Review of 2017: The year graphene became a teenager.

Graphene was first isolated in 2004 in Manchester, UK. As James Baker at the NGI noted, 2017 was the year it became a teenager. Read on to take a look at what this thirteen-year-old miracle material has done and what it might be capable of in future…

Graphene is currently commercially made from graphite. This creates tiny pieces of material called nanoplatelets. Such is the exceptional nature of the material that these very small pieces can confer performance improvements in a range of materials. Here are a few of the topics we covered.

Composites and Rubbers

Graphene nanoplatelets were added to rubber tyres. They improve the wear resistance of the rubber. Two Italian companies Vittoria Industries Ltd and Directa Plus S.p.A found that graphene can increase the grip of rubber bike tyres and this means a potential 30-second time advantage for sports tyres. In a race five to ten seconds can mean the difference between winning and losing.

I was invited to the National Graphene Institute (NGI) in Manchester and saw the work Haydale Ltd has been doing adding graphene to carbon fibre composites. They made structural components for a BAC racing car that were stronger and thirty percent lighter than standard materials.

Not as obvious and less glamorous is a composite material you might not immediately think of. Asphalt is the material that surfaces roads worldwide. Directa Plus is collaborating with another company, Iterchimica S.r.l. to add graphene to the

bitumen binder. If their tests in 2018 are successful then we will have surfaces that last longer meaning less road works to hold up our journeys.

Graphene Oxide (GO) nano-platelets

During the year we looked at graphene oxide and found it was more complex than the casual observer might think.

Graphene oxide is nearly as strong as graphene. It doesn't conduct electricity, however it does attract water and repel oils. This latter property has enabled some clever researchers to create rather useful applications for GO nanoplatelets.

In April a team at Manchester University made a filter from graphene oxide that could separate salt from seawater to make drinking water.

Then at the graphene conference in Barcelona, Spain, Dr Vivek Pachauri announced that his team had created sensors from GO. They had developed a manufacturing technique that could mass-produce biosensors that could detect prostate cancer in blood samples. This reduced the waiting time from weeks to minutes.

If all that wasn't enough, last month a team in South Korea announced work that showed human nerve cells would grow on trails made of graphene oxide. This holds promise in the future for advanced surgery to treat brain and spinal cord injuries.

You can explore all of these stories and many more by following the hyperlinks in this column.

These stories are just the tip of the iceberg; a selection of the work around the world that I thought might catch your attention. I'll be closely watching developments in 2018 and beyond. Expect to be reading about more marvels right here

dear InvestorIntel reader.

Graphene oxide to help reconnect human nerve cells…

Nerves and their connections are the wiring in our bodies that connect brain to muscles. When this goes wrong we can end up paralysed and permanently incapacitated. So when I heard that a team in South Korea found that graphene oxide could help nerves reconnect I thought you might like to know too…

The global context

According to the World Health Organisation every year, around the world, between 250,000 and 500,000 people suffer a spinal cord injury. While there is a lot of research for treating brain/spinal cord injuries there is no cure.

The problem

Human nerve cells join to one another with long fibres called axons and connections called synapses. Ideally scientists would like to grow connected nerve cells so they can be used in transplant operations. Nerve cells can be grown in the lab but these connections grow out in uncontrolled, random directions. Repairing nerve damage means making axons grow in the direction needed and this isn’t what the nerve cells do in the lab.

The solution

The South Korean scientists have found a way to make the nerve

cells grow in any pattern they want. They reported their work a few weeks ago in a paper titled “Magnetic Force-Driven Graphene Patterns to Direct Synaptogenesis of Human Neuronal Cells”

Scientists know that graphene oxide nanoplatelets are not only compatible with human tissue but can form a scaffold over which human cells will grow. Graphene oxide can be printed on surfaces using lithography. The problem is that when repairing axons the printed structures need to be modified to make sure that the start and end points align with the nerve cells requiring repair.

The team made graphene oxide nanoplatelets with magnetic particles attached using a compound called (3-Aminopropyl) triethoxysilane (APTES).

The APTES can be thought of as glue that sticks the magnetic iron to the graphene oxide. This means the graphene oxide nanoplatelets can be steered using magnets to bridge the gap between two human nerve cells.

When in place the cells grow over the graphene oxide using it as a guide and accurately aligning the lab grown transplant cells to the ends of the damaged nerve fibres.

Summary

This is not a cure. This is lab work that shows graphene oxide can be used to manipulate the way nerve cells grow. It seems to me this is a big step forward giving researchers a method to tailor grown transplant cells to repair damaged connections in a human body.

This work should also be able to recreate damaged areas, at least in two dimensions so that the repair operation can be rehearsed before the actual operation is done.

And by now dear reader, you will be ahead of me. If this can

be done in two dimensions then it should be possible to manipulate the graphene oxide guides in three dimensions and form the basis for a future 3D printing of nerve fibres using CT scans to provide the model of the structures required.

All this is yet to come, however I hope you will agree that this work lays the foundations for repairing brain damage and spinal cord injuries that will give hope to millions of people in the future.

NASA's Graphene – Making holes within graphene nanoplatelets

NASA got in touch with me. "Would I like to attend a briefing on a new graphene technology they had been working on?" The first thing I did was check up to make sure this was real. Yes it was the NASA Langley Research Center. So I joined a few others and listened attentively to what their scientists had to say about something they call holey graphene. Read on to find out more…

Dear InvestorIntel readers, you are sophisticated. So I'll spare the usual graphene introductions and assume you know all about graphene's amazing physical properties. I will draw your attention to one aspect of this material though. It is impermeable, even gases cannot pass through.

This impermeability is seen as an advantage because there are few other materials with this property. However there are situations where putting holes in graphene could be an advantage, such as making filters or electrodes for batteries

and supercapacitors.

Graphene porosity currently means gaps between nanoplatelets

Regular readers will know about graphene filters, for example Manchester University has created a filter that can remove the salt from seawater.

They achieved this feat by making the filter from graphene nanoplatelets that were pressed together. Think of the nanoplatelets as stacks of playing cards viewed edge on. Water can be forced through the gaps between the layers, however salt molecules cannot pass through these gaps and this creates the separation effect.

Making holes within graphene nanoplatelets

Creating holes in graphene nanoplatelets makes graphene permeable. Other teams have done this. For example punching holes with an electron beam, or etching with oxygen plasma. Both of these methods are effective on the small scale but complicated and expensive to scale up.

The NASA process

What NASA has done is to develop a simpler way of making the holes. In essence they dust graphene with a solid powder of silver nanoparticles. This dust clings to defects on the nanoplatelets surfaces. Then they introduce oxygen. The metal nanoparticles act as a catalyst completely oxidising the surrounding graphene to carbon dioxide and this creates the holes. Because the silver nanoparticles act as a catalyst they are unaffected by the oxidation and remain. So they dissolve the metal with acid. Then wash the acid away.

NASA has already shown that this increases the surface area and can catalyse the breakdown of hydrogen peroxide into

hydrogen and oxygen. Other materials can do this so that is not unique.

So What?

The technology also relies on the graphene not being perfect. It needs to exploit defects in the graphene nanoplatelets. Regular readers will recall that near perfect sheets of graphene have been made by researchers in China. This single crystal graphene will not contain defects and so this process may not work as effectively on these new larger scale sheets that will emerge in the future.

Much was made of the applications of these holey platelets but I didn’t see any evidence for them actually making a measurable difference to filtration or energy uses yet. This means the technology is yet to be proved as a leap forward over standard graphene nanoplatelets. However, the NASA process for making holey graphene is straightforward and should not add much cost to conventional graphene nanoplatelets. It should be scalable too, which is good from a commercial point of view.

Graphene for Water Treatment

If you find yourself in Manchester, UK, the Museum of Science and Industry is well worth a visit. It has a whole gallery devoted to graphene. In that gallery you’ll see exhibits from the continuing story of graphene. One of these is a simple filter. It looks like a fairly ordinary piece of filter paper, but is worth closer inspection, read on…

It starts with a filter

These ordinary looking small white filter samples are coated in graphene oxide.

Image courtesy of G2O Water Technologies Ltd

The coated filters can separate salt and oil from water and were made by a start up company called G2O Water Technologies Ltd. founded by the equally remarkable Tim Harper, a serial high tech entrepreneur.

So, why did these filters attract my attention? Well, this product is an exercise in pragmatism. The filter membrane samples you can see in the image are a set of perfectly ordinary polyamide filters, except for the fact that they are coated in graphene oxide. They look slightly different, the colour difference is due to the degree of oxidation of the graphene coating. Graphene is black and the more it is oxidised the lighter and more yellow the material becomes.

G2O has a granted patent “Ultrathin, molecular-sieving graphene oxide membranes for separations along with their methods of formation and use” Because the coating method is straightforward this means they also have a scalable manufacturing process. This coating enhances its properties in a number of ways. Let’s look at treating water contaminated with oil.

Taking oil from troubled waters

Everyone knows that oil and water don’t mix. Well that is not quite true. Get the oil droplets small enough and they form something called an emulsion and this is surprisingly hard to separate. A familiar example is milk, which is an emulsion of fatty droplets in water.

The standard polyamide filters have a good initial performance for separating oil and water emulsions but this declines with time because the filter becomes blocked at the surface. This is called fouling and this paper describes the problem.

What G2O have discovered is that coating the surface of the filter with graphene oxide reduces this fouling problem making the filter perform better for longer. The graphene oxide coating allows water to pass through but prevents the oil. As further oil droplets accumulate on the filter they normally block it. The graphene oxide coating makes the oil droplets coalesce forming bigger drops, which float away from the filter and rise to the surface of the water. This makes the oil easier to remove and also improves the performance of the filter.

The market

Oil in water emulsions are a problem for industry. Everything from the obvious oil and gas industry to food processing and car washes have to deal with the problem of separating oil from water. The global market segment is called industrial water treatment and is worth $146.81 Billion in 2016 with a growth rate of 5.4% in 2016. Within this is a sub market segment of industrial water and wastewater treatment that is estimated to be worth $26.77 Billion with a growth rate of 5.8%.

More than oil in water

G2O have found that graphene oxide coatings can improve the performance of a wide range of other membranes used in the water treatment sector. They can prove a four-fold increase in the membrane operation times of Polyether Sulphone (PES) membranes that are used in bioreactors for wastewater treatment.

All this work would be impressive enough, but the company has

also found that their graphene oxide coating can improve the performance of desalination membranes. The graphene oxide coating improves the permeability of pure water through the membrane while increasing salt rejection.

Why this is important

What this all means is that G2O has developed a scalable method for coating graphene oxide on to standard filter media. The coating improves the performance of water treatment filters. This enhances the performance of the filter and potentially reduces the costs of operation too. Waste water treatment is a large global market, measured in the $Billions, with a growth rate over 5%. We'll continue our watch on graphene activity in this sector in general and G2O in particular.