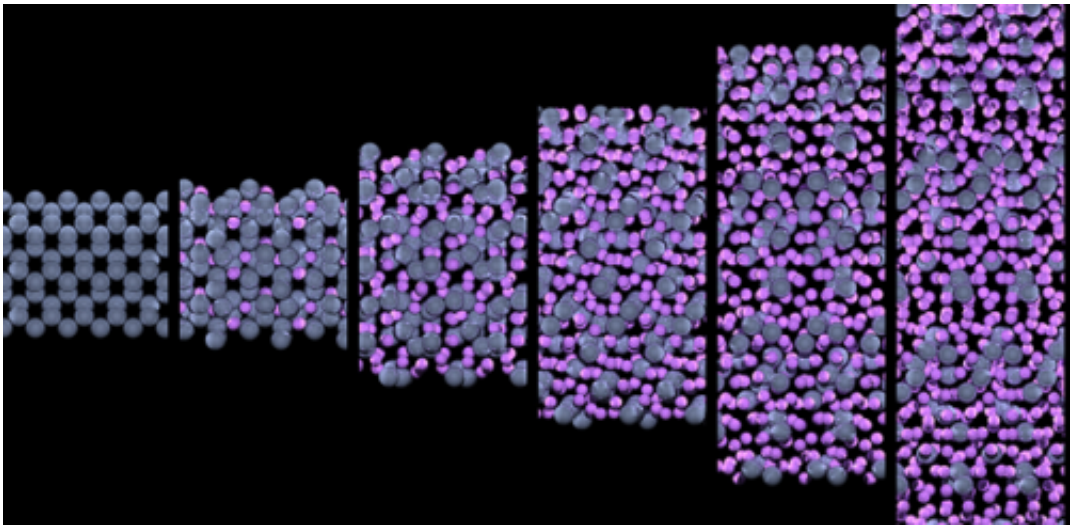
Lifting the lid on silicon batteries

February 4 2014, by Sarah Collins



(Phys.org) —Resolving the mystery of what happens inside batteries when silicon comes into contact with lithium could accelerate the commercialisation of next-generation high capacity batteries, for use in mobile phones and other applications.

Next-generation batteries based on silicon have come one step closer to commercial reality, after the mystery surrounding what is happening inside batteries when silicon comes into contact with lithium has been understood in unprecedented detail. Silicon-based technology would greatly expand the capacity of the batteries used in mobile phones, electric vehicles and other applications.

Using a combination of nanotechnology and nuclear magnetic resonance (NMR) techniques, researchers have developed a new probing system that gives a view into what is happening inside the batteries at the atomic level, enabling greater control over the properties of the materials.

Silicon has been proposed as a replacement for carbon in battery anodes (negative electrodes) for the past 20 years, as it has roughly ten times more storage capacity than carbon. However, difficulty in managing silicon's properties has prevented the technology from being applied at scale.

The primary problem with using silicon in a lithium-ion battery is that silicon atoms absorb lithium atoms, and the silicon expands up to three times in volume, degrading the battery. Although controlling this expansion has become easier over the past decade, a lack of understanding about what is happening inside the batteries and what governs the reactions have continued to hold silicon batteries back.

Researchers at the University of Cambridge have developed a new method to probe silicon batteries and determined what causes the expansion to take place. The results are reported in the 3 February edition of the journal *Nature Communications*.

"The most basic challenge for delivering such high-capacity batteries is to understand the reactions going on inside them," said lead author Dr Ken Ogata of the Department of Engineering.

Using nanoscale wires made of silicon and NMR techniques, the researchers developed a robust model system able to accommodate the expansion of the silicon over multiple cycles, and integrated it with short-range probing techniques that reveal what is happening inside the battery at the atomic level. The team found that the reactions proceed with interactions of various sizes of silicon networks and clusters, energetics

of which partly govern the path of the reaction.

Using these combined techniques, the researchers were able to develop a 'map' of how silicon transforms when it is put into contact with lithium in a battery. The insights opened up by the technology will boost further developments of silicon batteries, as it will be easier for engineers to control their properties.

"Using this technique will help make battery design much more systematic, and less trial and error," said Dr Ogata. "The nanowire-based batteries coupled with the NMR system enabled us to follow the reaction kinetics over multiple cycles with various cycling strategies. Importantly, the insights achieved by the new technology are relevant to current state-of-the-art silicon-carbon composite anodes and will lead to further development of the anodes."

This versatile nanowire-based technology can be applied to other battery system such as tin and germanium-based lithium-ion batteries and sodium-ion batteries, and studies are currently on going with the NMR spectroscopy under a wide variety of electrochemical regimes.

More information: "Revealing lithium–silicide phase transformations in nano-structured silicon-based lithium ion batteries via in situ NMR spectroscopy." K. Ogata, E. Salager, C.J. Kerr, A.E. Fraser, C. Ducati, A.J. Morris, S. Hofmann & C.P. Grey. *Nature Communications* 5, Article number: 3217 DOI: 10.1038/ncomms4217. Received 26 June 2013 Accepted 07 January 2014 Published 03 February 2014

Provided by University of Cambridge

https://phys.org/news/2014-02-lid-silicon-batteries.html