Investigations on the effect of reduced dimensions on the insulating states of SmB_6

Park, J., Rosa, P., Chan, M., Harrison, N. (Los Alamos National Laboratory)

Introduction

SmB_6 is one of the first topological Kondo insulators reported which forms a unique surface conducting band structure within the Kondo gap[1],[2]. Although several experiments (*e.g.* de Haas-van Alphen effect, non-local transport, Hall effect measurement) showed compelling evidence for the existence of the surface states, the bulk properties of the insulating states are still not properly characterized[3],[4]. Recent theoretical prediction shows that due to crystalline defects, Weyl metal states can also coexist in SmB_6, which raises a general question how these electronic states will interact with the surface states[5].

Experimental

We measured AC electrical transport on a fabricated SmB_6 single crystal via focused ion beam milling (FIB). We used the sorption pump type He3 system for temperature control installed in a 20 T superconducting magnet in the Los Alamos National Laboratory. We note that the results described below are incomplete due to a magnet power supply module failure in the 20 T system which only provided magnetic field up to 12.5 T and the 65 T short pulse magnet (LANL) time which has not been scheduled yet.

Results and Discussion

We have successfully fabricated a sample capable of measuring the effect of dimensional reduction in a single sample using the FIB (sample photo in the inset of Fig.1(a)). We found a quasi-logarithmic cross-sectional area dependence on the inverse resistivity ratio. We have also found that the activation behavior of the Kondo gap depends significantly on the cross-sectional area of the sample. By measuring the magnetoresistance(MR), we extracted the behavior of the dominant carriers(Fig.1(b)). We found that there is a crossover between a negative MR to a positive MR at a given cross section, in which for our case was ~ 1100 um^2. Combining these results, we estimate that the surface states of SmB_6 become dominant at significantly reduced dimensions. We anticipate to measure the Fermi surface of the surface states at pulsed magnetic field in the following measurements and also determine the mobility of the carrier via measuring the Hall effect.

Acknowledgements

The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida. Authors acknowledge UU DOE BES Support for "Science of 100 Tesla"

References

[1] Dzero, M., *et al*., Annual Review of Condensed Matter Physics **7**, 249 (2016).
[2] Dzero, M., *et al*., Physical Review Letters **104**, 106408 (2010).
[3] Li, G., *et al*., Science **346**, 6214, 1208 (2014).
[4] Tan, B.S., *et al*., Science, aaa7974 (2015).
[5] Harrison, N., Physcial Review Letters **121**, 026602 (2018).
[6] Li, Y., *et al*., Science Advances **4**, 1, eaap8294 (2018)
[7] Shahrokhvand, M., *et al*., Phys. Rev. B **96**, 205125 (2017).

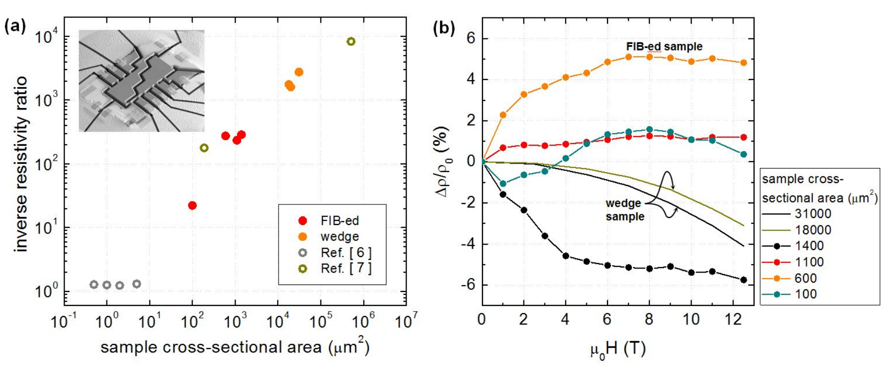

Fig.1 Results (a) A plot of inverse resistivity ratio verses the sample's cross-sectional area. Samples measured in the National High Magnetic Field Laboratory are plotted with filled circles. **(b)** Magnetoresistance measured up to 12.5 T in a superconducting DC magnet at temperature of T = 300 mK.