MoP124

Surface Magnetotransport due to Helical Edge State in the Organic Dirac Fermion System at the Quantum Limit

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It is known that the ν=0 quantum Hall (QH) state of undoped graphene is a spin-unpolarized insulating phase (QH insulator). In this paper, in contrast, we show that the spin-polarized ν=0 QH state with gapless edge mode (QH ferromagnet) is realized in another 2D massless Dirac fermion system, an organic conductor α-(BEDT-TTF)$_2$I$_3$ [1]. We present experimental evidences of QH ferromagnet by detecting surface transport due to its helical edge state.

In sufficiently strong magnetic field, the 2D massless Dirac fermion system with charge neutrality shows the ν=0 QH effect resulting from the breaking of four-fold (spin and valley) degeneracy of the n=0 Landau level. In the case that the spin splitting is dominant, the ν=0 QH state is the QH ferromagnetic phase with a gapless helical edge state, which consists of a pair of n=0 QH edge states with opposite spin and chirality (Fig.1(a)) [2]. In the multilayer system, the helical edge states contribute to the surface interlayer transport causing the saturation of interlayer resistance. The finite in-plane magnetic field breaks the interlayer coupling causing rapid increase of saturation resistance (Fig.2(a)).

Based on the above picture, we have performed two kinds of experiments on the saturation of interlayer resistance to confirm the existence of the helical edge state in α-(BEDT-TTF)$_2$I$_3$. (1) The saturated value was not scaled by sample sectional area (Fig.1(b)). This means that the saturation does not originate from bulk transport. (2) The saturated value became minimum when the magnetic field was parallel to the stacking direction. as expected (Fig.2(b)). These results strongly suggest the realization of the helical surface state.

In addition, we also report several experiments on the in-plane transport. The results suggests that the edge channel transport is dominant but dissipative. It is consistent with the fact that the helical edge state is not topologically protected because of the lack of time reversal symmetry.

[1] T. Osada, J. Phys. Soc. Jpn. **80**, 033708 (2011); *ibid.* **77**, 084711 (2008).
[2] T. Osada, Phys. Status Solidi B **249**, 962 (2012).

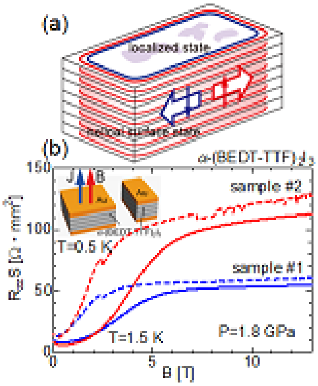

Fig. 1: (a) Concept of the helical surface state. (b) Saturation of interlayer resistance due to surface transport not scaled by sectional area.

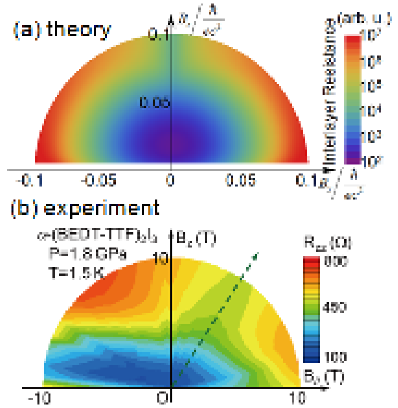

Fig. 2: Dependence of interlayer resistance on field orientation and strength. (a) theory, (b) experiment.