Quantum Hall effect and zero plateau in bulk HgTe

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The quantum Hall effect (QHE) is one of the most striking phenomena in the physics of two-dimensional systems. The main requirements for the QHE formation are a sufficiently low level of disorder and the two-dimensionality of the system. Recently, resistance quantization in the three-dimensional gapless semimetal ZrTe5 was demonstrated [1]. In this work, the transport response of a 1000 nm thick mercury telluride film equipped with a gate in quantizing magnetic fields is investigated. Such films are a bulk semimetal with an inverted band structure and topological electrons near the surface. An accumulation layer filled with two-dimensional electrons or holes is formed near the gate. In a magnetic field of 10 Tesla, the system is found to exhibit a distinct gate-driven QHE with deep minima in ρ_{xx} and quantized plateaus in ρ_{xy}. At first glance, the observed behavior is similar to the behavior of other electron-hole systems, but the system under study has some unique features. First, it was found that 2D carriers in the accumulation layer hybridize and form QHE, while bulk carriers are localized and serve as a charge reservoir. As the magnetic field increases, a charge transition occurs from bulk carriers to two-dimensional carriers with a simultaneous shift in the point of charge neutrality. This, in turn, leads to an unusual scaling of the QHE around the first electron plateau. Secondly, but more interesting, at the charge neutral point, a maximum ρ_{xx} of a relatively small value (of the order of h/e^2) is observed, accompanied by a non-usual "weak" zero plateau of ρ_{xy}. The study of non-local transport response under these conditions reveals the edge nature of transport. Phenomenologically, the detected behavior resembles the quantum spin Hall effect, but retains the quasi-ballistic regime at macroscopic (hundreds of microns) distances. Such transport can be formed by edge channels of electrons and holes propagating in opposite directions, in which mutual scattering is suppressed.

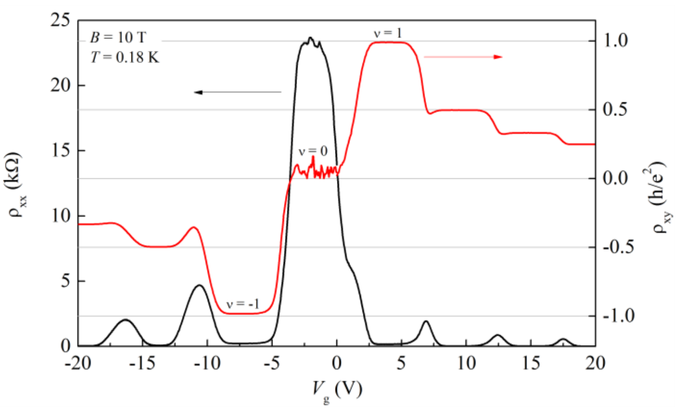

Fig.1 Gate dependences of longitudinal ρ_{xx} (black, axis on the left) and Hall ρ_{xy} (red, axis on the right), measured in a magnetic field B = 10 T and at a temperature T = 0.2 K

[1] F. Tang, Y. Reт et al., Nature 569, 537 (2019).