NATIONAL HIGH MAGNETIC FIELD LABORATORY
2018 ANNUAL RESEARCH REPORT

Search for Interaction Effects in Dual-Gated Topological Insulators in the Quantum Hall Regime

Chong, S.K. (U. of Utah, Physics); Sparks, T.D. (U. of Utah, MSE); and Deshpande, V.V. (U. of Utah, Physics)

Introduction

3D topological insulators (TIs) exhibit novel properties arising from their Dirac surfaces, which have been extensively studied to probe exotic quantum states. Our research is focused on studying interaction physics between and within high-quality TI surfaces.

Experimental

We have grown high-quality bulk-insulating $BiSbTeSe_2$ (BSTS) TI using a melting-Bridgman method [1], and realized fabrication of van der Waals (vdW) heterostructures in graphite/hBN/BSTS device configuration [2]. The effect of inter-surface coupling on quantum Hall (QH) plateaus, as a function of TI thickness, was thoroughly studied in our MagLab visit in April 2018 and is reported in [3]. In our visit to NHMFL end of 2018, furthering development from our previous visit, we explored the quantum capacitance (C_q) of BSTS vdW devices. C_q is a direct measure of density of states and a powerful tool for detection of novel gapped states.

Results and Discussion

Fig. 1(a) and (b) compare the R_{xx} and C_q of a thin BSTS vdW device as function of magnetic field (B) and gate voltage (V_{tg}). The vanishing of R_{xx} and developing of symmetric dips in C_q about the Dirac point indicate Landau level (LL) formation. The LLs in individual surfaces can be studied by performing dual gating to separately control chemical potentials of each surface, as presented in Fig. 1(c) and (d). The well-defined C_q dips in the lowest LLs (with largest LL gaps) correspond with QH plateaus in Hall conductivity (σ_{xy}). The inverse compressibility (dμ/dn) and chemical potential (μ) as a function of charge density (n) can be calculated from measured C_q to extract the LL gaps. This data is summarized in [4] to be submitted shortly, and to be presented at the 2019 APS March Meeting. Further advancing our device fabrication, we have fabricated vdW heterostructures with ultrathin BSTS, where surfaces can be tuned from strongly-coupled to hybridized (Fig. 1(f) and (g)) and gapped states can arise from interaction between surfaces. These phenomena will be interesting to explore at the MagLab.

Conclusions

Strong interactions are observed between TI surfaces in the quantum Hall regime at 18 T as they are brought closer together (in thin samples) and may give rise to interesting gapped states.

Acknowledgements

The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida.

References

[1] Han, K.B., *et al.*, Scientific Reports, **8**:17290 (2018).
[2] Chong, S.K., *et al.*, Nano Letters, **18** (12), 8047–8053 (2018).
[3] Chong, S.K., *et al.*, Physical Review Letters (under review)
[4] Chong, S.K., *et al.*, (to be submitted)

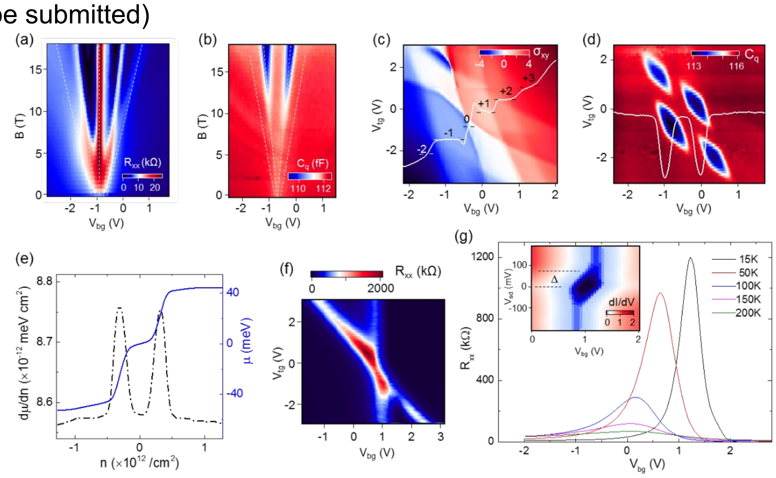

Fig.1 Color maps of (a) R_{xx} and (b) C_q as a function of B and V_{bg} for BSTS. Maps of (c) σ_{xy} and (d) C_q as a function of dual-gate voltages at 18T. (e) dμ/dn and μ as a function of n. (f) Dual-gated R_{xx} of an ultrathin BSTS. (g) R_{xx} of the ultrathin BSTS versus V_{bg} at different temperature. (inset) dI/dV as a function of V_{bias} and V_{bg}.