Intraparticle entanglement for enhanced spin-orbit torque in graphene

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Spin-orbit torque (SOT) magnetic memories represent an emerging technology that leverages spin-orbit coupling (SOC) within metals to convert charge current into a spin source further harnessed to manipulate a magnetic state, offering new possibilities regarding energy efficiency and miniaturization of devices [1]. Simultaneously, graphene-based van der Waals heterostructures offer highly tunable spin-orbit and magnetic properties via proximity effects [2, 3], along with graphene's unique Dirac fermion characteristics, allowing to tailor the current-to-spin conversion process for optimising spin-orbit torque magnetisation reversal.

In this work we elucidate the SOT mechanisms in magnetic graphene-based van der Waals heterostructures, revealing a crossover from semi-classical to fully quantum mechanical physics driven by spin-pseudospin entanglement. We begin developing a semi-classical theory for the ubiquitous damping-like torque, who's origin in 2D materials is discussed due to the absence of vertical bulk transport. By these means, we tune graphene's proximity-induced spin-orbit properties to surpass the semi-classical SOT efficiency activating quantum mechanisms driven by spin-pseudospin entanglement [4, 5]. Overall, our work reveals novel charge-to-spin conversion mechanisms to enhance SOT devices.

References

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