An introduction to

GRAPHENE

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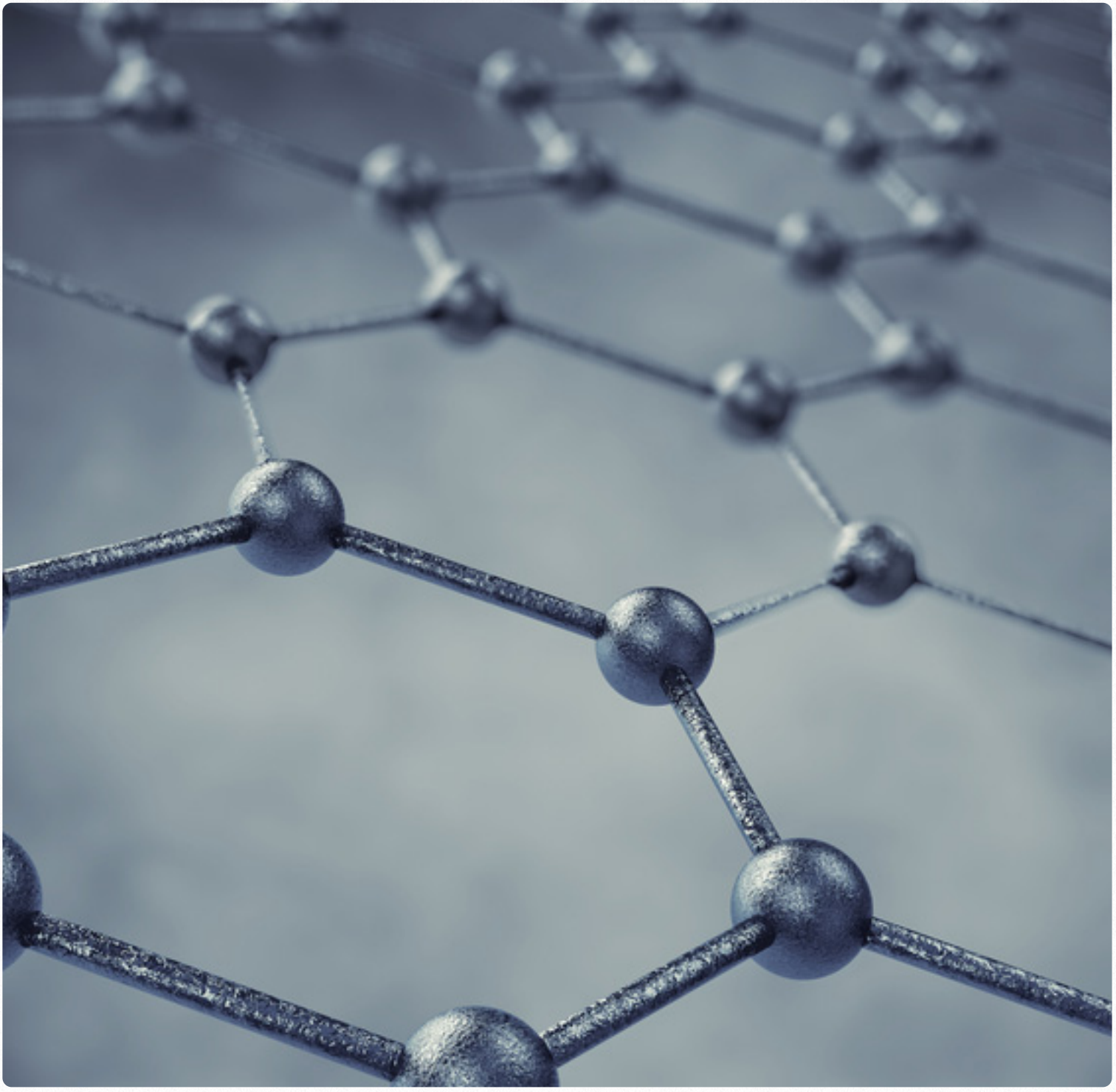


Introduction

An amazing new material was discovered by two physicists working for Manchester University Konstantin Novoselov and Andre Geim .It happened by chance during a "Friday evening experiment". The scientists were bored and they decided to do useless things. So they rubbed a lead of pencil on a sticky tape, a layer of carbon came out : graphene..

Graphene is bound to transform technology forever. Looking at it in a microscope,it doesn't look much but it won a Nobel prize in 2010 to the two scientists who discovered it. It is stronger than diamond, more conductive - heat and electricity- than copper, more flexible than rubber, lighter than aluminum and it is so thin its layer is 3 million times thinner than a sheet of paper.

Graphene is made from graphite which is the material you find on the lead of your pencil . In graphite there are millions of microscopic layers of carbon which is one of the most abundant element in the universe.

"After years of academic research, we are today in a transition period where researchers and industries have to cooperate" says Ber-

nard Plaçais from Ecole Normale Sup. That's why the European Union granted a €1 billion fund in 2013 for the "Graphene Flagship" project. 75 teams from academic and industrial backgrounds from 17 different countries are taking part in the project. 15 of these teams are French and come from the CNRS, universities or private companies such as Thales. 150 patents have been registered by the European Union so far but they aren't even close to China and its 2200 patents.

Here is the outline of our report

I/ The properties of graphene

II/ The applications of graphene

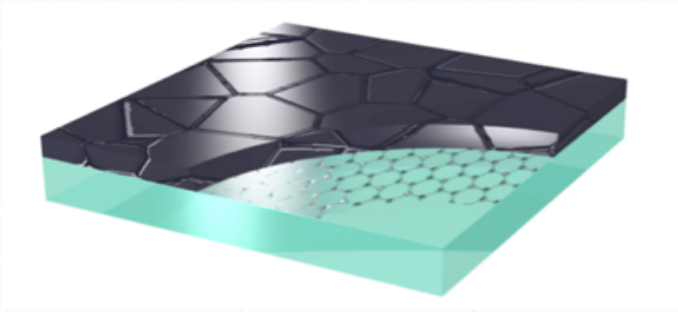
III/ The issues that may rise

I/ The properties of graphene

1) Thickness

We live in a three-dimensional world. It means that everything has a width. Scientifically, having a width means having more than one atom. Every material observes this condition except graphene.

Graphene is made of a single layer of carbon atoms which makes it the thinnest material in the world. Considering the scientifically agreed definition of thickness/width , graphene is the first known 2D element on earth. It is 0,03 nanometer (3 Angstrom) thick which means 3 millions of its layers make up for the thickness of a pencil stub print as can see on the picture below.



2) Conductivity

Technology has changed over the last century. Electricity lightened homes and we found ways to heat a house without wood. In order to do so, one needs conductive materials. Copper is the most used electrical conductor but gold is more efficient although it is more expensive. Graphene questions gold supremacy in this field. Heat makes every material vibrate but graphene's monoatomic structure reduces the vibrations. Thus, the electric wave travels on a straight line therefore faster. As its electrons move very fast, grapheme is also an impressive heat and cold conductor.

3) Strength

Grapheme is a very strong material. It has a tensile strength of 130 Giga Pascals (the measurement of strength) whereas Steel barely measures up to 400 Mega Pascals. For Aramid (Commonly known as Kevlar), it is 375 Mega Pascals. A grapheme plastic wrap can bear an elephant on a pencil tip says CNRS scientist Giancarlo Faini.

This strength is amazing but what makes it even more amazing is the fact that even thought it is stronger, grapheme remains way lighter than steel and kevlar. It weights 0.77 milligrams par square meter. For comparison purpose, 1 square meter of paper is 1000 times heavier. In fact, grapheme is so light that one gram of it can cover a football pitch.

4) Filtration

Graphene is an atomic structure. It is mostly composed of emptiness. Water molecules can pass through that emptiness. The carbon atoms impede everything that is not a water molecule from going through the grapheme layer.

5) Graphene and light

Graphene captures only 2.3% of the light it captures. Adding an extra layer will increase this value. A superimposition of seventy layers would capture 99% of the light.

When it loses a carbon atom, the layer automatically captures an other one. As there are carbon atoms in the ambient air, we can say that a grapheme layer can repair itself under certain circumstances.

Scientists have discovered a lot of properties so far and these are the most important. Thanks to what they know about graphene, scientists and private companies collaborate in order to find possible practical applications for this amazing tool.

II/ Applications of graphene

1) Graphene in energy transfer and storage

Graphene thanks to its wonderful properties is one of the most important innovation in several fields of activity. Let's start with energy storage. Indeed, American physicists have just managed to use graphene as a super condenser. A random condenser is an electric storage device characterized by a huge load rapidity but a very low storage space. Moreover, it unloads quickly just like a battery. If the random condenser gave way to a graphene made one, the outcome would be the ultimate storage tool. We know how to capture natural energy through windmills, solar panels, hydraulic dams and even bolts but we are not able to store it on the long run because random batteries tend to lose the energy they store. It's like your smartphone. You turn it off 100% charged and when you turn it

on, it is only 90% charged while graphene reduces the energy loss to an infinitesimal level. Storing natural energy is no longer an unattainable dream.

2) Graphene in smartphones and computing

Have you ever heard of the Graphene Valley ? Because Silicon is bound to give way to graphene. Indeed, Silicon, the generally used material in the IT industry, is not as efficient as graphene.

Graphene thanks to its amazing energy storage abilities like we have just seen is currently the most popular element in the R&D departments of the biggest electronics companies. Sticking a graphene layer on a glass makes this glass conductive while remaining transparent. It can also be used in computer LEDs so it is very likely to replace the main components of our touch screens. The resulting screen would be brighter, flexible and wouldn't break if hit with a hammer. It's good news because it can replace tin oxide - the thing that makes a random screen touch sensitive- that is less efficient, toxic and rare.

Furthermore, a graphene made battery would last way longer and recharge way faster than a lithium battery. Korean researchers managed to charge a smartphone battery in an incredible 17-second lapse of time. It is not a coincidence that a company like Samsung, the world's first cellphone manufacturer, has recently patented a way to produce graphene on an industrial level.

IBM also work on graphene-based chips that would be able to replace silicon chips in computers. It would slightly enhance the calculations of the computer and accelerate the data transfer because graphene electrons move 100 times faster. Therefore, we can conclude that a grapheme chip is 100 times faster than a silicon chip.

There are already a lot of products that use graphene. Here is a short list :

- Samsung Galaxy S6 Edge
- Samsung Galaxy Note 4 edge
- Samsung InCurve TVs
- LG G Flex

Samsung plans to release a smartphone with a fully flexible screen in 2016.

3) Graphene and cars

Creating an efficient pollution free car is a huge challenge for the automotive industry. A few car manufacturers have decided to build electric cars. Those do not pollute but are not really efficient since the battery doesn't last long. Graphene would be interesting on two points :

- First, a grapheme battery would sensibly increase the battery life of the car. The current cars can drive for 300 kilometers only while they could cover 1500km with a graphene battery.

- Secondly, a graphene chassis would lighten the weight of the car and make it faster and add some extra kilometers to your battery life.

Tesla Automotive and Honda are currently experimenting grapheme-lithium batteries.

Tesla CEO Ellon Musk said “it will be possible to have a 500-mile range car,” adding “in fact, we could do it quite soon.”

4) Graphene and solar panels

Solar panels are very important. Their main component is silicon. Do you wonder how solar panels work ? In fact it is easy. The core of the panel is made of two electron layers. The first one on the top faces the light while the second one is just below. The light heats the first layer therefore the electrons move -the more you heat an electron, the faster it moves- very quickly. As the second line is motionless, the friction between the two layers creates static electricity that is stored in a battery

5) Graphene and health

Graphene allowed a group of German scientists to develop an interface between the retina and the nerves. A French company, Pixium Vision aimed at creating a completely artificial retina and they apparently succeeded. Given that nervous signals are electric signals, graphene can conduct them. Moreover, unlike copper which is an other conductor , graphene doesn't block the light since it is transparent.

In a foreseeable future, blind people who don't suffer from brain damage will be able to see again.

Graphene is also a plausible way to cure cancer. "It has the ability to agglutinate on tumors" says CNRS researcher Alberto Bianco. Even if scientist don't really know the origin of this property, they hope to use it to target carcinogenic cells . Furthermore, adding golden nanoparticles to graphene would allow physicians to track down carcinogenic cells

thanks to ultrasounds. Lightening these particles would burn the problematic cells. Graphene is a viable research path in prder to spot and cure a cancer.

6) Graphene and water

A while ago we've seen how much treating water is important. Water consumption has increased 500% over the last century. This growth actually makes up for twice the growth of the population. It is a problem because we will probably run out of water. To tackle this issue, many processes are being developed like the Omniprocessor for instance (cf a previous report) . The Earth's surface is made of 70% of water but only 2,5% of this water is fresh water.

Since graphene blocks everything but water, we can certify that graphene filters water and its tensile strength allows it to bear the pressure. It is cheaper than an omniprocessor, more efficient, and smaller.

III/ Graphene and its drawbacks

1) Graphene is rare

We've seen how much graphene can be a groundbreaking material that can enhance the living standards of both first world and third world. Graphene appears as the miracle element. Can a chemical element do all that without having any kind of drawback ?

Graphene doesn't have any proved or known drawback but its efficiency is often questioned.

Graphene is a new element which has so far been more used in virtual simulations than in concrete applications. Creating graphene is not very complicated as we've just said since you can do it easily if you know how to manipulate a few chemicals. However, these methods do not meet the needs of mass-production. The process is too long, too expensive and the outcome is a low quality graphene that is not on par with the amazing abilities graphene provides. Hopefully, Samsung, Kyocera and LG have patented a process that allows them to produce graphene but they still have a hard time incorporating it in their products since they can’t merge it with silicon.

2) Graphene is risky

Moreover, graphene is relatively new. It might comprise risks that have not been discovered so far.

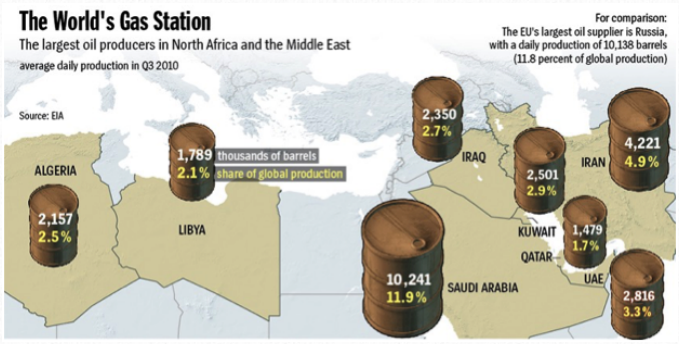
« We can’t say there is a danger, but we can’t say there isn’t one » says CNRS researcher Alberto Bianco. However, Brown University released a study in 2013 showing that the borders of a grapheme layer can cut through the cellular membrane and get into the cell.

According to Bianco, this is not dangerous since it is not toxic.

In light of these arguments, it would be problematic to release a graphene made product on a large scale.

3) Graphene and jobs

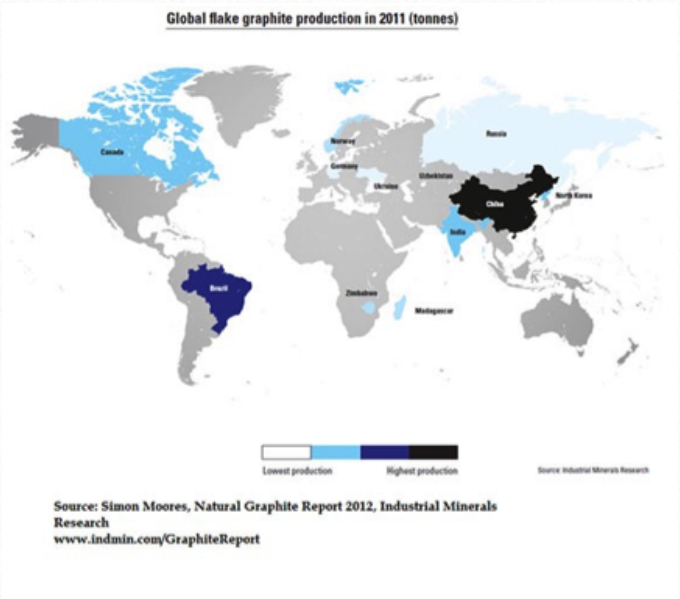
Graphene will probably have a negative impact on the short run on employment since it can make oil pointless. The oil industry can be damaged by graphene. Thousands people are likely to lose their job and oil-dependent countries will find it difficult to face the ensuing crisis. Silicon too is bound to disappear and the companies that will not innovate with graphene will suffer the consequences. This outlook is similar to the guess of the creative destruction ventured by the economist Joseph Schumpeter.



4) China controls graphene

Graphene is created from graphite, a mineral that is mostly produced in China.

The Chinese government may restrict the exports in order to give their companies an advantage as they do to with ferrosilicon (1st producer). Brazil produces graphite too but not as much as China. At least China doesn't have a monopoly.



5) Graphene is expensive

Graphene is very expensive. A 250ml bottle costs $119.
http://www.graphenea.com/products/graphene-oxide

It is a barrier for the companies that want to create graphene-made products. Even if they create graphene themselves from graphite, it would be very expensive and not profitable in a $700 smartphone.

6) Graphene and pollution

Given that graphene is really close to silicon and tin oxide that are polluting and/or toxic we may assume that it is the same for graphene. Researchers at the University of California attest the fact that carbon atoms solve in water very easily. It can embed itself in the soil, move itself through the ground via rain and other water sources, end up in agricultural fields. This could affect the growth of produce and, ultimately, the people consuming the products. Moreover graphene oxide which is very popular among researchers and physics fans is toxic and affect lungs

Graphene itself is difficult to manipulate. Using graphene alone won't lead to any particularly successful result. It is more like a complementary material. The majority of the experiments made on graphene basically involve mixing graphene with an other material.

Conclusion

Graphene is a revolutionary element that is able to change the world. It brings advantages to the health sector , the IT industry, automotive industry but is not beyond rebuke. Indeed, even if a lot of industries will be given a new momentum, the viability of many others such as the oil industry, the silicon industry will be jeopardized. A few questions remain pending about graphene. Is it a hazardous material ? Is it really efficient ? Further studies will determine that.

In our opinion, it would be mistake to miss this opportunity

Links

http://www.graphenea.com

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