# Graphene looking promising for future spintronic devices

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The researchers fabricated the spintronics devices at the Nano fabrication laboratory at Chalmers University of Technology. From left: Saroj Prasad Dash, Venkata Kamalakar Mutta and André Dankert. Credit: Oscar Mattsson

Researchers at Chalmers University of Technology have discovered that large area graphene is able to preserve electron spin over an extended period, and communicate it over greater distances than had previously been known. This has opened the door for the development of spintronics, with an aim to manufacturing faster and more energy-efficient memory and processors in computers. The findings will be published in the journal *Nature Communications*.

"We believe that these results will attract a lot of attention in the research community and put graphene on the map for applications in spintronic components," says Saroj Dash, who leads the research group at Chalmers University of Technology.

Spintronics is based on the quantum state of the electrons, and the technology is already being used in advanced hard drives for data storage and magnetic random accesses memory. But here the spin-based information only needs to move a few nanometers, or millionths of a millimetre. Which is lucky, because spin is a property in electrons that in most materials is extremely short-lived and fragile.

However, there are major advantages in exploiting spin as an information carrier, instead of, or in addition to electric charges. Spintronics could make processors significantly faster and less energy consuming than they are today.

Graphene is a promising candidate for extending the use of spintronics in the electronics industry. The thin carbon film is not only an excellent electrical conductor, but also theoretically has the rare ability to maintain the electrons with the spin intact.

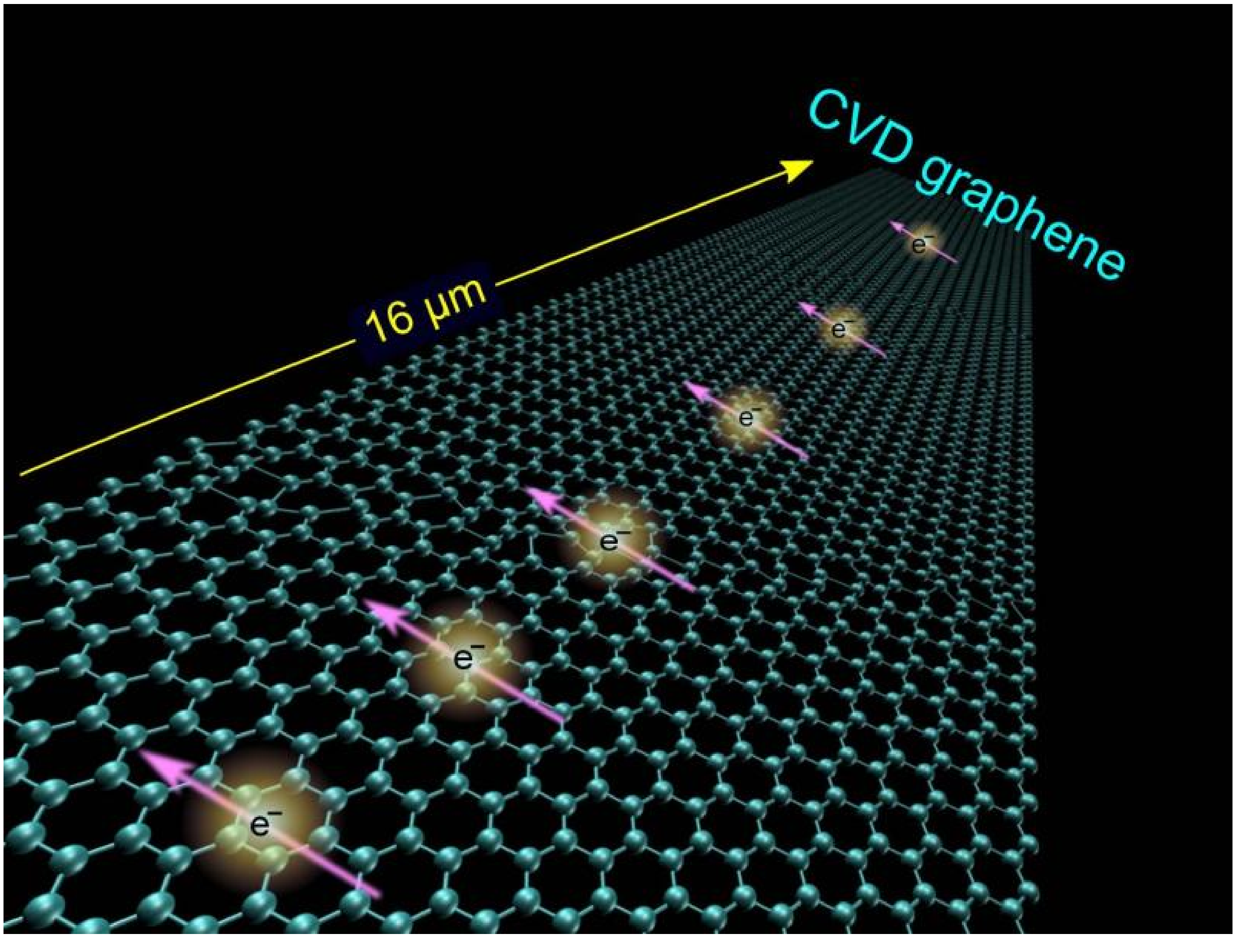
"In future spin-based components, it is expected that the electrons must be able to travel several tens of micrometers with their spins kept aligned. Metals, such as aluminium or copper, do not have the capacity to handle this. Graphene appears to be the only possible material at the moment," says Saroj Dash.

Today, graphene is produced commercially by a few companies using a number of different methods, all of which are in an early phase of development.

Put simply, you could say that high-quality graphene can only be obtained in very small pieces, while larger graphene is produced in a way that the quality is either too low or has other drawbacks from the perspective of the electronics industry.

But that general assumption is now being seriously questioned by the findings presented by the research group at Chalmers. They have conducted their experiments using CVD graphene, which is produced through chemical vapour deposition. The method gives the graphene a lot of wrinkles, roughness and other defects.

But it also has advantages: There are good prospects for the production of large area graphene on an industrial scale. The CVD graphene can also be easily removed from the copper foil on which it grows and is lifted onto a silicon wafer, which is the semiconductor industry's standard material.




In graphene, electrons keep their magnetization, their spin (the pink arrows in the picture) much longer than they do in ordinary conductors such as copper and aluminum. This characteristic of graphene may enable spintronics to become a complement to traditional electronics, which only utilizes one of the electron´s degrees of freedom, namely their charge. Credit: M Venkata Kamalakar et al, *Nature Communications*

Although the quality of the material is far from perfect, the research group can now show parameters of spin that are up to six times higher than those previously reported for CVD graphene on a similar substrate.

"Our measurements show that the spin signal is preserved in graphene channels that are up to 16 micrometers long. The duration over which the spins stay aligned has been measured to be over a nanosecond," says Chalmers researcher Venkata Kamalakar who is the article's first author.

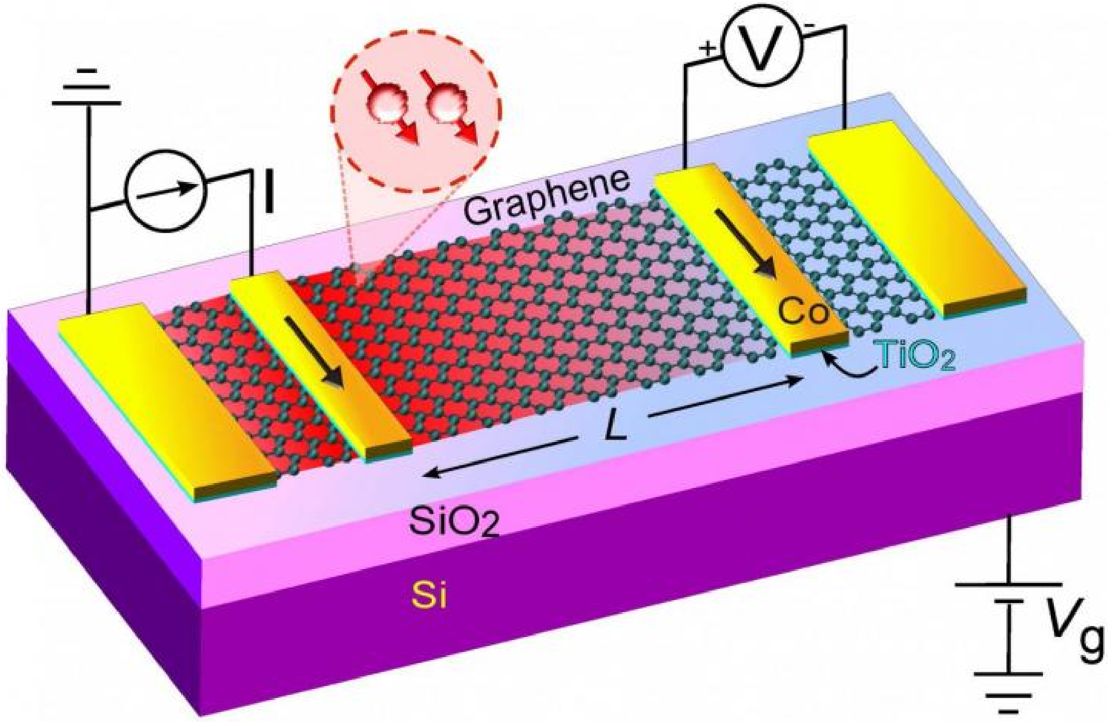
"This is promising because it suggests that the spin parameters can be further improved as we develop the method of manufacturing.

That researchers are focusing on how far the spin current can be communicated should not be thought of as just being about sending information in a new material or replacing metals or semiconductors with graphene. The goal instead is a completely new way of performing logical operations and storing information. A concept that, if successful, would take digital technology a step beyond the current dependence on semiconductors.

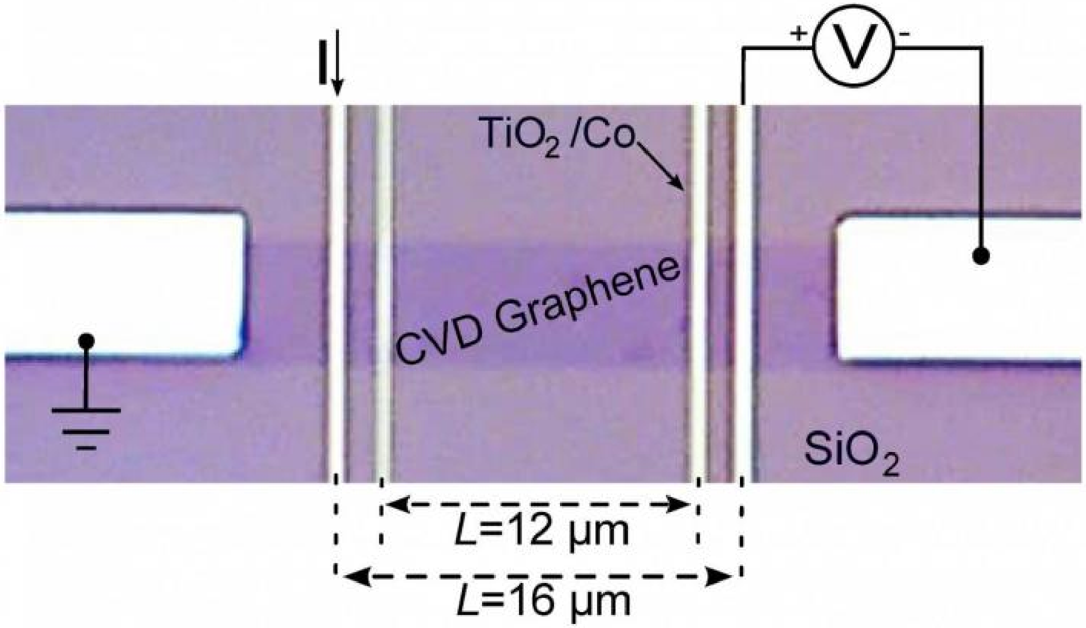
"Graphene is a good conductor and has no band gaps. But in spintronics there is no need for band gaps to switch between on and off, one and zero. This is controlled instead by the electron's up or down spin orientations," Saroj Dash explains.

A short-term goal now is to construct a logical component that, not unlike a transistor, is made up of graphene and magnetic materials.

Whether spintronics can eventually fully replace semiconductor technology is an open question, a lot of research remains. But graphene, with its excellent spin conduction abilities, is highly likely to feature in this context.



I
V
+
-
Graphene
Co
$TiO_2$
L
$SiO_2$
Si
$V_g$

I
V
+
-
$TiO_2$ /Co
CVD Graphene
$SiO_2$
$L$=12 μm
$L$=16 μm

Top image: Schematics illustrating spin transport in CVD graphene on Si/SiO2 substrate, with ferromagnetic contacts (Co/TiO2) for spin injection and detection.Bottom image: An optical microscope image of a spintronics device fabricated on CVD graphene, with long channels (up to 16 micrometer) on Si/SiO2 substrate with multiple ferromagnetic contacts (Co/TiO2) for spin injection and detection. The devices were fabricated at the Nano fabrication laboratory at Chalmers University of Technology. Credit: M Venkata Kamalakar et al, *Nature Communications*

**Background:**

## This is spin:

Spin is a quantum mechanical property of elementary particles, which among other things gives rise to the phenomenon of magnetism. The spin can be directed either up or down. For the electrons in a normal electric current, the spin is randomly distributed, and the stream carries no spin signal. But with the help of magnets, electrons that are fed into a conductor can be polarised, which means they all have their spin directed up or down. You could liken the electrons to a series of small compass needles, all pointing towards north or south. The challenge is to maintain this state long enough and over sufficiently long distances.

## Why spin works in graphene:

The spin of electrons can easily be disturbed by environmental factors. Atoms and their crystal structures in the conductive material have an electric field, which is perceived as a magnetic field by the electrons rushing by. But as carbon is such a light atom with only six protons arranged in a symmetrical hexagonal structure, this magnetic interference will be very limited.

The internal spin in an atomic nucleus is also a potential source of interference. But the net spin from the nucleus is negligible, as the majority of the carbon atoms are of the C12 isotope, with as many neutrons as protons.

## Three ways of producing graphene:

The Nobel Laureates Geim and Novoselov manufactured graphene from graphite using ordinary household tape. Similar methods are used today to produce high quality graphene. But the pieces are small.The Graphensic company, created by researchers at Swedish Linköping University, manufactures large area graphene that is "cultivated" from a substrate of silicon carbide.

At Chalmers University of Technology, large area graphene is produced using the chemical vapour deposition method (CVD). For the study in *Nature Communications*, the researchers have used CVD graphene purchased from the company Graphenea in Spain.

**More information:** Long Distance Spin Communication in CVD Graphene, *Nature Communications*, 2015.

Provided by Chalmers University of Technology

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