Stories of Discovery & Innovation

The Breakthrough Behind the Chevy Volt Battery

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A revolutionary breakthrough cathode for lithium-ion batteries—the kind in your cell phone, laptop and new hybrid cars—makes them last longer, run more safely and perform better than batteries currently on the market.

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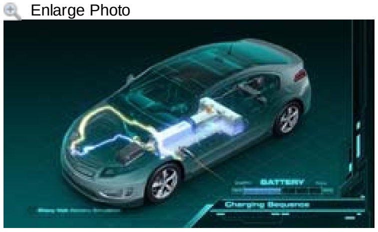

Image courtesy of General Motors

The 2011 Chevrolet Volt's 16 kWh battery can be recharged using a 120V or 240V outlet. The car's lithium-ion battery is based on technology developed at Argonne National Laboratory.

In 2010, GM rolled out the first mass-produced plug-in hybrid electric car: the Chevy Volt. While much of the car's engineering is unique, consumers may be unaware that some of its most extraordinary technology is inside the nearly 400-lb. battery that powers the vehicle in electric mode.

The battery's chemistry is based in part on a revolutionary breakthrough pioneered by scientists funded by the U.S. Department of Energy. The new development helps the Volt's battery—a lithium-ion design similar to those in your cell phone or laptop—last longer, run more safely and perform better than batteries currently on the market.

The story begins in the late 1990s, when the DOE Office of Science funded an intensive study of lithium-ion batteries. "Existing materials weren't good enough for a high-range vehicle," explained Michael Thackeray, an Argonne National Laboratory researcher who is one of the holders of the original patent. "The Argonne materials take a big step forward in extending the range for an electric vehicle."

In order to improve the design, scientists had to know how batteries worked at the atomic level. "What we really needed to do was understand the molecular structure of the material," said Argonne chemist Chris Johnson.

At its most basic level, a lithium battery is composed of a negatively charged anode and a positively charged cathode. Between them is a thin membrane that allows only tiny, positively charged lithium ions to pass through. When a battery is fully charged, all of the lithium ions are contained in the anode. When you unplug the battery from the charger and begin to use it, the lithium ions flow from the anode through the membrane to react with the cathode—creating an electrical current.

The team wanted to improve the cathode, the positively charged material. They began by using incredibly intense X-rays from the Advanced Photon Source (APS) at DOE's Argonne National Laboratory to monitor and understand reactions that occur in lithium batteries—in real time. The APS is one of several large, high-intensity light sources supported by the DOE Office of Science at national laboratories around the nation. These are among today's most powerful tools for observing the behavior of matter at the atomic and molecular levels.

Powerful X-rays from the APS allow scientists to "watch" the battery—at the molecular level—as it cycles. The team wanted to monitor both the electron flow in the materials, and how stable the molecular structure stayed while the battery was working. To do this, the scientists used a technique called X-ray absorption spectroscopy to measure the charge state of the metals in the cathode and the stability of the bonds in the structure. These measurements provided critical molecular information on where the electrons were moving in the material, and the effect on the cathode's structure. This knowledge, in turn, helped them to design and synthesize new cathode compositions.

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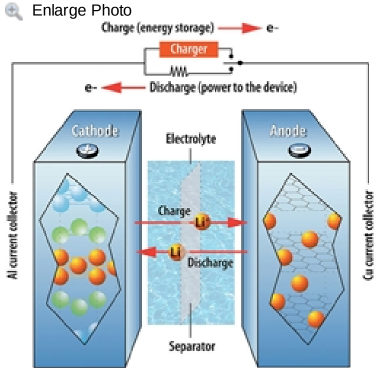

Illustration courtesy Argonne National Laboratory

This illustration shows the inner workings of a lithium-ion battery. When delivering energy to a device, the lithium ion moves from the anode to the cathode. The ion moves in reverse when recharging. Compared to other rechargeable

As the research transitioned from basic science to applied R&D, initial DOE Office of Science support was succeeded by major multi-year funding from the Vehicle Technologies Program of DOE's Office of Energy Efficiency and Renewable Energy, which provided the support needed to translate the insights gained from basic science into a viable new battery technology.

Using new synthesis methods, researchers created lithium- and manganese-rich materials that proved remarkably more stable than existing designs.

Because manganese-rich cathodes are more stable than those used in today's batteries, the new batteries are safer and less likely to overheat. Manganese is cheap, so the battery will cost less to manufacture. The researchers also boosted the upper charging voltage limit to 4.6 volts—higher than the usual operating voltage—and saw a tremendous jump in the battery's energy storage capacity.

The Argonne battery design became, in a radical leap forward, cheaper, safer, and longer-lasting.

"To me, that's exceptional," said Jeff Chamberlain, who heads Argonne's battery development initiative. "New advances often sacrifice cost or safety for performance; it's a rare breakthrough that improves all three."

batteries, lithium-ion batteries can store more energy in smaller, lighter packages. This unsurpassed energy-to-weight ratio make them the battery of choice for consumer electronics like cell phones and laptops, but also a great fit for electrified vehicles.

Batteries for electric and plug-in hybrid cars are much larger—and thus far more expensive—than laptop batteries, and they make up a large percentage of the car's price. Lowering the cost of the battery will lower the cost of all-electric and hybrid cars, according to Khalil Amine, an Argonne senior materials scientist, and subsequent improvements will improve battery performance even further.

"Based on our data, the next generation of batteries will last twice as long as current models," Amine said.

The team is happy to see the technology make its way from the laboratory to the road.

"I would love to point to a car on the street and tell my son, 'This car has our invention in it!'" Amine said.

"Seeing homegrown innovations going into a large-scale production like the Volt—that's really exciting and good for America," Johnson added. "It's really the ultimate goal for a researcher."

Furthermore, Chamberlain said that the new battery technology pioneered by the lab can boost American manufacturing and create new jobs.

"Batteries are a large, heavy component of electric and hybrid cars, and so it's best to manufacture them near the factory where the cars are assembled," Chamberlain explained. "This means cars assembled in U.S. factories will also need battery factories nearby—creating more American jobs."

A total of $1.5 billion in grants from the American Recovery and Reinvestment Act went to several companies in 2009 and 2010—including A123 Systems, Johnson Controls and Compact Power, an LG-Chem subsidiary—to build battery plants in the U.S. (A full list of the grants is available online.)

—Louise Lerner, Argonne National Laboratory, Louise@anl.gov

Funding

Basic Research: DOE Office of Science, Office of Basic Energy Sciences

Follow-on Applied R&D: DOE Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program

Publications

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