Lithium-Ion Battery Research and Development

Rechargeable lithium batteries have become very popular power sources for consumer electronic devices, because of their high energy density (energy per unit weight or volume) relative to nickel cadmium and nickel metal hydride batteries. Cellular telephones, digital cameras, camcorders, laptop computers, and other electronic devices currently use lithium-ion batteries. Due to their success in these applications, they are under development for other applications such as energy storage devices for electric vehicles, hybrid electric vehicles, and specialty battery applications.

Transportation: A Historical Perspective

The Chemical Engineering Division (CMT) has been involved in the development of advanced lithium batteries for transportation applications since 1994. Our early work was on lithium-polymer batteries that employed metallic lithium negative electrodes, a polyethylene oxide solid electrolyte, and a metal oxide positive electrode. This technology was being developed for use in electric vehicles (EVs) under a cooperative research and development agreement, or CRADA, with 3M Corporation and Hydro-Quebec. The U.S. Advanced Battery Consortium (comprising DaimlerChrysler, Ford Motor Company, and General Motors Corporation) and the U.S. Department of Energy (DOE) sponsored this research and development (R&D) from 1994 to 2001.

In 1998, the Division helped DOE to organize and initiate a new multi-national-laboratory R&D program (the Advanced Technology Development or ATD Program) on high-power lithium-ion batteries. Lithium-ion batteries employ a liquid or gel-polymer electrolyte and lithium insertion compounds in both the positive and negative electrodes. The development of high-power lithium-ion batteries for hybrid electric vehicle (HEV) applications was begun under the Partnership for a New Generation of Vehicles (PNGV) Program. This program was a federal government/U.S. auto industry partnership to develop low-emission full-size passenger vehicles with an 80-mile-per-gallon fuel economy. The PNGV Program focused on the

Preparing to test a "pouch" cell

storage device to level the load on the internal combustion engine and recapture regenerative braking energy. The ATD Program, was initiated to assist PNGV industrial developers of high-power lithium-ion batteries overcome the barriers of life, abuse tolerance, and cost for this promising technology. The ATD Program covers a broad range of R&D activities associated with understanding the mechanisms that limit life and abuse tolerance, as well as evaluating and developing advanced materials designed to overcome these limitations, while simultaneously reducing material costs. It also involves the development of novel approaches for reducing cell packaging costs.

Transportation Research Today

In 2002, the PNGV Program was replaced by a new auto industry/federal government partnership, denoted the FreedomCAR Partnership. It expands on the PNGV Program, with a long-term focus on the development of fuel cell electric vehicles (FCEVs), while it continues to support the development of HEV technologies in the nearer term. DOE's ATD Program continues to address the high-power lithium-ion battery needs for HEV and FCEV applications. The Division continues work on the ATD Program under the

FreedomCAR Partnership and expanded its efforts to study low-temperature performance in 2004.
CMT also conducts longer-range, but focused, research on advanced materials for lithium batteries. These longer-range research activities seek to develop novel new materials that can enhance the performance, life, and/or safety of advanced lithium batteries, while reducing cost. In recent years, a new family of intermetallic negative electrode materials was discovered, as was a new family of lithium-rich composite metal oxide positive electrode materials. We continue our efforts to develop optimal electrode compositions for both high-power and high-energy lithium batteries for use in transportation applications.
Specialty Applications

The Division works collaboratively with industry on rechargeable lithium batteries for specialty applications. In a major project funded by the U.S. Department of Commerce, Advanced Technology Program, the Division was under contract to the industrial leader of the project (Quallion, LLC) to develop advanced cell chemistries for long-life rechargeable lithium microbatteries. The microbatteries are used as the power source in neuromuscular microstimulator implants.

The microstimulators are designed to treat patients suffering from stroke, Parkinson's disease, epilepsy, urinary urge incontinence, and other conditions involving neuromuscular impairment. The advanced cell chemistry involves a new polymer electrolyte that has high ionic conductivity at room temperature. The bion® microstimulator ("bion®" is a registered trademark of Advanced Bionics Corporation) won a 2005 R&D 100 Award for its developers—Argonne, Quallion LLC, the Alfred Mann Foundation, and Advanced Bionics Corporation, which manufactures the device.

CMT also is working with an industrial partner to develop a battery for the U.S. Army's Power Vest, which requires almost double the best energy density currently available and safe, stable operation at varying temperatures. Some of CMT's patented electrode materials and one of its electrolyte systems are being adapted for the Power Vest. Compared with conventional materials, Argonne's new cathode material extends the useable capacity from 150 milliampere-hours per gram to 260. When combined with Argonne's new process for making spherical dense cathode particles, the combination will provide a major increase in available energy from the same size battery.

Additionally, CMT operates the Electrochemical Analysis and Diagnostics Laboratory, which was established by DOE to conduct independent evaluations of advanced battery systems for applications such as EV, HEV, FCEV, and stationary energy storage. This facility has been cited as a valuable resource by battery users, developers, and DOE program managers, who must evaluate and make choices regarding competing battery technologies and research directions. Since it was established more than two decades ago, the laboratory has tested more than 4,000 cells and batteries, ranging from individual 4-Wh cells to 50-kWh batteries, representing numerous technologies and battery developers. The test facility has expanded to include the testing and evaluation of fuel cell stacks and fuel cell systems up to 80 kW.

For More Information

Gary Henriksen, Manager
Battery Technology Department
Chemical Engineering Division
Argonne National Laboratory
9700 S. Cass Ave.
Argonne, IL 60439
630-252-4591, fax 630-252-4176
henriksen@cmt.anl.gov
www.cmt.anl.gov/Science_and_Technology/Batteries/