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Linear response in topological semimetals

Yan Sun
Max Planck Institute for Chemical Physics of Solids, Germany

Topological insulators have been expected to be ideal spintronic materials due to the spin currents carried by the surface states with spin-momentum locking. However, the bulk doping problem still remains to be an obstacle that hinders such application. While this kind of problem is naturally avoided in topological semimetals due to the large anomalous Hall and spin Hall effect originated from the intrinsic bulk band structures. We have found that the strong spin Hall effect in TaAs is mainly dominated from the Weyl points and nodal-line-like Fermi surface, which implying a strong interplay between the topological band structure and Berry curvature in topological semimetals. With this guiding principle, we have successfully understood the strong spin Hall effect in IrO_2 and found the nodal line band structures in it. Generalizing this principle to time reversal symmetry breaking system, we have predicted strong anomalous Hall effect in magnetic Weyl semimetal $CO_3 Sn_2S_2$, which was verified by our experimental collaborators. Owing to the low charge carrier density and large Berry curvature from the nodal line band structure, the anomalous Hall conductivity and anomalous Hall angle experimentally reach up to 1130 S/cm and 20% respectively. Further, the anomalous Hall effect can even exist with zero net moments in the absence of the symmetry operation that changes the sign of Berry curvature. And the anomalous Hall effect can be strongly enhanced by the special band structures of Weyl points and nodal lines. Following this guiding direction, we have predicted a strong anomalous Hall effect in the compensated ferrimagnetic Weyl semimetal Ti_2MnAl with vanishing magnetic net moments. Our work is helpful for the comprehensive understanding of the linear response effect in topological materials and their future applications.

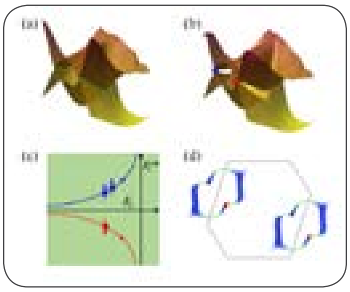

Figure 1: Topological band structure induced anomalous Hall and spin Hall effect. a-b: Schematic of nodal line and Weyl semimetals. c: Schematic of anomalous Hall and spin Hall effect. d: Berry curvature induced from the nodal line and Weyl points

Recent Publications:

1. Yan Sun, Yang Zhang, Claudia Felser, and Binghai Yan (2016) Phy. Rew. Lett. 117:146403.
2. Yan Sun, Yang Zhang, Chao Xing Liu, Claudia Felser and Binghai Yan (2017) Phy. Rew. B 95:235104.
3. E Liu, Y Sun, L Müchler, A Sun, L Jiao, J Kroder, V Süß, H Borrmann, W Wang, W Schnelle, S Wirth, S T B Goennenwein and C Felser (2017) arXiv:1712.06722.
4. Wujun Shi, Lukas Muechler, Kaustuv Manna, Yang Zhang, Klaus Koepernik, Roberto Car, Jeroen van den Brink, Claudia Felser and Yan Sun (2018) Phy. Rew. B 97:060406(R)
5. Jonathan Noky, Claudia Felser and Yan Sun (2018) arXiv:1803.03439

Biography

Yan Sun has his research interests mainly focus on the theatrical study of topological materials. Through the analysis of the relationship between Berry curvature and band structure, we revealed strong spin Hall effect (SHE) and anomalous Hall effect (AHE) in WSMs and nodal line semimetals. The generalized relation between SHE/AHE and topological band structure suggests a way of the application of topological semimetals in spintronics. Fundamentally, the intrinsic AHE just depends on the symmetry of Berry curvature, but not the magnitude of net magnetic moments. Guiding by this principle, we have deeply studied two ideal strong AHE systems with vanishing net magnetic moment, non-collinear antiferromagnets (Mn3Ge) and compensated ferrimagnetic WSM (Ti_2MnAl)

yansunning@gmail.com