Micro-Fuel Cells
"Tomorrow's Power Source Enabled by Carbon-Nanotubes"

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

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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
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)
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

- Catalyst Support
- Polymer Electrolyte Membrane
- Gas Diffusion Layer
- Bipolar Plate
- H₂ in
- Air in
- H₂O, N₂ Out

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Geometric issues effect electrode performance.

- Mass Transport
- Charge Transport
- 3 Point Contact
SWNT enable a thin film “free standing” electrode

< 1μ

• 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.

Side View

Front View
SWNT ensures catalyst and PEM contact while providing “super-highways” for electrons.
SWNT’s ability to conduct protons as well as electrons, further enhances ability to achieve 3-point contact.
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.
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!
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.....
...... 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