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Lithium-ion technology is now the limiting factor

Batteries

A breakthrough in research is needed, says **Robin Harding**

A dream of inventors in the 19th century was the steam-powered aircraft, but none succeeded because steam engines were simply too heavy.

Now a modern-day dream – the electric car – faces a similar threat. Their range is limited by lithium-ion batteries that cannot store enough energy relative to their weight, and that has sent both companies and scientists on a technological quest.

Leading electronics companies with decades of battery expertise, chemical companies strong in battery materials, and carmakers that have long focused on fuel efficiency make Japan a leader in this race.

Most of the companies are working to improve existing lithium-ion batteries and get electric vehicles on the road. At the same time, however, some scientists and corporations are in pursuit of what is sometimes called the "ultimate battery" – which would use a combination of lithium and air.

NEC has formed a joint venture with Nissan to supply the lithium-ion batteries for its Leaf electric vehicle. "By modifying the materials, I think we can improve the energy density of our batteries by 20 or 30 per cent," says Takemitsu Kunio, who leads the company's research and development.

To increase the capacity of a battery by a factor of two or more, Mr Kunio says, new materials may be needed. The trouble is that it may take at least a doubling of capacity to produce an electric car that can compete head-to-head with petrol.

A kilogram of petrol contains about 13,000 watt-hours of chemical energy – of which about 4,500 watt-hours might be captured by an internal combustion engine. But a kilogram of today's lithium-ion battery stores only 100 watt-hours of electricity. Cost apart, for the same amount of energy, today's lithium-ion batteries are 45 times heavier (and 16 times bigger) than petrol.

The result is doubt about whether consumers will buy them. Mitsuru Homma, who as head of Sanyo Electric's world-leading lithium-ion battery business has everything to gain from their success, said recently that for full electric vehicles "we need a breakthrough".

That breakthrough will not come by waiting for lithium-ion batteries to improve, and for two reasons. First, batteries follow the rules of chemistry rather than the rules that have allowed computer processing power to double every two years. It has taken almost 15 years for the capacity of Sanyo's consumer lithium-ion batteries to double.

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Second, even if lithium-ion makes rapid progress, the theoretical upper limit on the chemistry is between 400-500 watt-hours per kg – still only a 10th of petrol – and the practical limit is likely to be much lower.

What is needed is an all-new battery chemistry – and the most exciting possibility is lithium-air, which in theory could match the storage capacity of gasoline.

"A lithium-air battery could achieve an energy density 10 times that of lithium-ion, which would let a car travel hundreds of miles between charges," said Dr Haoshen Zhou, a researcher in the field at Japan's National Institute of Advanced Industrial Science and Technology.

Dr Zhou and other research groups have lithium-air cells working in the lab but there are fundamental problems still to resolve. The batteries made by Dr Zhou, for example, contain a thin sheet of glass that conducts lithium ions but prevents anything else getting through to react with the lithium metal.

The material, developed by Japanese glassmaker Ohara, is fine in the lab but, put such batteries in a car, and the glass would break. Battery makers could use a thicker and stronger sheet of glass but then its conductivity would be insufficient.

Ohara has been making further advances in its lithium-ion conducting glass, but to get to the levels of conductivity needed to make a durable, lithium-air car battery "we will still need a breakthrough", says Kosuke Nakajima, head of new business promotion for Ohara.

For that reason Dr Zhou says that he expects alternatives such as lithium-copper rechargeable batteries – a step up from lithium-ion although no match for lithium-air – to appear first. He estimates that lithium-copper could be commercialised in three to five years.

It takes a long time to prove a battery's safety and put it into mass production, however, and companies such as NEC, Sanyo Electric, Panasonic and Toshiba are still putting much of their effort into lithium-ion.

Whether that is an error will soon become clear.