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Thermal Hall effect by phonons in a rare-earth garnet and a spin liquid system

A heat current perpendicularly flowing to a magnetic field induces a transverse temperature gradient. This is the thermal Hall effect (THE). It was reported in the paramagnetic insulator, terbium-gallium-garnet (TGG) at low temperatures [1,2]. Since the TGG has a large band gap of several eV and then only phonons can carry the heat, it is called "phonon Hall effect (PHE)". However, phonon does not have charge nor spin. Hence, an origin of the PHE is not trivial. The PHE is reported in another non-magnetic insulator, $Ba_3CuSb_2O_9$ (BCSO), which is in the quantum spin liquid state with the spin gap of about 50 K [3,4]. Hence, the heat transport in temperatures lower than 50 K must be dominated by phonons instead of spins. So that the THE in the BCSO is also the PHE.
In the former half of my talk, I will discuss that the PHE in TGG originates from a resonant scattering of phonons by Tb^{3+} ions with total angular momentum J=6 [5]. The crystal electric field (CEF) is expanded with respect to lattice strains. Thanks to the large J, a modulation of the CEF is a function of J and lattice strains. This is the origin of spin-phonon coupling in the TGG. On the other hand, however, the origin of PHE in BCSO is still uncovered, since the BCSO does not contains any ion with large J and is composed of only spin 1/2, which is isotropic in the charge degree of freedom. In the latter half, I will discuss that an "orphan spin" is the key of the PHE in the BCSO. The orphan spin is an additional Cu^{2+} spin located in the center of Cu^{2+} hexagonal. It is said that there are about 5%–16% of the Cu^{2+} orphan spins in BCSO, and the thermal conductivity in low temperatures is dominated by scattering at orphan spins [1]. We find that an elongation of Cu^{2+} hexagonal with an orphan spin leads to a charge redistribution with a quadrupole symmetry. The quadrupole electric field can couple to lattice strains. This must be the origin of spin-phonon coupling in the BCSO. Since the Cu^{2+} hexagonal is a spin-1/2 cluster, a spin-flip scattering of phonon is also possible. In short, the extended cluster multipole of Cu^{2+} hexagonal with an orphan spin must be the origin of PHE in the BCSO.

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References

[1] C. Strohm, G. L. J. A. Rikken, and P. Wyder, Phys. Rev. Lett. 95, 155901 (2005).
[2] A. V. Inyushkin and A. N. Taldenkov, JETP Lett. 86, 379 (2007).
[3] K. Sugii, M. Shimozawa, D. Watanabe, Y. Suzuki, M. Halim, M. Kimata, Y. Matsumoto, S. Nakatsuji, and M. Yamashita, Phys. Rev. Lett. 118, 145902 (2017).
[4] J. A. Quilliam, F. Bert, E. Kermarrec, C. Payen, C. Guillot-Deudon, P. Bonville, C. Baines, H. Luetkens, and P. Mendels, Phys. Rev. Lett. 109, 117203 (2012).
[5] M. Mori, A. Spencer-Smith, O. P. Sushkov, and S. Maekawa, Phys. Rev. Lett. 113, 265901 (2014).

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