Magnetotransport of InAs/GaSb Quantum Wells Near Topological to Semiconducting Band Transition

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Introduction

The quantum Spin Hall Insulator (QSHI) is a two-dimensional version of a new class of quantum matter which is characterized by topological order, whose unique properties have recently triggered much interest and excitement in the condensed matter community. Based on previous work using the NHMFL facility, we have shown that the inverted semiconductor, InAs/GaSb, is a QSHI [1], and the helical edge properties have been demonstrated in superconductor-contacted InAs/GaSb [2]. Besides 1D massless Dirac fermions at the sample edge in the inverted regime, this system also hosts 2D massive Dirac fermions at the critical point where the band structure changes from inverted to normal. Here we tune the band structure from inverted towards normal regime via the front and back gate bias, and study magnetotransport under a perpendicular or in-plane magnetic field.

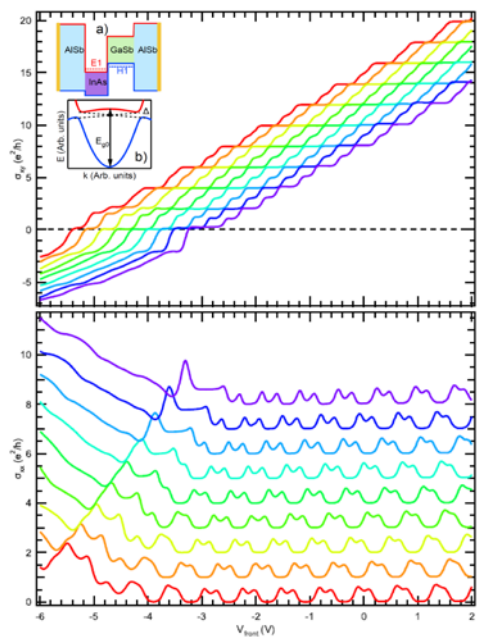

Figure 1. Hall (σ_{xy}) and longitudinal conductivity(σ_{xx}) measured near the critical point, where bands change from inverted to normal alignment. The inset shows a) band structure of InAs/GaSb quantum well, and b) an inverted band alignment.

Experimental

Experiments were performed in SCM1 system with a base temperature of 20 mK and a magnetic field up to 18 T. Magnetic field axis with respect to sample normal was adjusted using an *in situ* sample rotator. Magnetotransport data were taken using a standard low frequency lock-in technique.

Results and Discussion

In **Figure 1** we show the Hall and longitudinal conductivities σ_{xy} and σ_{xx} versus front gate bias, at different values of back gate bias, at a fixed perpendicular field at B = 4T. As V_{front} is tuned across the hybridization gap, σ_{xy} changes sign indicating a transition from the electron to hole dominated regime. On the electron side, clear plateaus in σ_{xy} are observed, while concomitantly σ_{xx} goes to zero. For V_{back} = 8V (red trace) the sample is in an inverted regime. Note the apparent zero plateau in σ_{xy}, as expected for a typical semiconducting band.

As V_{back} is tuned to more negative values, the overlap between E1 and H1 bands, hence the band inversion, is reduced. For example at V_{back}= - 4V (middle blue trace), all lower index quantum Hall plateaus are developed on the electron side, including ν = 1, indicating a smaller anti-crossing density, and hence only a small overlap between E1 and H1 bands. Interestingly, as V_{back} is tuned to even more negative values, the zero conductance plateau starts to liftoff, suggesting a transition from an ordinary fermion type quantum Hall effect to a chiral fermion quantum Hall effect, as expected when the critical point where E1 = H1 is approached.

Conclusions

We have demonstrated that the band structure in InAs/GaSb system can be tuned from the deeply inverted to the critical regime. Preliminary data suggest the existence of chiral fermions near the transition point between topological to semiconductor band .

Acknowledgements

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References

[1] Knez, I. *et al.*, Phys. Rev. Lett. **109**, 186603 (2012). [2] Knez, I. *et al.*, Phys. Rev. Lett. **107**, 136603 (2012).