量子物理学･ナノサイエンス第 207 回セミナー

Giant charge-to-spin conversion in atomically-thin van der Waals heterostructures

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概　要

In the past decade, graphene has emerged as a strong contender for next-generation spintronic devices due to its long spin diffusion lengths and gate tunable spin transport at room temperature [1]. However, the lack of a band gap and its weak spin–orbit coupling (SOC) pose major limitations for injection and control of spin currents. The recent capability to assemble 2D crystals into layered heterostructures offers a realistic prospect of overcoming the weaknesses of graphene [2]. When graphene is paired with semiconducting dichalcogenide monolayers [MX2 (M = Mo, W; X = S, Se)] its band structure develops rich spin–orbital textures with helical (in-plane) and out-of-plane components. The proximity-induced SOC enhancement experienced by the Dirac electrons at the graphene layer was confirmed by several groups [3-4], providing an exciting new direction towards realising novel types of spin devices from ultra-thin, high-mobility and gate-tuneable van der Waals (VDW) heterostructures.

In this talk, I will present our latest results on graphene with interface-induced SOC [5-6]. We find that graphene/MX2 generally supports *current-driven spin polarization*; a relativistic transport phenomenon known as inverse spin galvanic effect (or Edelstein effect). Owing to the characteristic spin winding of interfacial states in graphene heterostructures, the Edelstein effect shows striking similarities to charge-to-spin conversion (CSC) generated by *ideal* topologically protected surfaces. A detailed study shows that the CSC efficiency is little sensitive to the scattering strength of random impurities and can be as great as 30% at room temperature (for typical SOC energy scales smaller than *k*B*T*).

The robust inverse spin galvanic effect in a VDW heterostructure promises unique advantages for low-power spintronic applications, including the tuning of spin polarization by a gate voltage. Implications of our quantum transport theory [4-6] beyond standard VDW materials will be discussed. For example, ferromagnetic 2D layered (VDW) materials have been recently discovered [7], which could be used to generate strong interfacial exchange interactions and corresponding non-equilibrium spin phenomena.

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