

Spin Hall effect in Weyl semimetal for energy-efficient information technology

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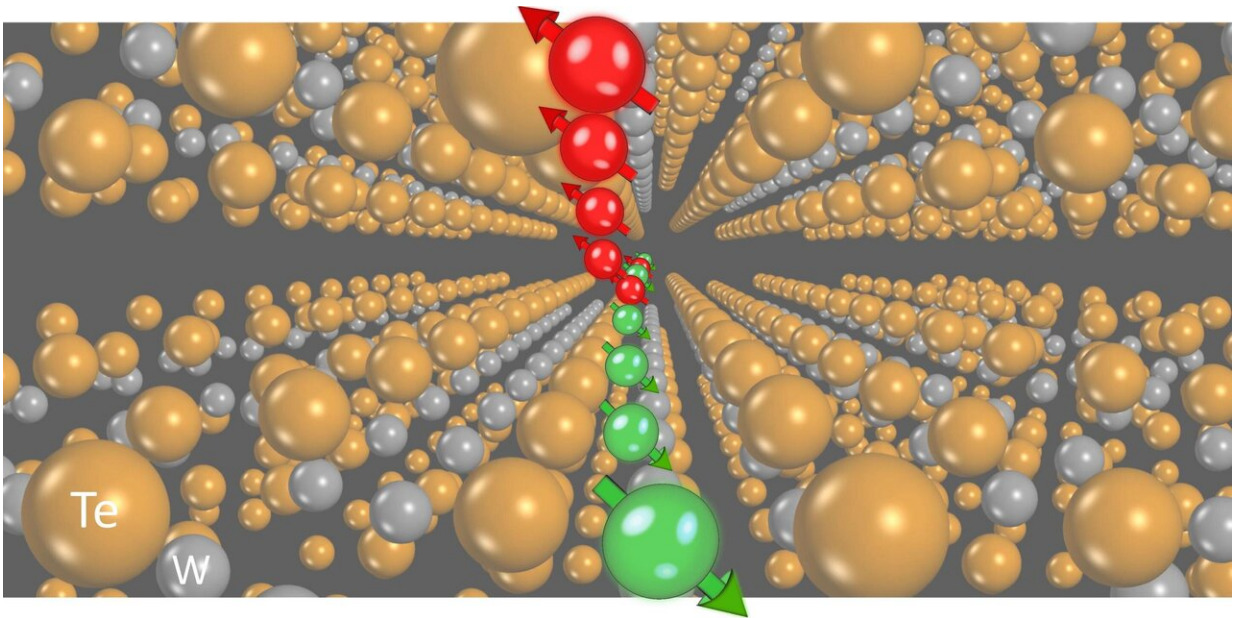


Fig 1. A schematic presentation of spin Hall effect in Weyl semimetal 1T' WTe₂, showing the separation of spin-polarized electrons (up and down spin) on the surfaces of a sample by just passing a charge current. Credit: Bing Zhao

The discovery of topological Weyl semimetals in 2017 has revealed opportunities to realize several extraordinary physical phenomena in condensed matter physics. Now, researchers at Chalmers University of Technology have demonstrated the direct electrical detection of a large spin Hall effect in this topological quantum material. Weyl semimetal

takes advantage of its strong spin-orbit coupling and novel topological spin-polarized electronic states in its band structure. These experimental findings can pave the way for the utilization of spin-orbit induced phenomena in developing next-generation of faster and energy-efficient information technology and have been published in the scientific journal *Physical Review Research*.

As our society is becoming more integrated with artificial intelligence (AI) and Internet-of-Things (IoT), the demand for low-power, nanoscale, and high-performance electronic devices have been increasing.

Spintronic devices are promising for the next generation of information technology in order to lower the power consumption while increasing the performance and non-volatile properties. Recently, the current induced magnetization switching by spin-orbit torque (SOT) using the basic spin Hall effect is identified as a vital ingredient for non-volatile spintronic memory and logic devices. The SOT mechanism is specifically useful, as a spin current can be generated by just passing a charge current in heavy metals due to the spin Hall effect, without the use of an external magnetic field. However, there are several challenges related to the limited switching speed and high-power consumption in these devices.

A group led by Saroj Dash, Associate Professor at the Quantum Device Physics Laboratory at Chalmers, used electronic devices made from novel topological quantum material, called Weyl semimetals, which is like a three-dimensional version of graphene but have a strong spin-orbit interaction and novel spin-polarized surface and bulk [electronic states](#) in their band structure.

"Weyl semimetals hold Weyl fermionic states, which are characterized by a linear dispersion of Weyl cones and Fermi arc surface states. Due to the monopole like Berry curvature in the momentum space and strong spin-orbit interaction, a unique spin texture in Weyl cones and Fermi arc surface states are predicted to exist in such novel materials," says Saroj

Dash.

The researchers at Chalmers take advantage of such novel properties to electrically detect a large charge-to-spin conversion, i.e. the spin Hall effect, in such a Weyl semimetal candidate WTe_2 at room temperature.

"The detection of the spin current generated by spin Hall effect in WTe_2 was realized by making devices of van der Waals heterostructure with graphene, taking advantage of its layered structures and long spin coherence length in graphene and spin transmission at the heterostructure interface," explains Ph.D. student Bing Zhao who is supervised by Saroj Dash at MC2, Chalmers.

Saroj Dash continues, "Our detailed spin sensitive electronic measurements, both in spin transport and Hanle precession geometries, its angle and gate dependent studies, and theoretical calculations manifest the existence of the large and gate-tunable spin Hall phenomena in WTe_2 devices at room temperature. The demonstration of an efficient charge-to-spin conversion process in Weyl semimetal candidate WTe_2 at room temperature can pave the way for its utilization in spintronics and quantum technologies."

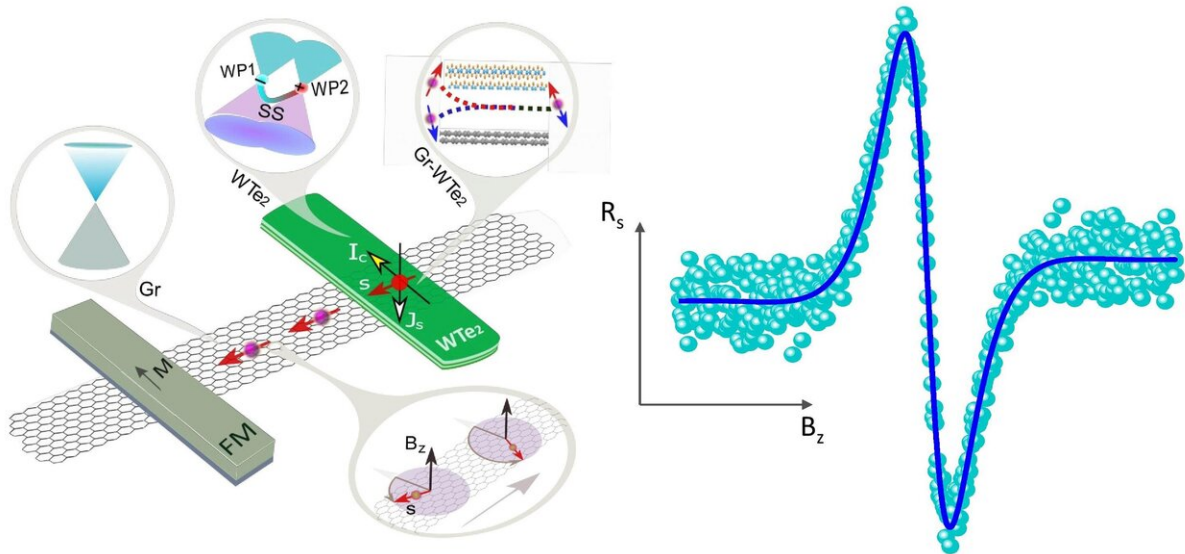


Fig 2, left part: Schematics of a measured device showing the heterostructure of WTe₂ with graphene (Gr) and a ferromagnetic contact (FM) for the measurement of spin Hall effect in WTe₂. The insets in the schematics show the band structures of the WTe₂, graphene and the structure at the interface. Fig 2, right part: The electrical resistance signal (R_s) is measured due to the spin Hall effect in WTe₂. The spin polarization can be created by passing a current in WTe₂ and precession is created by sweeping a perpendicular magnetic field, while the injected spins diffuse in the graphene channel. Credit: Bing Zhao

The advantages of topological semimetals 1T' WTe₂ is that it has a multitude of interesting properties, such as it is a van der Waals layered materials, a Weyl semimetal in bulk with a chiral anomalous (negative magnetoresistance) behavior, presence of quantum spin Hall states in monolayers, and novel spin-texture of surface and bulk electronic state providing a large current-induced spin polarization.

Saroj Dash group further aims to utilize such topological quantum materials for energy-efficient spintronic and quantum technologies by exploiting their electronic band structure through Berry curvature design

and their novel spin topologies.

"Such developments have a great potential for realizing ultra-fast and low-power electronics for the next generation of memory, logic, communication, and quantum technologies," he says.

The research work is done in a multi-national collaboration between Chalmers University of Technology, Sweden; University of Science and Technology Beijing, China; Weizmann Institute of Science, Israel; and Max Planck Institute at Dresden, Germany.

More information: Bing Zhao et al. Observation of charge to spin conversion in Weyl semimetal WTe_2 at room temperature, *Physical Review Research* (2020). [DOI: 10.1103/PhysRevResearch.2.013286](https://doi.org/10.1103/PhysRevResearch.2.013286)

Provided by Chalmers University of Technology

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