ThePowerof3
Driving the future further
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Overview

As noted in *The Power of 3* issue 23, nanotechnology has delivered (or promises to) on some of the wilder concepts in 20th century science fiction. Consider, for instance, the following.

> Buckypaper, made from millions of carbon nanotubes, is ten times lighter and can be 500 times stronger than steel.

> Energy from heartbeats can now be harnessed and built into fabrics, meaning clothes could soon be recharging portable devices.

> Nanofibres injected into mice with paralysed limbs have facilitated the regeneration of lost or damaged cells, allowing the limbs to be used again.

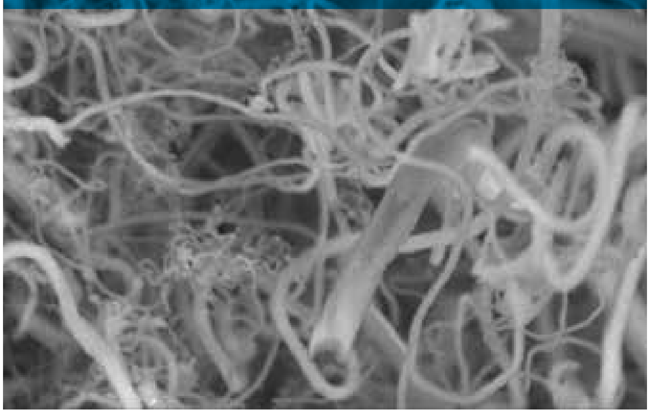
> Bullet- and knife-proof business suits made of carbon nanotubes (shaped with a saw) retail for US$20,000.

> At extreme temperatures, nanotube sheets cause light to bend away from objects so they 'disappear', creating potential for a 'cloak of invisibility'.

With nanotechnology the possibilities, it seems, are endless …

Climate change

According to *New Atlas*, US scientists can convert atmospheric carbon dioxide (CO_2) into high-yield carbon nanofibres (at low energy) for use in anything from bulletproof vests and artificial muscles to wind-turbine blades and commercial airliners. Scaling up their operation to cover an area of less than 10% of the Sahara Desert would, the researchers claim, cut the concentration of CO_2 in the atmosphere to pre-industrial levels within a decade – supplying materials for manufacturing in the process.



High-yield nanofibres produced from atmospheric CO_2.

Size matters – the intriguing world of nanotechnology PART TWO

The Energy Revolution

In the pursuit of higher energy densities, lower costs, and longer life, nanotechnology is regularly employed to create new materials and processes … A wonderful example is the commercialisation of the lithium iron phosphate cathode, which functions as a high power material only in a nanophase form, clearly demonstrating the benefit of nanotechnology.[1]

Some surmise that oil companies could pipe or pump (or deliver in tankers) electricity as a nanofluid using existing infrastructure, just as petrol is distributed today.[2]

While interest in proposals like this continues to grow, the ubiquitous lithium-ion battery (LIB) is also undergoing many transitions, with nanotechnology supporting ever-improving performance.

The electric vehicle (EV) industry offers a great example of how rapidly things can change. In just a few short decades, EVs have progressed from employing macro-technologies (like towing a trailer load of lead-acid batteries to achieve the required range) to being powered by LIBs, thanks to the development of nanopowders that enable those batteries to outperform their lead-acid predecessors by an order of magnitude – making today's self-contained EVs a reality.

Meanwhile, the use of graphene nanotubes in LIB anodes is hailed as a means of improving their performance. Although the addition of silicon and lithium metal in the anode may also yield much higher energy densities, such advances are never simple. Silicon, for example, coordinates with far more lithium atoms than carbon and should therefore be ideal as a cathode material. However, the large quantity of lithium that silicon can consume creates a problem, in that the silicon in the anode expands and contracts by up to 400% on charge and discharge cycles. This puts immense strain on the cathode and results, ultimately, in degradation. The solution? Nanotechnology! Incorporating the silicon as nanowires or encapsulated particles – like the yolk within an egg – allows its electrochemical advantages to be exploited while negating many of its disadvantages.

Also on the drawing board is a cheap, non-toxic LIB with sand rather than graphite in the anode. Purifying the sand, powdering it, grinding it with salt and magnesium and then heating it to remove oxygen produces porous 'pure' silicon, which unlike normal nano-silicon not only degrades slowly but is also easier to produce in large quantities. While still in the R&D stage, the Sand Battery is said to perform three times better than current types of LIB.

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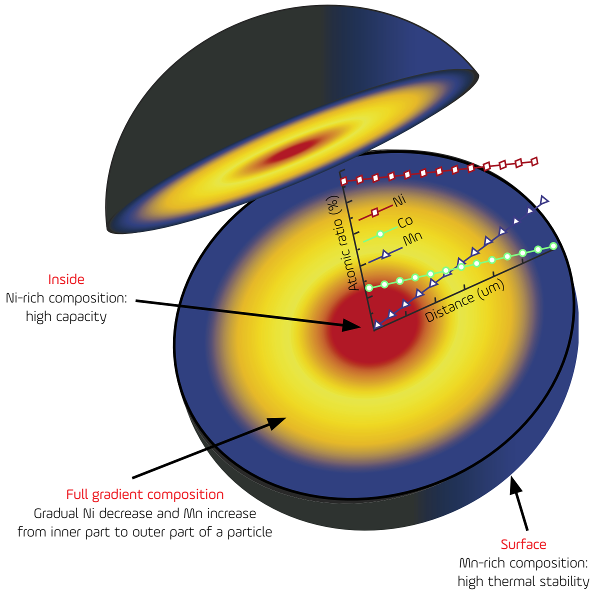


The Energy Revolution *(cont.)*

Another issue with some LIBs (NCM compositions in particular) is the propensity of the cathode to react with the electrolyte. This dramatically shortens battery life. Again, though, the problem can be overcome with nanotechnology: today, particles with a graduated composition can be produced, the nanoparticles in the cathode powder having a nickel-rich core and a manganese-rich rim. (Ni = nickel; Mn = manganese in the diagram above). The nickel improves battery capacity but cannot react dangerously with the electrolyte, while the manganese improves the safety of the material by forming the front line of defence. Further, atomic layer deposition[3] can be used to develop a protective coating that permits the passage of lithium ions but prevents the electrolyte penetrating and degrading the cathode particles.

Another innovation, the StoreDot charger, comes courtesy of the nanotechnology department at Tel Aviv University. It uses biological semiconductors made from peptides (the building blocks of proteins) to recharge a smart phone in 60 seconds. An EV battery that charges in five minutes and offers a range of 300 miles (480+ kilometres) is also in the works.

With the blue battery concept, meanwhile, molecular sieves decompose water into both hydrogen ions and hydroxyl ions for charging, with those ions then recombining to form water as the battery discharges. The technology required to control the molecular movements is not dissimilar to the reverse-osmosis equipment commonly used to remove salts from domestic water supplies. The concept is compelling in that it utilises active materials from the ocean to produce rechargeable batteries and can store energy for use when the wind doesn't blow and the sun doesn't shine. A pilot project has been underway since November in The Netherlands; however, the system still has some way to go before commercialisation.

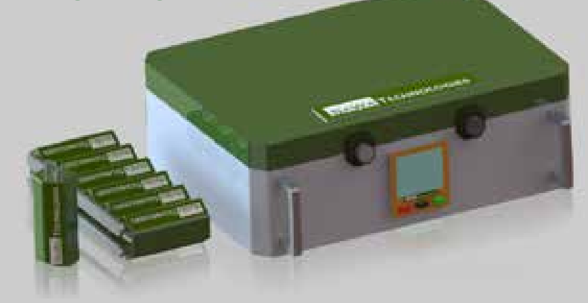
Also getting the nano-treatment are flow-cell batteries[4], which are usually pretty large! Bi-ION is the liquid energy carrier for the nanoFlowcell®, an extremely compact version of the technology with output scaleable for various applications. Said to be cost-effective, eco-friendly, sustainable and safe, its manufacturers aver that this innovation will produce "the electricity of tomorrow," surpassing all currently available battery technologies for static and mobile applications.

Conclusion

Presented above are just a few leading-edge transformations in energy storage achieved thanks to nanotechnology. Major innovations aside, much can also be gained by manipulating the particle sizes within the cathodes of existing LIBs. The Goldilocks formula applies here: the particles should be neither too big nor too small, porous enough for the lithium ions to move through freely but with a surface area small enough to prevent unwanted reactions between the cathode and the electrolyte. While the parameters vary for each type of battery chemistry – and there is no 'one size fits all' – nanotechnology is hard at work here too.

And finally …

New Atlas reports that Nawa Technologies, a French startup, is working on a new type of battery using carbon nanotube ultra-capacitors to produce "crazy-fast charging [while saving] a ton of weight" and adding significant power output. Unlocking its full potential in the EV space, however, means combining it with a lithium battery for maximum range and energy storage.



NOTES

1. Bruce Dunne *et al* 2013 Nanotechnology 24 420201.
2. John Katsoudas, *Nano-liquid batteries*: https://www.youtube.com/watch?v=YZuYnX3IQSQ
3. Atomic layer deposition (ALD) is a technique capable of depositing a variety of thin film materials from the vapour phase. ALD has shown great promise in emerging semiconductor and energy conversion technologies.
4. In a flow-cell battery, energy is produced by two chemical components dissolved in liquid and separated by a membrane.

Which Perth-based company is generating advanced cathode powders directly from solution?

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