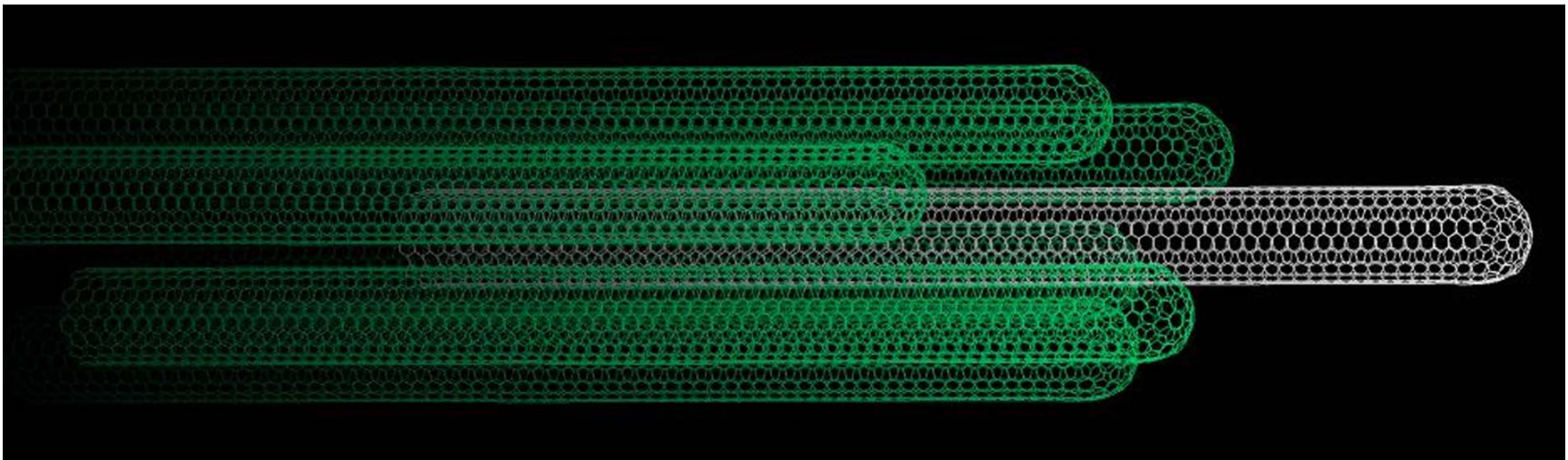


Micro-Fuel Cells

"Tomorrow's Power Source Enabled by Carbon-Nanotubes"



T.J. Wainerdi
Director of Business Development
Project Director – Fuel Cell Electrode Project

April 4, 2005



Carbon Nanotechnologies, Inc. (CNI)

- Company founded in 2000
- Exclusive, worldwide license of carbon nanotechnology IP from Rice University
- Developing markets – over 500 customers worldwide
- Production scale up to commercial units



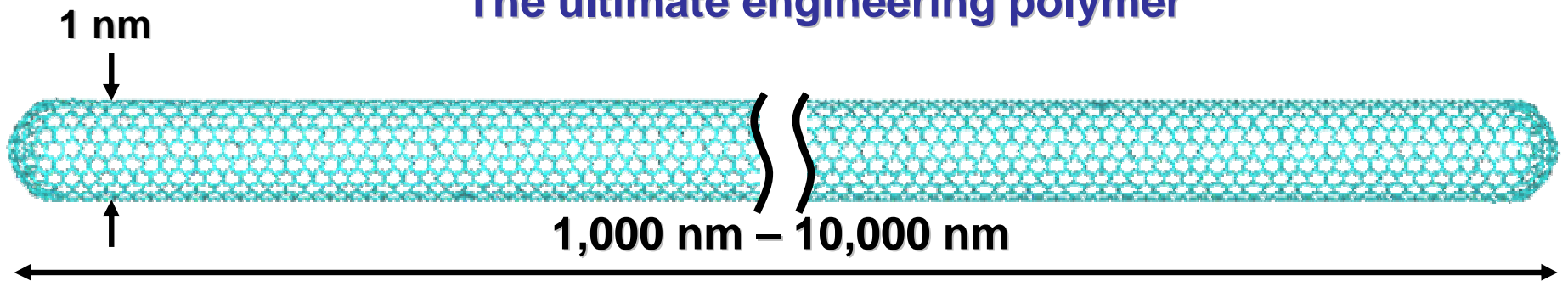
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Single Wall Carbon-Nanotubes (SWNT)

- SWNTs are unique
 - Polymers of pure carbon
 - High aspect ratio (up to 10,000:1)
 - Unique electron configuration
- SWNTs have extraordinary properties
 - Strength (100x steel, 1/6th weight)
 - Electrical conductivity (copper)
 - Thermal conductivity (3x diamond)

The strongest, stiffest, toughest molecule there will ever be
The most inherently conductive organic molecule
The ultimate engineering polymer



SWNTs Offer Incredible Opportunities!

Composites

- **Electrically conductive composites**
 - **Wide range of conductivities**
 - Antistatic
 - Electrostatic dissipation
 - EMI/RFI shielding
 - **Parts, films, sealants, inks, adhesives, coatings**
- **Reinforced composites**
Tougher, stronger, stiffer, wear resistant
 - **Thermosets and thermoplastics**
 - Parts, coatings
 - **High performance fibers**
 - Ballistics protection, offshore
 - **High performance ceramics**
 - Structural parts, thermal coatings
- **Thermally conductive composites**
 - **Electronics packaging**

Energy

- **Fuel cells**
- **Supercapacitors**
- **Photovoltaic cells**
- **Lightweight composites**
- **“Quantum Wires”**
 - **Electricity generation**
 - **Power transmission lines**

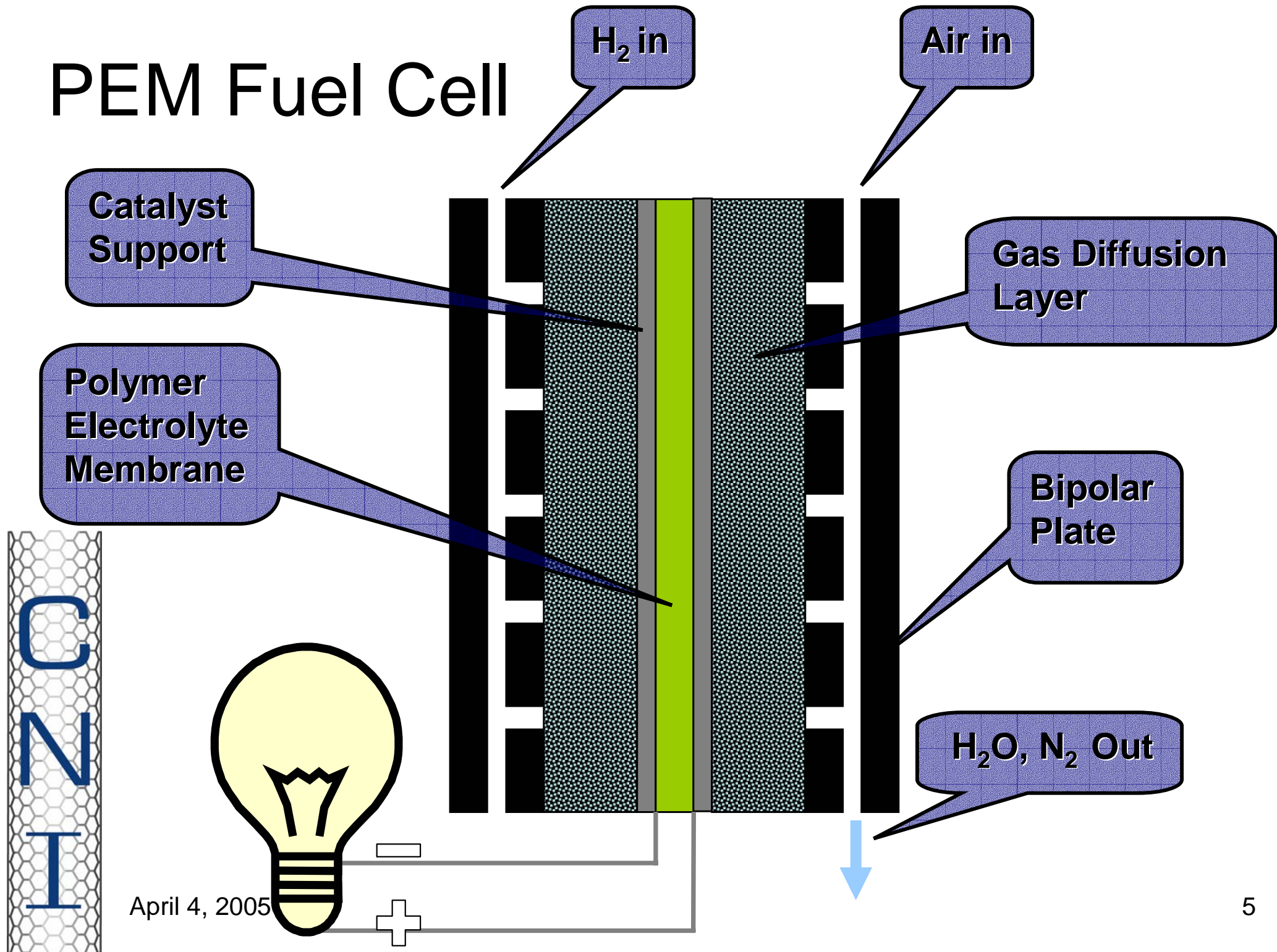
Electronics

- **Field emission**
 - **Flat panel displays**
 - **Electron device cathodes**
 - **Lighting**
- **Sensors**
 - **Chem/bio**
 - **Gas**
 - **Pressure**
 - **Flow**
- **Logic and memory devices**
- **Interconnects**

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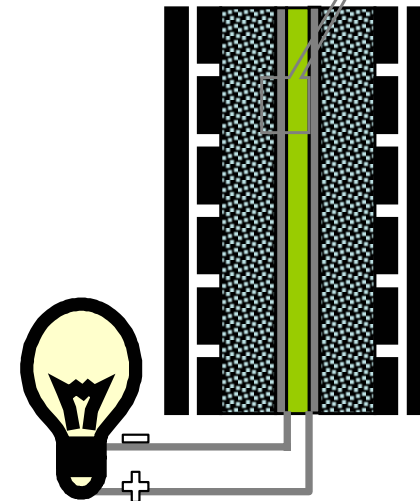
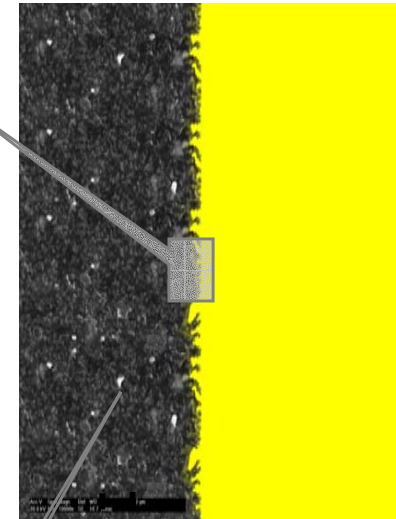
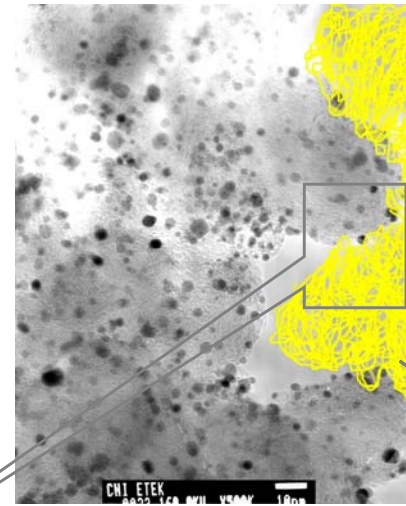
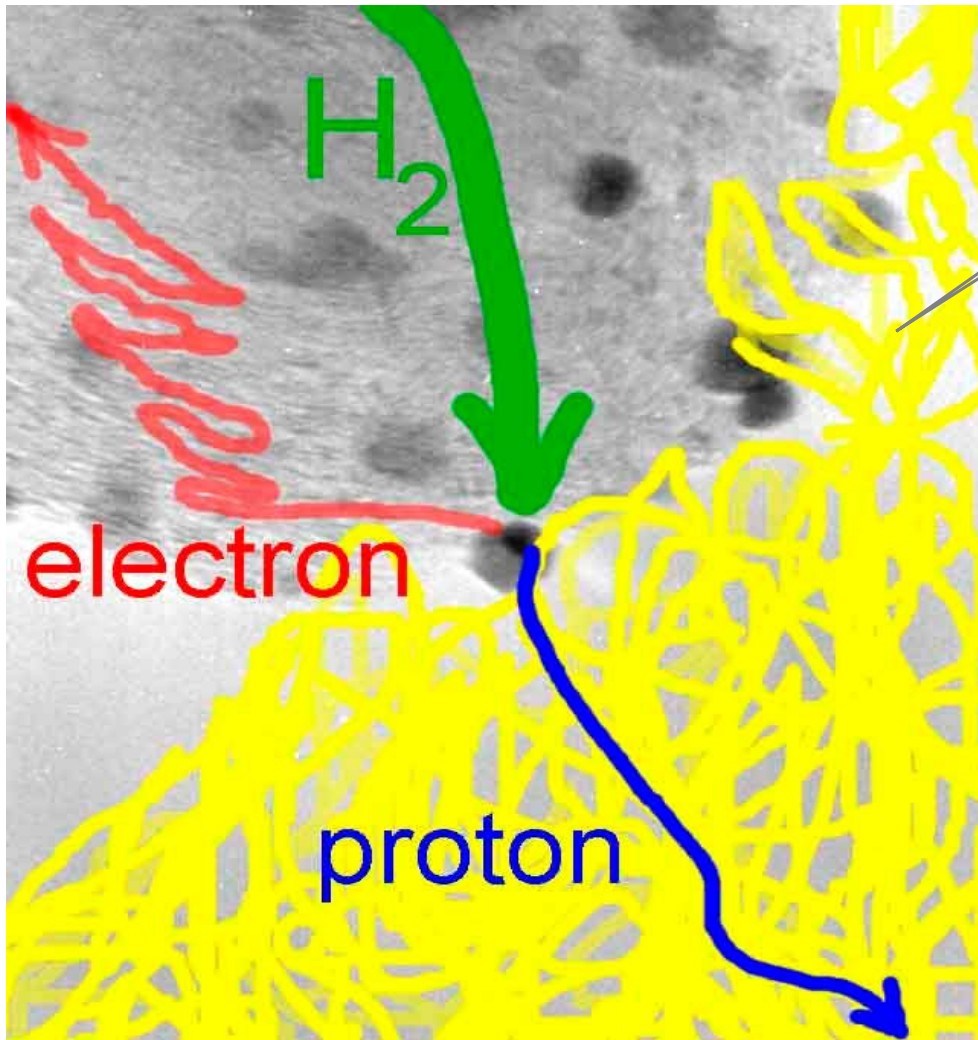


PEM Fuel Cell



Geometric issues effect electrode performance.

- Mass Transport
- Charge Transport
- 3 Point Contact



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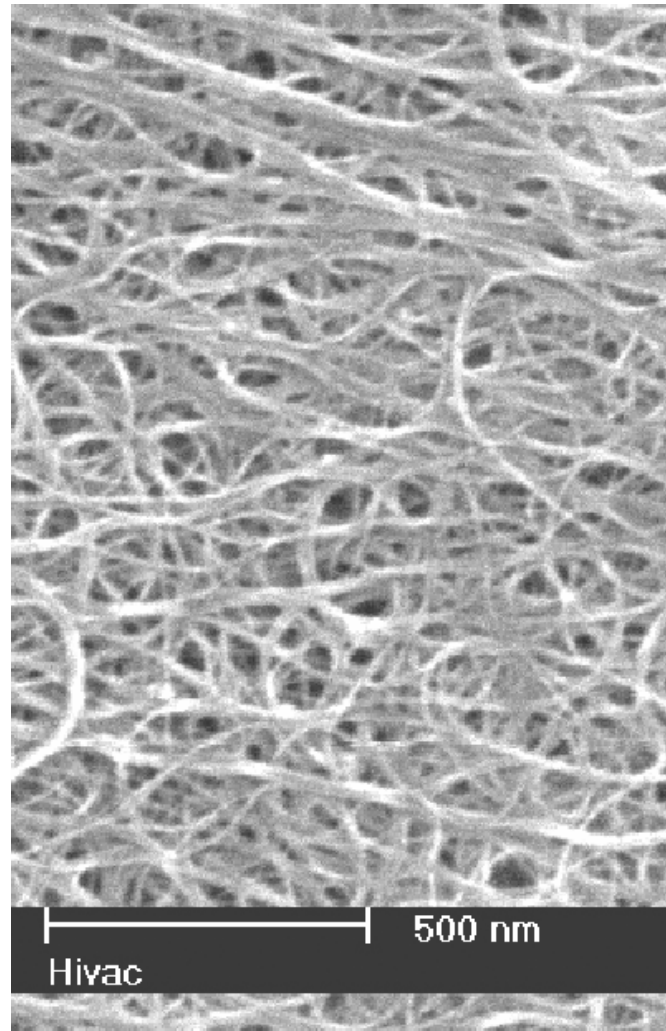
20 nm

SWNT enable a thin film “free standing” electrode

→ ← $< 1\mu$



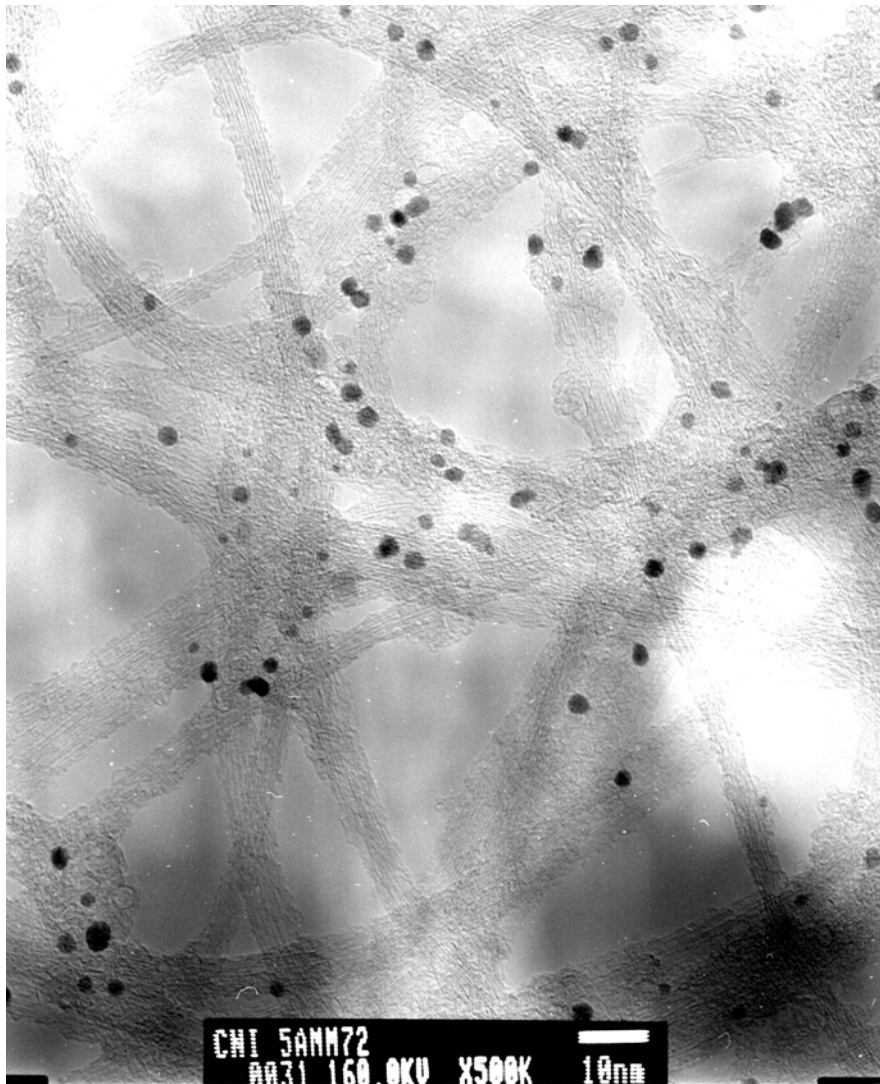
Side View



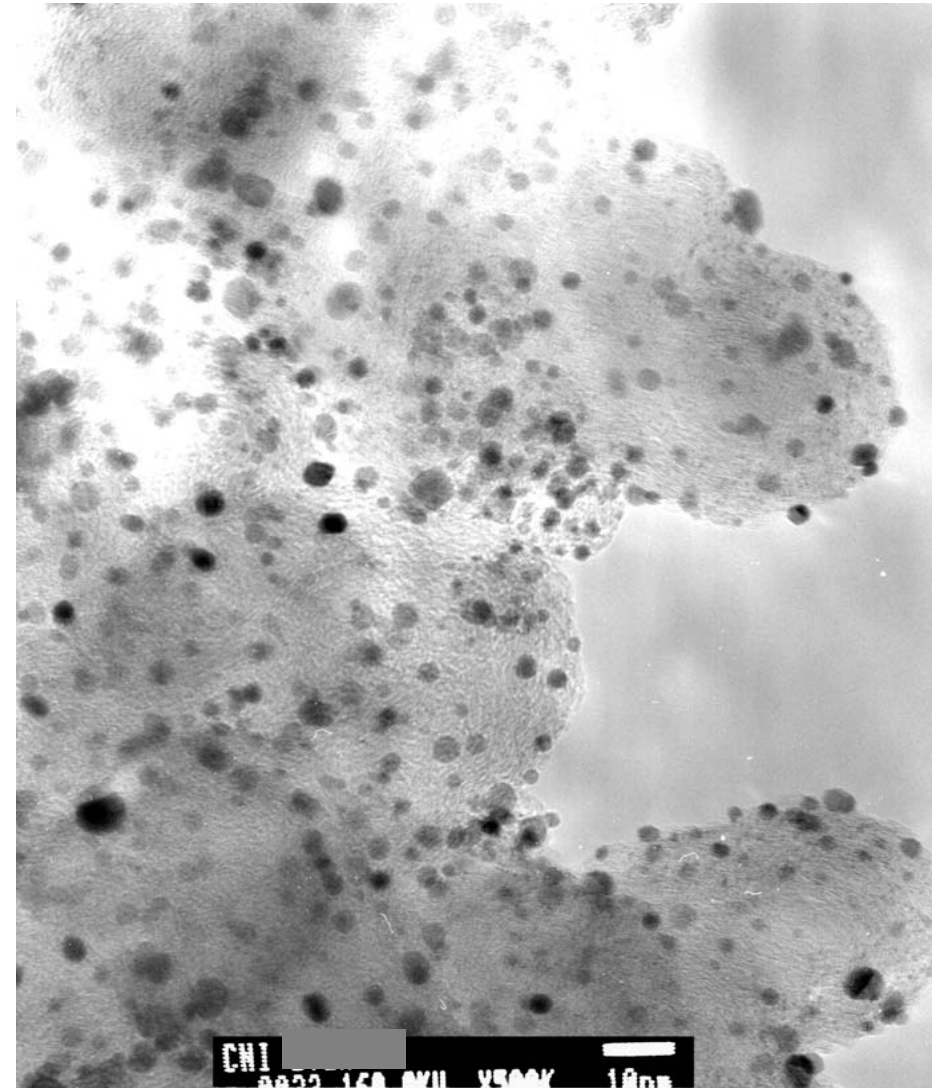
Front View

- SWNT known to form thin, strong, high conductivity films (up to ~ 5000 S/cm)
- High porosity for good mass transport
- Enhance 3 Point contact of gas, catalyst and PEM.

SWNT ensures catalyst and PEM contact while providing “super-highways” for electrons.



SWNT Electrode

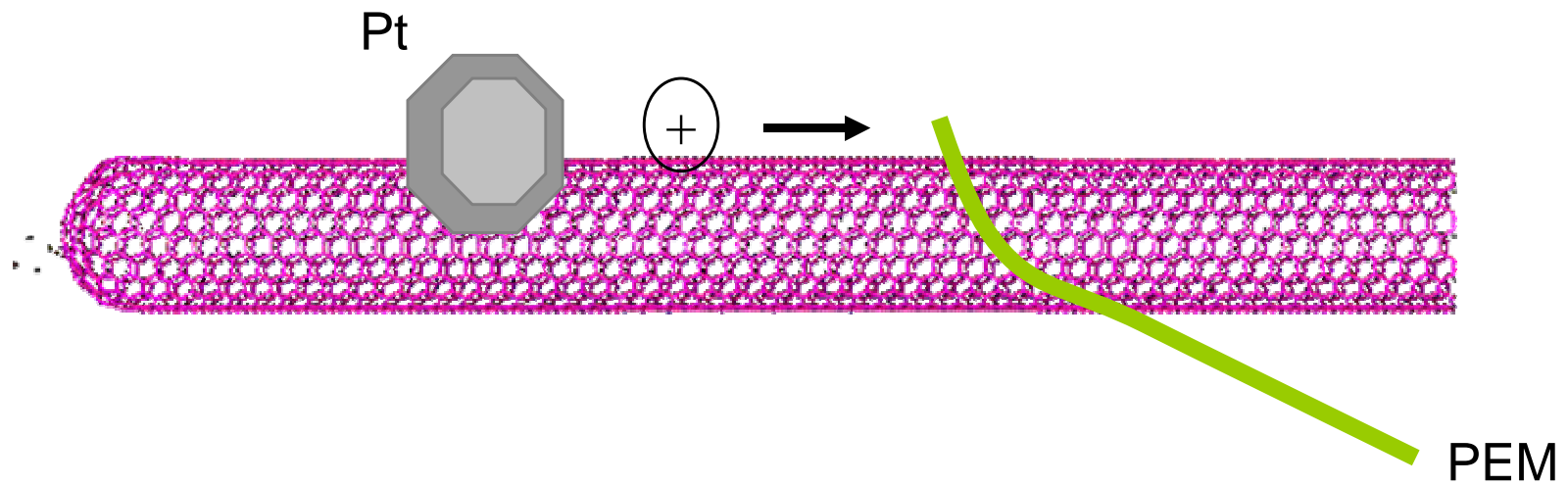


Carbon Black Electrode

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SWNT's ability to conduct protons as well as electrons, further enhances ability to achieve 3-point contact.



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SWNT should demonstrate significant enhancement in chemical stability compared to carbon black.

Sides are extremely inert

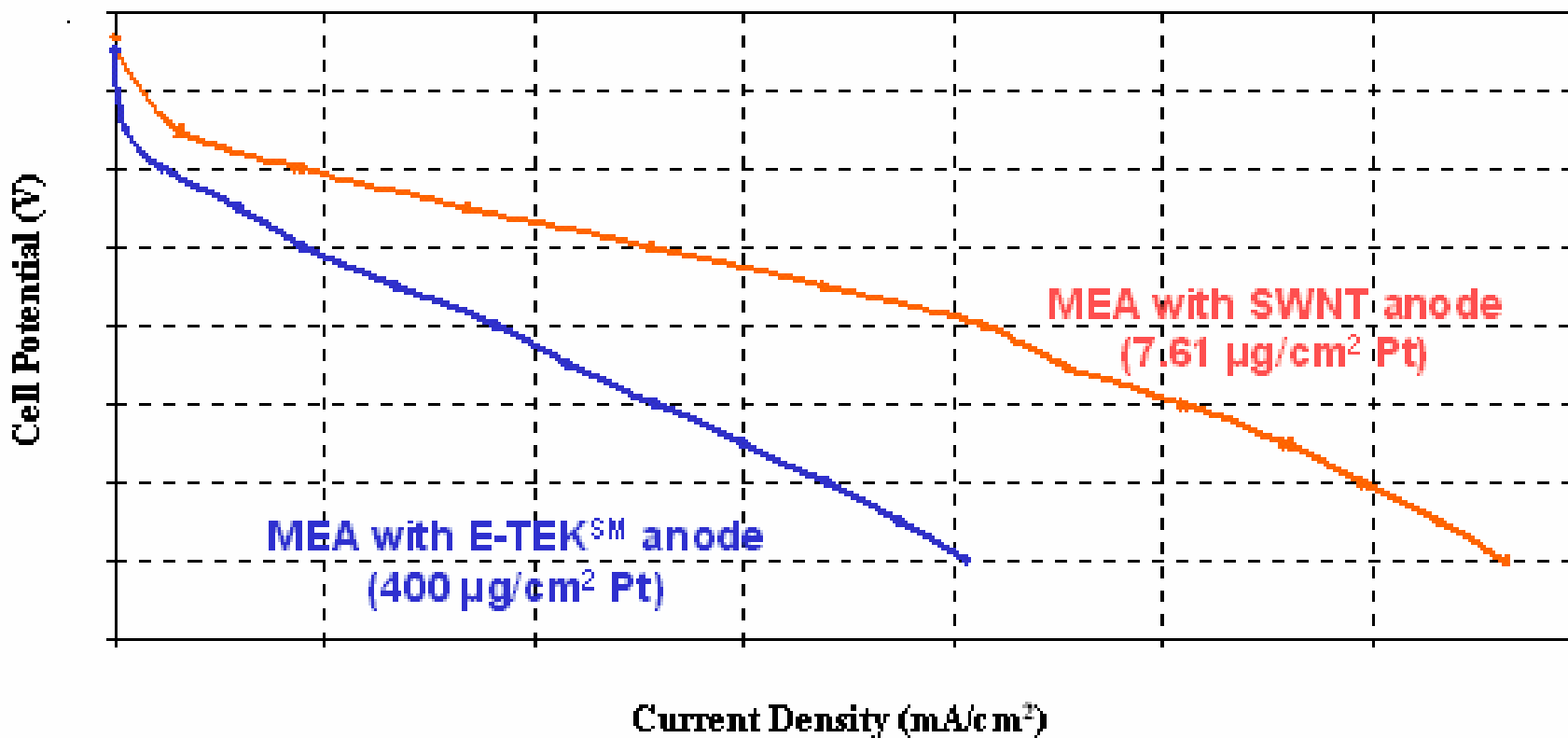
Oxidation proceeds only at open ends



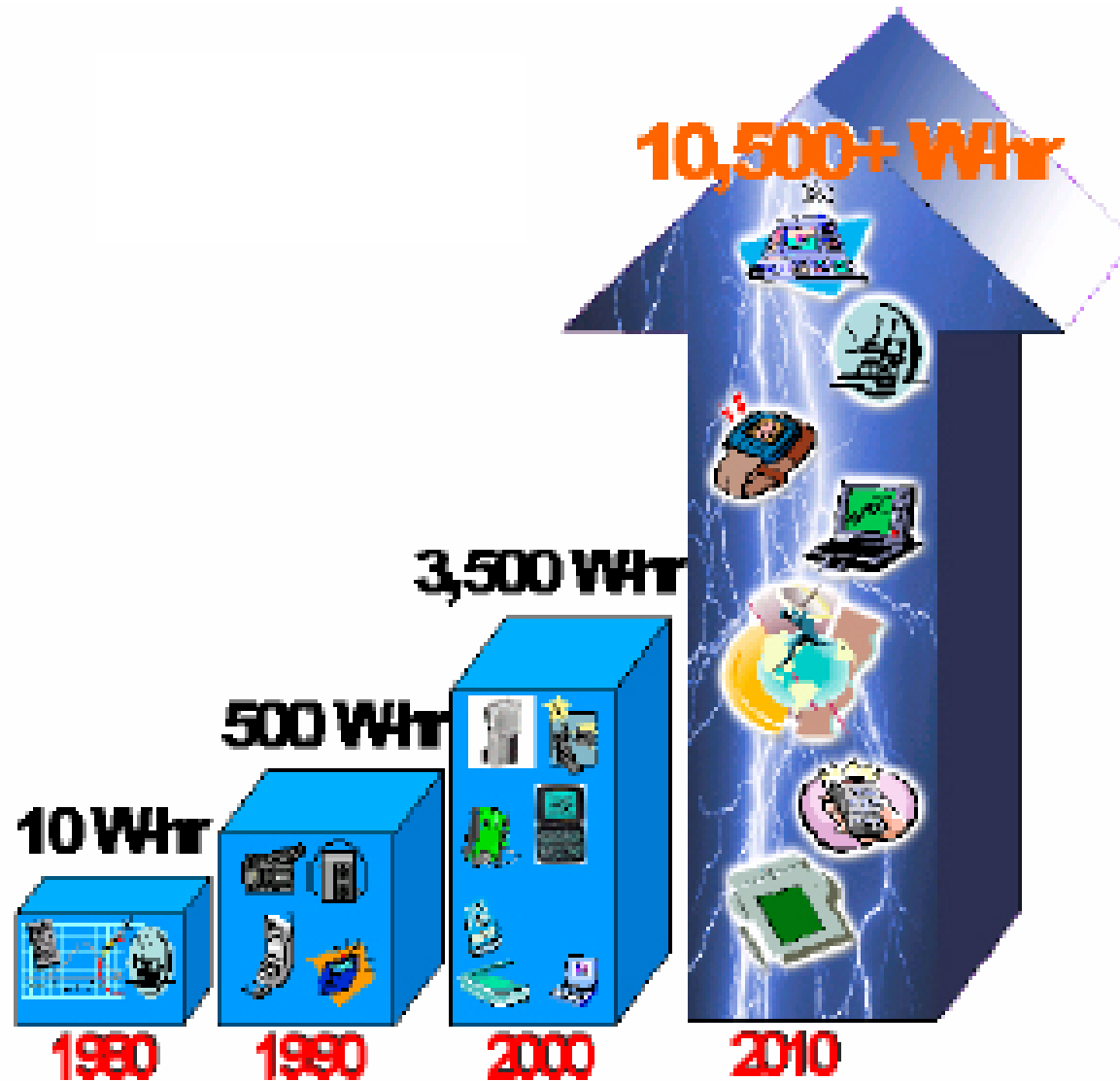
- 99.99% of the carbon atoms are on the sides.
- Tubes can be provided with closed ends.

SWNT anode doubled power density while reducing Pt catalyst by 98%!

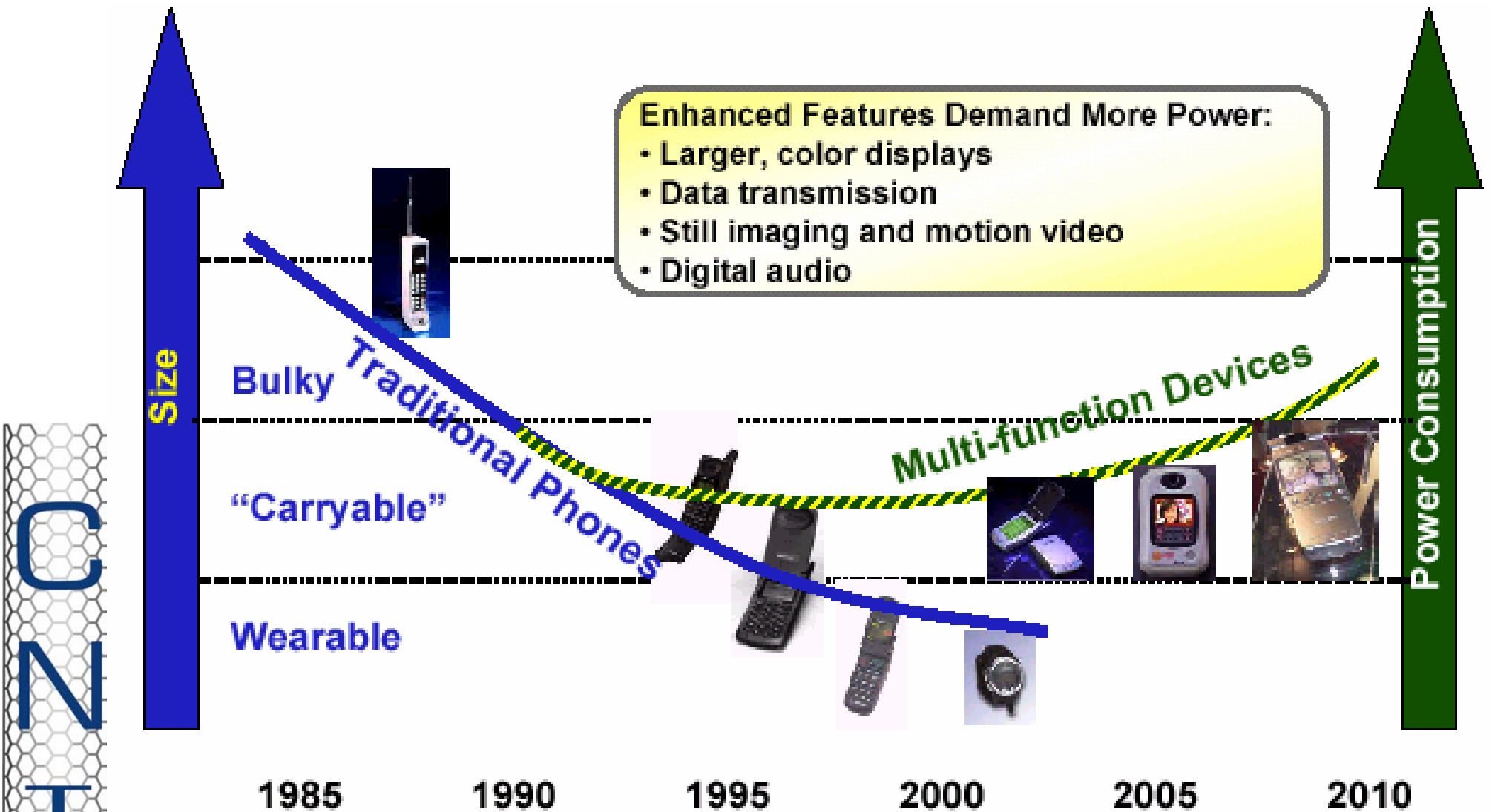
Hydrogen PEM Fuel Cell



Exponential growth in energy requirements driven by enhanced multifunctional electronics....

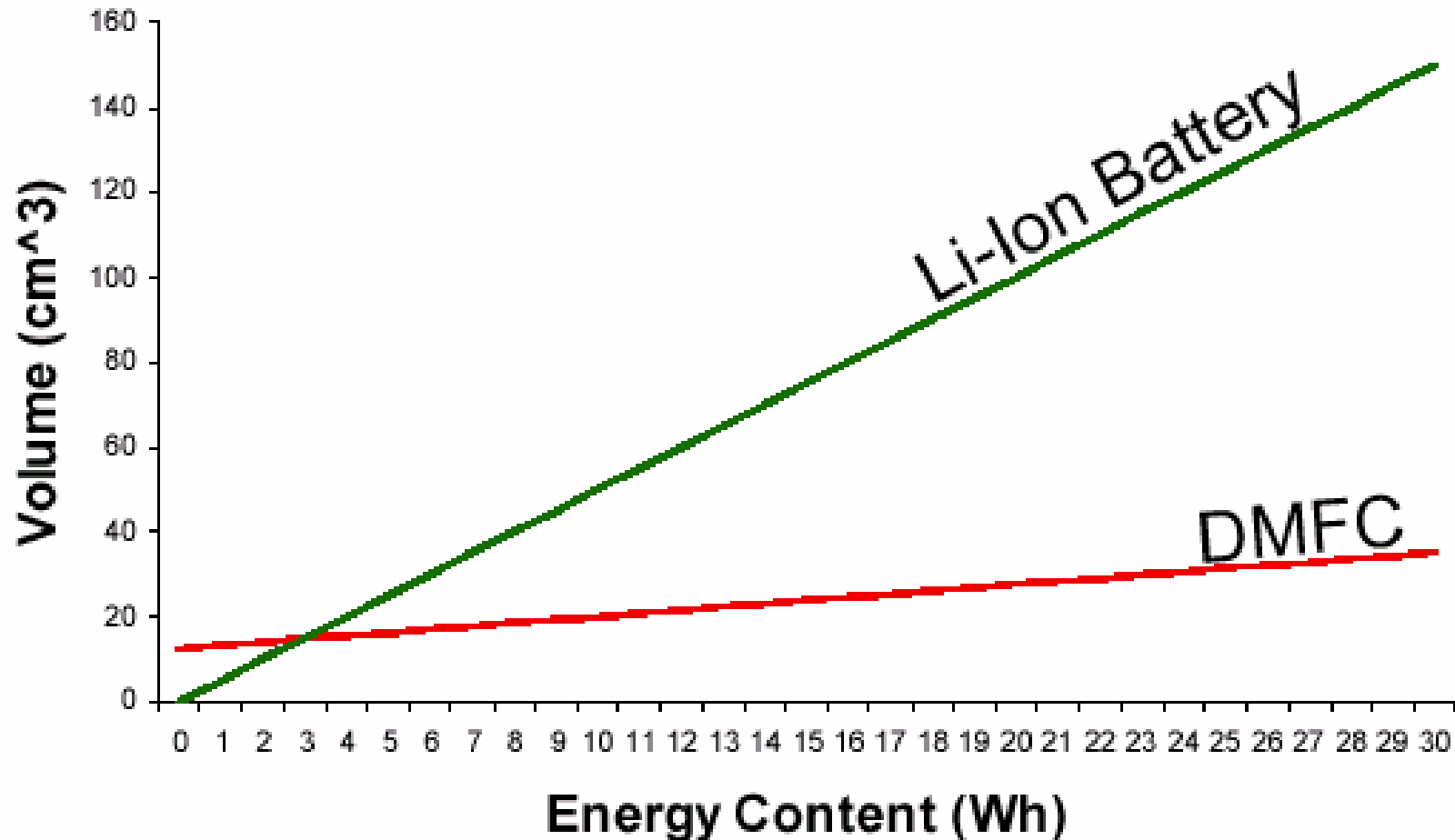


..... while maintaining wireless portability.



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Micro-fuel cells offer dramatic potential for improvements in energy density.



Improved power densities and reduced cost are required to achieve mass replacement of Li-Ion battery technology!

MICRO FUEL CELLS

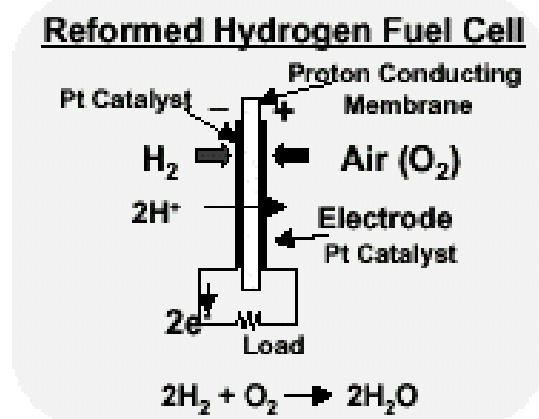
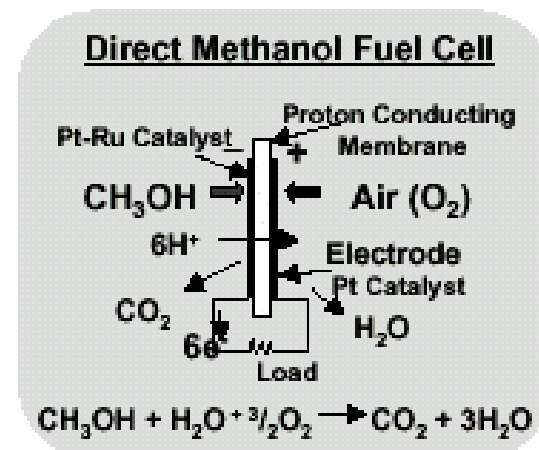
Two Approaches

Direct Methanol Fuel Cells

- Lower Power Density (10-50mW/cm²)
- RT - 80°C Operation
- Liquid & Gas Handling

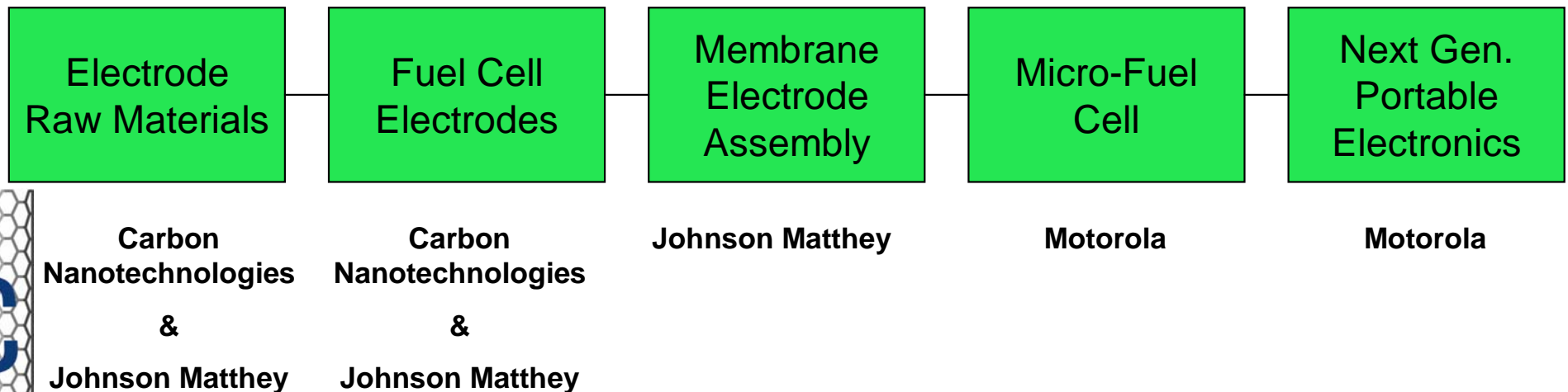
Reformed Methanol-Hydrogen Fuel Cells

- Higher Power Density (25-200mW/cm²)
- Reformer Operating Temp >200°C
- Liquid & Gas Handling



CNI's Partnership with Industry Covers the Entire Value Chain

“Free Standing” Single Wall Carbon-Nanotube Fuel Cell Electrode

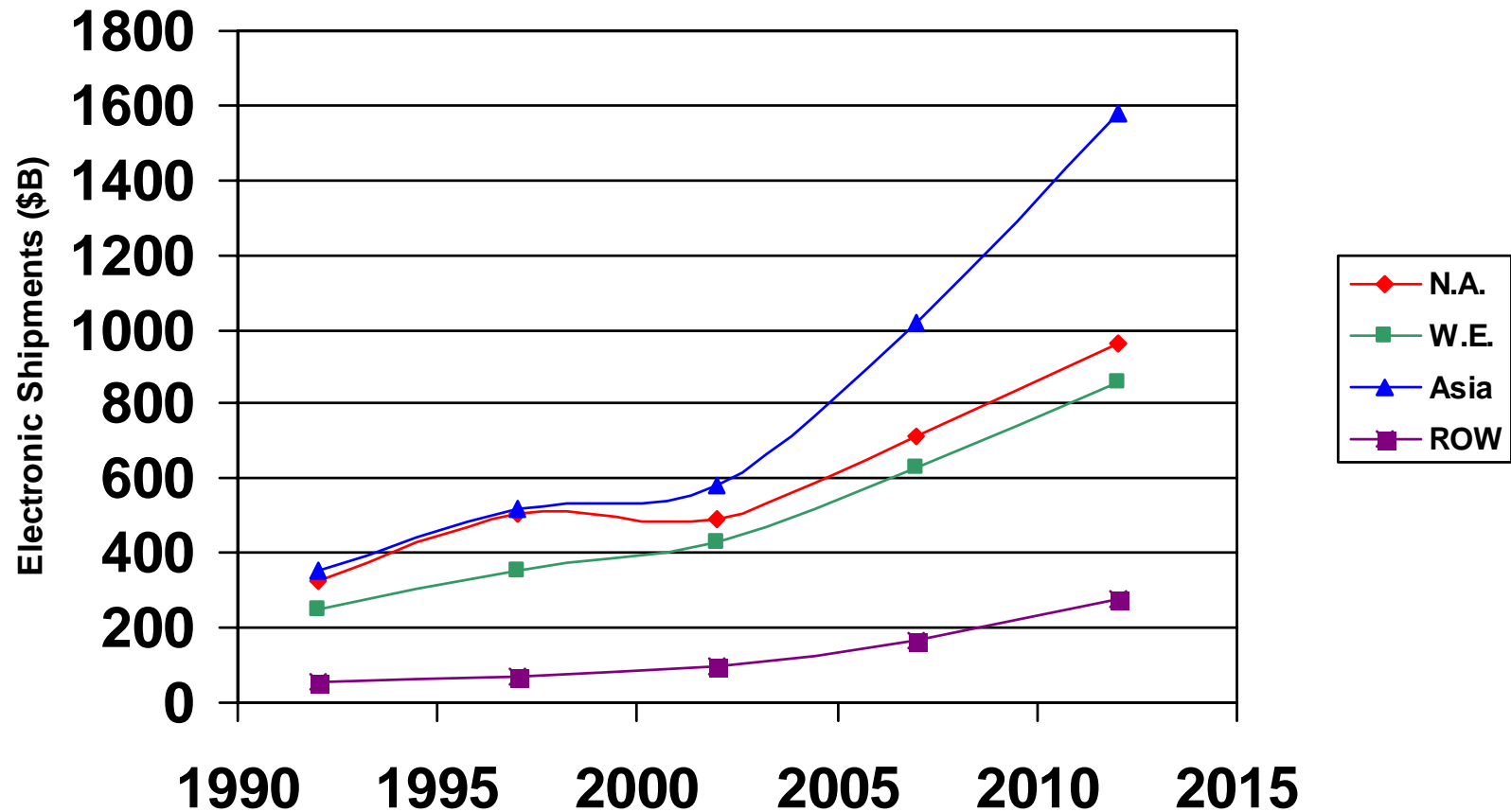


The Partnership won a \$3.7 Million grant from the National Institute of Standards & Technology – Advanced Technology Program!

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Introduction of next generation electronics is anticipated to fuel demand.....

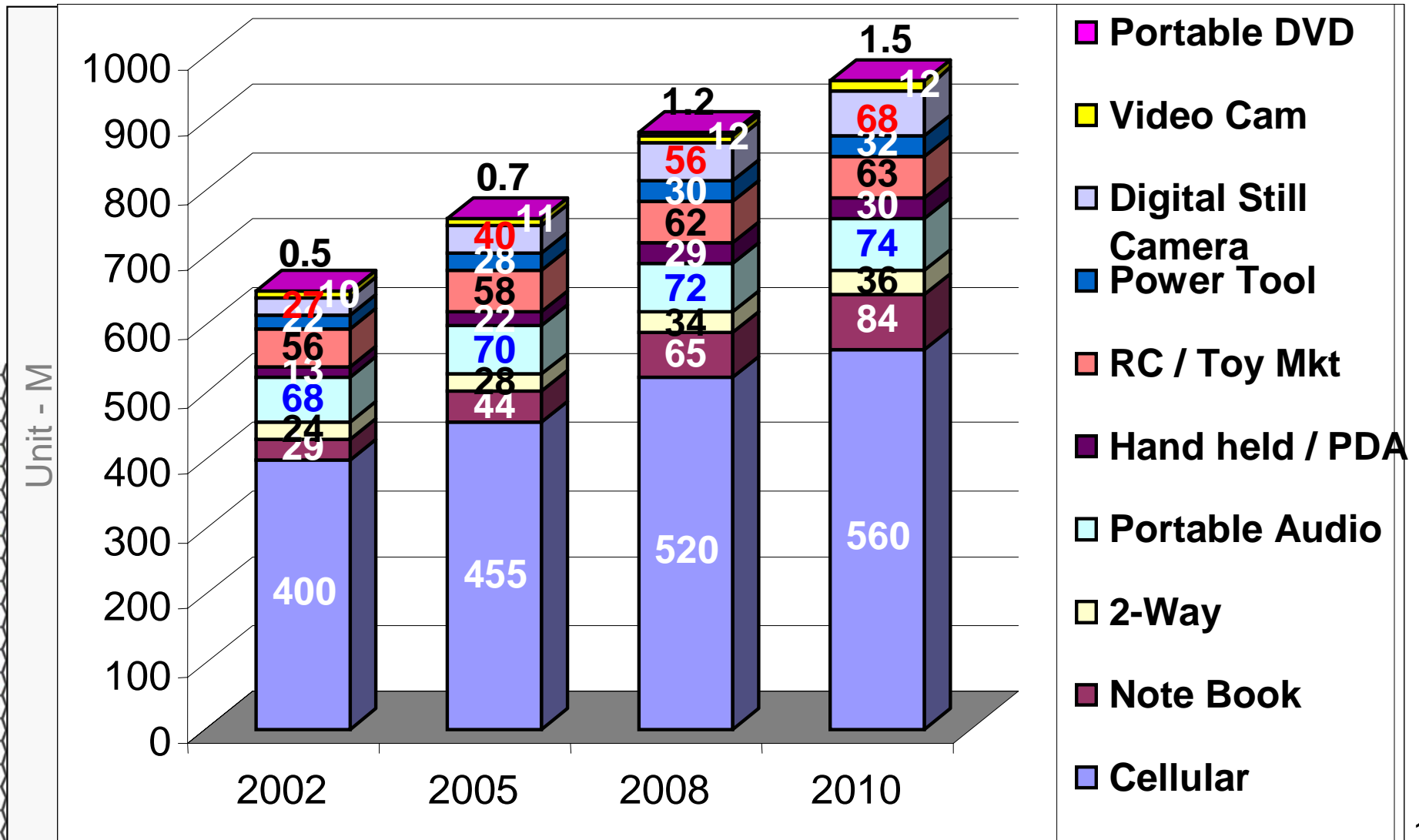


Source: World Fuel Cells to 2007, Freedonia Group, May 1, 2003, Table 10



.....thereby fueling the demand for longer lasting power!

Potential Portable Electronic Market Size for Micro-Fuel Cell Technology



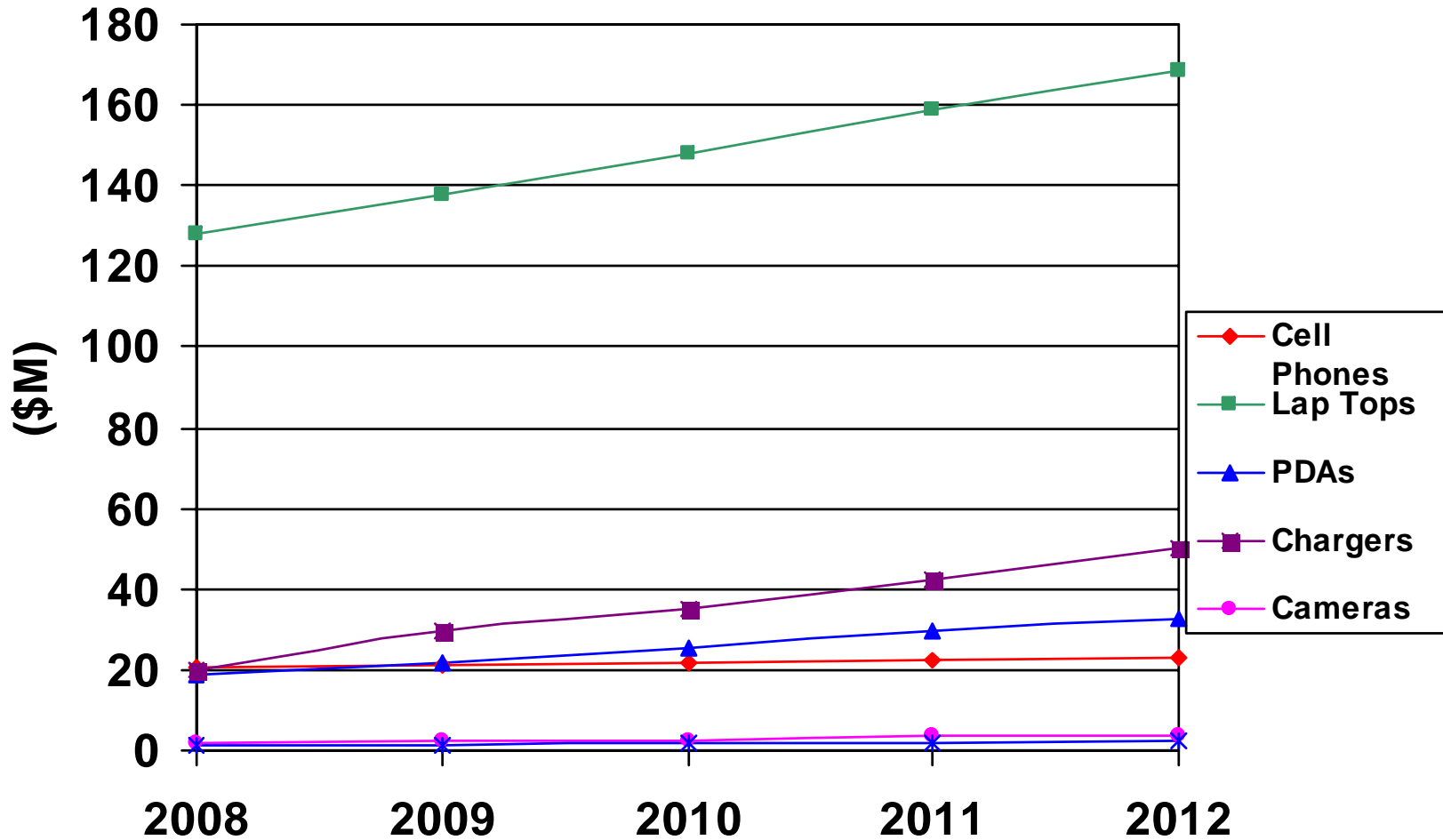
Potential for value creation from micro-fuel cells is high.....



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..... and potential value capture from SWNT is significant!

Projected Global Sales Revenue for Fuel Cell Electrode



Assumes comparable energy cost to a Li-Ion Battery ~ \$3000/KW

