Quantized surface transport in topological semimetal films

Masaki Uchida [1,2]
[1] Department of Applied Physics and Quantum-Phase Electronics Center (QPEC),
the University of Tokyo, Tokyo 113-8656, Japan
[2] PRESTO, Japan Science and Technology Agency (JST), Tokyo 102-0076, Japan

Topological materials, which have nontrivial electronic structures in the momentum space, have recently attracted burgeoning research interest especially in terms of novel magnetotransport phenomena and emergent spintronic functions. In contrast to topological insulators, topological semimetals host three-dimensional Dirac or Weyl cones in the bulk state, besides the helical surface state due to the bulk band inversion. Exotic quantum magnetotransport proposed for such topological semimetals, such as chiral anomaly and Weyl orbit, are derived from characteristic Landau levels formed in the bulk Dirac dispersions, called a chiral zero mode.

Cd_3As_2 is an ideal material for exploring exotic magnetotransport and spintronic functions proposed for topological semimetals. In addition to its high electron mobility and long mean free path, its growth orientation is different from the rotational axis connecting the two Dirac points. This allows us to detect possible orbital motions in topological semimetal surfaces, which include the Weyl orbit, looping the two surface (top and bottom) arcs through a called bulk chiral mode. We have successfully developed a growth technique realizing high mobility Cd_3As_2 films with excellent surface flatness, and first observed quantum Hall states induced by quantum confinement [1)]. Related film techniques such as electric gating and chemical doping also enable systematic transport studies of the topological semimetal films, with controlling the bulk dimensionality [2)], Fermi energy [3)], and band topology [3)].

More recently, by fabricating three-dimensional Cd_3As_2 films with controlled thickness above 85 nm, we have found surface quantum oscillations and their evolution into quantized states [4)]. This is confirmed by distinct differences in oscillation frequnecy, field angle dependence, and temperature change from the bulk ones. On the other hand, we have also revealed essential contribution of bulk carriers to the quantized surface transport and resultant changes in quantum Hall degeneracy depending on the bulk occupation. We discuss possible magnetic orbits realized in the quantized surface transport.

Reference

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