Hallmarks of the Weyl semimetal: magnetotransport properties in Sb-doped Bi

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Weyl fermions, massless chiral fermions in quantum field theory, are also realized in solid state physics; they appear in certain crystals without time reversal or inversion symmetry called Weyl (semi)metals [1]. The electronic band structure of a Weyl metal contains Weyl nodes, pairs of singular points separated in momentum space, at nondegenerate band touch. Spin and momentum are locked except at nodes, and thus chirality is well defined. Due to the existence of a pair of chiral Fermi surfaces, the electromagnetic properties of Weyl metals are described by axion electrodynamics given by the topological $\boldsymbol{E}\cdot\boldsymbol{B}$ term.

Transport properties of Weyl metals, particularly their magnetoelectric and magnetothermal conductivities are expected to show distinct behaviors of topological origin. Recent theoretical investigations of electrical (σ) and thermal (κ) conductivities of Weyl metals, based on Boltzmann transport theory with Berry curvature and chiral anomaly terms, predict that σ and κ are enhanced proportional to B^2 when the electrical or thermal current direction and the B direction are parallel [2, 3]. In Weyl metals, Ohm's law in electrical conductivity is expected to break down and the Wiedemann-Franz (WF) law would also fail when a magnetic field is applied. Ohm's law indicates a linear I-V relationship while the WF law states that $\kappa/\sigma T = L_0$, where L_0 is the Lorentz number depending on universal constants only, and holds generally in ordinary metals.

We have grown single crystals of bismuth antimony alloy, $Bi_{1-x}Sb_x$, which becomes a 3D Dirac metal with time reversal symmetry at x ~ 0.03. When a magnetic field is applied, time reversal symmetry is broken and the Dirac metal becomes a Weyl metal. We have measured σ and κ without and with B up to 9 T. We indeed observed the breakdown of Ohm's law and the magnetic enhancements of σ and κ when B is in parallel with electrical and thermal currents. We discuss the details of the measurements and compare the experimental data with theoretical predictions. In particular, the status of Ohm's law and WF law in the Weyl state is discussed.

References

[1] D. Shin,Y. Lee, M. Sasaki,Y. H. Jeong, F. Weickert, J. B. Betts, H.-J. Kim,6, K.-S. Kim, and J. Kim, Nature Materials submitted
[2] S. Murakami, New J. Phys. 9 (2007), 356
[3] D. T. Son and B. Z. Spivak, Phys. Rev. B 88 (2013), 104412
[4] Ki-Seok Kim, Phys. Rev. B 90 (2014), 121108(R)