Influence of the Microstructure Shape on Edge Channel Resistance in HgTe/(Hg,Cd)Te Quantum Wells

M. Majewicz[1], J. Wróbel[1,2], G. Grabecki[1] , P. Nowicki[1], Ł. Szyller[2] , N. N. Mikhailov[3], S. A. Dvoretskii[3], W. Knap[4], F. Teppe[4] and T. Dietl[1,5,6]

[1] *Institute of Physics, Polish Academy of Sciences, Warszawa, Poland*
[2] *Faculty of Mathematics and Natural Sciences, Rzeszów University, Rzeszów, Poland*
[3] *Institute of Semiconductor Physics, Russian Academy of Sciences, Novosibirsk, Russia*
[4] *Laboratoire Charles Coulomb, University of Montpellier & CNRS, Montpellier, France*
[5] *International Research Centre MagTop, Warszawa, Poland*
[6] *WPI-Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Sendai, Japan*

Quantum Spin Hall effect (QSHE) in HgTe quantum wells (QWs) has been theoretically predicted and experimentally verified more than 10 years ago [1]. However, in contrast to the QHE in a magnetic field, the quantization accuracy is poor and the resistance magnitude usually exceeds the predicted value $\frac{h}{2e^2}$ indicating the existence of scattering between edge helical channels [2]. Several mechanisms breaking topological protection have been proposed [3] but not yet conclusively verified. We show here that sample geometry determines also the magnitude of experimentally measured edge channel resistance.

We present simulations of charge transport in 2D topological insulators in comparison to experimental data obtained by us for HgTe QWs. We use both classical simulations of the current distribution in leads and edge channels (finite element method) and the quantum approach taking into account disorder that mimic charge puddles characteristic for quantum structures of narrow band gap semiconductors [4]. In either of the two approaches the obtained values of resistance are affected by the number of probes and overall geometry of the sample, in agreement with the experimental data. The quantum approach shows that for smaller (*quasi*-ballistic) structures resistance gets modified by changing the relative orientation of source and drain probes. For this reason, resistance values obtained for the bulk or edge conduction regime can be suppressed or enhanced. Classical simulations, which are more suitable for larger (diffusive) structures, indicates that even without any additional backscattering inside edge channels four-probe resistance can be enhanced.

In summary, our calculations compared to the experimental data demonstrate that observed deviations from quantized values of conductance are caused not only by scattering between helical channels but also by specific geometries of disordered samples. By using our simulations we determined more realistically the resistances of individual edge channels as a function of the channel length.

The research was partially supported by National Center of Science in Poland (Decision No. 2015/17/N/ST3/02314), by grants RBFR 15-52-16017 NTSIL_a and 15-52-16008 NTSIL_a. Partial support by LIA TERAMIR is appreciated.

References

[1] B. A. Bernevig et al., Science **314**, 1757 (2006); M. König et al., Science **318**, 766 (2007).

[2] G. M. Gusev et al., Phys. Rev. B **88**, 195305 (2013); G. Grabecki et al., Phys. Rev. B **88**, 165309 (2013).

[3] J. Väyrynen et al., Phys. Rev. B **90**, 115309 (2014); J. Wang et al., Phys. Rev. Lett. **118**, 046801 (2017).

[4] M. Papaj et al., Phys. Rev. B **93**, 195305 (2016); see, https://kwant-project.org/.