Advanced Batteries: Longer-Lasting Power for Cordless Power Tools and Plug-In Hybrid Electric Vehicles

Challenge

In the early 1990s, high-power consumer electronics relied mainly on nickel cadmium (NiCd) and nickel metal hydride (NiMH) batteries. These batteries were heavy, bulky, and expensive to use, causing manufacturers of high-power applications to seek lightweight, cost-effective, and more efficient alternatives. However, design modifications to boost battery power proved challenging as they risked reducing battery life or even causing explosions.

At that time, the first generations of lithium-ion (Li) batteries were delivering long-lasting power to small consumer electronics devices, such as laptop computers and cell phones. Their compact size and light weight, combined with high energy density, provided an efficient means of generating power on a small scale. While these characteristics were appealing to high-power application manufacturers, first-generation Li batteries were not well suited for those applications due to a short life span, capacity losses over time, and long recharge times.

Innovating Solutions

Researchers at MIT had been working on an innovative lithium cathode material with great potential to help meet the need for better batteries for high-power applications. They had begun developing the material, primarily for power generation in the hybrid electric vehicle (HEV) market, but faced a major technical challenge: producing it in sufficient amounts to demonstrate commercial potential. In 2001, the MIT team successfully applied for a DOE SBIR Phase I grant to complete development of the material and establish their start-up company, A123Systems. The company was awarded a Phase II grant in 2003 to demonstrate a cost-effective, pilot-scale process for manufacturing the lithium cathode materials for hybrid electric vehicle batteries. The funding enabled A123Systems to test and refine their technology, yielding a proof-of-concept to market to potential investors.

The A123Systems cathode is made of a highly conductive, chemically doped nanophosphate material. This material eliminates problems usually associated with high-power batteries, yet still meets the most aggressive battery life cycle requirements. Unlike conventional Li metal oxide cathode materials—which can go to thermal runaway when handled improperly—the material is intrinsically stable and does not combust or release oxygen when exposed to high temperatures. As a result, it increases power capability without compromising safety or battery lifetime.

With proprietary high-performance, laser-welded, dual-plate tubular construction, the A123Systems cells weigh only 70 grams, are capable of high discharge rates, and offer high electrical efficiency. Their low impedance ensures longer life and effective temperature management because they can be operated without the artificial cooling that is required for higher impedance products. In addition, the technology offers the highest volumetric power density of comparable products now commercially available. It also functions effectively at low temperatures, while displaying a four-fold improvement in life cycle at high temperatures. Compared to conventional batteries—which lose as much as 20% capacity at 77°F and up to 35% capacity at 104°F—the A123Systems Li battery delivers power effectively at temperatures ranging from -22° to >140°F.

The A123Systems battery provides enhanced safety and environmental benefits due to the use of phosphates instead of the toxic heavy metals found in current Li batteries. The chemically doped nanophosphate material provides a level of safety that is essential in vehicle applications, as its unique chemistry reduces the risk of explosive runaway oxidation reactions that can occur with conventional oxide-based Li cells. Those metal oxide cathodes release oxygen when exposed to high voltage or temperature. This exothermic reaction creates a positive feedback loop that promotes further oxygen production, eventually leading to thermal runaway. A123's nanophosphate material does not release oxygen and thus does not cause thermal runaway.

DOE Small Business Innovation Research (SBIR) support enabled A123Systems to develop their pioneering product—the M126650 Lithium-Ion Battery—offering higher performance than high power NiCd and NiMH batteries and current generations of standard consumer Li batteries. They offer:

- Improved battery life by up to 10 times compared to Li batteries
- More than twice the power density compared to high power NiCd and NiMH batteries
- Improved electronic and ionic transport, delivering power more efficiently than Li batteries
- Operation over a wide temperature range, from -30 to >60°C
- Charging to more than 90% capacity within 5 minutes
- Capability for discharge rates as high as 100 rated capacity, >200 Amps, in short pulses
- Potential for reduced emissions and increased fuel economy in hybrid electric vehicles

A123Systems (Watertown, MA) was founded in 2001 by a team of MIT materials scientists when they received SBIR funding to develop their advanced battery technology. The effort was a success, leading the company to enter the cordless power tool market and giving them standing to compete in the HEV market, their ultimate goal. The firm has attracted substantial capital investment and grown exponentially as a direct result of the technology developed with SBIR support.

www.a123systems.com

A case study from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy SBIR program, providing competitive grants for scientific excellence and technological innovation to advance critical American priorities and build a strong national economy – one small business at a time.

Advanced Batteries for Longer-Lasting Power

A123Systems' SBIR research enabled the company to develop—and ultimately manufacture—lightweight, rechargeable Li batteries as an alternative to NiCd, NiMH, and current Li batteries for high-power applications.

UPDATE: A123System continues to make progress in its HEV market strategy. Among the major milestones:

- In 2008, the company began taking consumer orders for its Hymotion plug-in conversion modules, capable of converting the Toyota Prius to a plug-in hybrid with a fuel economy of more than 100 miles per gallon.
- In 2009, they formed a strategic partnership with Chrysler for a new line of HEVs.

They are on track for increased domestic manufacturing capacity and a share of the hybrid car market for Li technology, which overall is projected to reach $2.17 billion/year in 2013.

SBIR Impacts

Benefits of A123 Li Batteries in Power Tools & Hymotion™ Hybrid Vehicle Range Extender

Energy	Increased power density (A123 Li vs. NiMH in power tools)	3,000 W/kg vs. 1,000 W/kg[1]	
	Reduced gasoline usage (vehicle with Hymotion plug-in vs. typical mid-sized gas-powered car)		4,820 gallons[2]
Economic	Revenue from battery and battery system sales (2006 – 2008)	$96 million	
Environmental	Reduced CO_2 emissions		46.77 tons
	Reduced Greenhouse Gas (CH_4, N_2O, HFCs) emissions		2.46 tons

Innovation

Power Tools

Black & Decker introduced the DEWALT product line of heavy-duty, 36-volt power tools using A123Systems' battery technology. This line delivers substantially more power for tools currently used by builders and contractors, including circular saws, reciprocating saws, hammer drills, and a powerful impact wrench.

Hybrid Electric Vehicles

Replacing conventional vehicles with HEVs will increase fuel efficiency and reduce emissions per gallon of gasoline, allowing drivers to fuel less frequently. A123Systems' battery overcomes barriers to wider HEV adoption such as cost, reliability, and performance, which can help increase potential HEV market share and associated benefits.

Company Success

SBIR support enabled university researchers with a powerful idea to demonstrate its feasibility and attract venture capital. With initial financial backing following their SBIR award, A123Systems was able to recruit a CEO and management team to develop their business plan and raise additional funds. Prior to its initial public offering in 2009, the company had raised over $250 million.

A123Systems has grown from a new Massachusetts start-up company in 2001 to an international business with 1700 employees and over $70 million in revenue in 2008. In late September 2009, A123 closed its initial public offering of 32.4 million shares and raised $437.5 million—the second-best IPO of the year.

A123Systems' ultimate target market is hybrid electric vehicles. Before approaching automakers, the company established a strong customer base by collaborating with Black & Decker in the power tools industry, the second largest battery market after hybrid cars. This partnership enabled A123Systems to become the world's second-largest producer of high-power Li batteries and paved the way for it to raise $20 million to finance manufacturing operations in Asia. As of 2008, A123Systems facilities had the capacity to produce over 10 million batteries per year.

[1] Power density indicates how much power a battery can deliver on demand, a major advantage of the A123 battery over conventional high-power batteries (the A123 figure is from A123's website; the other battery figure estimated is from various on-line sources).

[2] 143 gallons (Hymotion™) vs. 625 gallons (gas car) of gas consumed per year over 10 years (estimated using A123's online calculator).

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