Nanomaterials-Based Electrodes for Energy Storage Devices with Fast Rate Capabilities

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Acknowledgments

US Department of Energy, Energy Storage Research Program
US DOE Small Business Innovative Research (SBIR)
DOE 2002 Project
NEI Markets
-Nano enables the application of-

- Polymer Nanocomposites: coatings and bulk
  - Nanoparticles for Drug Delivery
    - Nanoparticle laden fluids
    - Specialty Nanopowders
    - Rechargeable Batteries
High Rate Energy Storage Devices
Goals of the Program

• Develop nanostructured anodes for a new type of high rate energy storage device called Asymmetric Hybrid Cell

• Fabricate prototype Asymmetric Hybrid Cell with following features-
  – Capable of working efficiently over a wide temperature range (-30°C to 70°C)
  – Long cycle life (> 100,000 cycles)
  – Power density as good as that of a supercapacitor
  – Energy density comparable to, or higher than, that of Pb-acid batteries
  – Fast rate of charge (complete charge in 1 min.)
Concept of High Rate
Asymmetric Hybrid Cell

A thin, flexible, highly manufacturable and non-aqueous plastic laminar device

Ultrafine Electrodes Exhibit Faster Rate Capabilities

- Li$_4$Ti$_5$O$_{12}$ Electrodes -
Long Cycle Life of Prototype Hybrid Cells

- **Cathode**: High surface area activated carbon (700 – 2000 m²/g)
- **Anode**: Ultrafine Li₄Ti₅O₁₂; **Electrolyte**: 1M LiPF₆ in 2:1 volume ratio of ethylene carbonate: dimethyl carbonate
- **Dimensions**: 6” X 4” (Courtesy Telcordia Technologies)
Rationale for Lithium Intercalating Anode Materials

Intercalation voltage
Carbon: ~ -3V SHE
Li$_4$Ti$_5$O$_{12}$: -1.5V SHE
WO$_2$: - 2.3V SHE

Carbonaceous materials are unsafe to operate in high rate applications, because of the risk of Li plating.
**WO₂ has the Highest Output Voltage**

Use of WO₂ anodes will enhance the energy density of asymmetric hybrid cell.

*Courtesy Telcordia Technologies*
Low Temperature Synthesis

The diagram shows the X-ray diffraction patterns for different temperatures:
- Green line: 600 °C
- Blue line: 550 °C
- Red line: 500 °C

The peaks indicate the presence of WO₂ at these temperatures.
Spherical Particles with Ultrafine Crystallites

Spherical particles will result in high packing density of electrodes
Surface area = 15 m²/g
Ultrafine WO₂ Powders Are Electrochemically Active

Discharge rate: 22.72 mA/g

Capacity (mAh/g)

Time (hr)

Cycle
Electrochemical Data in An Asymmetric Hybrid Cell

- Spring
- Current Collector
- Counter Electrode (a)
- Ref. Electrode (b)
- Separators
- Working Electrode (c)
- Plungers

Potential vs. Ag quasi reference or full Output V

- Full cell output V: 60 mAh/g
- Activated C vs. ref
- WO_3 vs. ref

Time (hr)
Program Overview

- **NEI**
  - Develop nanostructured anode powders
  - Scale up the synthesis process

- **Telecordia**
  - Fabricate and characterize prototype asymmetric hybrid cell

- **Battery Manufacturers**
  - Partner with battery manufacturer to produce Asymmetric Hybrid Batteries

- **Sandia National Laboratories**
  - Research support and scientific input

- **Manufacturers of Energy Storage Systems**

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- **Supply anode materials**