High Field Studies of Magnetic Weyl Semimetals

Suzuki, T., Ye, L., Zhu, J., Kurumaji, T. and Checkelsky, J.G. (MIT, Physics)

Introduction

Emergent Weyl fermions in condensed matter, which appear at the crossing points of linearly dispersing non-degenerate bands in momentum space, show various distinct properties originating from the inherent chirality such as presence of surface Fermi arc state and magnetotransport potentially related to the chiral anomaly [1]. For Weyl semimetals that host the Weyl fermions, it is required that either the inversion or time-reversal symmetry is broken. The former type including TaAs [2] and WTe_2 [3] are well studied by spectroscopy and transport techniques, while less for the latter candidates. Among them, *R*AlGe (*R* is rare-earth) offers a unique opportunity to investigate the effect of time-reversal symmetry breaking on the properties. This series of compounds have the inversion symmetry broken crystal structure (space group $I4_1md$) and possess Weyl nodes near the Fermi level which is observed by recent angle resolved photoemission spectroscopy for the La compound. In addition, it is predicted for the magnetic counterparts CeAlGe and PrAlGe that the magnetic ordering of rare-earth moments breaks the time-reversal symmetry of the system while possessing the nodal band structure [5]. The detailed studies of fermiology and magnetotransport in *R*AlGe would provide the insight into the role of magnetic ordering in topological semimetal, the effect of time-reversal symmetry breaking and beyond. Here, we explore the fermiology of the nonmagnetic LaAlGe with torque magnetometry technique.

Experimental

Single crystals of *R*AlGe (*R* is rare-earth) were grown by a flux method. Transport and torque magnetometry measurements were performed at the NHMFL DC facility in a ^{3}He cryostat with a rotation probe in Cell 8 and Cell 9. The torque data taken in Cell 8 is shown here.

Results and Discussion

Figure 1 shows the torque response of LaAlGe at various field directions at temperature T = 0.6 K. Clear de Haas-van Alphen (dHvA) oscillations were observed above $\mu_0 H$ ~15 T with $\boldsymbol{H}$ || [001]. The observed frequency ≈140 T (corresponding to Fermi wave vector $k_F \approx 0.065$ Å^{-1} under the assumption of isotropic Fermi surface in the tetragonal (001) plane) is consistent with one of the Fermi surfaces observed by ARPES study [4]. The frequency increases systematically by tilting H to the [100] direction, indicating the anisotropic Fermi surface as expected from the tetragonal crystal structure. We obtained the effective mass of $0.13m_0$ (m_0 is the electron mass) from the temperature dependence. Further studies of fermiology of magnetic CeAlGe and PrAlGe, where we have observed unusual magnetotransport and anomalous Hall Effect, and the detailed comparison to the observation here would reveal the coupling of the magnetic ordering and topological electronic state, which is the subject of future study.

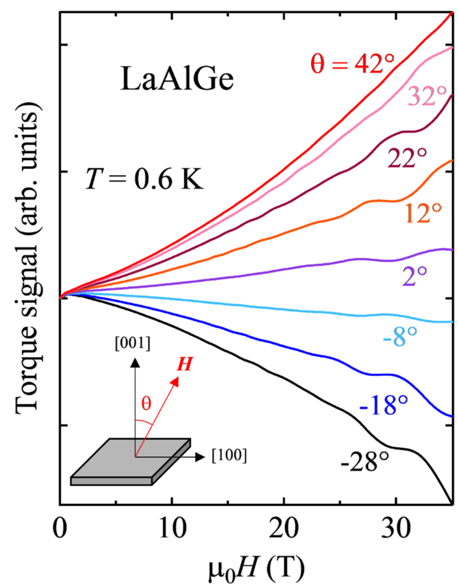

Fig.1 Torque signal of LaAlGe at T = 0.6 K at various field direction θ. The inset is a schematic showing the field direction and crystallographic axes.

Conclusions

We have measured the Fermi surface of Weyl semimetal LaAlGe by high magnetic field torque magnetometry. Further studies in magnetic *R*AlGe would provide the insight into the coupling of magnetism and topology in magnetic Weyl semimetals.

Acknowledgements

A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida.

References

[1] Armitage, N.P., *et al.*, Rev. Mod. Phys, **90**, 015001 (2018).
[2] Weng, H., *et al.*, Phys. Rev. X **5**, 011029 (2015).
[3] Wu, Y., *et al.*, Phys. Rev. B **94**, 121113(R) (2016).
[4] Xu, S.-Y., *et al.*, Sci. Adv. **3**, e1603266 (2017).
[5] Chang, G., *et al.*, Phys. Rev. B **97**, 041104(R) (2018).