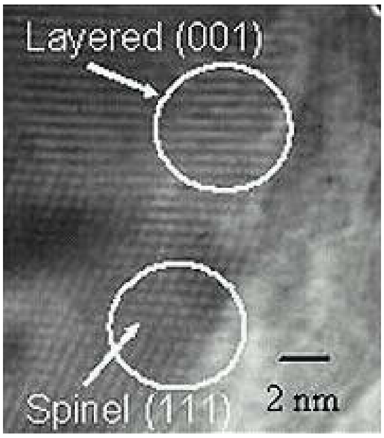
Developing new lithium-ion batteries



Next-generation soldiers will wear vests with a battery to power the many high-tech devices that modern soldiers use in battle. Argonne – the nation's expert in lithium battery research – is developing the materials and cell chemistry for that battery.
Argonne's Chemical Engineering Division (CMT) researchers have the key to more robust lithium-ion (Li-ion) batteries: new materials and improved cell chemistries. CMT has developed Li-ion technology for batteries small enough to be implanted in the human body and large enough to power hybrid electric cars.

Image: GROWING CATHODES – Intergrowing layered and spinel components is one way CMT creates new composite-structure cathode material, as seen in this high-resolution transmission electron micrograph.

Modern military personnel rely on non-rechargeable batteries to power communications, night vision goggles and global-positioning sensors used in training and on the battlefield. In an ongoing project for the U.S. Army Communications-Electronic Research & Engineering Center, Argonne is developing a new battery chemistry for research partner Quallion LLC's battery pack for the Power Vest. The partners are developing a rechargeable, safe, low-cost, lightweight, high-energy density, Li-ion battery system for this application.

“For the same size, lithium batteries store more energy than alkaline batteries,” explained Jim Miller, Manager of Argonne's Electrochemical Technology Program. Li-ion batteries power many consumer electronic devices, such as cameras, camcorders, portable computers and cell phones.

“As manufacturers build more features into items such as cell phones,” said CMT's Battery Technology Department Head Gary Henriksen, “they require more energy to operate, so we are challenged to pack as much energy as possible into a given weight and volume.”

CMT's Battery Technology Department began its work with Li-ion batteries in 1998, when the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy provided funding for the laboratory to help industrial developers overcome key barriers – insufficient safety and calendar life – to using these energy-storage devices in hybrid electric vehicles. This research led CMT to develop advanced electrodes, electrolyte additives and cell chemistries that extend the life and improve the inherent safety of Li-ion cells. Much of CMT's new technology is being used to develop improved cell chemistries for batteries in non-automotive applications.

Battery background

Batteries chemically store and release electrical energy. They produce electricity when the electrode materials – cathodes (positive electrodes) and anodes (negative electrodes) – react with each other electrochemically via the conductive lithium ions in the electrolyte.

“Our strengths are in developing advanced materials and chemistries for batteries,” said Henriksen. “Lithium-ion batteries are thermodynamically unstable. The active materials in the electrodes react chemically with the electrolyte, and only the formation of protective passivation films on electrode surfaces allows this system to function as a practical battery system.

“We continue to research more stable electrode materials and electrolytes, as well as electrolyte additives that create more stable passivation films,” Henriksen said. Argonne's battery researchers are developing new materials for Li-ion batteries to increase their:

-- Life
-- Safety
-- Power density – watts per unit weight – by allowing faster reactions, and
-- Energy density – watt-hours per unit weight – by storing more lithium per unit weight of host material.

“New cathode and anode materials,” Henriksen said, “will improve the performance of Li-ion batteries, while simultaneously enhancing their inherent stability for longer life and better safety.” More stable electrode-electrolyte interfaces will also lead to longer-life and inherently safer batteries.

Vest batteries

The Army's Power Vest 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 to 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 could provide a 40 percent increase in available energy from the same size battery.

Existing applications for Li-Ion batteries — consumer electronics — only require the batteries to operate at or near room temperature. The required operating temperature range for the army vest is much larger. “In the Iraq desert, for example,” said CMT's Amine, “soldiers are serving in temperatures exceeding 100 degrees Fahrenheit.” CMT's new electrolyte system allows extended operation at higher temperatures than available from conventional Li-Ion liquid electrolyte systems

Body batteries

With research partners Quallion and the University of Wisconsin, Argonne developed the battery chemistry for a tiny rechargeable battery – the smallest cylindrical polymer rechargeable battery ever made. The battery is 100 times smaller than a standard AA battery, and powers an implantable microstimulator system designed to help patients with neurological disorders and muscular impairments, such as stroke, Parkinson's disease and urinary incontinence. These microstimulator systems would be implanted near nerves, where they emit electrical micropulses that stimulate nearby muscles and nerves. Batteries previously used for medical devices are large, have short lives and are not rechargeable.

CMT researchers developed and patented two new electrolyte systems for this battery. One is a new class of polymer electrolytes, made of silicon-oxygen chains called siloxane, that provides the highest conductivity ever reported in polymer materials. The second is a new class of liquid electrolytes based on silanes, which are more stable in the cell environment than conventional liquid electrolytes.

"These materials exhibit excellent conductivity, operate at room temperatures and provide good electrochemical, chemical and thermal stability compared to conventional lithium-ion battery electrolytes," said Amine.

These are just two examples of how Argonne works with private companies to develop new cell chemistries for specialty battery applications and to help battery manufacturers meet the performance and life requirements of their applications.

Argonne works with industry under a variety of working arrangements, including collaborative research, reimbursable research and licensing agreements. The cathode materials for the army vest project are an extension of Argonne's prior discovery, covering a new family of composite layered cathode materials.

CMT is currently in discussions with organizations worldwide regarding licensing rights to these base cathode material patents. "This new family of cathode materials," said CMT's Michael Thackeray, "is already starting to replace the conventional cathode materials in batteries for consumer electronic applications."

Source: Argonne National Laboratory (by Evelyn Brown)