Researchers realize a spin field-effect transistor at room temperature

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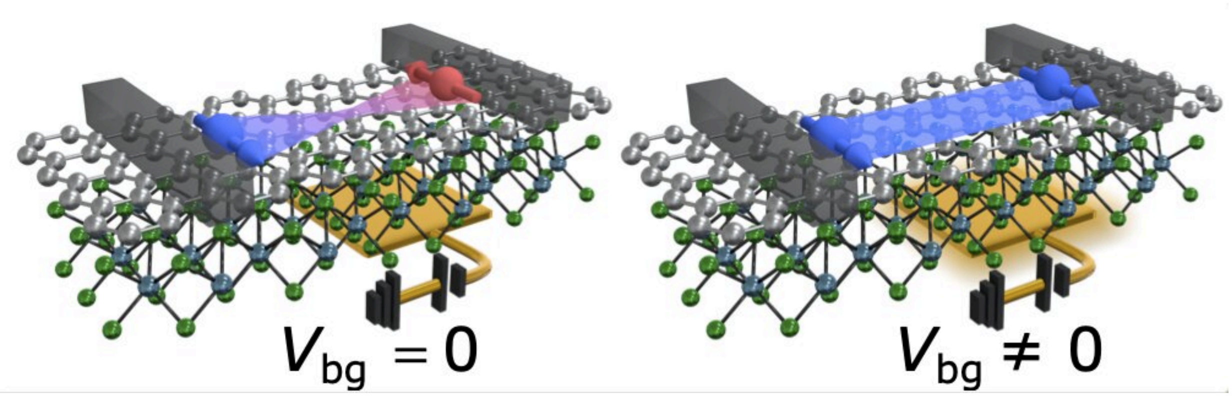

Sketch of a graphene-WSe2 spin field-effect transistor. At zero backgate voltage (Vbg), the spins reverse sign when propagating through the channel. In contrast, when the Vbg is not zero, precession is reduced and the spins do not reverse sign. Credit: Ingla-Aynes et al.

A crucial goal of spintronics research is to coherently manipulate electron spins at room temperature using electrical current. This is particularly valuable as it would enable the development of numerous devices, including spin field-effect transistors.

In experiments using conventional materials, engineers and physicists have so far only observed coherent spin precession in the ballistic regime and at very low temperatures. Two-dimensional (2D materials), however, have unique characteristics that could provide new control knobs to manipulate spin procession.

Researchers at CIC nanoGUNE BRTA in Spain and University of Regensburg in Germany have recently demonstrated spin precession at room temperature in the absence of a magnetic field in bilayer graphene. In their paper, published in *Physical Review Letters*, they used 2D materials to realize a spin field-effect transistor.

"In our group, there is a long tradition of studying spin transport in multiple materials, such as simple metals, for instance," Josep Ingla-Aynes, Franz Herling, Jaroslav Fabian, Luis E. Hueso and Felix Casanova, the researchers who carried out the study, told Phys.org via email. "Our main goal is to understand how the spin of the electron can carry information and how this degree of freedom can help to create devices with new functionalities."

Graphene is among the materials with the greatest spin relaxation lengths. Nonetheless, manipulating spins as they travel on graphene can be very challenging and has so far only been achieved using external magnetic fields, which is far from ideal for practical applications.

Recently, Ingla-Aynés and his colleagues have been examining how heterostructures based on different 2D materials, also known as van der Waals heterostructures, perform in spintronics. Van der Waals heterostructures, are a class of graphene-based 2D materials with layers that are not chemically bonded.

"We have particularly been exploring structures where a material with weak spin-orbit coupling (such as graphene) is stacked with a material with a strong spin-orbit coupling (such as WSe_2) and observing experimentally how this spin-orbit coupling is actually transferred into the graphene by proximity," the researchers explained. "More technically, by achieving a strong interaction between the layers, it is possible to imprint such an efficient spin-orbit coupling on the graphene (that acts as an effective magnetic field) that can reverse the spins without the need for applying a magnetic field and this is what we wanted to do."

Instead of using a single material, Ingla-Aynés and his colleagues used a combination of two materials with different significant properties. The first of these materials is graphene, which has a weak spin-orbit coupling and long spin relaxation length. The second is WSe_2, which has a strong and anisotropic spin-orbit coupling.

"We prepared bilayer graphene/WSe_2 van der Waals heterostructures using a dry polymer-based stacking technique," the researchers said. "Then, to promote proximity between the layers, we annealed our samples above 400 degrees Celsius. To measure spin transport, we used ferromagnetic electrodes that, combined with magnetic fields, allow us to measure in-plane and out-of-plane spins that travel across the graphene/WSe_2 channel."

Ingla-Aynés and his colleagues were able to control the spin transport times in the material they used by applying an in-plane electric field and a backgate voltage to them. This ultimately enabled the electrical control of spin precession at room temperature, without the need to apply an external magnetic field.

"This has been sought by the community for decades and exploring many different materials, yet no one was successful, until now," the researchers said. "This finding has implications for the applicability of spintronics, as our device operates like the long sought-after Datta-Das spin transistor, which has been one of the goals of spintronics since it was first proposed in 1990."

In their paper, the researchers presented the first spin field-effect transistor at room temperature using the spin precession strategy they developed. In the future, their work could pave the way towards the practical implementation of energy efficient spin-based logic.

"Our study also has a fundamental consequence, as it provides valuable information on how spin transport is affected by the spin-orbit interactions in graphene-based van der Waals heterostructures," the researchers said. "In our next studies, we plan to study multiple other combinations of 2D materials which will provide new physical effects related to the spin degree of freedom."

More information: Electrical control of Valley-Zeeman spin-orbit-coupling-induced spin precession at room temperature. *Physical Review Letters*(2021). DOI: 10.1103/PhysRevLett.127.047202

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