SAND2016-0041R

Quantum Oscillations in an Interfacial 2D Electron Gas

Zhang, Bingpo (Zhejiang Univ.); Lu, Ping (Sandia National Labs); Liu, Henan (Univ. of North Carolina, Charlotte); Jiao, Lin (Zhejiang U); Ye, Zhenyu (Zhejiang U); Jaime, Marcelo (NHMFL); Balakirev, Fedor F. (NHMFL); Yuan, Huiqiu (Zhejiang U); Wu, Huizhen (Zhejiang U); Pan, Wei (SNL); and Zhang, Yong (UNCC)

Introduction

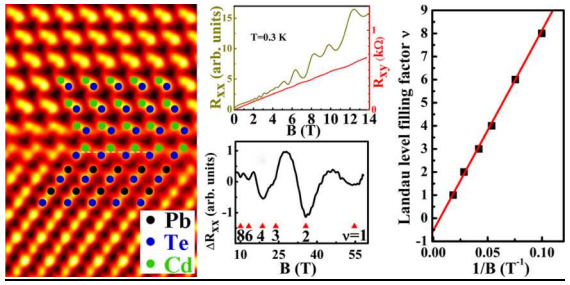
Recently, it has been predicted that topological crystalline insulators (TCIs) may exist in SnTe and $Pb_{1-x}Sn_xTe$ thin films [1]. To date, most studies on TCIs were carried out either in bulk crystals or thin films, and no research activity has been explored in heterostructures. We present here the results on electronic transport properties of the 2D electron gas (2DEG) realized at the interfaces of PbTe/ CdTe (111) heterostructures. Evidence of topological state in this interfacial 2DEG was observed.

Experimental

Electronic measurements of the transport properties were performed in a 3He cryostat with a 15T superconducting magnet. Ultra-high magnetic field measurements were carried out at the Pulsed Field Facility of the National High Magnetic Field Laboratory at Los Alamos National Lab. Our samples were wired up with a Van der Pauw configuration. Four gold wires were pasted on the four Au/Cu film electrodes deposited on the CdTe surface by silver paint.

Results and Discussion

Quantum oscillations are observed in the 2DEG system at the interface of novel heterostructures, PbTe/CdTe (111), with nearly identical lattice parameters (a_{PbTe} = 0.6462 nm, a_{CdTe} = 0.648 nm) but very different lattice structures (PbTe: rock salt, CdTe: zinc blende). The 2DEG formation mechanism, a mismatch in the bonding configurations of the valence electrons at the interface, is uniquely different from the other known 2DEG systems. The aberration-corrected scanning transmission electron microscope (AC-STEM) characterization indicates an abrupt interface without cation inter-diffusion due to a large miscibility gap between the two constituent materials. Electronic transport measurements under magnetic field up to 60 T, with the observation of Landau level filling factor ν = 1, unambiguously reveal a p Berry phase, suggesting the Dirac Fermion nature of the 2DEG at the heterostructure interface, and the PbTe/CdTe heterostructure being a new candidate for 2D topological crystalline insulators.



Left: Aberration-corrected scanning transmission electron microscope (AC-STEM) image of a CdTe/PbTe heterostructure, showing the arrangement of atoms near the interface.
Center top: Magneto-resistance R_{xx} and Hall resistance R_{xy} measured in a superconducting magnet. Quantum oscillations are observed at high magnetic fields.
Center bottom: R_{xx}, measured to 60T in a pulsed magnet, after a smooth background is subtracted. The triangles mark the positions of the Landau level filling factors ν = 1, 2, 4, 6, and 8.
Right: Landau level fan diagram.

Conclusions

Our results suggest PbTe/CdTe heterostructures being new candidates for topological crystalline insulators.

Acknowledgements

The work at Zhejiang University was supported by National Key Basic Research Program of China and Natural Science Foundation of China. The work at UNC-Charlotte was supported by Bissell Distinguished Professorship. The work at Sandia was supported by the Department of Energy, the Office of Basic Energy Science, Division of Material Science and Technology. Sandia National Laboratories is a multiprogram laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. The work at NHMFL-LANL was performed under the auspices of the National Science Foundation, Department of Energy and State of Florida. We thank Ross McDonald and Jon Bettes for helpful discussions.

References

[1] Liu, J. W.; Hsieh, T. H.; Wei, P.; Duan, W. H.; Moodera, J.; Fu, L. Nat. Mater. **13**, 178−183 (2014).