New cell power

Focusing on energy storage, it's clear that carbon and silicon play an on-going role in innovating battery technology, as Ronald Durando of mPhase Technologies explains

Through the ages, Mankind has discovered the many valuable properties of silicon, yielding innovation and technology that has shaped the way we live today. Inventions as far-reaching as glass, silicone rubbers and semiconductors are based on this most abundant element in the Earth's crust. Between silicon and its nearest family member on the periodic chart of the elements – carbon – the flexibility to invent a host of materials with a wide range of properties is limited only by our imagination. In recent times, our imagination includes engineering silicon and carbon at the nanoscale.

Anode materials

In the early 1990s, Sony developed the first practical lithium ion cells with breakthrough carbon anode technology and commercialised them for the first portable music player, the Sony Walkman. Essentially, these hard graphitic carbon anodes enabled the universal portable electronics market that is a hallmark of life today. Innovation with various grades of synthetic graphite followed, spawning longer-lasting batteries for mobile phones, laptops and today's emerging electric cars.

Silicon can store even greater amounts of lithium ion than graphitic carbon anodes. However, it fractures easily as it cannot handle repeated expansion and contraction as the lithium ion cycles in and out during battery charging and discharging.

Graphene, the newest form of carbon now known to mankind, is incredibly efficient at moving electronic charge, and may well develop into a technology to improve cell energy efficiency and result in cells that provide greater usable energy and power.

Researchers at universities and national laboratories as well as at start-up companies and major material manufacturing concerns have developed composite materials with silicon and graphitic carbon that promise to enable practical use of silicon in lithium ion anodes. Most of these involve nanostructured layers of silicon and graphite – the latter down to the ultimate in small, namely, graphene materials.

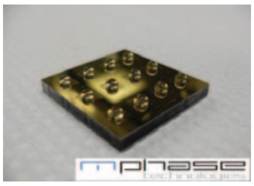

Fig. 1 Electrolyte Control

Electrolyte control materials

In addition to storing lithium ion very effectively, silicon possesses other properties of value in energy storage - it can be engineered into a nanostructure that repels liquid. mPhase Technologies, Inc. OTCBB: XDSL (http://www.otcmarkets.com/stock/XDSL/quote) has developed a 'bed of nanonails' that does just that for a battery electrolyte solution, which is ideal for storing energy with essentially unlimited shelf life. In addition, the silicon component can be energised to let the electrolyte wet and wick through it to activate a cell when needed – reliable stored power on demand.

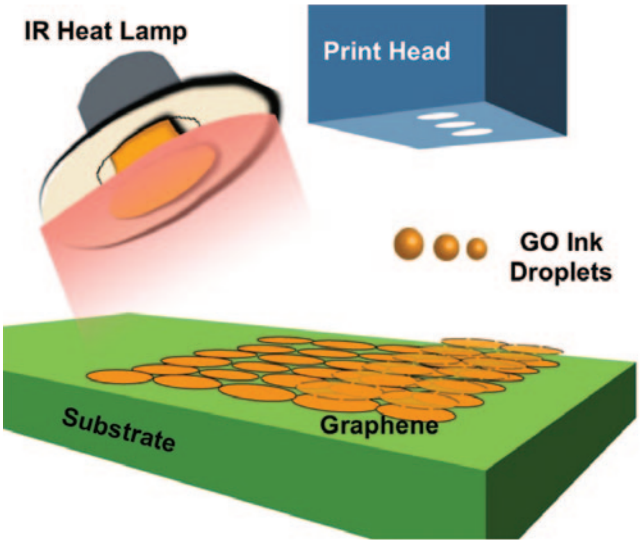

Fig. 2 The first ever inkjet-printed graphene

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Powering 21st Century devices

It is intriguing to consider the combination of silicon technology – with its high capacity anodes and controlled electronic activation – and graphene technology – for its more efficient use of cell

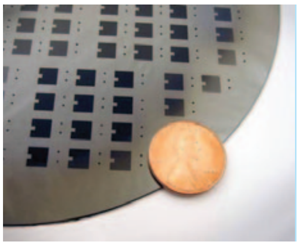

Fig. 3 Silicon Nano-Nails

power and energy cells. Imagine the synergies that could result for applications such as ultra-lightweight RFID tags, remote sensors and small devices that harvest energy from environmental sources. These devices need compact, high energy density, long-lasting and smart power sources that are simply not workable from conventional lithium ion cells – they are too large and do not have a long shelf life.

Lithium, air, silicon and graphene

One solution that is positioned to cover the needs for these devices is the lithium-air cell. Today, the development of lithium-air cells is past the concept stage. Laboratories at universities, national laboratories and private industry have demonstrated that non-rechargeable lithium-air cells are feasible and some have shown promise in extending metal-air technology to rechargeable cells.

Designing a 21st Century lithium-air battery

The encouraging first steps in developing lithium-air cells must be followed by second generation designs focused on commercially viable solutions. Lithium-air cells must overcome two barriers: very low power capability that limits use and continual degradation in the field that shortens battery life.

'mPhase will collaborate with Stevens to develop advanced batteries leveraging Stevens' patent-pending 'drop-on-demand' inkjet printing of graphene and mPhase's patented silicon-based Smart NanoBattery technology. The programme will address cathode construction/morphologies that optimise the use of graphene and silicon, with input from leading researchers at institutions like Argonne National Laboratory.'

Lithium metal anodes introduce the prized high capacity to the lithium-air cell, which is matched with an efficient carbon air electrode that must preserve high energy density. With graphene in the cathode, its optimally high specific surface area would markedly increase contact with air and provide ideal electrical conduction. To provide long shelf life, the electrolyte can be managed using Smart NanoBattery technology, controlled by a microprocessor.

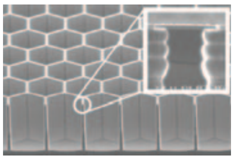

Fig. 4 Overhang Nanostructure

mPhase recognises several challenges in advancing the implementation of silicon and graphene based technology in practical batteries. These materials require precise deposition for controlled spatial distribution of individual layers and composites to maximise their valuable properties. Coupling this with the electronically controlled electrolyte solution and enveloping the system in a small package requires both product and manufacturing innovation.

Building a 21st Century lithium-air battery

Production-scale fabrication methods exist for silicon nanostructures, but must be developed for graphene if we are to produce practical battery materials that combine silicon and graphene nanostructures.

Stevens Institute of Technology has addressed the graphene fabrication issue. Their novel inkjet printing technique controls the placement and thickness of graphene layers. Inks formulated with oxidised graphene are deposited and subsequently reduced back to highly conductive graphene that could boost cell energy efficiency.

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mPhase envisions an outcome where this advanced air cathode technology extends to other metal anodes, including zinc and aluminium – presently under development by major corporations including IBM and General Electric for larger devices such as buses and backup power systems.

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