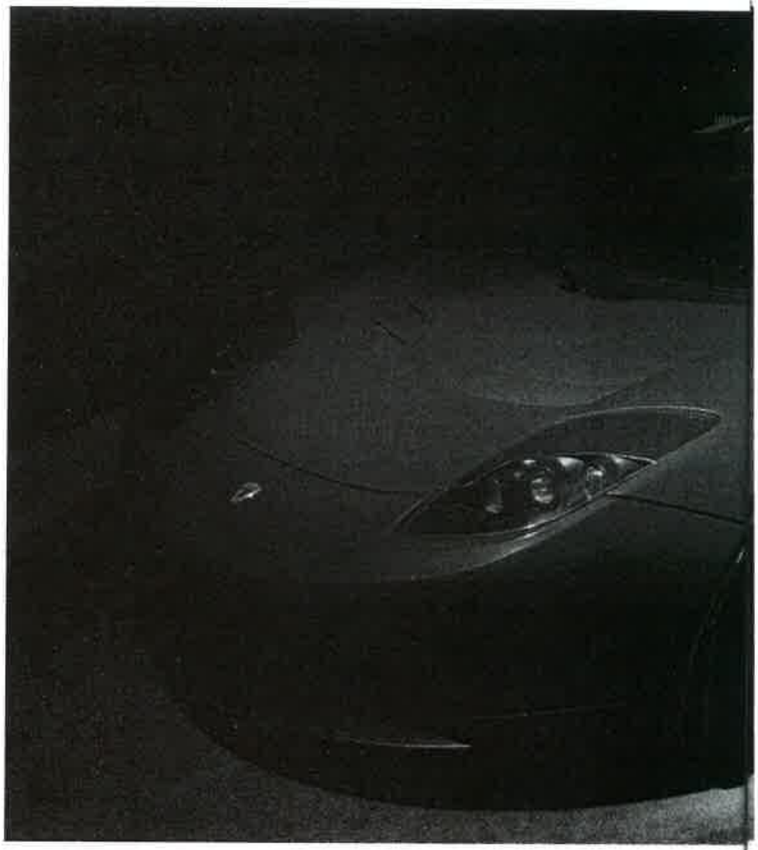
# Souped-up battery prepares to slay the gas guzzlers



Having overcome a small problem with spontaneous combustion, lithium ion cells are showing their power

**MARK ANDERSON**

THE dream of climate-friendly, petroleum-free motoring is creeping closer – thanks to a clutch of breakthroughs in nanotechnology. Several recently reported lab findings promise to vastly improve the safety and performance of the high-capacity batteries that electric cars will need, at last making them a viable alternative to today's petroleum-powered vehicles.

Until now the odds have been stacked against the electric car. A typical petrol-driven car can run for some 500 kilometres on a tank of fuel and can be expected to travel 150,000 kilometres (about 10 years' typical driving) without a major overhaul. Today's electric cars don't come close on either count.

Even legislation to clamp down on gas guzzlers is not helping much, as the car industry is responding by making petrol and diesel engines more fuel-efficient. Competitions like the Automotive X-prize – which is offering $10 million to the company that can develop a car able to travel 100 miles on a US gallon of fuel (equivalent to 42.5 kilometres per litre) – are having the same effect (*New Scientist*, 2 February, p 35). All in all, the internal combustion engine shows no sign of conceding defeat any time soon.

But in the long term, the likely option is that cars' fuel tanks will be replaced by scaled-up versions of the lithium ion batteries used in today's laptops and cellphones. That's because these batteries pack far more energy into a small package than any alternative.

Lithium ion batteries have been with us for some time now – long enough to reveal their major drawbacks. They have a relatively short lifespan and, in extreme circumstances, can catch fire or even explode. These are hardly the attributes needed to knock the internal combustion engine off its perch: battery engineers still have a job on their hands to make lithium power an everyday reality.

For now, most electric vehicles get their power from two other types of battery: lead-acid and nickel metal hydride (NiMH). Lead-acid cells are heavy and bulky for the amount of energy they can hold, which means they are only useful when the vehicle can make do with a limited range: golf carts and the UK's milk floats are classic examples. The tiny G-Wiz runabout made by the Reva Electric Car Company of Bangalore, India, also uses lead-acid cells.

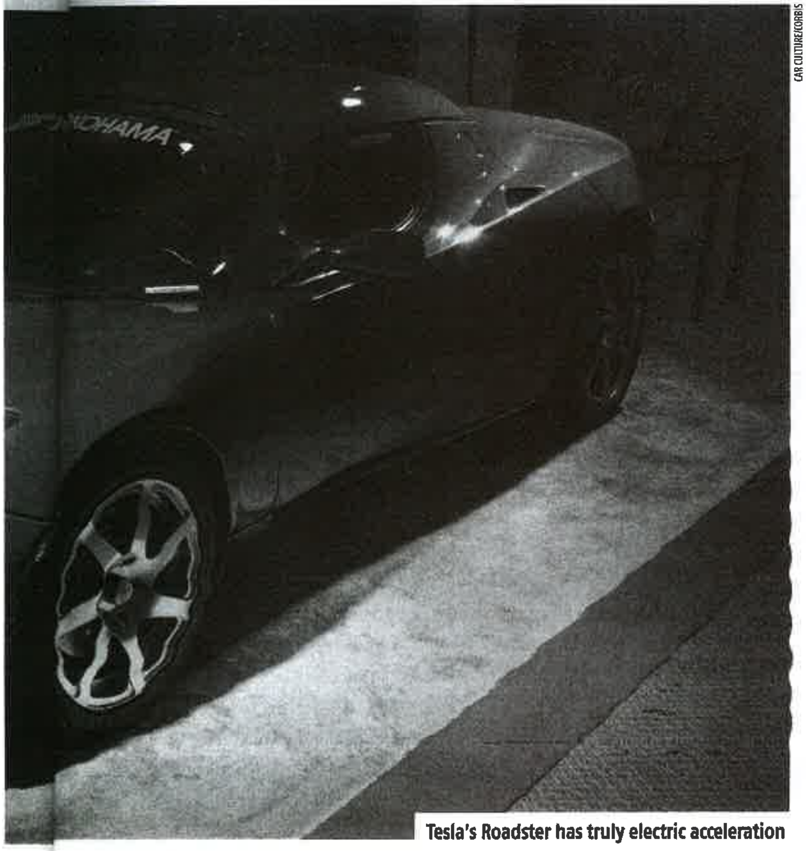
**"Google will soon be using kits to convert its entire hybrid fleet to lithium power"**

Today's best-selling hybrid petrol-electric cars – notably the Toyota Prius and the Honda Civic Hybrid – use NiMH batteries. "Nickel cells have less initial safety issues than lithium batteries," says Spencer Quong, senior vehicles engineer at the Union of Concerned Scientists in Berkeley, California. "The costs are known, and they've got the production plants up and running."

Yet where power is all-important, the advantages of lithium ion batteries can already win out. The new Roadster made by Tesla Motors of San Carlos, California, is an all-electric sports car with a chassis based on the Lotus Elise. It boasts a 185-kilowatt engine powered by nearly 7000 finger-sized lithium ion batteries packed into its trunk. This takes it from 0 to 100 kilometres per hour in around 5 seconds, and gives a top speed of 200 kilometres per hour. The range is a much more modest 350 kilometres – and then only if conservatively driven. Tesla hopes to sell 600 of the two-seaters by the end of this year.

Unfortunately, the performance figures are not the only spectacular numbers associated with the Roadster. It costs a cool $100,000, and the battery pack is expected to need replacing after three to five years at a cost of $20,000.

Lithium ion batteries have such a short life partly because the cathode, which is usually made from layers of lithium cobalt dioxide, wears out quickly. When the battery is being charged, positively charged lithium ions migrate from the cathode across a separator screen into the porous graphite anode, which becomes replete



Tesla's Roadster has truly electric acceleration

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with lithium atoms.
The battery delivers power when the lithium atoms feed electrons via the graphite electrode into the external circuit. The resulting lithium ions then leave the anode and migrate back into the cathode, where they are absorbed.

This repeated gain and loss of lithium ions causes a continual expansion and contraction that eventually degrades the cathode's layers. It also leads to a build-up of impurities that further reduce the cathode's ability to retain lithium ions. As a result, the cathode degrades after only a year or two of regular use. If stressed, it can also overheat, releasing volatile chemicals and leading to short circuits that can cause a spectacular electrical fire.

Now A123, a company in Watertown, Massachusetts, has found a way to make the cathode more durable, using a material called lithium iron phosphate in place of the delicate lithium cobalt dioxide. A123's lithium iron phosphate cathode has a birdcage-like nanostructure that allows lithium ions to enter and exit without causing damaging expansion and contraction. "Mother Nature was kind," says Bart Riley, A123's chief technical officer. "The crystal structure of the cathode is very similar in the charged and discharged state."

This means it can survive about 10 times as many charges and discharges, says Ric Fulop of A123.

A123's batteries pack twice the power of NiMH cells of the same size. While that's not as much as a standard lithium ion battery, the risk of conflagration is far lower. "They're very powerful little batteries," says David Swan, a consultant in rechargeable battery technology at DHS Engineering in Lawrencetown, Nova Scotia, Canada. "They seem to work very well."

A123's innovation has been taken up by Hymotion of Toronto, Canada, which has developed a kit for the Prius that allows it to have an additional high-capacity lithium ion battery that drivers charge from the mains electricity supply. The lithium kit will significantly improve the car's fuel efficiency compared with using NiMH cells alone because it will not always be using batteries charged by the engine. However, some of that improved fuel efficiency will be offset by emissions at the power station where the electricity is generated.

Search giant Google says it will be fitting the Hymotion kits to its entire hybrid car fleet. A123 is also developing batteries for possible use in General Motors' planned Chevrolet Volt hybrid car, which it expects to launch in 2010.

It could get even better, with improvements to the anode as well as the cathode. A group led by Yiying Wu at Ohio State University in Columbus has developed a novel anode made from nanoscopic wires of cobalt oxide. Because the nanowires have a much larger surface area than a flat substrate, lithium ions can flow in and out more easily, Wu says. This could increase both a battery's capacity and its peak power. "It should be interesting for practical applications for hybrid vehicles," Wu says. "The key thing for hybrids is high performance and high current," and according to Wu his nanowire array can achieve both.

Yi Cui of Stanford University in California has taken a similar approach but with a different material. By using nanoscale silicon wires instead of graphite he has made an anode that holds 10 times as many lithium ions as an equivalent graphite one (*Nature Nanotechnology*, vol 3, p 31). Though the diffusion of lithium ions into and out of the silicon's crystalline structure causes it to expand and contract with each cycle, this is only a problem with a flat silicon anode. Silicon nanowires, grown like grass on the anode's surface, thicken as they absorb lithium ions, and slim down when they leave, but because the wires are so small the stress is not great enough to do any damage.

Swan notes that a cathode with roughly the same capacity is still needed to supply the lithium ions, but Cui's group are on the case. "We are using a similar nanowire idea for the cathode," says team member Candace Chan.

"Every improvement counts," says Fulop. "The anode also affects the system's power and lifespan. Everybody is trying to improve both components."

Ideas are one thing, practice another. Quong recalls a Prius driver in Alaska complaining that he only gets half the fuel economy in the winter that he does in the summer. "The major question is durability," he observes. "Can they make a battery that will last as long as today's petrol-driven vehicles and which works well from the desert to Alaska? That's their challenge." ●

MORE LITHIUM, MORE POWER

**Replacing solid electrodes with an array of nanowires boosts storage capacity 10-fold**

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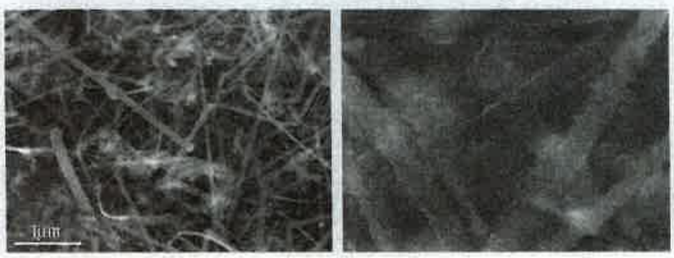
Anodes made from silicon nanowires provide a vast surface area for storing lithium atoms compared with today's technology

● **AFTER CHARGING**
The nanowires expand as they absorb lithium atoms. Unlike a flat anode they can withstand repeated cycles of expansion and contraction



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