Anomalous Fermi Surface in Fese Seen by Shubnikov-De Haas Measurements

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Introduction

FeSe is an intriguing material. Despite the fact that FeSe is isoelectronic with $(FeAs)^{-1}$ planes of LaFeAsO or $BaFe_2As_2$, it does not order magnetically but becomes superconducting below T_c ~ 8 K [1]. Detailed research into its electronic structure is highly desirable, but such research was obstructed by difficulties in crystal growth. Recently, Böhmer *et al*. [2] have succeeded in growing single crystals of unprecedented quality. Using those crystals, we have performed Shubnikov-de Haas (SdH) measurements [3].

Experimental

We have performed standard four-contact resistance measurements using a 35-T resistive magnet and a ^{3}He or ^{3}He/^{4}He dilution refrigerator at the NHMFL, Tallahassee. The four measured samples have T_c of 8.9 – 9.2 K and RRR evaluated at 11 K of 28 – 32.

Results and Discussion

Figure 1(a) shows the magnetoresistance (red curve) for *B* // *c* and its oscillatory part (blue curve). Clear SdH oscillations are seen. Figure 1(b) shows Fourier transforms of SdH oscillations for *B* // *c* and two other field directions. We see four fundamental frequencies α, β, γ, and δ, and two harmonics 2α and 2β. We note that the observed frequencies are very small, corresponding to the orbit areas of 0.2 – 2.3 % BZ. The associated effective masses are in a range between 1.9 (α) and 7.2 m_e (γ) for *B* // *c*. These values result in very small effective Fermi energies 3.6 – 18 meV, which are to be compared with k_BT_c = 0.78 meV. Detailed analyses suggest that α and γ are the minimum and maximum frequencies of the quasi-two-dimensional electron cylinder, while β and δ are those of the hole one. The two cylinders are estimated to give a Sommerfeld coefficient of ~6 mJ/molK^2, which is in agreement with reported specific heat data [4] and hence suggests that the entire Fermi surface has been observed. The carrier number is estimated to be ~0.01 carriers per Fe. Those observations are in stark contrast to results of an LDA band-structure calculation, which predicts two electron and three hole cylinders and a carrier number of 0.17 carriers per Fe.

Conclusions

We have observed SdH oscillations in FeSe for the first time. The observed Fermi surface differs significantly from that predicted by the LDA calculation, which clearly needs further investigations.

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References

[1] Hsu, F.-C., *et al.*, PNAS, **105**, 14262 (2008).
[2] Böhmer, A.E., *et al.*, Phys. Rev. B **87**, 180505(R) (2013).
[3] Terashima, T., *et al.*, Phys. Rev. B **90**, 144517 (2014).
[4] Lin, J.-Y., et al., Phys. Rev. B **84**, 220507(R) (2011).

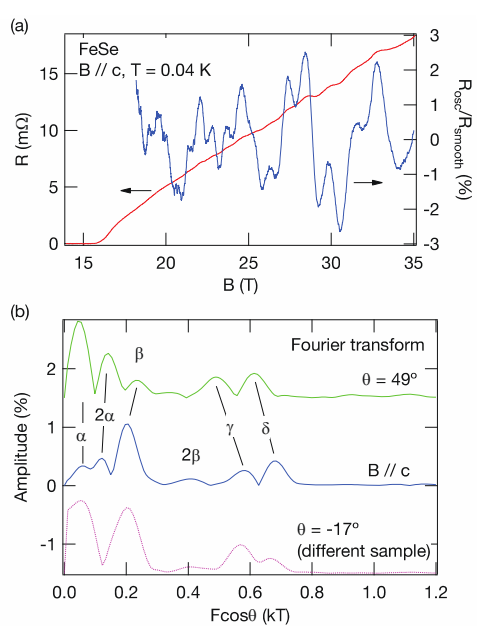

Fig. 1. (a) Resistance in FeSe (red) and its normalized oscillatory part (blue) as a function of magnetic field for *B* // *c*. (b) Fourier transforms of SdH oscillations in FeSe.