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Abstract

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„Preparation of nanostructures and investigation of transport properties in two-dimensional topological insulators"

The topic of topological insulators has become very popular in last few years. Attractiveness of the field is caused by unique properties of those systems. For example, the spin-momentum locking may open applications in spintronics.

In case of two-dimensional topological insulators theory predicts that one-dimensional dissipationless conducting edge states are formed. It means that conductance occurs through spin-polarized edge channels, while the rest of the sample remains electrically insulating. Unfortunatelly, it turned out that experimental observation of quantized edge conductance turned out to be extremely difficult. Up to now, the measured channel resistancea are at best only approximately equal to the quantized values and only for short edge channels.

The main goal of this work was systematic investigation of individual edge channel resistances in microstructures made of mercury telluride quantum wells and determining their dependence on channel length. The thickness of the quantum wells was chosen to be 8 nm which corresponds to the inverted band structure, necessary to observe Quantum Spin Hall Effect (QSHE).

In order to minimize interdiffusion of mercury atoms during microprocessing of initial material, new low-temperature method of microstructurization was developed. The method was used to prepare multiprobe microstructures equipped with top gate electrodes which serve to tune Fermi energy with respect to the bands, and enabling full depletion of the sample bulk. Under these conditions, the conductance occurs exclusively through edge channels. The geometries of the structures were chosen to define edge channel lengths in the range between 1 to 20 μm. Microstructures with global gates (electrodes that cover whole area of Hall bar) enabled determination of resistances of all channel segments surrounding the structure. Comparison of resistances of the segments with different lengths shows the increase with the distance between subsequent contacts. However, there are strong resistance fluctuations for short channels which suggest that it is governed by discrete and randomly distributed scattering centers. This confirms the model of breaking the topological protection by trapping the carriers by charge puddles occurring due to fluctuations of charge concentration. Because the trapped carriers loose their spin memory, they may be backscattered.

To complete experimental part of the work, classical transport simulation in investigated microstructures was performed. The results allow to recognize the relation between the sample geometry and expected four-probe resistances. The data shows, that even in the case of precise quantization of the edge channel conductance, the measured resistance is increased due to geometrical contribution of the contact regions.

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