Spin current generation in organic antiferromagnets

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The spin Hall effect [1,2], which arises from the relativistic spin-orbit coupling, enables us to generate and detect spin currents in inorganic materials, taking advantage of their constituent heavy atoms. In contrast, organic materials consisting of molecules with light elements have been believed to be unsuited for spin current generation. Here we show that a class of organic antiferromagnets with checker-plate type molecular arrangements, such as a typical strongly correlated system κ-(BEDT-TTF)$_2$X [3], can serve as a spin current generator [Fig. 1(a)]. The mechanism relies on a peculiar spin splitting of the energy bands and a real space anisotropy of the electron or magnon transfers, as shown in Figs. 1(b) and 1(c), owing to another type of "spin-orbit coupling". This is activated by glide symmetry breaking of the molecular arrangement due to the antiferromagnetic (AFM) ordering, i.e., an essentially non-relativistic effect. Based on the multi-site Hubbard model [4] and the effective Heisenberg model, we analyze the spin current transport properties by Kubo formula [5]. When an electric field is applied to the doped AFM metallic state, the up- and down-spin electrons drift to opposite ways due to the anisotropic transfer integrals, resulting in a spin current perpendicular to the electric field. In the AFM insulating phase, a similar spin current generation occurs by replacing the carriers and the external field to magnons and a thermal gradient. We find that the spin current conductivities are given by symmetric tensors, in stark contrast to the spin Hall and spin Nernst effects described by antisymmetric tensors. Our findings provide another route to generate a spin current and open a new field of spintronics based on organic magnets.

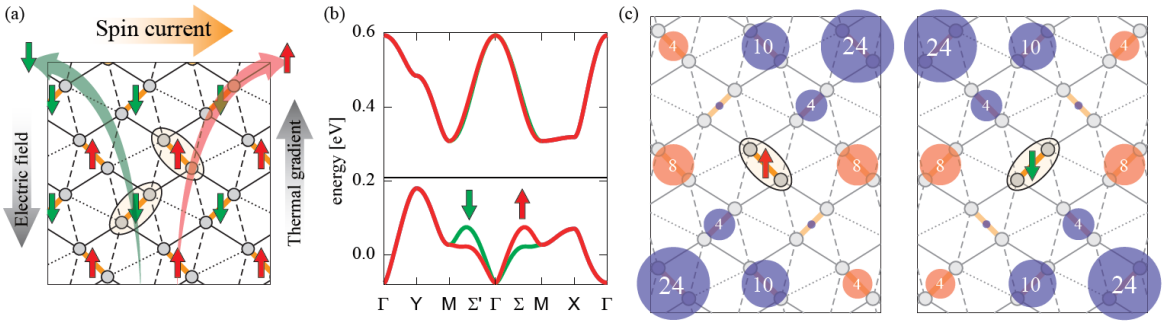

Figure 1 (a) Schematic illustration of the spin current generation in the AFM state. Circles and ellipses represent BEDT-TTF molecules and dimers. (b) Band structures of up and down spin electrons. (c) Anisotropic electron transfers of up and down spins between the central and surrounding dimers. The areas of red (blue) shaded circles represent the amplitudes of positive (negative) transfers in unit of meV.

References

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