OFFICE OF

TRANSPORTATION TECHNOLOGIES

Energy Storage Technologies . . . for Hybrid Electric Vehicles

High-power battery technologies are the principal energy storage devices that are being considered for application with Hybrid Electric Vehicles (HEVs). The Department of Energy (DOE) has investigated other technologies, such as ultracapacitors and flywheels, but is focusing on battery development as most promising for the near term. The Partnership for a New Generation of Vehicles (PNGV) high-power energy storage requirements for an 80 mpg automobile are significantly more challenging than for electric vehicles. The power-to-energy ratio, a key determinant of battery cell design, is greater by a factor of 10 for the PNGV hybrid vehicle.

High-Power Battery Candidates Have Emerged

HEV batteries require a higher power-to-energy ratio than electric vehicle batteries.

Two candidate battery chemistries have been identified as the most likely to succeed in meeting the HEV high-power requirements: nickel/metal hydride and lithium-ion. Nickel/metal hydride batteries are currently used in electric vehicles, computers, medical equipment, and other applications. They offer relatively good power capability as a result of the good ionic conductivity of the potassium hydroxide electrolyte, and their components are recyclable. The main challenges are their high cost, the need to control hydrogen loss, and their low cell efficiency. Lithium-ion batteries offer excellent energy density that can be traded for higher power. They are being investigated for use in HEVs in full-size modules in a two phase program to scale-up the basic performance and life capabilities demonstrated in small laboratory cells.

How Does Government-Industry Collaboration Work?

Developing high-power batteries for use in HEVs requires the coordination of battery developers and suppliers, government, automotive manufacturers, and university organizations. The United States Advanced Battery Consortium (USABC) is an industry consortium that includes DaimlerChrysler Corporation, Ford Motor Company, General Motors Corporation, and the Electric Power Research Institute, representing electric utilities. Selected national laboratories, under a Cooperative Research and Development Agreement (CRADA) with the USABC, are conducting performance and cycle life testing of competing battery cells.

DOE progress in HEV research and development is described in this series of fact sheets

What Are Tomorrow's Research and Development Goals?

Research sponsored under USABC subcontracts is establishing baseline cell chemistries and electrode designs to integrate full-size cells into a module assembly. This research includes inter-cell connections, instrumentation, monitoring, electronic controls, and a support structure suitable for installing a complete battery subsystem into a vehicle. The overall focus of technology development is on design and manufacturing improvements to reduce costs and improve battery performance and life. Energy storage devices are being designed for various HEV configurations. *See the HEV Technical Background fact sheet for additional information.* Whatever configuration is used, energy storage devices, needed for hybrid vehicles, must have high specific power; that is, the power-to-energy ratio must be greater than 20 W/Wh. The target life is 10 years and at least 120,000 cycles. Among the technical challenges facing developers are:

- ***Safety (abuse tolerance).*** The behavior of the candidate battery technologies in high-power applications needs to be determined. Multiple strings of cells pose a problem for some of the technologies, because they do not have overcharge or over-discharge protection. Electrical and mechanical safety device development needs to continue.
- ***Cost.*** The current cost of nickel/metal hydride and lithium-based batteries is prohibitively high on a kWh basis.
- ***Thermal management***. The candidate batteries all have operating temperature ranges that do not cover the entire operating temperature range required for automotive vehicles. To maintain the integrity of the battery and reduce cell imbalance, an active thermal control system will be required; one has not yet been developed.
- ***Calendar life***. Calendar life needs to be ascertained. A 10-year calendar life is required to reduce overall system costs.
- ***Recycling***. Recyclability of the components is a requirement for using high-power batteries in hybrid vehicles. The target goal is 80% recyclability of the vehicle.

Defining Terms

Energy density: the amount of energy a battery stores per unit volume at a specified discharge rate; also called volumetric energy density; usually measured in watt-hours per liter.

Power density: the amount of power a battery can deliver per unit volume at a specified state-of-charge; also called volumetric power density; usually measured in watts per liter.

Specific energy: the amount of energy a battery stores per unit mass at a specified discharge rate; also called gravimetric energy density; usually measured in watt-hours per kilogram.

Specific power: the amount of power a battery can deliver per unit mass at a specified state-of-charge; also called gravimetric power density; usually measured in watts per kilogram.

State-of-charge (SOC): the percentage of its total ampere-hour capacity stored in a battery.

USABC: United States Advanced Battery Consortium, a government/industry effort to encourage the development of batteries suitable for electric vehicles.

For additional information, contact:

Dr. Raymond A. Sutula
U.S. Department of Energy, EE-32
1000 Independence Avenue, SW
Washington, DC 20585
(202) 586-8064
raymond.sutula@ee.doe.gov

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