Helical Edge State in Organic Dirac Fermion System: Quantum Hall Ferromagnet vs. Quantum Hall Insulator

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Introduction

A layered organic conductor α-(BEDT-TTF)$_2$I$_3$ under high pressure (>1.5GPa) is a multilayer Dirac fermion system, in which 2D massless Dirac fermion layers stack, and the Fermi level is fixed at the Dirac point. Undoped 2D massless Dirac fermion systems, such as undoped monolayer graphene, shows the ν=0 quantum Hall (QH) effect at sufficiently high magnetic fields resulting from the spontaneous symmetry breaking (SSB) of four-fold degeneracy (spin and valley) of the singular n=0 Landau level. Generally, as the ν=0 QH state, two kinds of electronic phases are possible; the QH ferromagnetic phase with the metallic helical edge state and the QH insulating state. In graphene, the high-field ground state (the ν=0 QH state) is believed to be the QH insulator.

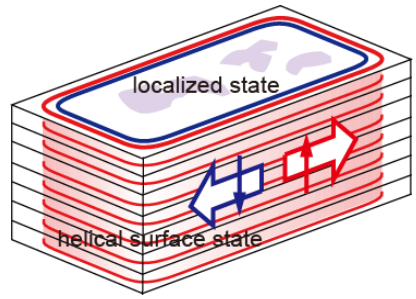

Fig.1 Helical edge state in the multilayer QH ferromagnet.

In contrast, the high-field ground state of α-(BEDT-TTF)$_2$I$_3$ is considered to be the QH ferromagnet, because this compound shows surface magnetotransport due to the helical edge state [1]. However, recently, Kanoda et al. observed the fine structures of the NMR lineshape at higher fields (B>15T), which suggests the appearance of some real-space structure accompanied by the QH insulator. Their result shows the possibility that the ground state changes in higher field region. The purpose of the present experiment is to check this possibility by detecting the change of surface transport.

Experimental

We have performed DC magnetotransport measurements on an organic conductor α-(BEDT-TTF)$_2$I$_3$ under pressure using the 31T/50mm bore magnet (Cell 9) , the top-loading ^{3}He cryostat (System B), and our piston-cylinder-type pressure cell generating P=1.8GPa.

Results and Discussion

As shown in Fig.2, the interlayer resistance shows rapid increase reflecting the activated bulk transport at low fields, and it switches to weak increase at higher fields up to 31T. This saturation is caused by the surface transport via helical edge state. We can see no anomaly in the saturation region, especially around 15T. This result means that the QH ferromagnetic state survives up to 31T with the helical edge state.

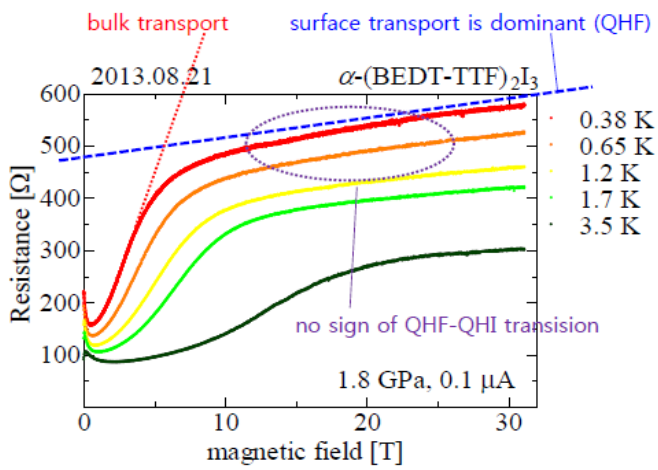

Fig.2 High-field interlayer resistance of α-(BEDT-TTF)$_2$I$_3$. The saturation crystals with the same thickness.

Conclusions

The QH ferromagnetic state is stable as a ground state of the organic Dirac fermion system α-(BEDT-TTF)$_2$I$_3$ up to 31T. There is no transition from QH ferromagnet to QH insulator suggested by NMR measurements.

Acknowledgements

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References

[1] Osada, T., Phys. Status Solidi B **249**, 962–966 (2012).