Band Theory of the Anomalous Hall Effect in Spintronic and Graphene-like Materials

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Anomalous Hall effect (AHE) refers to the transverse charge current in magnetic solids generated by an applied electric field. The AHE is an archetypal spin-related transport phenomenon and thus has received renewed interest recently [1], although discovered long ago in 1881 by Hall. In this talk, we will first give an introduction to band theoretical approaches to the issues in the field of AHE, especially, Berry phase theory and relativistic band structure methods for studying intrinsic Hall effects [2-4]. This will be followed by a review on our recent relativistic band theoretical studies on the AHE in isoelectronic $L1_0$ $FePd_{1-x}Pt_x$ alloys [5], Co-based Heusler compounds [6] and proximity-induced ferromagnetic Pt metal. In particular, our theoretical calculations revealed that by increasing the Pt composition x, the intrinsic AHE in the $FePd_{1-x}Pt_x$ alloys can be significantly increased and that this chemical composition tuning of the AHE is afforded by the stronger spin-orbit coupling on the Pd/Pt site when the lighter Pd atoms are replaced by the heavier Pt atoms [5]. Furthermore, we predicted that the charge Hall current in Heusler compounds Co_2XZ (X=Cr and Mn; Z=Al, Si, Ga, Ge, In and Sn), except Co_2MnGa, would be almost fully spin polarized even though Co_2MnAl, Co_2MnGa, Co_2MnIn and Co_2MnSn do not have a half-metallic band structure. This suggests that these Heusler compounds have valuable applications in spintronics such as spin valves as well as magnetoresistive and spin-torque-driven nanodevices [6]. We will also show that a significant anomalous Hall conductivity can be found in nonmagnetic Pt metal, which exhibits a giant spin Hall effect [3], when placed next to a ferromagnet, thus lending support to the possible contamination of the pure spin current phenomena such as spin Seebeck effect measured by Pt [7]. Finally, we will demonstrate possible topological phase transitions among the quantum anomalous Hall phases in graphene-like monolayers under the influence of the exchange field [8].

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