Quasi-Two Dimensional Dirac Fermions in LaAgBi2

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Introduction

We report on the quasi-two dimensional (2D) Dirac fermions and quantum magnetoresistance in $LaAgBi_2$. The band structure shows several narrow bands with nearly linear energy dispersion and Dirac-cone-like points at the Fermi level. The quantum oscillation experiments revealed one quasi 2D Fermi pocket and another complex pocket with a small cyclotron resonant mass. Our results suggest existence of quasi 2D Dirac fermions in materials with 2D double-sized Bi square nets similar to $(Ca,Sr)MnBi_2$ [1] irrespective of magnetic order.

Experimental

Single crystals of $LaAgBi_2$ were grown from Bi flux [2]. The de Haas–van Alphen (dHvA) oscillation experiments were performed at the NHMFL Tallahassee, FL. The crystals were mounted on to miniature Seiko piezoresistive cantilevers on a rotating platform. The field direction can be changed between B↑↑ and perpendicular to the c axis.

Results and Discussion

Band structure calculations with spin orbit (SO) coupling indicate two Dirac-cone-like points along the Γ-M and R-Z directions and at the X points in the Brillouin zone. The SO coupling induces the gap at the Dirac cone-like points. The conducting electrons in $LaAgBi_2$ are mainly due to bismuth (Bi_2) *5p* states in rectangular bismuth layers. The unit cell contains two Bi_2 atoms per unit cell due to occupation of La ions (above and below Bi_2 layer). This leads to folding of the dispersive *p* orbital of Bi_2. The two $p_{x,y}$ bands from two Bi_2 atoms cross at a single point and then form the nearly linear band and Dirac-cone like point around the Fermi level. Consequently, the Fermi pockets along the Γ-M direction and the one along the R-Z direction and at X point host Dirac fermions.

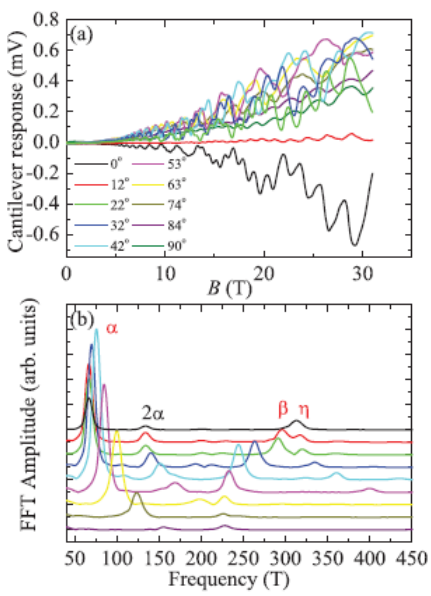

Figure 1: (a) Quantum oscillation with different tilting angles. (b) The Fourier transform spectrum of the SdH oscillation.

When the magnetic field is perpendicular to the ab plane (θ close to 0°), the dHvA signal of $LaAgBi_2$ exhibits significant oscillation. The FFT spectrum shows two peaks at approximately 67 T (α) and 300 T (β) (peak at 135 T is double frequency of α). With increasing θ, oscillations are weaker and α shifts to higher frequency whereas β splits into two peaks (β and η). Moreover, the angular dependence of α is inversely proportional to $|\cos\theta|$ indicating quasi-2D Fermi pocket (corresponding to electron pocket at X) whereas two other frequencies correspond to highly anisotropic pockets located along the edge and diagonal in the Brillouin zone [2]. In electronic system with charge or spin density wave, the phase transition often induces band folding of some Fermi surface sections (eg. $LaAgSb_2$ or $BaFe_2As_2$). The absence of such transitions in $LaAgBi_2$ shows that the Dirac cone formation can be independent of the long range order.

Conclusions

The electronic structure of $LaAgBi_2$ shows striking similarity to $(Sr,Ca)MnBi_2$. $LaAgBi_2$ has no magnetic ions and is paramagnetic metal. Yet, both first principle calculations and the experimental dHvA results are consistent with Dirac-cone-like states at the Fermi level. This indicates possible universal existence of 2D Dirac fermions in layered structures with 2D Bi square nets irrespective of magnetic order.

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References [1] J. Park *et al*., Phys. Rev. Lett. 107, 126402 (2011) [2] Kefeng Wang, D. Graf and C. Petrovic, Phys. Rev. B 87, 235101 (2013)