BBC NEWS

Is graphene a miracle material?

By Alex Hudson
BBC News

The material graphene was touted as "the next big thing" even before its pioneers were handed the Nobel Prize last year. Many believe it could spell the end for silicon and change the future of computers and other devices forever.

Graphene

the "miracle material" of the 21st Century.

Said to be the strongest material ever measured, an improvement upon and a replacement for silicon and the most conductive material known to man, its properties have sent the science world - and subsequently the media - into a spin.

WHAT IS GRAPHENE?

- Graphene is taken from graphite, which is made up of weakly bonded layers of carbon
- Graphene is composed of carbon atoms arranged in tightly bound hexagons just one atom thick
- Three million sheets of graphene on top of each other would be 1mm thick
- The band structure of graphite was first theorised and calculated by PR Wallace in 1947, though for it to exist in the real world was thought impossible
- Due to the timing of this discovery, some conspiracy theorists have linked it to materials at the Roswell "crash site"
- In 2004, teams including Andre Geim and Konstantin Novoselov demonstrated that single layers could be isolated, resulting in the award of the Nobel Prize for Physics in 2010
- It is a good thermal and electric conductor and can be used to develop semiconductor circuits and computer parts. Experiments have shown it to be incredibly strong

"Our research establishes graphene as the strongest material ever measured, some 200 times stronger than structural steel," mechanical engineering professor James Hone, of Columbia University,

"It would take an elephant, balanced on a pencil, to break through a sheet of graphene the thickness of Saran Wrap [cling film]."

And the way this material can be utilised is as surprising as its properties.

"Graphene does not just have one application," says Professor Andre Geim, the current co-holder of the Nobel Prize in physics for his work with the material at Manchester University.

"It is not even one material. It is a huge range of materials. A good comparison would be to how plastics are used."

Much has been made of graphene's potential. It can be used for anything from composite materials - like how carbon-fibre is used currently - to electronics.

Since its properties were uncovered, more and more scientists have been keen to work on projects. About 200 companies and start-ups are now involved in research around graphene. In 2010, it was the subject of about 3,000 research papers.

And the benefits to both businesses and to the consumer are obvious - faster and cheaper devices which are thinner and flexible.

"You could theoretically roll up your iPhone and stick it behind your ear like a pencil," Professor James Tour, of Rice University,

> " **We feel that it's rather difficult to imagine graphene as a replacement to silicon** "
> Dr Phaedon Avouris, IBM

If graphene can be compared to the way plastic is used today, everything from crisp packets to clothing could be digitised once the technology is established. The future could see credit cards contain as much processing power as your current smartphone.

"It can open completely new applications in transparent electronics, in flexible electronics and electronics that are much faster than today," says Jari Kinaret, professor of technology at Chalmers University in Sweden.

And beyond its digital applications, just one example of its use would be graphene powder added to tyres to make them stronger.

Unlimited speed

Samsung has been one of the biggest investors in research, in collaboration with South Korean Sungkyunkwan University. It has already demonstrated a 25-inch flexible touchscreen using graphene.

"[Samsung has its] own roadmap where they believe there will be a dozen products [on the commercial market] using graphene in the next five years," says Prof Geim.

> " **According to the Nobel prize committee, a hypothetical one-metre-square hammock of perfect graphene could support a four-kilogram cat - the hammock would weigh 0.77 milligrams, less than a cat's whisker, and would be virtually invisible** "
> Richard Van Noorden, Nature Magazine

But companies like IBM and Nokia have also been involved in research. IBM has created a 150 gigahertz (GHz) transistor - the quickest comparable silicon device runs at about 40 GHz.

"In terms of the speed of the transistor, we currently see no intrinsic limits into how fast it can go," says Dr Yu-ming Lin, of IBM.

"We've already found a number of [problems] that have to be resolved but I don't think it's limited by the intrinsic properties of graphene."

In Europe, research about the material is a frontrunner to receive a 1bn euro investment from the European Commission over the next 10 years.

'Switching off'

Despite this frenzy of progress, investment and press attention, many researchers are cautious. Some are certain that graphene will not do everything that has been thought up for the material.

What has been reported as "potential" seems to be - at the moment - just that, with few real-world examples of it working to replace other materials.

"We feel that it's rather difficult to imagine graphene as a replacement to silicon," says Dr Phaedon Avouris, of IBM.

"The material itself does not have a

an essential property [meaning that graphene cannot stop conducting and be 'switched off', making it unusable in this way]. The applications of graphene and the application of silicon are in different domains."

And even the most revered academics think that a replacement to silicon is a long way off.

"It is a dream," says Prof Geim. "The prospect is so far beyond the horizon that we cannot even assess it properly."

The problem that scientists face is that these "miracle" properties have only ever been demonstrated on a tiny scale.

"The kind of strengths that people quote may not even apply to microscopic samples," says Dr Lin.

"So, while it may be true that on a local level it has this strength much stronger than steel, we have to be careful about these claims.

"We recognise the limitations of graphene and are trying to do things that do not bend the rules of physics.

"We are not setting out to replace silicon as the goal but we are trying to find unique applications that can take advantage of its properties."

With the seemingly unstoppable march of progress in this field, especially as it is less than 10 years old, swift advances could be just around the corner.

Yet with all this money and market demand, scientists are cautious about how quickly all this potential can be turned into reality.

"We would be the happiest people in the world if we could replace silicon," says Dr Avouris.

"But the main thing is to be truthful and not exaggerate because we actually have to deliver."

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