New magnetic graphene may revolutionise electronics

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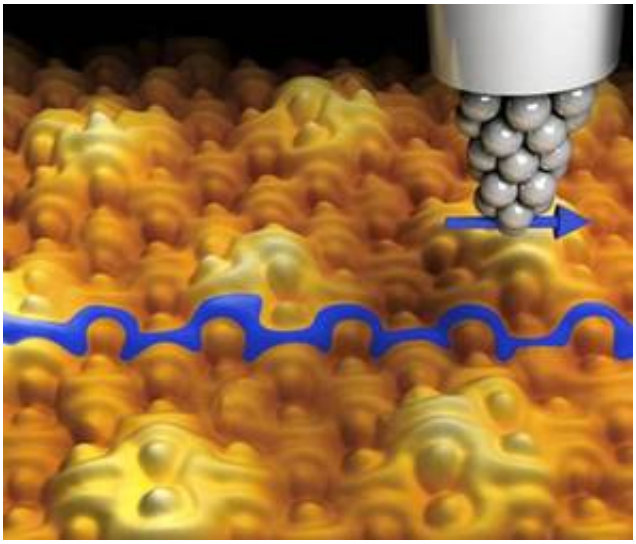


Computerised simulation of TCNQ molecules on graphene layer, where they acquire a magnetic order. Credit: IMDEA-Nanoscience

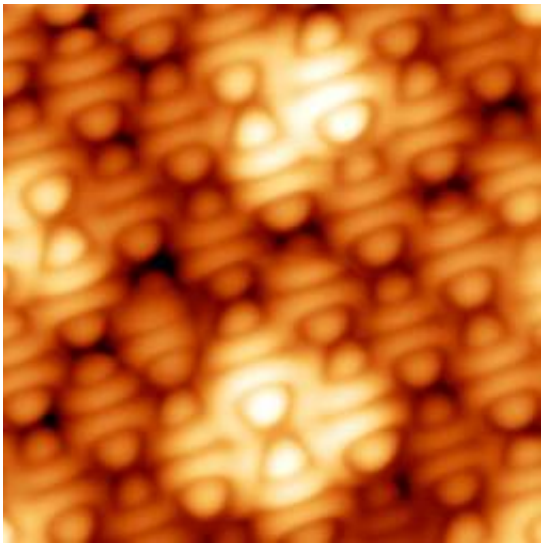
Researchers from IMDEA-Nanociencia Institute and from Autonoma and Complutense Universities of Madrid (Spain) have managed to give graphene magnetic properties. The breakthrough, published in the journal *Nature Physics*, opens the door to the development of graphene-based spintronic devices, that is, devices based on the spin or rotation of the electron, and could transform the electronics industry.

Scientists were already aware that graphene, an incredible material formed of a mesh of hexagonal carbon atoms, has extraordinary

conductivity, mechanical and optical properties. Now it is possible to give it yet one more property: magnetism, implying a breakthrough in electronics.

This is revealed in the study that the Madrid Institute for Advanced Studies in Nanoscience (IMDEA-Nanociencia) and Autonoma Autonomous (UAM) and Complutense (UCM) universities of Madrid have just published in the *Nature Physics* journal. Researchers have managed to create a hybrid surface from this material that behaves as a magnet.

"In spite of the huge efforts to date of scientists all over the world, it has not been possible to add the magnetic properties required to develop graphene-based spintronics. However these results pave the way to this possibility," highlights Prof. Rodolfo Miranda, Director of IMDEA-Nanociencia.



A TCNQ molecule on the graphene mesh which in turn has been grown on a ruthenium crystal. Credit: IMDEA-Nanoscience

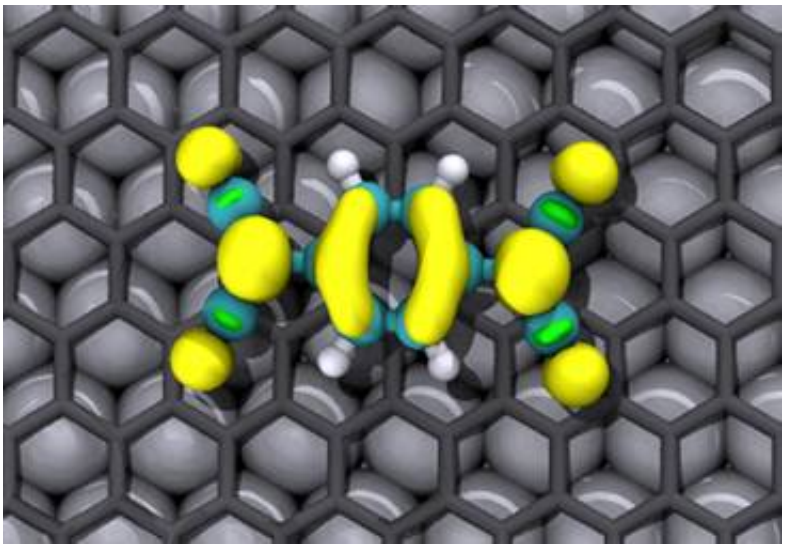
Spintronics is based on the charge of the electron, as in traditional electronics, but also on its spin, which determines its magnetic moment. A material is magnetic when most of its electrons have the same spin.

As the spin can have two values, its use adds two more states to traditional electronics. Thus, both data processing speed and quantity of data to be stored on electronic devices can be increased, with applications in fields such as telecommunications, computing, energy and biomedicine.

In order to develop a graphene-based spintronic device, the challenge was to 'magnetise' the material, and researchers from Madrid have found the way through the quantum and nanoscience world.

The technique involves growing an ultra perfect grapheme film over a ruthenium single crystal inside an ultra high vacuum chamber whereorganic molecules of tetracyano-p-quinodimethane (TCNQ) are evaporated on the grapheme surface. TCNQ is a molecule that acts as a semiconductor at very low temperatures in certain compounds.

On observing results through an scanning tunnelling microscope (STM), scientists were surprised: organic molecules had organised themselves and were regularly distributed all over the surface, interacting electronically with the graphene-ruthenium substrate.



Topographic STM images of a TCNQ monolayer on graphene/Ru. Credit: IMDEA-Nanoscience

"We have proved in experiments how the structure of the TCNQ molecules over graphene acquireslong-range magnetic order, with electrons positioned in different bands according to their spin," clarifies Prof. Amadeo L. Vázquez de Parga.

Meanwhile, his colleague Prof. Fernando Martin has conducted modelling studies that have shown that, although graphene does not interact directly with the TCNQ, it does permit a highly efficient charge transfer between the substrate and the TCNQ molecules and allows the molecules to develop long range magnetic order.

The result is a new graphene-based magnetised layer, which paves the way towards the creation of devices based on what was already considered as the material of the future, but which now may also have magnetic properties.

More information: Garnica, M. et al. Long-range magnetic order in a

purely organic 2D layer adsorbed on epitaxial grapheme. *Nature Physics*, 28 April 2013. Doi:10.1038/nphys2610.