Highly efficient charge-to-spin interconversion in graphene heterostructures

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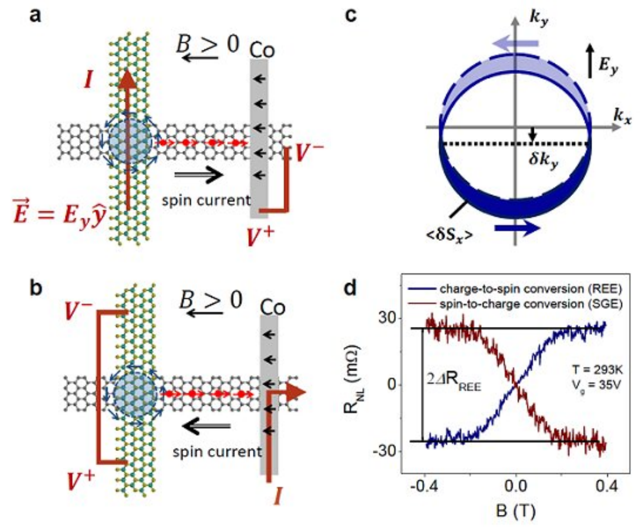

a) Direct and (b) inverse Rashba-Edelstein effect (inverse Rashba-Edelstein effect also called the spin galvanic effect; SGE) mechanism and measurement setup, (c) Fermi surface of the Rashba state with electric field applied, and (d) the comparison of the direct and inverse Rashba Edelstein effect resistance measured. Credit: The Korea Advanced Institute of Science and Technology (KAIST)

KAIST physicists described a route to design the energy-efficient generation, manipulation and detection of spin currents using nonmagnetic two-dimensional materials. The research team, led by Professor Sungjae Cho, observed highly efficient charge-to-spin interconversion via the gate-tunable Rashba-Edelstein effect (REE) in graphene heterostructures.

This research paves the way for the application of graphene as an active spintronic component for generating, controlling, and detecting spin current without ferromagnetic electrodes or magnetic fields.

Graphene is a promising spintronic component owing to its long spin diffusion length. However, its small spin-orbit coupling limits the potential of graphene in spintronic applications since graphene cannot be used to generate, control, or detect spin current.

"We successfully increased the spin-orbit coupling of graphene by stacking graphene on top of 2H-TaS_2, which is one of the transition metal dichalcogenide materials with the largest spin-orbit coupling. Graphene now can be used to generate, control, and detect spin current," Professor Cho said.

The Rashba-Edelstein effect is a physical mechanism that enables charge current-to-spin current interconversion by spin-dependent band structure induced by the Rashba effect, a momentum-dependent splitting of spin bands in low-dimensional condensed matter systems.

Professor Cho's group demonstrated the gate-tunable Rashba-Edelstein effect in a multilayer graphene for the first time. The Rahsba-Edelstein effect allows the two-dimensional conduction electrons of graphene to be magnetized by an applied charge current and form a spin current. Furthermore, as the Fermi level of graphene, tuned by gate voltage, moves from the valence to conduction band, the spin current generated by graphene reversed its spin direction.

This spin reversal is useful in the design of low-power-consumption transistors utilizing spins in that it provides the carrier 'on' state with spin up holes (or spin down electrons) and the 'off' state with zero net spin polarization at so called 'charge neutrality point' where numbers of electrons and holes are equal.

"Our work is the first demonstration of charge-to-spin interconversion in a metallic TMD (transition-metal dichalcogenide) and graphene heterostructure with a spin polarization state controlled by a gate. We expect that the all-electrical spin-switching effect and the reversal of non-equilibrium spin polarization by the application of gate voltage is applicable for the energy-efficient generation and manipulation of spin currents using nonmagnetic van der Waals materials," explained Professor Cho.

More information: Lijun Li et al, Gate-Tunable Reversible Rashba–Edelstein Effect in a Few-Layer Graphene/2H-Ta_S2 Heterostructure at Room Temperature, *ACS Nano* (2020). DOI: 10.1021/acsnano.0c01037

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