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DICK PARSONS FIGHTS BACK

New Wheels From Toyota
$1.2 Billion Hedge Fund Horror

Forbes

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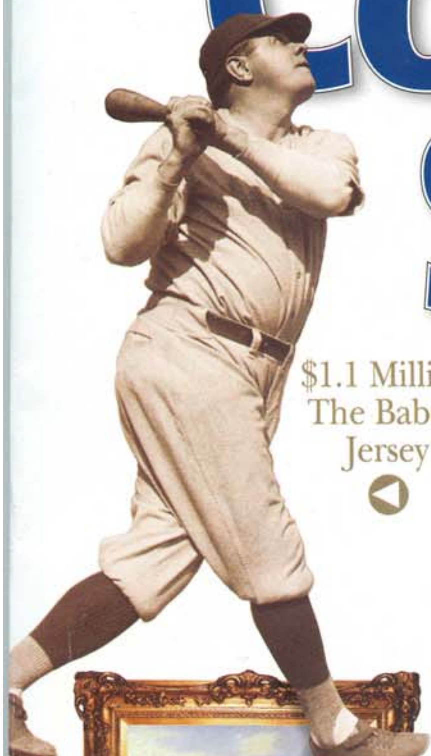
2006 ANNUAL GUIDE



$1.1 Million
The Babe's
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$27.7 Million
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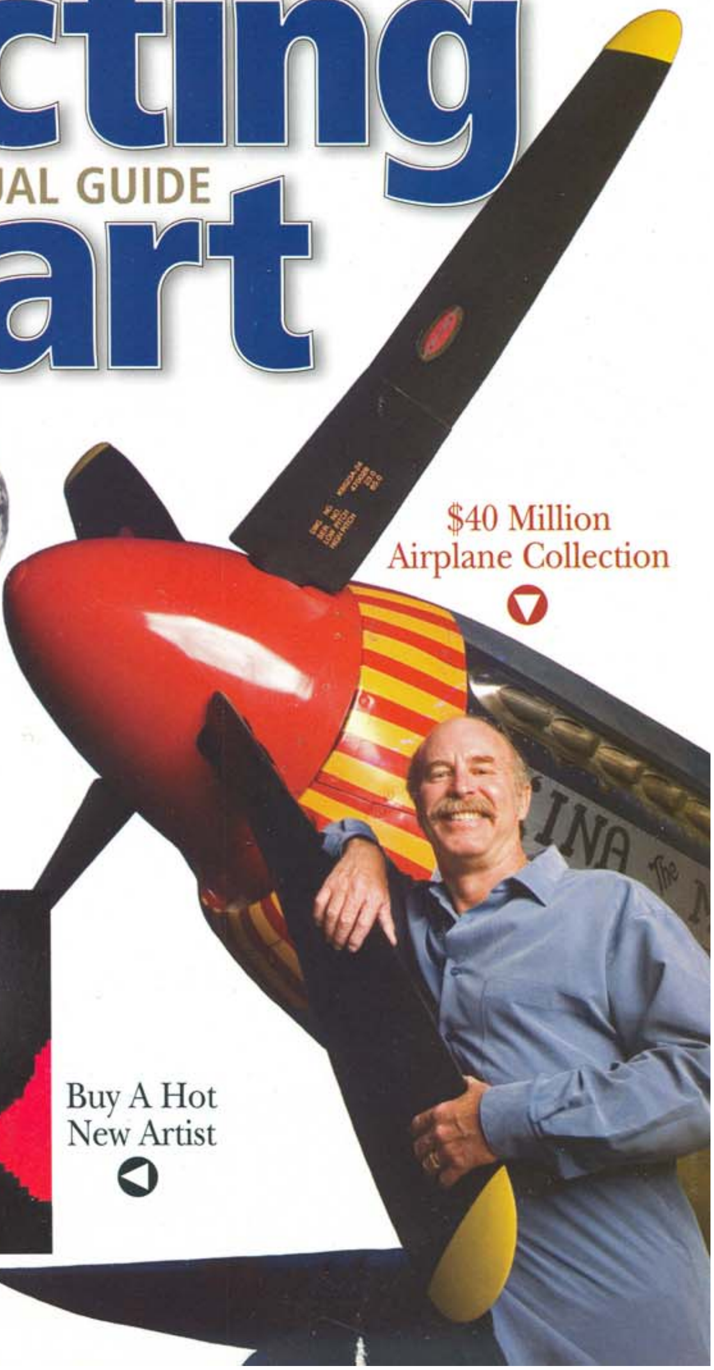
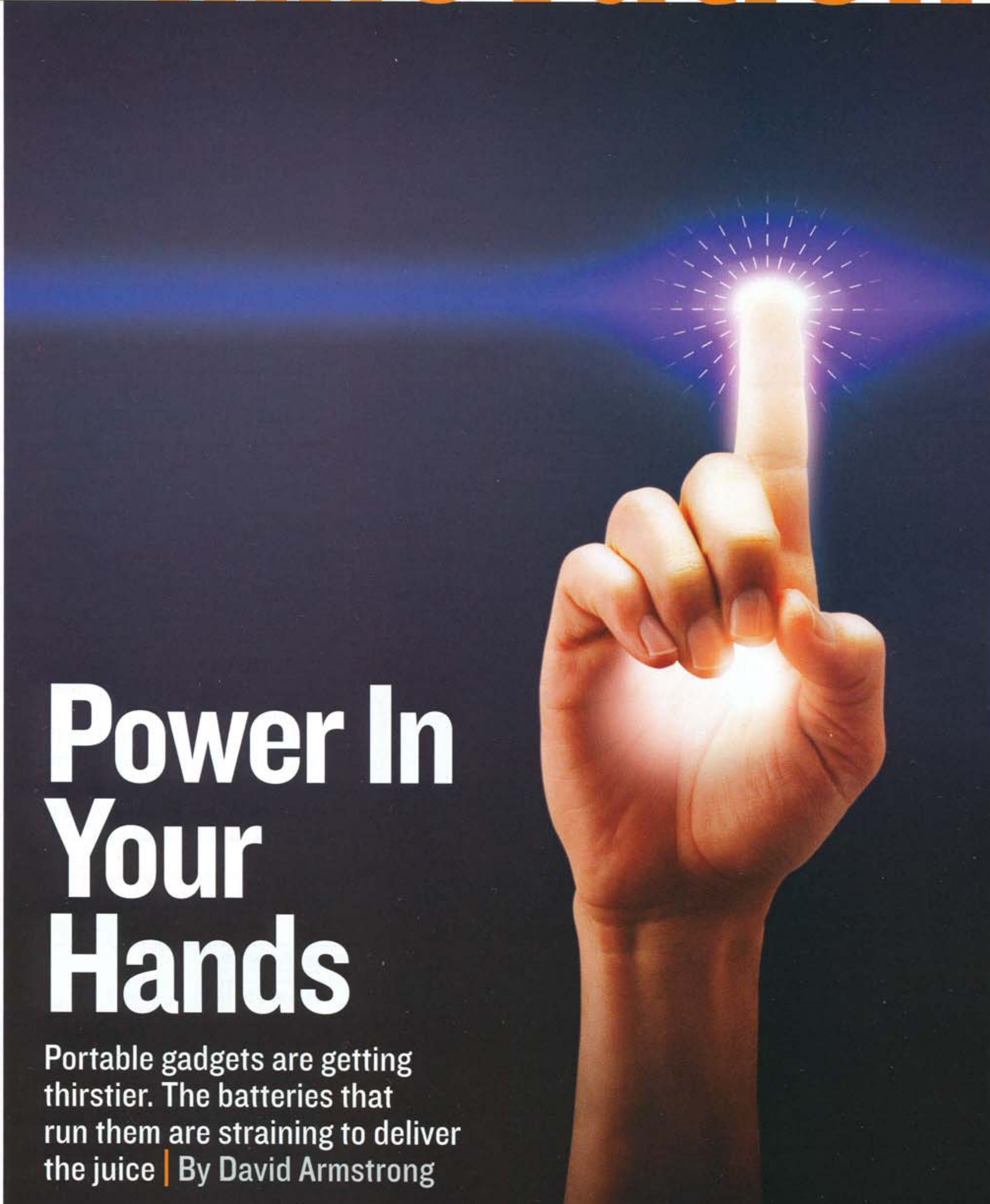
New Artist



$40 Million
Airplane Collection

$4.99/ CANADA $6.99

Innovation



Power In Your Hands

Portable gadgets are getting thirstier. The batteries that run them are straining to deliver the juice | By David Armstrong

SLIM FILM FOR FORBES

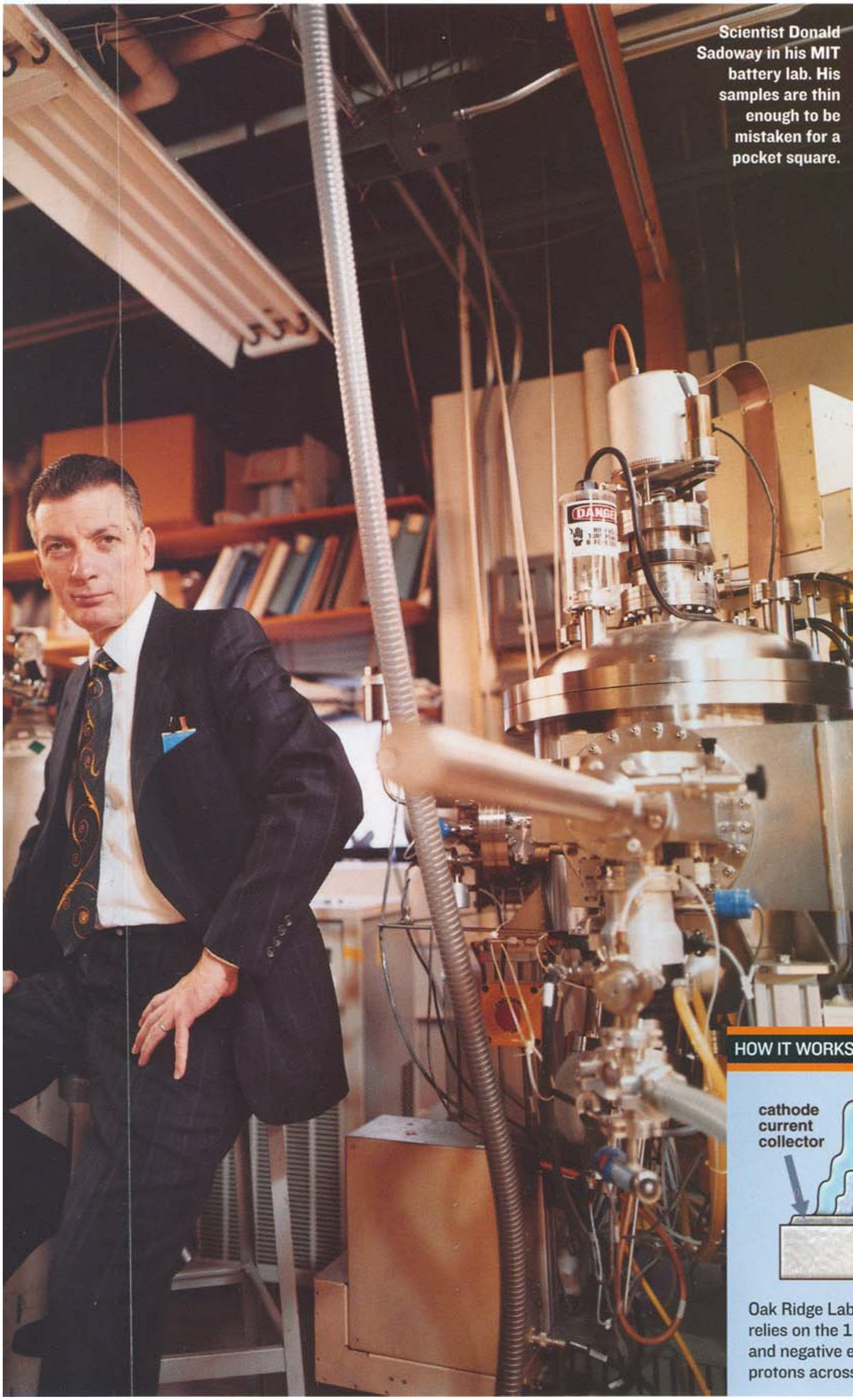
(Please turn the page for our special Innovation gatefold.)

AS PORTABLE ELECTRONICS pack more features, they're rapidly outstripping the ability of batteries to fuel them. Lithium ion batteries, now used in nearly all laptops, mobile phones and BlackBerrys, have eked out 8.5% annual improvements in the length of time between recharges—but left unchecked, the demand for portable power will climb 26% per year, according to the Boston Consulting Group.

Our wireless world, it turns out, is anything but. "We're tethered," says Donald Sadoway, a professor of materials science and reigning battery guru at the Massachusetts Institute of Technology. "We spend all our time hunched over, looking for an outlet. It's like we've printed Gutenberg Bibles, but all the Bibles are still chained to trees." Adds Intel's power source manager, Andrew Keats: "We've pushed the chemistry about as far as it can go."

Maybe not, says professor Sadoway, 55, one of a cluster of engineers who still see plenty of potential in lithium ion batteries. He and his cohorts are employing exotic materials to produce ribbon-thin rechargeable li-ion batteries that would go twice as long between charges as current models. Companies such as Altair Nanotechnologies in Reno, Nev. and A123 in Watertown, Mass. are using nanoscale engineering to develop li-ion batteries with more power and longer lives. Sadoway is in the shadow of an even bigger research effort into miniature fuel cells, the same technology automakers use for their hydrogen-powered cars. At a Tokyo trade show in October Toshiba unveiled an MP3 player that lasted 60 hours between charges, the "charge" here being 10 milliliters of methanol inside a fuel cell slightly larger than a pack of gum. Toshiba also has an experimental fuel cell laptop battery that can go 10 hours on a charge, two times the current average.

The big battery manufacturers, along with perhaps 50 smaller firms, are working on micro fuel cells, says James Balcom, chief executive of Polyfuel, a manufacturer of the membranes used inside fuel cells. He's seen the typical order jump from 80 units during the first six months of the year to 500 in the second half, he says. "That tells me they are moving from research into development." The market for portable fuel cells is



Scientist Donald Sadoway in his MIT battery lab. His samples are thin enough to be mistaken for a pocket square.

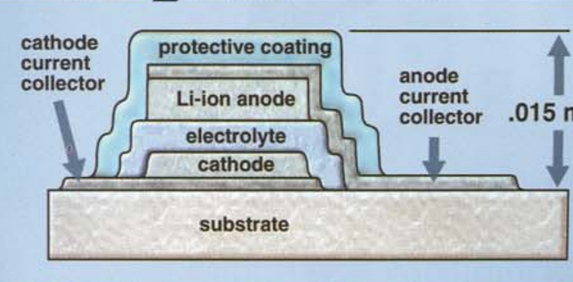
predicted by NanoMarkets to be $2.6 billion by 2012.

And in a decade (or longer) we could see the advent of nuclear batteries that would recharge your phone's own battery with a trickle of electrons from the radioactive decay of the hydrogen isotope tritium. Similar nuclear batteries now provide power for deep-space probes. But a Houston startup called BetaBatt has teamed with researchers at the Rochester Institute of Technology to begin work on a tritium battery that could, in theory, last 12 years—that is, if the user does not succumb first to radiation poisoning. BetaBatt Chief Executive Larry Gadeken says that radiation won't be a problem—a piece of paper is shielding enough. But he concedes considerable p.r. issues must be resolved.

The science behind the $48 billion (revenue) battery industry is little changed in the 200 years since Alessandro Volta first drew electricity off a stack of cardboard sheets soaked in a brine of zinc and silver. Today's lithium ion rechargeables still use a voltaic stack of a positive cathode separated from a negative anode by a liquid or gel electrolyte. The electrolyte solution is especially sensitive to conducting ions between the cathode and the anode. The drawback is that these highly corrosive electrolytes force battery makers to use rigid protective enclosures and space-hogging microchips to enable the batteries to dole out the charges and keep from exploding during recharges.

Fishing around a box of clunky metal batteries in a room near his MIT office, Donald Sadoway pulls out what looks like two pieces of blue cellophane taped together, about the size of a credit card. It is an early

HOW IT WORKS **Thin-Film Solid Polymer**

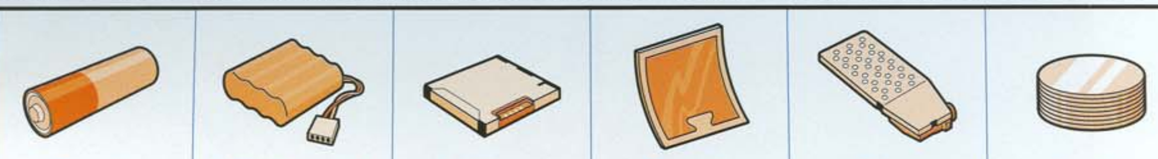


Oak Ridge Laboratory's battery is thinner than a hair but still relies on the 19th-century ideas of Alessandro Volta. Positive and negative electrodes (light gray) create a charge by passing protons across a conductive electrolyte (purple).

PHOTOGRAPH BY ASIA KEPKA FOR FO... TECHNICAL DIAGRAMS BY JOHN KOCON FOR FORBES

Choose Your Juice

The newest ideas in portable power promise less weight and longer life for your mobile and laptop.



Battery	Reusable alkaline	Nickel-metal hydride	Lithium ion	Thin-film solid polymer	Micro fuel cell	Nuclear
Energy (wh/kg)[1]	80	60–120	110–160	300	1,500	1,790–4,550
Cost	$5	$60	$100	Not available	Not available	Not available
Comments	Suitable for lower-power uses like flashlights and radios. Too heavy for most gadgets.	Heavy. Being replaced by lithium ion in portable devices.	Lightweight. Today's top choice for laptops and mobile phones.	Lighter and more flexible than liquid or gel lithium ion. Will see first uses in RFID tags and pacemakers.	Still in prototype. High power density, but fuel is flammable.	Still in prototype. Its high density masks fact that power trickles out slowly over years as isotope decays.

[1]Energy density for watt hour per kilogram. *Sources: Isidor Buchmann, Batteries in a Portable World; Betabatt; Polyfuel.*

prototype of his SlimCell battery and powerful enough to energize a transistor radio.

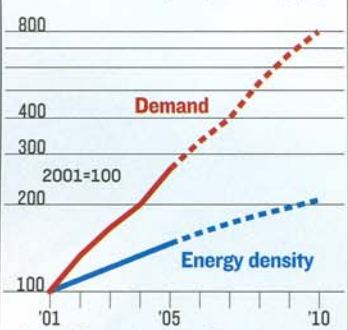
The SlimCell does away with Volta's 200-year-old liquid chemistry by using flexible and extremely thin solid laminates that can be manufactured cheaply, rolled up into a tube or molded right into a handheld device. "We have to change the image of a battery. Stop thinking soda cans. Start thinking potato-chip bags," says Sadoway.

Solid-state, paper-thin batteries have been an unrealized goal of industry for a decade. Chemists at firms such as 3M struggled to find a solid that conducts ions with the ease of a liquid or gel. In the mid-1990s Sadoway, a Canadian metallurgist who has spent his entire career teaching at MIT, was searching with his students for ways to reduce air pollution in Los Angeles. One idea was electric cars, but a lithium ion battery of the size needed doesn't make any sense, as it would require its own cooling system and wouldn't work well in extreme climates. Solid electrolytes, as elusive as they seemed, would be far lighter, safer and more versatile.

He pitched the problem to MIT materials scientist Anne Mayes, who suggested a recipe: two polymers, polyoxyethylene and polylauryl methacrylate, woven together like strands of cooked spaghetti and brushed with a highly conductive goop called polyethylene oxide. The result is a dry electrolyte that is about the thickness of cellophane but could ultimately be made as thin as one micron, a thousandth of a millimeter. Prototypes of Sadoway's SlimCell can deliver 300 watt-hours per kilogram, twice the energy density of traditional lithium ion batteries.

Demanding

If left unchecked, the power demands of portable gadgets will dramatically outpace supply.



Source: Boston Consulting Group.

Researchers at the Oak Ridge National Laboratory in Tennessee have created their own version of thin, solid-state lithium ion batteries that use phosphate glass as an electrolyte. The batteries are created by depositing the anode, electrolyte and cathode directly onto silicon, similar to the way semiconductors are made. Cymbet Corp. of Elk River, Minn., which raised $16.5 million last year from a group of funders including Intel, is looking at using Oak Ridge's technology to create microbatteries that can be grafted directly onto microchips. And unlike traditional li-ion batteries, which typically break down after 500 recharging cycles, Cymbet's thin-film batteries could, in theory, be recharged thousands of times.

Cymbet Chief Executive William Priesmeyer says that, with some improvements, these thin-film batteries could be scaled up to provide power separately to parts of portable electronics. Screens, which typically account for a third of the drain on the battery, would have their own power source.

Micro fuel cells hold out the promise of longer run times than li-ion batteries, but they still have serious technical hurdles to overcome. Most micro fuel cells generate power by the reaction of diluted liquid methanol with a catalyst. When the two react, the methanol releases protons and electrons. The protons on the fuel cell side pass through a membrane into an air chamber, where they bond with oxygen atoms, pulling the electrons along for the ride. That flow creates a charge, and the only by-products are water vapor, heat and a small amount of carbon dioxide.

But for Toshiba, Sony or Sharp to start selling fuel cell mobile phones, they need to do

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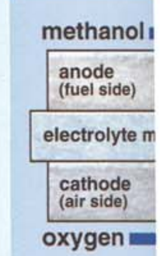
HOW IT WORK



A micro fuel ce
When the met
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electrons in ox

PHOTOGRAPH BY JAMES WHITLOW DELANO / REDUX FOR FORBES; BATTERY ILLUSTRATIONS BY COLIN HAYES FOR FORBES nobile and laptop.

Nuclear

1,790–4,550

Not available

Still in prototype. Its high density masks fact that power trickles out slowly over years as isotope decays.

theory, be recharged

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something about the fact that their customers would be carrying around a hot flask of highly combustible methanol. Most micro fuel cells in development convert only 30% or so of the latent energy in the fuel into usable electrons; the rest get dissipated as heat. Manufacturers plan on users refilling these cells, but left unanswered is how to get cartridges to consumers. In June 2004 Nokia demonstrated a headset powered by methanol, but eight months later it announced it was temporarily abandoning its micro fuel cell program.

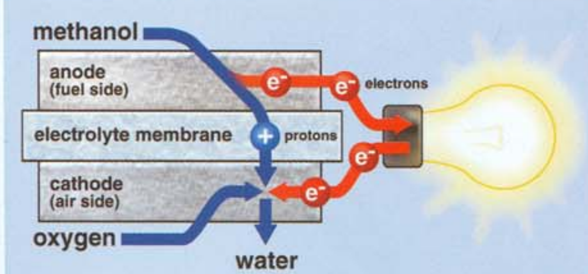
Toshiba and the others also have to get around the airline ban on methanol. After intense lobbying by manufacturers, an advisory panel of the International Civil Aviation Organization, which regulates air safety, voted in November to begin the approval process for passengers to carry and use micro fuel cells and methanol cartridges in cabins of commercial aircraft, though not stored in checked baggage.

One hurdle already overcome is the size of a fuel cartridge. Methanol works best at a 3% to 9% concentration, which would require a tank of liquid ten times bigger than a cell phone. Toshiba claims to have solved this problem by using a 99.5% methanol solution and diluting it with the water by-product from the fuel cell. Same power, smaller package. Some methanol fuel cells get, in the laboratory, 1,500 watt-hours per kilogram.

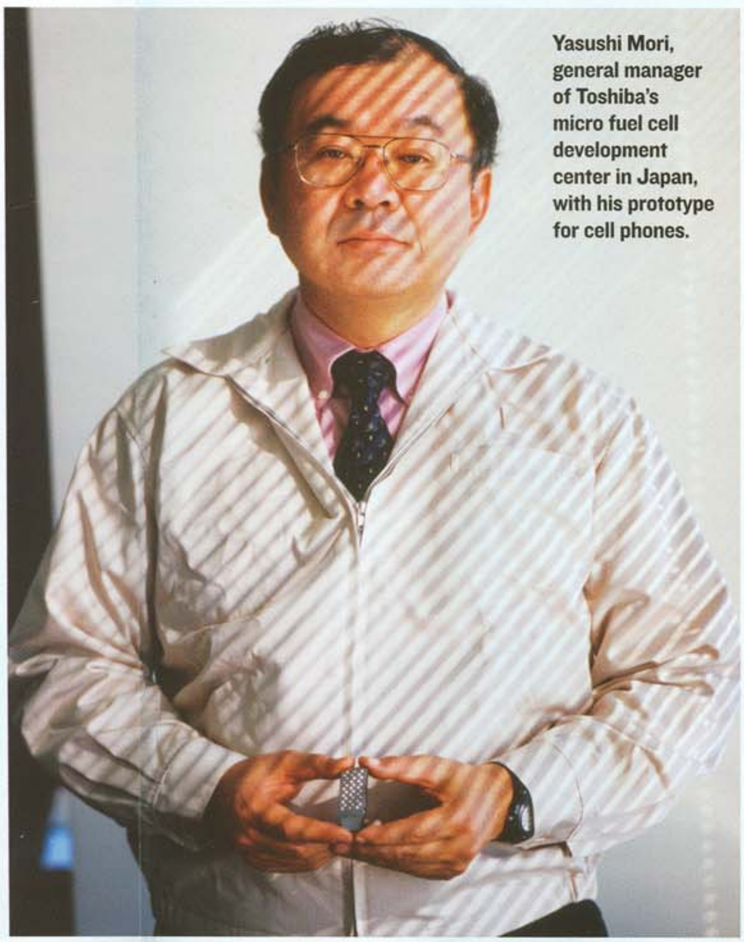
Motorola in November made an investment in Tekion, a Burnaby, B.C. fuel cell manufacturer whose fuel is formic acid, the same acid red ants drool when they bite into flesh. The advantage is that it is less flammable than methanol. "The ultimate goal would be replacement fuel cartridges," says Warren Holtsberg, director of Motorola Ventures. "You'd be off the grid."

To a li-ion believer like MIT's Sadoway, all these research dollars going to fuel cells take away money better spent on more viable, noncombustible technologies. "If you look at how we are spending money on research, it's fuel cells or bust," he says. "Have Americans given up on batteries? If we put that money into batteries, we'd have better ones." ■

HOW IT WORKS **Fuel-Cell Battery**



A micro fuel cell combines chambers of methanol and air. When the methanol hits a catalyst, it loses its electrons, the protons pass through a membrane and reunite with the electrons in oxygen. By-products: a charge, water and CO_2.



Yasushi Mori, general manager of Toshiba's micro fuel cell development center in Japan, with his prototype for cell phones.