Topological Hall effect due to skyrmion in canted antiferromagnets

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We study theoretically the topological Hall effect (THE) due to skyrmions in a two-dimensional (2D) noncollinear antiferromagnet (AFM). It is well known that THE in ferromagnetic materials is described by the Berry phase [1] acquired by the wave-function when an electron spin follows adiabatically the local magnetic texture. In this picture the influence of skyrmions is characterized by an emergent magnetic field which leads to the spin-dependent force acting on the itinerant electrons.

Such an adiabatic approximation fails in collinear (and thus also in noncollinear) AFM materials, since an electron cannot adjust its spin momentum to the spin texture of AFM due to alternating magnetic moments of the two sublattices. In this work we use the approach that allows for a description of the quasi-adiabatic dynamics of electron spin in canted AFMs with slowly varying component of the spin texture due to antiferromagnetic skyrmions. To do this, we first diagonalize the Hamiltonian of the canted AFM and derive the eigenvalues and eigenstates of the system. The magnetization due to canting of the sublattice moments is shown to give rise to a splitting of the conduction and valance electron bands. Then, we calculate the contribution of each sublattice to the emerging magnetic field, and obtain the total effective emergent magnetic field. As in ferromagnets, the effective emergent magnetic field gives rise to the spin-dependent force which leads to an adiabatic contribution to the electron spin dynamics. Considering such a picture of quasi-adiabaticity and using the semi-classical Boltzmann approach, we obtain the diffusion equation for spin accumulation in the presence of spin-flip scattering [5]. Effective emergent magnetic field acts as a source for spin accumulation and spin-flip scattering. The latter, however, originates mainly from extrinsic spin-dependent scatterings. As a result, we find the corresponding THE conductivity/resistivity and analyze in detail its dependence on total magnetization, spin-flip scattering, and skyrmion size.

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