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An Electrifying Startup

A new lithium-ion battery from A123 Systems could help electric cars and hybrids come to dominate the roads.

By Kevin Bullis

It is the quickest electric motorcycle in the world. On a popular YouTube video, the black dragster cycle nearly disappears in a cloud of smoke as the driver does a "burn-out," spinning the back wheel to heat it up. As the smoke drifts away, the driver settles into position and hits a switch, and the bike surges forward, accelerating to 60 miles per hour in less than a second. Seven seconds later it crosses the quarter-mile mark at 168 miles per hour--quick enough to compete with gas-powered dragsters.

What powers the "Killacycle" is a novel lithium-ion battery developed by A123 Systems, a startup in Watertown, MA--one of a handful of companies working on similar technology. The company's batteries store more than twice as much energy as nickel-metal hydride batteries, the type used in today's hybrid cars, while delivering the bursts of power necessary for high performance. A radically modified version of the lithium-ion batteries used in portable electronics, the technology could jump-start the long-sputtering electric-vehicle market, which today represents a tiny fraction of 1 percent of vehicle sales in the United States. A123's batteries in particular have attracted the interest of General Motors, which is testing them as a way to power the Volt, an electric car with a gasoline generator; the vehicle is expected to go into mass production as early as 2010.

In the past, automakers have blamed electric vehicles' poor sales on their lead-acid or nickel-metal hydride batteries, which were so heavy that they limited the vehicles' range and so bulky that they took up trunk space. While conventional lithium-ion batteries are much lighter and more compact, they're not cost effective for electric vehicles. That's partly because they use lithium cobalt oxide electrodes, which can be unstable: batteries based on them wear out after a couple of years and can burst into flame if punctured, crushed, overcharged, or overheated. Some automakers have tried to engineer their way around these problems, but the results have been expensive.

A123's batteries could finally make lithium-ion technology practical for the auto industry. Instead of cobalt oxide, they use an electrode material made from nanoparticles of lithium iron phosphate modified with trace metals. The resulting batteries are unlikely to catch fire, even if crushed in an accident. They are also much hardier than conventional lithium-ion batteries: A123 predicts that they will last longer than the typical lifetime of a car.

The battery's promise has made A123 one of the best-funded technology startups in the country, with $148 million in venture capital investments so far. With the funding, A123 has been pursuing an ambitious business plan that calls for it to do everything from perfecting the material to manufacturing batteries and selling them to customers in the auto and power-tool industries.

The A123 batteries for GM's Volt store enough energy for 40 miles of driving, enough to cover daily commutes. (On longer trips, the small gasoline engine would kick in to recharge the battery, extending the range to more than 400 miles.) GM plans to sell the vehicles for around $30,000 to $35,000; the company thinks it can sell hundreds of thousands at that price in the first several years, and J. D. Power and Associates estimates that GM will sell nearly 300,000 by 2014.

Materials Matter

In early 2001, a 26-year-old Venezuelan entrepreneur named Ric Fulop walked into the office of Yet-Ming Chiang, a professor of materials science at MIT, without an appointment. "He just showed up and knocked on the door," recalls Chiang. Fulop, who had already founded three venture-backed companies, wanted help starting a battery company, and he knew that Chiang was conducting battery research involving nanotechnology. Chiang himself had cofounded a successful startup in the late 1980s, but he spent most of his time researching nanotechnology and the chemistry of advanced ceramics.

By the fall, Fulop and Chiang, along with Bart Riley, an engineer Chiang knew from his previous venture, had cofounded A123 Systems. The plan was to commercialize one of Chiang's more radical ideas: materials that, when stirred together, would spontaneously assemble to form a working battery. The process promised to multiply energy storage capacity while lowering manufacturing costs.

Chiang's big idea turned out to be a hit with investors. By the end of 2001, a first round of funding had brought in $8.3 million from various venture capital firms. Motorola and Qualcomm, intrigued by the prospect of better batteries for portable electronics, soon added $4 million. But it quickly became clear that a commercial self-assembling battery was years away from reality. The technology "was still pretty rudimentary," Chiang says.

In early 2002, however, Chiang made a surprising discovery that would completely change the company's direction. He had begun to work with lithium iron phosphate, which is nontoxic, safe, and inexpensive, unlike the materials used in other lithium-ion batteries. But it appeared to have some serious drawbacks. It stores less energy than lithium cobalt oxide, the electrode material in conventional lithium-ion batteries, so it seemed unsuitable for use in portable electronics, where energy storage is paramount. Also, it charges and discharges slowly, ruling out its use in high-power applications such as hybrid electric vehicles; even for fully electric cars, which use many more battery cells than hybrids, the material couldn't deliver enough power.

So Chiang started to modify it by adding trace amounts of metals. Soon the material was discharging power at relatively high rates. In mid-2002, he flew to Monterey, CA, to present his findings at a conference. While he was there, a graduate student back at MIT continued running tests. By the time Chiang was scheduled to talk, the material was performing at rates four times those he had come to announce. "At that point, we knew we had something special," he says.

Eventually, Chiang would demonstrate that the material could deliver bursts of electricity at 10 times the rate of those used in conventional lithium-ion batteries. After studying the high-performing material in detail, he determined that it owed its power both to the size of the particles he'd used (less than 100 nanometers) and to the addition of the extra metals. The combination of those factors, he says, causes a fundamental difference in the way the atoms that make up the material rearrange themselves when they receive and release a charge.

In all lithium-ion batteries, electricity is generated when lithium ions shuttle between two electrodes while electrons travel through an external circuit. In Chiang's early experiments with lithium iron phosphate, the parts of the material that contained lithium would separate from those that didn't as the lithium ions moved in and out of an electrode. That changed the crystalline structure of the material, and its performance deteriorated. But, Chiang discovered, when the particles of lithium iron phosphate are small enough--and the electrode has been modified, or "doped," through the addition of other metals--the material's crystalline structure changes far less. As a result, the lithium ions can move in and out faster, without degrading the material. Altogether, Chiang found that the modified material charged and discharged faster than ordinary lithium iron phosphate, and it lasted longer, too.

Extraordinary though the new battery material seemed to be, Chiang realized immediately that it wasn't ideal for portable electronics. There didn't seem to be a ready market for light, compact batteries that delivered large bursts of power. Hybrid vehicles, a natural fit, were only beginning to appear on the market. What Chiang didn't know was that a major power-tool company was working quietly on a new generation of cordless tools, and it was having trouble finding a battery that would meet its needs.

Powerful Start

In 2003, representatives of Black and Decker met with Fulop and A123's CEO, Dave Vieau, and told them that they wanted to make cordless power tools that would perform better than tools plugged in to the wall. A123's material seemed like a perfect fit. In short bursts, it can deliver more power than a household circuit. And it had other features that would be attractive on a construction site. It could be recharged quickly (to 80 percent of capacity in 12 minutes or less), and unlike batteries made with lithium cobalt oxide, it could survive harsh treatment without catching fire.

That, at least, was the theory. When Fulop and Vieau first met with Black and Decker, they had only a model of a battery cell, half a gram of material, and a PowerPoint presentation. What Black and Decker needed was a company that could produce millions of batteries. "There was a lot of emphasis on the material, but what we had to learn how to do is to engineer the complete cell," Chiang says.

Within a year of signing its initial agreement with Black and Decker, however, A123 had produced a commercially feasible battery. By November 2005, its first products were coming off assembly lines in Asia. In less than three years, the company went from building a demonstration battery the size of a coin to building 50-meter-long coating machines and 28,000-square-meter factories run by hundreds of employees. By 2006, customers were buying its batteries in a new line of professional tools sold by Black and Decker. In short order, A123 was manufacturing batteries at the rate of millions a year.

Charging Up Cars

Meanwhile, GM was rethinking its technology strategy as Toyota began to dominate the hybrid-vehicle business. A hybrid uses a battery only part of the time, relying on a gasoline engine for much of its power. GM decided to develop a car that would allow its customers to stop using gasoline entirely for most daily driving. But to pull it off, the automaker needed a high-performance, reliable battery. And for that it turned to A123.

GM knew that it wanted to use lithium-ion batteries because of their storage capacity, says Denise Gray, GM's director of energy storage systems. But it also knew that existing technology wouldn't do the trick. Though a lithium-ion laptop battery might survive 500 complete charge-and-discharge cycles before its capacity fades, no car owner wants to buy a new battery every 18 months. According to A123's projections, however, its batteries should be able to deliver more than 15 years' worth of daily charges. And in addition to being safer than other lithium-ion batteries, A123's operate at a lower temperature, which makes it simpler to pack hundreds of them together into a large battery pack, Gray says.

Where A123's power-tool batteries are cylindrical, the battery it developed for the Volt is flat, to save space and more efficiently dissipate heat. The cells have been assembled into complete battery packs, which are T-shaped and nearly two meters long. This spring, the batteries will be bolted into vehicle prototypes for road testing. And later this year, A123 plans to increase production of the batteries to meet anticipated demand. The first cars powered by A123 technology could be rolling off assembly lines in 2010. (GM is also testing batteries from another company, and may use batteries from either or both companies.)

If the Volt is popular, electric cars could finally start to take off--and that could reduce greenhouse-gas emissions and petroleum consumption. A recent study by the Electric Power Research Institute and the Natural Resources Defense Council suggests that electric vehicles similar to GM's car could eliminate billions of tons of greenhouse-gas emissions between 2010 and 2050. A study by General Electric indicates that if half the vehicles on the road in 2030 are electric-powered, petroleum consumption in the United States will shrink by six million barrels a day.

And batteries like A123's could have repercussions far beyond the Volt. Even cars with internal-combustion engines are being engineered to rely more on electricity: the simplest examples involve batteries recharged by souped-up alternators that would allow a car to shut off its engine when it approaches a stoplight and restart when the driver hits the accelerator. In conventional hybrids, versions of A123's batteries can deliver as much power as nickel-metal hydride batteries at one-fifth the weight. The new batteries could also benefit plug-in hybrids, which can be recharged from a standard electrical outlet. Indeed, A123's batteries may be used in a plug-in version of the Saturn Vue hybrid SUV that's due out in 2010.

Whatever their design, future cars will be likely to rely much more on electricity. "We're not there yet," Chiang says. "There aren't Volts all over the place. But the potential to have a big impact, both on the oil supply issue and greenhouse gases--I didn't imagine that we'd be able to do that. Certainly not when I started working on batteries."

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