Bio-Battery: A Novel Micropower Source for Portable Electronics

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• CFDRC Corporate Overview

• Traditional Battery Shortfalls

• Bio-Battery Story and Applications

• Bio-Battery Technology Overview
CFDRC develops and transitions cutting-edge technologies into innovative solutions for:

- Aerospace & Defense
- Biomedical & Life Sciences
- Energy & Materials

- Recognized for Innovative Solutions
  Designs, Prototypes, Simulation Tools & Analysis, 50+ Patents, …
- Supporting Government and Industry since 1987

Seeking Partners
for Technology Integration and Commercialization
Thermal Runaway – catastrophic battery failure

- Replacement of device
- Multiple surgeries
- Increased risk of infection
- High cost

>3,000 people unintentionally swallow “button” batteries each year.
- 62% are children under the age of 5 years
- Swallowed coin cells can cause serious injury or even be fatal

Traditional Battery Shortfalls
Solution: CFDRC’s Bio-Battery

Platform technology with multiple applications

Prototypes
Flexible, Paper-based Devices
Implantable Power Source

- $5M in Government and IR&D funded research Since 2004
- Advantages:
  - High Energy Density,
  - Flexible Fuel (sugar, alcohol, diesel, etc),
  - Renewable Bio-Catalysts
How it Works

Uses enzymes to convert sugar directly into electrical energy

Enzymes extracted from microorganisms

Enzymes immobilized in Carbon Nanotube based electrode

Nanocomposite electrodes integrated with fuel cell hardware
**Bio-Battery Performance**

**Single Cell**

- \( \sim 10 \text{mW/cm}^2 @ 25 \text{mA/cm}^2 \)

**Six Cell Stack**

- \( 0.25 \text{W} @ 125 \text{mA}, 2.0 \text{V} \)

**Graphs:**
- **Left Graph:**
  - Cell Voltage (mV) vs. Current Density (mA/cm²)
  - Power Density (mW/cm²) vs. Current Density (mA/cm²)
- **Right Graph:**
  - Stack Voltage (V) vs. Current Density (mA)
  - Power Density (mW) vs. Current Density (mA)
- >6 months shelf life at +55°C (results from 6 test cells).
- Significant increase over enzyme in free solution (denatured at 40°C).
- Proprietary ink process (patent app. 13/155,752 and 13/155,811).

- Devices (3 cells) show stable current (>1.5mA/cm²) over 72 hrs continuous operation with 160µL/min of fuel recirculation.
MRE sugar packets obtained from Combat Feeding (NSRDEC).
- Shows same performance as laboratory grade sugar from Sigma.
- **Bio-Battery uses supplies already in Army supply chain for fuel.**
Advantages

- High Energy Density (size/weight)
- Readily-Available Fuel (instant recharge)
- Renewable Biocatalysts
High Energy Density w/ Instant Refueling (Mobility)

~130 Wh/kg

~250 Wh/kg

~2500 Wh/kg

~Tethered to wall for ~2hrs

~2 min to Refuel
Energy in Li ~ 700Wh/kg
Energy in Glucose ~ 4,000Wh/kg
(upto 10,000Wh/kg for other fuels)

4g = 138g
~ 1 day of personal power
Fuel Flexibility
Current Recharging Solutions

Traditional Solutions
(Generators, HUMVEEs)

Renewable Solutions
(Flexible Solar Panels)

Not Portable
Require Diesel Fuel

Limited Availability (<20%)
For missions where >1,000 Wh of Energy are required, the Bio-Battery offers advantages in total mission weight.

Example 100hr Mission:
- SINCARS Radio – 1,600 Wh
- DAGR GPS – 400 Wh
- Misc devices – 1,000 Wh

TOTAL – 3,000 Wh

Bio-Battery provides >15kg of weight savings
Applications

Bio Battery
- Cell phones
- Soldier Power

Disaster Relief
- Generators
- Remote Power

Medical Implants
- Pace makers
- Insulin pumps

Replacing Batteries
- Toys
- Greeting Cards

Portable Charging
• Bio-Battery Powering Microprocessor and LCD
• Maximum Parameters: OCV > 4.0V, Short-Circuit Current > 125mA
• Load Conditions: V >2.0V, I ~ 0.5mA → P ~ 1mW
• 5mL of glucose fuel is sufficient for >100 hrs operation
Temperature sensor with TI 2.4GHz radio attached powered by Bio-Battery. Wirelessly transmits data to computer (temperature and voltage).

- Average power draw is 5mA (peak 20mA) at 3.0V.
- Transmitting every 1sec allows ~1.5-2hrs operation with Bio-Battery. Transmitting every 60sec would allow ~100hrs operation.
5W Prototype – 15-Cell Graphite Stack

new prototype, released in March 2013

- Designed and fabricated graphite bipolar plate configuration
- **Stack provides 5V at 1A (5W)**
- Fitted with USB connector and demonstrated powering electronic devices and recharging an iPhone
AFRL’s Strategic Vision: “Ubiquitous, Swarming Sensors & Shooters”

“Biomimetic bird-sized UAV platform, semi-autonomous operations with WMD sensing capability”

“Biomimetic insect-sized UAV platform with WMD sensing, tracking and targeting capability, capable of autonomous persistent operation”

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Miniaturized Biological Fuel Cell

Implantation into Beetle

Continuous power generation for >2 weeks after implant
High performing, stable, and reproducible enzymatic fuel cell technology developed over last 5 years.

Scaled-up demonstration of Bio-Battery powering electronic circuit (performed at both Power Sources and Army Science Conf's).

Fully-integrated Bio-Battery charging prototype developed.

Funding secured from multiple DoD agencies for multiple target applications over the next 3-5 years.

**Future Direction**: Fully-integrated demonstrations, executed in close collaboration with customer, for relevant applications