Anomalous Hall effect in collinear antiferromagnets

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Anomalous Hall effect (AHE), where electrons in magnetic materials drift in the transverse direction to the applied electric field, has a long history of research rooting back to the 19th century. It is typically observed in ferromagnets but also in magnets with non-trivial spin structures, sometimes called as the topological Hall effect [1]; coplanar spin structures, without a net moment, can also host the AHE under certain conditions [2]. Here we show that AHE appears even in collinear-type antiferromagnetic states, realized in organic compounds [3] and in perovskite transition metal oxides [4] as examples.

First, we theoretically investigate a typical organic correlated electron system κ-BEDT-TTF_2X; we study an effective Hubbard model on the κ-type lattice including the spin-orbit coupling [Fig.1], and calculate the conductivity tensor $\sigma_{\mu\nu}$ in its antiferromagnetic state. Indeed, AHE appears in the metallic state, and its finite frequency counterpart, the magneto-optic Kerr effect, is activated in the insulating state. Next, we apply this mechanism to other systems, namely, compounds with the perovskite-type structure, by studying a multi-orbital Hubbard model for transition metal oxides; AHE can appear depending on the pattern of spin ordering. In both cases, the collinear antiferromagnetism is essential for the AHE, but not the small ferromagnetic component due to canting. We further provide an intuitive understanding in terms of the effective magnetic field felt by the up/down spin electrons [Fig.2], leading to the microscopic Lorentz force and resulting in their drift motion.

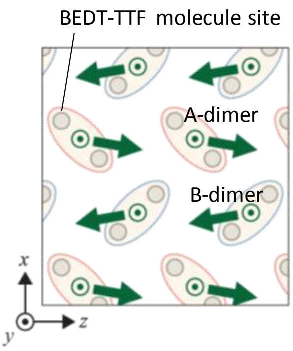

Fig. 1 Collinear-type antiferromagnetic spin structure in κ-BEDT-TTF_2X. Antiparallel spin directions appear in the two kinds of dimers, while a small canting exists.

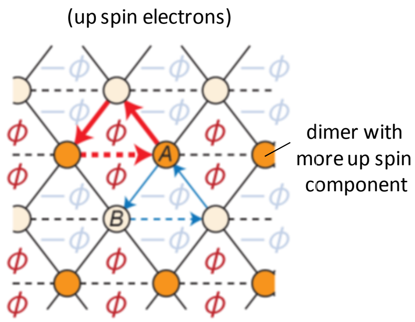

Fig. 2 Effective magnetic field felt by the spin polarized electrons. The up spins existing more on the *A* dimers feel the magnetic flux ϕ when moving along the red arrows.

References

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