

Overview of Emerging Energy Technologies at CFD Research Corporation



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CFD Research Corporation

www.cfdrc.com

CFD Research Corporation

Advanced Technology and Service Company

- Supporting Federal Agencies and Global Businesses since 1987 (founded in Huntsville)
- 95+ Staff (over 70% with advanced degrees)
- 45+ Patents (awarded & pending)

CFDRC develops and transitions technologies into commercially viable solutions:



Aerospace & Defense



Biomedical & Life Sciences



Energy & Materials



HQ – Huntsville, AL



Bio-Laboratories
HAIB, Huntsville, AL



Engineering T&E
Scottsboro, AL

Gov't Sites

MSFC, Huntsville, AL
AMRDEC, Huntsville, AL
USAARL, Ft. Rucker, AL

Capabilities Background

- To accelerate developments of innovative Energy solutions, CFDRC has unique capabilities and expertise in:
 - ✓ Advanced engineering analysis & design; and
 - ✓ System-level prototyping and performance characterization;
- CFDRC's expertise in winning and executing SBIR projects can also be leveraged to offer our partners advanced technology solutions with data rights and IP protections.
- ***We are actively seeking partnerships with medium and large-sized businesses to validate early design concepts and help transition them to market.***

Portable Power:

Bio-Battery / Sensors / Energy Harvesting

Bio-Battery:

Clean, Renewable Energy Source

Renewable & Environmentally-Friendly

- ✓ Generates electricity from renewable, readily-available fuel sources such as glucose, sucrose, and fructose.
- ✓ Uses biocatalysts (enzymes) in place of rare-earth metals.

Advantages over Traditional Batteries

- ✓ 10X the theoretical energy density
- ✓ Instant Recharge
- ✓ Room temperature operation
- ✓ Neutral pH
- ✓ Biocompatible for implantable applications

Portable

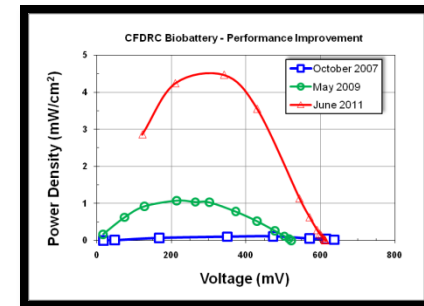
- ✓ Can be scaled to provide necessary power in nearly any size or shape (including flexible substrates).



Stack Cell



Hybrid Prototype



Cell and Stack Performance:

Cell: $>4.5\text{mW/cm}^2$ @ 15mA/cm^2 and 300mV
5-Cell Stack: OCV $>3.5\text{V}$, Current $>100\text{mA}$
 $>100\text{hrs}$ operation with 5mL of glucose fuel
 >6 months shelf-life at $+55^\circ\text{C}$

Energy Storage:

Li-ion / Thermal Batteries / Advanced Materials / Grid Scale

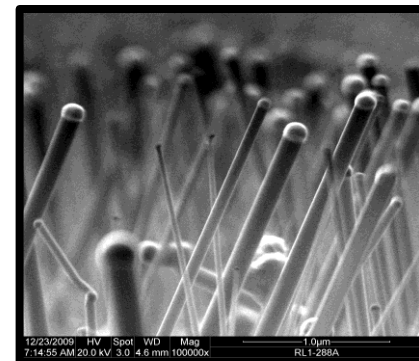
Silicon Based Nanostructured Electrode: High Capacity Lithium Ion Storage

High Lithium Ion Storage Capacity

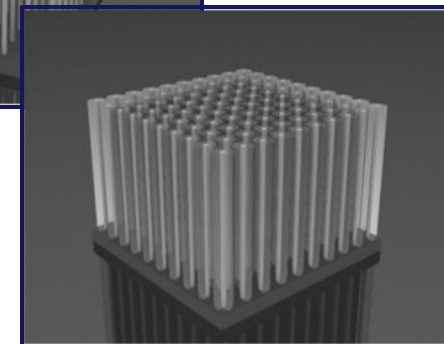
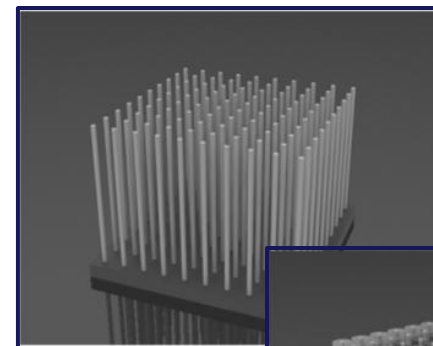
- ✓ Theoretical Capacity 3579 mAh/g
 - 10x higher than conventional Li⁺ storage materials
 - **Recently demonstrated in half-cell testing**
- ✓ Nano-structured material
 - Silicon Nanowires
 - High material stability in repetitive lithiation cycling
 - **Demonstrated >350 cycles (10 months testing)**
 - Silicon Coated Carbon Nanotubes
 - Highly conductive core
 - Large surface area current collector
 - High tensile strength

Technical Applications

- ✓ Applicable to Rechargeable Systems
 - Laptops, cell phones, and other portable electronics
- ✓ Pioneering Nano Structured Material Application for Thermal Battery
 - Collaboration with Los Alamos and Georgia Tech



SEM of Silicon Nano Wire



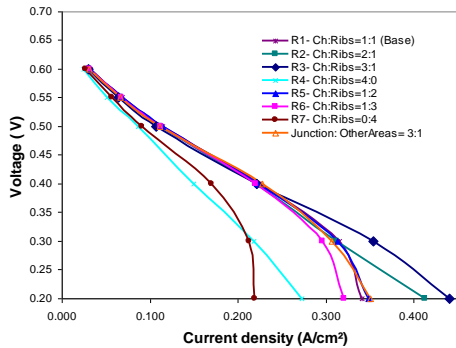
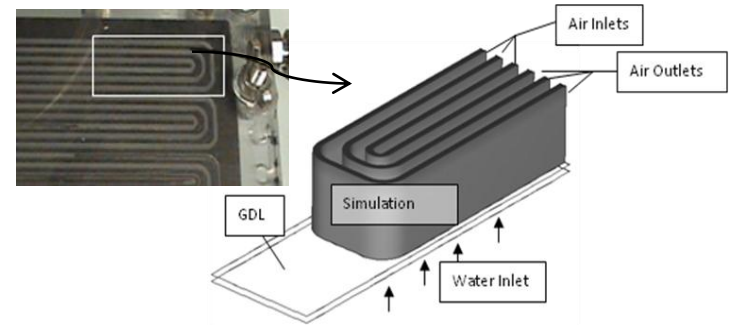
Conceptual image of Si coated CNT

Fuel Cells:

Transportation (PEMFC) / Stationary (SOFC/CHP)

Leaders in Fuel Cell Modeling & Simulation

- ✓ Multiphysics codes under development since 1999
 - Full electrochemistry on CFD platform
- ✓ **Leading DOE 4yr / \$6M effort for water management**
 - Includes Ballard Power Systems, SGL Carbon, ...
 - Improving understanding and affecting designs



Polarization Curve for Various Catalyst Loadings

Fuel Cell Performance Analysis

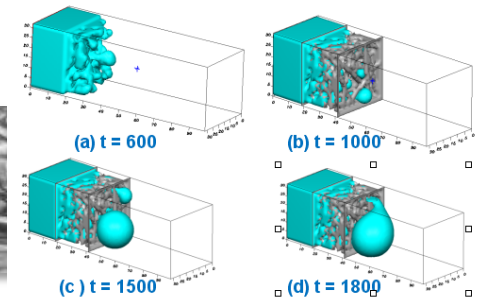
- ✓ Voltage-current characteristics (polarization curves)
- ✓ Overpotential and loss mechanisms
- ✓ Temperature distribution and thermal stress
- ✓ Effects of pressure, relative humidity, temperature, porosity, tortuosity, and catalyst loading
- ✓ Performance assessment and parametric design

PEMFC MEA Integration Analysis

- ✓ Cell level MEA performance simulations provide local mass transport, thermal, and electrochemical performance data
- ✓ Catalyst durability / degradation predictions
- ✓ Start-up / Shut-down effects and mitigation
- ✓ Water management & mitigating designs



GDL Micrograph



LBM Modeling of GDL Transport

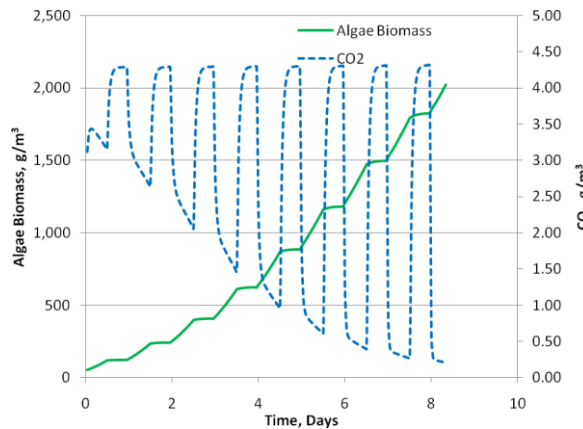
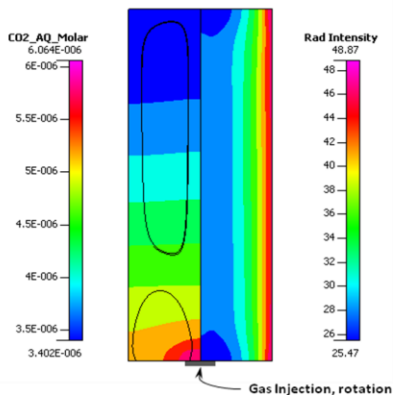
Algal Biofuels:

Growth / Harvesting / Conversion

3-D Algae Growth Analysis Tools

Developed/Demonstrated Fully Coupled Multi-physics Models

- ✓ Flow dynamics in closed photobioreactors and open ponds with turbulence and heat transfer
- ✓ Algae concentration tracking with a model for effective properties of the algae-laden flow
- ✓ Photon intake with light-dark cycles and absorption/scattering, coupled to detailed radiation models
- ✓ Kinetics of reaction and algae growth
- ✓ Gas transport

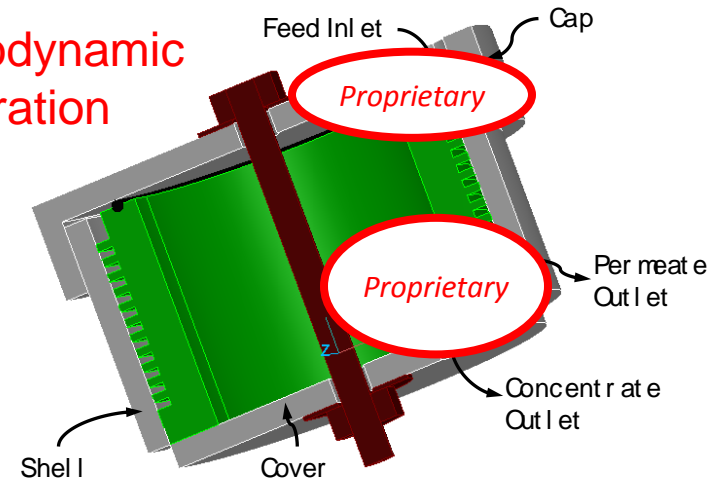


Novel Dewatering Device

Harvesting Algae is Problematic

- Dilute concentrations (~1g / liter water)
- Centrifugation difficult (neutrally buoyant)
- Filtration is difficult due to blinding (<10 um)

Hydrodynamic Separation



Low CAPEX & OPEX

- ✓ Simple & automatable manufacturing
- ✓ Unskilled labor assembly & installation
- ✓ Minimal pumping required (gravity feed)
- ✓ Minimal control required (passive system)

What CFDRC Provides and Needs

Provides

- ✓ Unique ability for rapid development and screening of concepts and designs
- ✓ State-of-the-art multiphysics M&S tools
- ✓ Application of M&S for design & evaluation
- ✓ Early Stage prototyping, test & evaluation
- ✓ Independent (un-biased) assessment of technologies
- ✓ Infrastructure and proven track record for Government contracting
e.g., DoD/DoE/NASA/NSF/USDA

Needs

- ✓ Partnerships to validate and transition concepts
- ✓ System Integrators
- ✓ Product design and manufacturing
- ✓ Specific material synthesis
- ✓ Specific test & evaluation capabilities

Partnership Opportunities

With CFDRC's extensive and diverse technology base, we can be your partner (and extension of your business) for:

- ✓ Advanced Analysis & Objective Assessments
- ✓ Rapid Screening of Innovative Concepts
- ✓ Design & Prototype Developments

- ✓ Small Business Set-aside Requirements
- ✓ Engineering Support Services

- ✓ Strategic Partnerships (e.g. JVs, JDAs, IP Licensing...)

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