

Topological spintronic functionalities in magnetic Weyl semimetals

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Magnetic Weyl semimetals have emerged as a promising platform in which topology, magnetism, and electron correlations intertwine to generate novel quantum functionalities. In this talk, I will discuss our recent theoretical study of the compensated ferrimagnetic Weyl semimetal Ti_2MnAl . To describe real-space magnetic phenomena, we construct a minimal effective Hamiltonian based on first-principles electronic structures. The model parameters are optimized using automatic differentiation, enabling an accurate yet physically transparent description of the low-energy electronic structure.

The resulting four-band model captures the spin-gapless Weyl semimetallic state and provides insight into the microscopic origin of Weyl points in the inverse-Heusler structure. In particular, it clarifies how crystal symmetry and hybridization generate Weyl nodes even in the absence of spin-orbit coupling, demonstrating the utility of physically transparent effective models for understanding and designing topological quantum materials.

As an example of the functionalities accessible through the effective model, I will discuss current-induced spin-transfer torques acting on magnetic domain walls. Our calculations indicate a dominant non-adiabatic torque, in contrast to conventional ferromagnetic metals where the adiabatic contribution is typically dominant. Since non-adiabatic torques can overcome the intrinsic pinning problem that has long limited current-driven domain-wall devices, these results suggest a route toward efficient magnetic manipulation based on topological electronic states. More broadly, this work illustrates how effective-model design can bridge first-principles materials theory and emergent quantum functionalities, providing a concrete example of quantum-material design based on topology and electronic-structure engineering.

[1] Y. Furusho, K. Kobayashi, K. Nomura, unpublished