Advanced Batteries R&D: A Status Update and Future Directions

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By

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Outline

- Current Status of Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Batteries
- Energy Storage Budget and Program Structure
  - Focused Fundamental Research
  - Applied Battery Research
    - Current Research Directions
  - Battery Development Activities (via USABC)
- Plug-in Hybrid Electric Vehicle (PHEV) Batteries

Current Status: HEV Batteries

- Conventional lithium-ion batteries for power-assist HEVs appear about ready for commercialization
  - Lack of manufacturing bases in North America is a concern
- Major focus remains on cost reduction
  - Abuse tolerance and low-temperature performance still remain issues.
    - Emerging technologies with nanostructure materials ($Li_4Ti_5O_{12}$, $LiFePO_4$) appear to address these issues.
  - Batteries, even those incorporating "stable" materials, will require appropriate thermal controls and electronic protection circuits to extend battery life and to avoid thermal runaway.
  - Battery life projections of 10-15 years are based on limited data.

Current Status: EV Batteries

- Current battery technologies limit a vehicle's range on a single charge to less than 300 miles
- Cost and low specific energy remain critical barriers
  - Most lithium-ion systems are limited to 100 Wh/kg (system).
  - Metallic lithium systems (150 Wh/kg) offer a longer driving range, but have poor cycle life due to dendrite formation.
- Additional technical issues include
  - High energy batteries are power-limited, especially at 80%DOD after many cycles.
  - Batteries that idle at a high state of charge (SOC) experience a reduced calendar life.
  - Most lithium systems can not accommodate fast charge.

Status/Technology Characteristics

Cell Energy, 10-s Power

Conventional lithium-ion

- ❑ Accurate SOC
- ❑ Excellent power density
- ❑ Good energy density
- ❑ *Well matched for charge-sustaining*

HEV	EV
70 Wh/kg 2,500 W/kg	140 Wh/kg 500 W/kg

High-rate, high-energy lithium ion (titanate anode/iron phosphate cathode)

- ❑ SOC determination problematic
- ❑ Good power density
- ❑ Very good energy density
- ❑ *Well matched for PHEVs and potentially charge-sustaining HEVs*

HEV	EV
100 Wh/kg* 2,000 W/kg	-

* Projected

NiMH

- ❑ Very difficult to ascertain the SOC accurately
- ❑ Good power density
- ❑ Abuse tolerant and proven technology
- ❑ Moderate energy density; *good for charge-sustaining HEVs*

HEV	EV
50 Wh/kg 1,000 W/kg	-

Budget and Program Structure

Fiscal Year	Budget ($, Million)
2006	**$24.442**
2007	**$31.139*** ***President's Request**

- **Focused Fundamental Research**
  - Conduct innovative, cutting-edge long term research on the next generation of lithium battery systems
- **Applied Battery Research**
  - Assist battery developers to overcome barriers associated with high power Li-ion battery technology
- **USABC Activity – Battery Development**
  - Develop energy storage devices meeting FreedomCAR requirements

Focused Fundamental Research

A multi-laboratory, multi-university effort to conduct innovative, cutting-edge research on the next generation of lithium battery systems

Research effort coordinated with the DOE Office of Science

Focus

- Develop novel materials (for cathodes, anodes, and electrolytes) that promise greatly increased power and energy
- Develop and apply advanced electrochemical models
- Employ advanced diagnostic tools to investigate failure mechanisms

Applied Battery Research

A multi-laboratory effort assisting battery developers to overcome performance barriers associated with high-power Li-ion battery technology

Focus

- Understand, extend, and more accurately predict **battery life**
- Search for and develop **low-cost** cell materials and components
- Understand factors that affect **abuse tolerance**
- Understand factors that limit **low-temperature performance**

Research Directions

- Negative electrode material
  - Develop novel inter-metallic alloys and new binders to accommodate volume change during cycling
  - Investigate nanophase metal oxides
- Electrolytes
  - Develop high voltage electrolytes (4.5 – 5 Volts)
  - Develop electrolyte additives to improve interfacial stability
  - Develop solid polymer electrolytes with improved conductivity and mechanical strength
- Interphase studies
  - Continue to search for better membranes or glasses to stabilize the surface of the metallic lithium anode

USABC Activities

Battery Development

Develop energy storage devices meeting FreedomCAR requirements

- The United States Advanced Battery Consortium (USABC) is a partnership of DaimlerChrysler, Ford, and General Motors, formed in 1991, to foster the development of advanced batteries
- Full battery systems are developed through competitive subcontracts through the USABC
  - Performance targets developed through modeling and simulation
  - Candidate technologies benchmarked before full-scale development
  - All contracts require a minimum cost-share of 50%
- Deliverables are tested and analyzed against performance targets using standardized test procedures

Current USABC Developers

USABC-FreedomCAR Energy Storage Programs with Developers (August 2006)

Programs	Developer
HEV (Li-ion)	Johnson Control – Saft (JCS)
	EnerDel
	CPI-LG Chem
	A123 (in negotiation)
Ultracaps	Maxwell
	NessCap
Separators	Celgard
	UMT
Modeling	Battery Design Studio (BDS)
DOE Research Activities	Advanced Technology Development (ATD)
	Batteries for Advanced Transportation Technologies (BATT)

Total annual budget corresponds to ~$40 million

PHEV Batteries

- Lithium-ion batteries are technically feasible
  - No batteries specifically built for this application are available
  - Synergies between development of PHEV, EV, and HEV batteries
  - Impact of dual mode of operation during charge depleting and charge sustaining on battery life is not understood
- Cost is a potential show stopper
  - USABC recommended short-term goal is $300/kWh and long-term goal is $200/kWh
- PHEV battery requirements are being developed

Thank You

for

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