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Need for Battery Power Runs Into Basic Hurdles of Science

By DAMON DARLIN and BARNABY J. FEDER

It always seems to happen: Long before it is time to stow your tray table, your laptop battery gives out, and you spend the rest of your cross-country trip reading the SkyMall catalog.

In the information age, people want their electronics everywhere they go, and they want them to be on all the time. But they rely on batteries that have not improved as rapidly as the devices they power. Moore's Law, which offers a yardstick for the exponential advances in computer chips, has no counterpart in the world of batteries.

Researchers are certainly trying to improve the situation, in part because there is money to be made. Portable rechargeable batteries are expected to be a $6.2 billion market this year, and more than one billion batteries will be made by some of the largest electronics companies in the world: Sony, Sanyo, Matsushita and Samsung.

But scientists are running into some basic hurdles of chemistry and physics. The more energy they store in a small package, the more volatile and dangerous that package becomes.

The volatility of batteries in laptops, and those powering millions of portable consumer devices from cellphones to power drills, was made apparent Monday with Dell's recall of 4.1 million laptop batteries. Dell said the batteries, made by Sony, could catch fire because of a problem in the manufacturing process.

Though the chance of a flaming notebook is small, the number of incidents involving burning batteries is rising each year because there are so many more devices using small and powerful power sources.

There is another pressing reason for the quest for improvements: battery-powered cars. An electric car needs a power source that is 2,000 times as powerful as a laptop battery. "That size would be extremely dangerous," said Sanjeev Mukerjee, a chemistry and chemical biology professor at Northeastern University. "This technology has a downside, and that is that it is very sensitive to how it is manufactured."

The potential for fire in a lithium-ion battery is a result of its chemical composition. Contained in that small package are all the elements needed for a fierce blaze: carbon, oxygen and a flammable fluid. The battery is made of a thin layer of lithium cobalt oxide, which serves as the cathode, and a strip of graphite, the anode. These are separated by a porous insulator and surrounded by fluid, a lithium salt electrolyte that happens to be highly flammable.

When the battery is charged, lithium ions on the cathode migrate to the anode. As the battery is used, the ions migrate back to provide the energy. In the charged state, the cathode without most of its ions is highly unstable. If a spark occurs, the temperature of the cathode can exceed 275 degrees.

That is hot enough to cause the cathode to decompose and release oxygen. A fire starts, and as heat builds the battery begins what scientists call a "thermal runaway." In the case of the Sony-made batteries recalled by Dell, a microscopic metal particle that contaminated the electrolyte during manufacturing caused the spark.

Scientists are looking for new battery chemistry that does not involve carbon, oxygen and fuel. One route is to make an electrolyte that is not flammable, said Jai Prakash, associate professor of chemical engineering at the Illinois Institute of Technology. But much of the work is concentrated on replacing the cobalt-based cathode with magnesium. Others want to get the carbon out of the system. Sony, for instance, has a new generation of batteries that use tin.

Valence Technology, a maker of alternatives to lithium-ion batteries in Austin, Tex., uses a phosphate-based cathode. "Consumers do a lot of bad things to battery packs," said James R. Akridge, Valence's chief executive. "These provide an extra measure of safety if they shake it or smack it."

Valence products are used in Segway scooters and hospital diagnostic equipment. But the company has no intentions of competing against the large lithium-ion battery makers in the market for consumer devices. Mr. Akridge said the big companies dominate because they compete on price, and "price is determined by scale."

As consumers demand more from notebooks and cellphones, the electronics industry may need a whole new way of thinking about power supplies. The most likely candidates are miniaturized versions of the fuel cells that are being developed for cars. Fuel cells use hydrogen, but because hydrogen is hard to store and handle, many microcells get hydrogen from fuels like methanol.

Microcells intrigue companies that make laptops, cellphones and other portable devices because they can store far more energy than comparably sized batteries. Methanol-based microcells, for instance, have roughly 10 times the energy density, creating the prospect of wireless laptops that could run all day without recharging, according to Rick Cooper, vice president for business development of PolyFuel Inc. The company, based in Mountain View, Calif., supplies components to several Asian manufacturers that have been working on such devices.

"The energy capacity of batteries is increasing 5 percent to 8 percent annually, but demand is increasing exponentially," Mr. Cooper said.

The tweaking of materials and chemicals in the lithium-ion battery will extend its usefulness for at least another decade or more, said Gao Liu, a scientist at Lawrence Berkeley National Laboratory. He expects innovation to come slowly.

"We don't see any new energy storage devices," Mr. Liu said. The best bet for the future is probably fuel cells, he said, but it may be more than a decade before they start appearing in mass-market portable devices.

Microcells have been just over the industry's horizon since Toshiba demonstrated a prototype at a trade show in 2003. Pulling together all of the components has proved more challenging than fuel cell advocates predicted.

Manufacturers of fuel cells have been looking to the military and niche markets like users of professional video cameras as their first customers.

Nanotechnology, the fast-developing field that involves manipulating materials at scales measured in billionths of a meter, is likely to play a significant role in the future of consumer batteries. One essential for further development of current battery designs is the ability to cram more energy into today's packaging. Nanoscale processes could be used to make the surfaces of electrodes more porous, creating a larger surface area for chemical reactions.

Nanotechnology could also help improve the performance of competing technology like fuel cells. "Designer" molecules and films that could act as improved catalysts in fuel cells are a hot research area.

But to some nanotechnology companies, consumer batteries are too competitive to be a high priority. Altair Nanotechnologies, based in Reno, Nev., claims that its technology has safety advantages over lithium-ion batteries, but Altair executives say the difference would not be enough to win over makers of laptops and cellphones. Nor could Altair compete on cost.

"If you go into laptops, you are competing with well-entrenched companies that make millions of batteries and have been doing it for years," said Alan J. Gotcher, Altair's chief executive.