Quantum Oscillations of Surface States in $Bi_{0.91}Sb_{0.09}$ (111)

Dongxia Qu and George F. Chapline (Lawrence Livermore National Lab)

Introduction

Three dimensional topological insulator Bi_xSb_{1-x} has a complex surface band structure with chiral spin textures, as revealed by angle-resolved photoemission spectroscopy (ARPES) and scanning tunneling microscope (STM) experiments. Finding the transport information of these surface states is a key factor to evaluate whether or not they are suitable for future device applications. In recent experiments, we tuned the Fermi level into the bulk band gap in $Bi_{1-x}Sb_x$, which have three times higher bulk resistivity compared to Bi_2Te_3[1]. From the weak-field Hall signal and high-field magnetoresistance measurements, we show that the Bi_xSb_{1-x} may have a fairly high surface mobility μ ~ 85,000 cm^2/V s, almost 8x higher than that of Bi_2Te_3[2].

Experimental

The temperature and field orientation dependent experiments were performed on single crystal $Bi_{0.91}Sb_{0.09}$ (111) in the Magnet Lab using the 31-Tesla DC magnet.

Results and Discussion

We report the detection of quantum oscillations in the resistivity tensors at a tilting magnetic field up to 31 T, which is within the ultraquantum limit regime of bulk carriers. Previous studies on $Bi_{0.91}Sb_{0.09}$ also identified that the bulk quantum limit is attained by a field $H \leq 3$ T. As shown in Fig. 1 (a), the raw trace of Hall resistivity, ρ_{yx}, displays well resolved oscillations, sitting on top of a strongly nonlinear background for fields exceeding 10 T. As T is raised from 0.3 to 21 K, the oscillation amplitudes decrease quickly, accompanied by the decrease of the Hall anomaly [inset of Fig. 1 (a)]. Figs. 1 (b) and 1 (c) plot the derivative $d\rho_{xx}/dH$ and $d\rho_{yx}/dH$ versus the perpendicular field component $H_\perp = H\cos\theta$ along the trigonal axis [111] (θ is the tilting field relative to the trigonal axis), for samples S3 and S1, respectively. For both samples, the most pronounced dip (marked by dashed lines) depends only on $H_\perp$, and they are absent for $55° \leq \theta \leq 90°$. This distinct feature is a direct evidence of the surface origin of the high-H quantum oscillations.

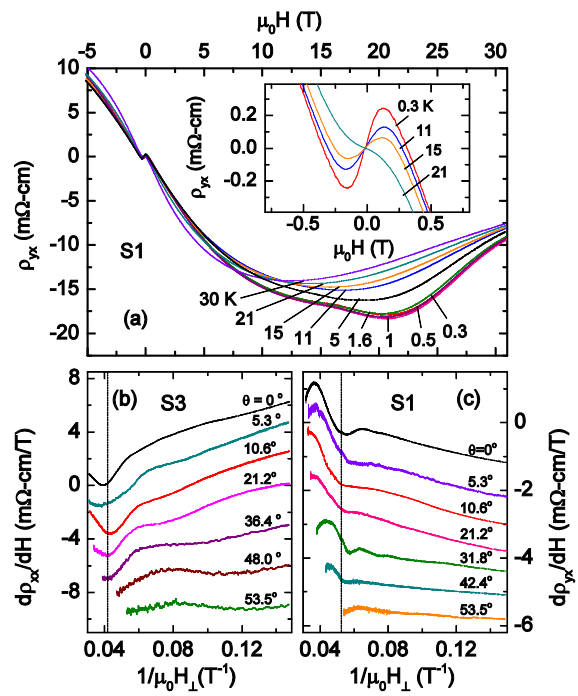

Figure 1 (a) The trace of Hall resistivity ρ_{yx} vs H in sample S1 measured at temperature T between 0.3 and 30 K. The inset shows the amplitude of weak-field Hall anomaly decreases rapidly as T is raised from 0.3 to 21 K. (b) The resistivity derivative $d\rho_{xx}/dH$ vs $1/H_\perp$ with $H_\perp = H\cos\theta$ at selected tilt angles θ in sample S3. (c) The Hall resistivity derivative $d\rho_{yx}/dH$ vs $1/H_\perp$ at various θ in sample S1.

Conclusions

This work provides the first transport identification of the surface states in topological insulator $Bi_{0.91}Sb_{0.09}$ (111) from Shubnikov-de Haas oscillations. Our observation is consistent with the recent STM studies on $Bi_{1-x}Sb_x$, demonstrating that surface states in $Bi_{1-x}Sb_x$ intend to tolerate disorder resulted from random alloying.

Acknowledgements

The research was supported by LDRD (12-ERD-027) from Lawrence Livermore National Laboratory. We thank D. Graf for technical help.

References

[1] D.-X. Qu, Y. S. Hor, and R. J. Cava, Phys. Rev. Lett, **109**, 246602 (2012).
[2] D.-X. Qu, *et al.*, in preparation, (2012).