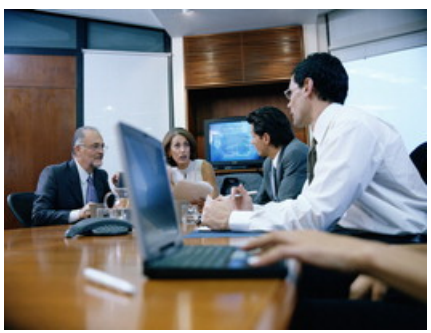
Penetrate Military and Commercial Markets First

Military Electronics

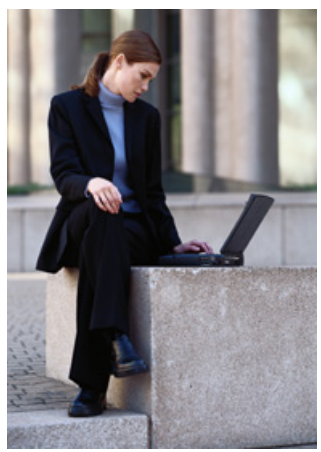
Portable Data Terminals

Public Safety Radios

Penetrate Consumer Markets as They Emerge



Corridor Warriors

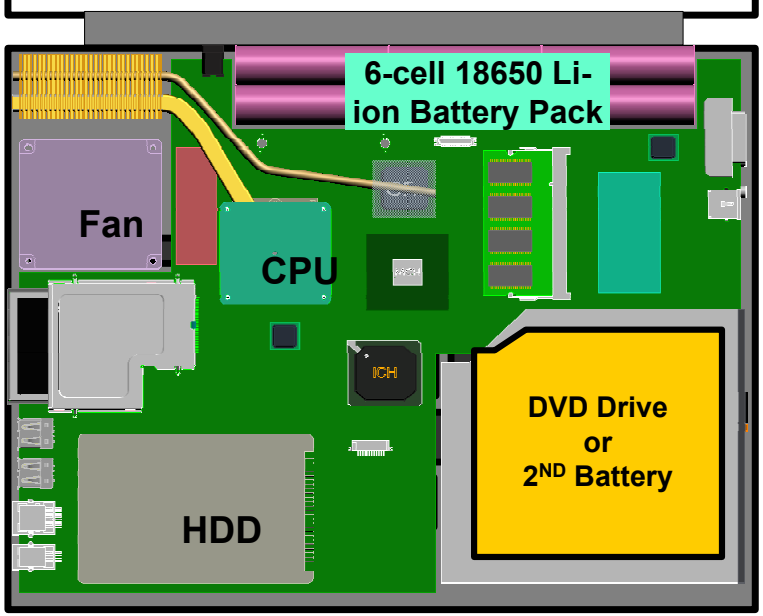


Road Warriors

Entertainment

OEM Adoption Process Known

- High OEM interest in fuel cells
- Need to deliver units that can perform
- Hybrid fuel cell power source proposal from Intel



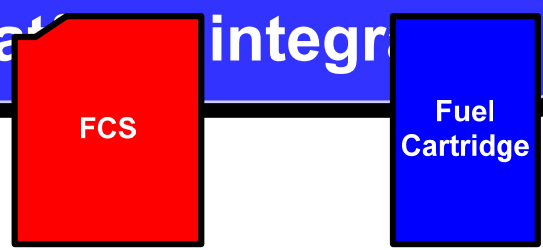
Device Bay supports DVD, 2ND Battery, or…

FCS (160cc) generates 12W avg.

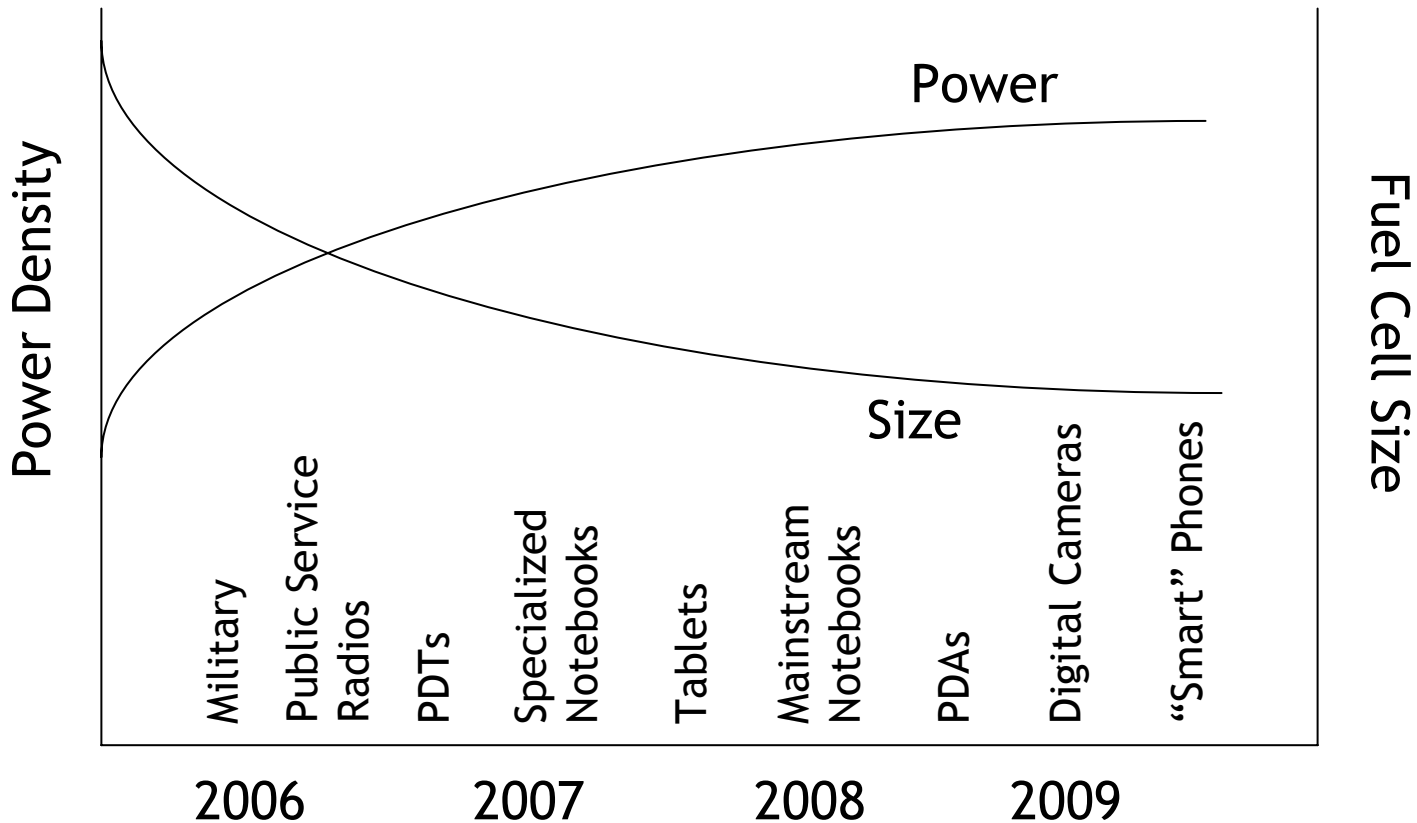
Cartridge (100cc)

Risk mitigation, ease of use

→ simplify pla… integr…



Increasing Power Density Reduces Fuel Cell Size to Expand Application Base



Chicken-and-Egg: Fuel Cartridge Distribution

- **Broad penetration requires convenient access to fuel cartridges**
  - Similar to battery availability
- **Retailers and distributors less likely to carry fuel cartridges until there is broad penetration and many units in the market**
  - Seek to maximize inventory turns
- **How do we get there?**
  - Target narrow vertical markets (military, industrial)
    - Broad distribution not required
    - Specialized distribution networks
    - Cartridges in the “office supply closet”
  - Build distribution for mainstream users over time
    - Specialized distribution initially – office supply companies, Web
    - Mass-market channels as products proliferate

Compliance with Regulatory Agencies and Safety Standards is Manageable

- **Safety and regulatory process is very device-oriented**
  - Specific device designs (fuel cells and cartridges) focus the process on detailed tests and uses
- **Disposable lighters fueled by flammable, compressed butane**
  - Two lighters per person allowed in passenger cabin of airplanes
  - Lighters can be shipped in bulk by air
- **USFCC an industry association fostering commercialization of fuel cells in U.S.**
- **UL established Portable Fuel Cell safety committee, UL 2265**
- **Neah supporting USFCC and UL efforts**
- **Major corporations like Intel, BIC, Duracell and Microsoft can help lead the regulatory process**

Fuel Cell Commercialization Requires Three Key Activities

- **Focus on high power density and efficiency to reduce size, weight, and cost**
- **Focus on markets and applications with greatest need for fuel cell benefits**
  - Carry spare cartridges, not extra batteries
- **Engage in partnerships to address barriers to market entry**
  - Materials suppliers, OEM customers, cartridge distributors and regulatory agencies

Fuel Cells Market Potential in 2009 Measured in $Billions

Worldwide Forecast - 2009

Scenario	No. Of Mkts	Notebook Penetration	Notebook Cartridges Units/user/yr	Fuel Cell Units (MM)	Cartridge Units (MM)	Total Revenue ($MM)
All Markets/ Conservative Estimate	14	5.0%	21.0	14.6	336	$1,048
All Markets/ Aggressive Estimate	14	15.0%	60.0	38.1	1526	$3,022

Neah Technology Can Revolutionize Micro Fuel Cell Industry

- **Capitalizing on "scalability" of silicon based electrodes**
  - Scale to high power density and low cost with 3D structure
- **2 to 3 times increase in energy storage in Li-ion form factor**
  - Cost allows pricing similar to Li-ion prices
- **15 U.S. patent applications filed and foundational patent issued**
- **Received $2 million NIST/ATP grant Sept. '03**
- **Strategic corporate relationships address barriers to market entry**
  - Signed $1.7MM development agreement with military OEM Dec. '03
  - Closed $2.5 MM investment and joint technical agreement with major corporation in silicon processing industry April '04
- **Recent achievements allow initiation of OEM design projects**
  - Established pilot production for porous silicon
  - Scaling silicon electrodes to prototype sizes