Spin Communication on 2D Quantum Material Devices and Integrated Circuits

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In modern society, where information and communication technology is an indispensable part of our everyday life, and Artificial Intelligence and Internet-of-Things become increasingly used, non-volatile spin based memory in computing technology is highly demanded. Recently discovered atomically thin two-dimensional (2D) quantum materials and their van der Waals heterostructures represent a novel platform to realize such spin-based phenomena and device applications. Followed by the successful use of graphene, a vast plethora of 2D materials with complementary spintronic properties have been discovered, such as 2D insulators, semiconductors, magnets, and topological materials. We used large-area CVD graphene as a robust spin interconnect (1,2), spin multiplexing (3) and finally demonstrated spin logic gate operation by all electrical means. To enhance the tunnel spin polarized of ferromagnets, we employed CVD h-BN tunnel barriers to achieve very large tunnel spin polarization (4). In order to control the spin polarization in graphene, we engineered 2D material heterostructures by combining the best of different materials in one ultimate unit and realized strong proximity induced spin-orbit coupling (5) and magnetism (6) in graphene. Recently, we detected current-induced spin-polarization in topological insulators (7) and Weyl semimetals (8) and their graphene-based heterostructures (9). Finally, a room temperature spin-valve devices could be realized using van der Waals itinerant ferromagnet in heterostructures with graphene (10). These findings open a novel platform for electrical creation and gate-control of spin polarization and provide new opportunities for all-2D heterostructure spintronic devices and integrated spin circuits.

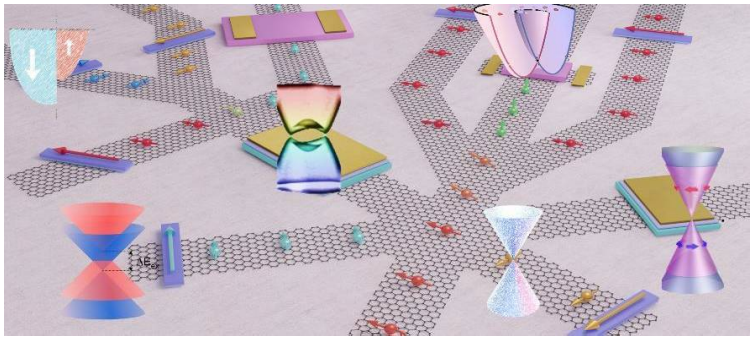

Figure 1: Schematics of 2D quantum materials van der Waals heterostructure for creation and control of spin current in the graphene circuit.

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