Power to the people

Research by UK companies is looking to develop higher capacity batteries. By **Graham Pitcher**.

Battery technology is one of the slowest moving areas of the electronics world and battery capacity has only increased fivefold in the last 100years. Compare that with the rate of semiconductor development.

It's no surprise to find out that a lot of work is going on in an attempt to change this and three UK projects are amongst the leaders.

Oxford based Nexeon, a spin out from Imperial College, is looking to modify lithium ion batteries in order to boost their storage capacity. Dr Scott Brown is Nexeon's chief executive. "Our technology is based on work done at Imperial by Professor Mino Green, during which he came across a method of making silicon in 'interesting shapes'."

Dr Brown said battery companies have been interested in using silicon for many years because of its high affinity for lithium. "If you can replace a carbon anode with silicon, you could store more lithium and get a higher capacity battery. That, in turn, translates to longer operating time between charges or the same performance from a smaller battery."

Despite their efforts, leading battery companies haven't been able to exploit the properties of silicon and that's what Nexeon is hoping to do.

One problem is that a silicon anode swells when it absorbs lithium. "It can end up two or three times its original size," said Dr Brown. "When you discharge the battery, lithium travels to the other electrode and the silicon anode collapses. That damages the silicon and companies haven't been able to demonstrate many charge/ discharge cycles."

Nexeon's approach is based on the shape of its silicon anode, which it terms a 'silicon structure'. These can be, in Dr Brown's words, 'long and thin or like a hedgehog'.

Nexeon is currently producing pilot plant quantities of two materials: Nex 1 and Nex 2. "Nex 1 is lower capacity and cheaper to make," said Dr Brown. "We start with silicon particles which are 25 to 30μm in diameter, then etch them using a special chemistry. This creates 4 to 5μm high 'pillars' on the surface, much like a hedgehog, that store lithium."

With Nex 2, the etch is deeper. The etched particles are then subjected to ultrasound, which breaks the pillars away to leave silicon fibres. "These can be used as a battery material in their own right," Dr Brown continued.

Both materials are held together by a polymer binder, with some carbon included to assist with conductivity. A battery capacity of 1200mAh/g is claimed, as is the ability to support 500 charge/discharge cycles.

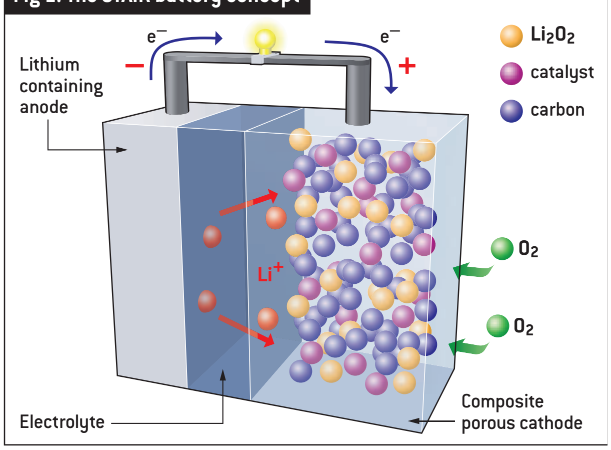
"Many people have been worried about the cost of our technology," he noted, "so we've built a pilot plant to make silicon structures and to show this is a low cost process. We've made demonstration batteries and have shown that we're more or less equal in price to carbon, so we can offer better performance and an economic case. Our problem now is to work out how to scale the process to commercial volumes."

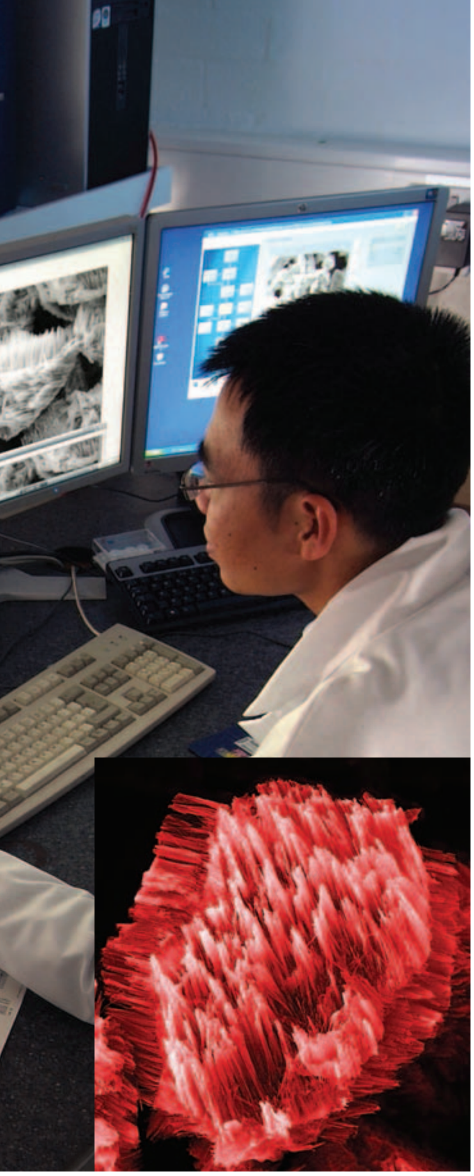
Air battery

A different approach is being take at St Andrews University with STAIR – the St Andrews Air Cell project. Leading the work is Professor Peter Bruce. He said: "In the future, lithium ion won't deliver what we need, so we've been looking for something that will go beyond that."

While air batteries aren't new –

Fig 1: The STAIR battery concept





1960s hearing aids featured zinc air batteries – STAIR is looking to use lithium. "Lithium cells store electrons in carbon," said Prof Bruce. "If you can get rid of carbon, you reduce mass."

The simplest material, he said, is 'some kind of lithium oxide'. "But you need to form this and the air is a good place to get oxygen."

The move to lithium oxide (Li_2O_2) is logical, said Prof Bruce, but he pointed out that working with Li_2O_2 was a process of learning from mistakes. "We're having to acquire knowledge, rather than make technological progress. We still need to understand more about what's going on."

Nevertheless, Prof Bruce said progress had exceeded expectations. "We've been able to show that energy storage can be increased substantially; probably by a factor of two or three."

Prof Bruce explained the process. "A lithium ion battery has a negative carbon electrode and a positive lithium cobalt oxide ($LiCoO_2$) electrode. When you charge the battery, the ions cross to the carbon electrode, where they are stored. When you discharge, the process reverses. In the lithium air battery, lithium comes from the $LiCoO_2$ electrode when you discharge. But when the ions reach the other electrode, they join with O_2 to form Li_2O_2, which is solid. When the battery is charging, the Li_2O_2 decomposes, lithium ions return to the $LiCoO_2$ electrode and O_2 is discharged."

Prof Bruce admitted more work needs to be done. "We don't know enough about what's going on; it's not simple. We don't know how the reactions are taking place, so we don't know exactly how to address the problems. That's what we're working on.

"Theoretically, the STAIR battery should have a specific energy 8 to 10 times that of current Li ion cells and we've already demonstrated a five fold increase in the lab," he concluded.

Integral batteries

More radical still is work underway at Imperial College, which hopes to create batteries – or at least energy storage devices – integral to the product being powered.

Professor Anthony Kucernak noted: "Today, you have to build products around batteries. Our idea is to develop materials which can replace a structural component, but which can store power. In an ideal world, these would have the mechanical properties of the material being replaced, along with the electrical properties of a lithium ion battery."

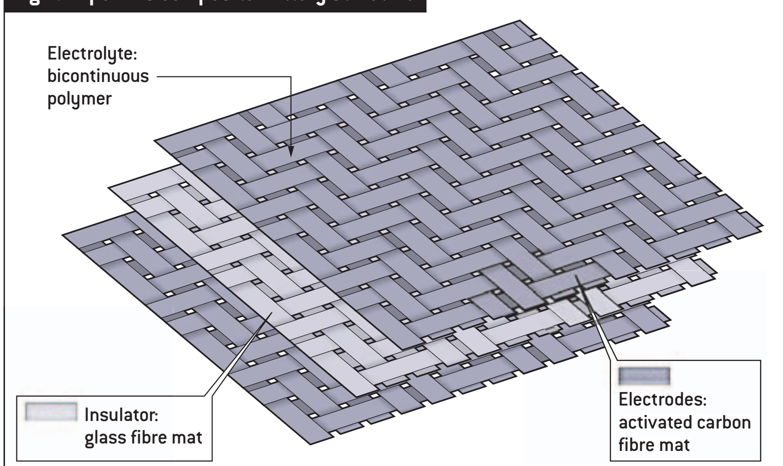
The work is based on carbon fibre. "We build the battery using an electrolyte," he noted, "but need to modify how we deposit that chemistry on the fibres so that it is integral to the structure. In theory, we can create a device which is smaller and weighs less for a given amount of energy storage. We have demonstrated the approach works for supercapacitors."

Initially, 7μm carbon fibres were used, but Prof Kucernak said these didn't work very well as capacitors. "We're now growing carbon nanofibres on their surface, effectively creating 'hairy fibres'. So far, we have achieved a specific capacitance of 14F/g with good structural performance."

A further avenue of research is hybrid structures – half supercapacitor, half battery. Prof Kucernak said: "This will provide the energy capacity of batteries and the high charge/discharge rates of supercapacitors."

For the moment, large scale applications are being targeted. "One area is cars," Prof Kucernak concluded, "another is planes; both areas where combining mechanical and electrical performance will be better than having a separate battery."

Fig 2: Imperial's composite battery structure



***Main picture:** Nexeon is looking to create silicon structures that store more lithium ions than can carbon.*
***Bottom:** Imperial College is looking to include energy storage within structural components.*
***Below:** Nexeon has already created batteries to demonstrate its technology.*
***Centre:** The STAIR cell will use lithium and air to provide higher energy densities than found in current batteries.*