Anisotropic Giant Magnetoresistance in $NbSb_2$

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Introduction

We report large transverse magnetoreistance MR (~ $1.3 \cdot 10^5$ % in 2 K and 9 T, and ~ $4.3 \cdot 10^6$ % in 0.4 K and 32 T field, without saturation) and field-induced metal-semiconductor-like transition, in $NbSb_2$ single crystal [1]. MR is significantly suppressed but the metal-semiconductor-like transition persists when the current is along the *ac*-plane. The sign reversal of the Hall resistivity and Seebeck coefficient in the field, plus the electronic structure reveal the coexistence of a small number of holes with very high mobility and a large number of electrons with low mobility. The large MR is attributed to the change of the Fermi surface (FS) induced by the magnetic field which is related to the Dirac-like point, in addition to orbital MR expected for high mobility metals.

Experimental

Single crystals were grown from Sb flux. High-field Shubnikov de Haas (SdH) oscillations were collected at the NHMFL Tallahassee. Electrical and thermal transport at low fields was measured in PPMS-9. First principle calculation were performed using WIEN 2k with general gradient approximation for exchange-correlation potential.

Results and Discussion

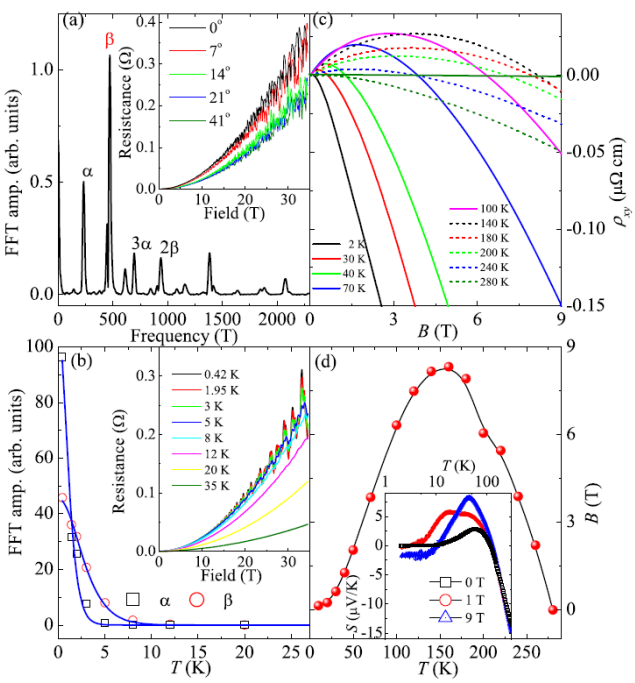

Figure 1: (a) The FFT spectrum of the quantum oscillation with typical SdH oscillation in inset. (b) The temperature dependence of quantum oscillation amplitude for two oscillation frequencies. (c) Hall resistivity ρ_{xy}. (d) Magnetic fields that correspond to ρ_{xy} sign change and Seebeck coefficient at different T and B.

SdH oscillations [Fig. 1(a,b)] show that MR is not saturated even in 35 T whereas the fast Fourier transform (FFT) indicates two Fermi pockets of different size. The Hall resistivity and Seebeck coefficient [Fig. 1(c,d)] suggest multiband transport, in agreement with calculations.

It was proposed that the magnetic field will induce the breaking of the time reversal invariance and will rearrange the Dirac Fermi surface in a Dirac semimetal [2]. This plus the high mobility of the Dirac carriers could induce large MR. The electronic structure of $NbSb_2$ hosts features similar to a Dirac semimetal. The hole pocket has very high mobility when compared to the electron pockets and the effective mass of carriers is very small, as revealed by the quantum oscillation and Hall resistivity. The DOS at the Fermi level is small, and the conduction band nearly touches the valence band at two points at the Fermi level in the band structure whereas the spin-orbit coupling opens a very small gap [1]. The magnetic field could rearrange the FS so that FS either splits into two disjoint Weyl pockets or two concentric spheres. If the Fermi level locates between the two disjoint Weyl pockets, the system will change to a semiconductor, contributing to MR.

Conclusions

Large magnetoresistance and the magnetic field induced semiconducting gap are observed in $NbSb_2$ single crystal. The Hall resistivity and the first principle electronic structure calculation indicate the coexistence of a small number of holes with high mobility and a large number of electrons with small mobility. The observed effects are consistent with the rearrangement of the Fermi pocket with high mobility induced by magnetic field.

Acknowledgements

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References

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[2] S. M. Young et al., Phys. Rev. Lett. 108, 140405 (2012).