# Graphene and recent energy storage developments

When you hear energy storage and graphene mentioned in the same sentence this usually refers to electrical energy. Let’s take a brief look at some of the research that has been coming out of the labs recently…

## Batteries

Energy storage is of critical interest in road transport because you have to carry the energy you need around with you. Electric vehicles (EVs) run on batteries.

Batteries work by storing electrical energy in a chemical reaction. When the battery is connected and circuit is made, the pathway for the reaction is opened and electricity is released in a controlled way.

There are two problems with the technology. Firstly the batteries take a long time to charge. Secondly they don’t store a lot of energy in comparison with liquid fuels like diesel.

This means you cannot travel long distances without recharging. Then when you connect to the power grid you have to wait quite some time for the batteries to recharge.

## Improving batteries with graphene

Recent work reveals that graphene could help with the charging time. Samsung claim to have developed a graphene coating for the electrodes that can make batteries recharge faster.

The secret seems to be that they have made a graphene powder from graphite with a sophisticated milling technique developed by the Hosokawa Micron Corporation in Japan. This machine is

called the Nobilta. It grinds up solid graphite to create an exfoliated graphene nanoplatelet powder that looks a bit like microscopic popcorn.

This form of graphene is coated on the battery electrodes. It has a high surface area, which means there are more sites for the chemical reaction to operate. This is why the reaction can go faster and this speeds up the charging time. However it is hard to see how this development can increase the energy density of the battery.

## Supercapacitors

Supercapacitors also store electrical energy. Instead of a chemical reaction they store a charge on the surface of conductive plates that are separated by a very narrow gap filled with an electrolyte. Large charges can build up on these plates and when a circuit is made between the plates, electrons flow to equalise the charge difference.

This means that supercapacitors are very good at charging quickly. They also discharge quickly, but you get everything at once, unlike batteries that release the current gradually.

## Improving supercapacitors with graphene

Because the charge is stored on the surface of the plates, electrodes with a high surface area are essential to the performance of a supercapacitor. Activated carbon has been used in the past but since graphene nanoplatelets were developed commercially these have started to find use as electrode material. Graphene has an extremely high surface area and nanoplatelets help increase the operational voltage. It will not surprise you, dear InvestorIntel reader, to learn that this is an area of intense research activity.

To take one example of a recent R&D project done jointly by teams in China and Australia. A mixture of carbon nanotubes

and graphene nanoplatelets (in a 1:3 proportion) was wet spun to make a fibre. The fibre was then coated with polyaniline (a polymer that conducts electricity very well)

The researchers found they could make a material that was suitable for use in supercapacitors and was very flexible. Coiled springs made from this fibre had an extraordinary 800% strain capability.

Making stretchy graphene fibres that conduct electricity and can hold an electrical charge could be the basis for incorporating electrical devices in to clothing. The polyaniline coating is a well-understood material and is already in use as a component in supercapacitors. So the adoption of this technology by the energy storage industry is likely to be easier because it is built on known technology

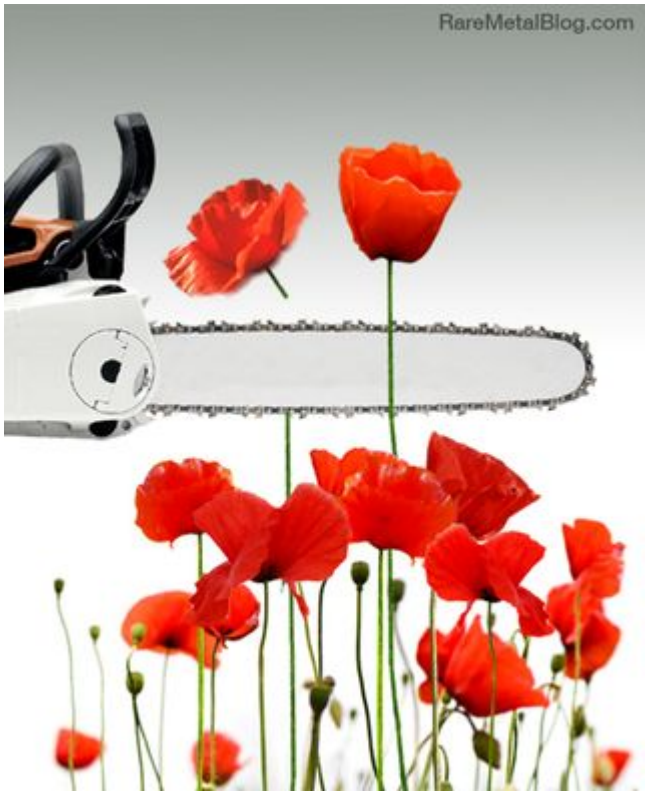
## In summary

Batteries for transport applications might not be improving much in terms of the amount of energy that can be squeezed into a given space. However graphene could improve the time spent charging so at least we can get moving again faster. Supercapacitors might not be ideal for transport applications but adding graphene can improve their performance too and also enable the development of flexible power packs that could find novel applications such as textiles that can store and release power.

---

# Flake Graphite, bubble or

# not, the risk is greater for those betting against




Australian graphite stocks have experienced a veritable boost in the past few weeks as many more companies have joined the graphite industry in expectation of much higher demand for Lithium-ion batteries (which, despite their name, use more graphite than lithium). Including China, the graphite sector now includes eight countries and there are promising resources being developed in Canada, the USA, Madagascar, Sri Lanka and Sweden among others. Naturally, there are concerns – and justified ones – that nobody knows where the volume of graphite demand will be heading in the future. Indeed, the graphite market is not all that big now and caution is well, almost always useful. The bets are that those companies that can produce high levels of purity will have a huge competitive advantage and the market will surely weed out the number of graphite companies as the realities of establishing a solid customer base and delivering consistent high quality at low cost take over. The current purity standard for high purity flake graphite is 99.9%, which would allow a company to be in an excellent starting position to open up numerous markets and achieve premium prices. The market is currently based on material ranging from only 94% to 97% purity and several emerging graphite companies have claimed to exceed in their tests.

The critics, who correctly observe that nobody, can tell what shape the future of the graphite market will adopt are absolutely correct and they are right to advise caution and perhaps they are even right to warn of potential ‘bubbles’. Nevertheless, the same might be said for any other commodity, mineral or otherwise, and any other stock. Nobody can predict the future. We can analyze trends and build scenarios but we cannot foresee what author Nicholas Nassim Taleb has called ‘black swan’ events. Nobody, other than the perpetrators of the heinous crime, knew what would happen on the morning of September 11, 2001. Apart from the human tragedy, the financial markets were affected and several bubbles burst. Therefore, based on the market information at our disposal now, investors cannot ignore the prospects for lithium-ion batteries that need high purity flake graphite.

The demand for these batteries is increasing, mainly due to the exploding use of consumer electronics (such as smartphones) as well as hybrid and electric automobiles. Forecasts predict that alone, this market will grow by 2020 to $ 34.3 billion. And the test results of a handful of graphite companies show that they will be able to produce concentrate suitable material for use in lithium ion batteries. Not all will succeed, but then, it will be the market and careful research into the individual companies that will determine which have the better chances. Of course, many emerging graphite producers are young and present considerable risks on the road to the intended objective to become significant producers of graphite, but the completion of metallurgical testing serves as a useful indicator of potential and the extent to which the companies have mastered this crucial hurdle. Those that produce resource estimates further reduce risk and so on.

For a lot of metals, but also for energy, economic growth plays a role in the medium term; in the long run technological progress will be more important in helping to de-risk graphite

investments. The higher commodity price, the more incentives arise to both produce – and replace – this raw material in production. The world is now engaged in the search to replace ever more expensive (even if abundant) oil. Graphite is one of the crucial materials to achieve this, because modern batteries and light weight materials require it. Technical progress both creates and destroys demand for commodities. Meanwhile, such industrial giants as BMW and Samsung have announced the expansion of their battery supply contracts. Bloomberg Samsung spoke of a "billion deal." For the next few years Samsung will provide more lithium-ion cells for the BMW i3, the i8 and the plug-in hybrid vehicles of the Bavarian luxury carmaker. The expansion of the partnership of the two companies aims to secure technology leadership. BMW since 2009 battery concerns already from the South Korean manufacturer. Tesla is still determined to build its battery GigaFactory. BMW and Tesla: just two of the giant automotive groups that have just started to build electric vehicles. Speculative bubble or not, who would pass up the chance to invest in a solid graphite company today, considering Toyota, Hyundai, Nissan, Fiat, GM, Ford and a host of others will also be needing graphite rich batteries? *Oh, and notice there was no mention of graphene…*

---

# Graphite & Graphene Weekly Review: The Contest for Graphene begins

The biggest news in graphite last week was all related to its graphene derivative. Graphene has been known to exist for well over a century. It is essentially a form of graphite

oxide and graphite oxide sheets (that have since been named graphene oxide) were discovered as a result of graphite chemical exfoliation experiments in the late 1800's. However, it has not been until the past few years – since the 2010 Nobel Prize for Physics was awarded to two researchers at the University of Manchester who have worked extensively with graphene – that graphene's multi-faceted potential has been discovered. So far graphene has been touted as nothing short of a miracle material: such attributes as "the strongest material known, the most flexible, the most versatile" are among the most common cited. Nevertheless, for all the enthusiasm, the actual benefit to industry deriving from graphene is low.

This may be about to change. The European Union has awarded a one billion Euro contract to Nokia and some partners to study the material and develop some practical applications. Nokia has been given the tools to effectively challenge Samsung in South Korea, which had already set up a special graphene research unit. The resulting competition among electronics giants would generate the necessary critical mass to generate much more demand for graphene, one might call it a new technological or industrial 'revolution' in the same sense that silicon radically changed technology in the 1970's and 80's. As a result, demand for high quality flake graphite can only increase given the multitude of applications that have been conceived already.

Researchers at Nokia, and no doubt elsewhere, will now be in a better position to evaluate just where and how graphene can be most useful and practical; it may start replacing other materials in existing products even while turning the wildest technological and scientific fantasies into reality. Indeed, the fact that such mainstream publications as the Financial Times are running articles about graphene shows how far the material has come along from 'science fiction' to science fact. While the article warned against being overly

optimistic, suggesting there “is too much hype” over graphene, the fact of the matter is that new applications are being discovered every day and methods for getting graphene into high volume production are also progressing thanks to efforts of companies such as Grafoid Inc., a 40% owned subsidiary of Focus Graphite (TSX: FMS; OTCQX: FCSMF).

Recent research in graphene, moreover, as noted by ProEdgeWire, has shown that graphene can absorb water. Apart from the fact that this could lead to the development of special applications where impermeability is crucial, it means that graphene could be used in complicated chemcial processing. One possibility of interest is in the rare earths space. Rice University and Lomonosov Moscow State University have collaborated in studying the ability of graphene platelets to absorb radioactive particles of water.

This characteristic would allow for more efficient processing of rare earth minerals, which often contain thorium, uranium or both. This phenomenon could be brought to commercial maturity and have tremendous impact in helping to clean up contaminated sites and in general mining, as well as rare earth mining. However, rare earth mining would be the most to benefit, and the more efficient purification process would facilitate the establishment of more rare earth mines in areas beyond China. Such ProEdgeWire sponsors as Focus Graphite, Zenyatta Ventures (TSXV: ZEN) or Galaxy Graphite (TSXV: GSX), Standard Graphite Corp. (TSXV: SGH; OTCQX: DARDF) are mining in some of the best graphite mineralization zones – eastern Ontario and western Quebec – in the world for the production of graphene.  Raw graphite, after all, can be found in many parts of the world, but not all of it is of the right quality or variety suitable for graphene.  Flinders Resources Ltd. (TSXV. FDR), for example, has a graphite project in Sweden with some advantages and a mineralization suitable for graphene production. Those companies producing graphene quality graphite are best positioned to take full advantage of

the new market interest in graphite. As for share performance, last week was rather stable as the average movement for the ProEdgeWire Graphite and Graphene was 3.07%. At the time of writing, Zenyatta, in particular, announced a second series of beneficiation tests of its vein or Sri Lankan graphite variety, achieving a 99.96% purity level.

The following are the monthly share price changes for January 2013:

---

# Billion Dollar Grant Launches Global Graphene Race

***EU gives Nokia a Billion Euro for R&D launching Global Race for Graphene***

Graphene is the strongest material ever tested and Nokia now has a major hand in its development having secured – in conjunction with the Graphene Flagship Consortium (GFC) – a grant worth  Euro 1.0 billion (USD 1.35 billion). Nokia is a member of the GFC, which brings together 74 European partners from the private sector and academia to advance what has been touted the strongest material yet known to man and one that could have an impact on technology and society comparable in scope to iron or silicon.

Graphene is an allotrope of carbon having a honeycomb shape.

It is thin, flexible and resilient and it is extremely light. Nokia has very clear plans for graphene. With it, the Company will be able to develop fully flexible and lighter phones. Nokia started working with graphene in 2006. Since then, the company has identified a number of areas where this material could be applied to great advantage. For instance graphene transistors could be made in almost microscopic sizes, which would allow Nokia, best known for its mobile phones, to create a whole new generation of consumer electronics featuring much improved portability due to a significant size and weight reductions. While, Nokia has been very pleased by its research to date, the company expects far more significant results in the near future and the grant announced today will no doubt accelerate development. Moreover, given the stakes involved with such a revolutionary material, the impact of Nokia's research could benefit all of Europe as it races against similar research being conducted in Asia and North America.

The one billion Euro grant sends a signal to European industry and science that it is high time to start investing in research again and that graphene should be among the highest priorities.Research spending in the West has dropped and the fact that the graphene grant has come now, with Europe continuing to struggle with its debt situation-meaning fewer incentives and liquidity available for investment- suggests that European governments have noted graphene's strategic importance and the need to catch up to the level of Asian competitors such as  Samsung, which is on the cusp of delivering the technology to consumers.

It is not surprising that Nokia would be leading graphene research at the industrial level. Indeed, one of Nokia's main competitors, perhaps its biggest, Samsung, recently produced and tested graphene transistors, much thinner and more conductive, overcoming problems related to controlling the current flow ( in other words, the current would be constantly 'on' – transistors  act as a "switchable gate" controlling the

current flow). The research for these new conductors was performed at Samsung's answer to the GFC, the Samsung Advanced Institute of Technology.  Samsung is just about ready to bring graphene to the market thanks to its plans to introduce flexible transparent screens in cell phones. It has also overcome problems in adopting graphene in circuit integration with its 'Barristor' – variable barrier transistor – a device that will make computer CPU's several times faster and smaller than the best on the market today. Samsung said it could be ready to launch cell phones with graphene-based flexible transparent screens, the Galaxy 'Skin', before the end of 2015. The advantage is more than cosmetic dazzle; a flexible, almost organic, phone could be folded and carried in any number of ways without risk of damage.

This technology has huge potential, as its flexibility can make electronic devices adapt to any shape and texture. Laptops and tablets will be almost as easily foldable and thin as a newspaper. We could even have electronic clothing – designer pants with built in mp3 player and CPU, flexible TV's that fold way and which can be installed in seconds without use of heavy hardware. The result of this battle of technology pitting Nokia vs. Samsung or East vs. West is that graphene technology will advance faster than imagined.

Nokia has quickly understood the advantage of graphene and its role in revolutionizing mobile phone technology and beyond. Nokia has been working with nine technology suppliers to explore the possibilities of graphene through the Nokia Research Center, Eurolab, in Cambridge, UK. In 2008, Nokia presented the 'Morph', a concept mobile phone featuring a flexible design and showcase for nanotechnology. As the name suggests the 'Morph' can change into many shapes and graphene is the tool that will bring the 'morph' and its derivatives to life. Nokia is also studying using graphene as a coating to make mobile phones and other electronic items waterproof. The so-called 'superhydrophibic' nano layer of graphene repels

water completely; the coating would also make devices impervious to fingerprints. Like Samsung, Nokia is also studying television screens that can be rolled out like a poster thanks to graphene screens. In the race to market graphene derived products, Samsung has the advantage of Asia's more favorable economics but Nokia's grant signals that Europe has woken up. Nokia and Samsung rival, Apple, has been rather quiet on the graphene front, but surely they too will have something to say on the matter.

Focus Graphite (TSX.V: FMS; OTCQX: FCSMF) is working on a method to bring graphene to the market through its partner Grafoid Inc in which it has a 40% stake. Grafoid's sole purpose is to develop a proprietary method of producing graphene more economically. Grafoid is close to a manufacturing approach that avoids oxidation of the material, which reduces its conductivity. Grafoid is quite confident that it has an economically viable graphene production process ready. From Gary Economo, President and CEO Grafoid Inc. "The European Community's grant to Nokia indicates the global race is on in earnest for graphene's use in consumer electronics. As an emerging source of high-energy graphene for industrial-scale applications, we see Grafoid, our graphene investment and application development company as being well-positioned to enter that race in the very near future."