Fermi surface in new layered organic conductors
(BEDT-TTF)$_3$Br($p$BIB) and (BEDT-TTF)$_3$Cl(DFBIB)

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Abstract

We report the measurements of Shubnikov–de Haas (SdH) oscillation and angular dependent magnetoresistance oscillation (ADMRO) in a new layered organic conductor (BEDT-TTF)$_3$Br($p$BIB), where $p$BIB stands for $p$-bis(iodoethynyl)benzene. When magnetic fields are applied perpendicular to the layers, two distinct SdH oscillations are clearly observed, which arise from the two extremal cross-sectional areas of the slightly warped cylindrical Fermi surface (FS). The cross-sectional areas correspond to 50.9 and 51.6% of the first Brillouin zone. From the analysis of the ADMRO, the area of FS is estimated to be 52.5% of the first Brillouin zone. The ADMRO data also shows that the anisotropy of the FS is enhanced by change of Br($p$BIB) for Cl(DFBIB), where DFBIB stands for 1,4-difluoro-2,5-bis(iodoethynyl)benzene. These results are consistent with the band calculation.

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Keywords: Transport measurements; Magnetoresistance oscillation; Organic conductor; 2D Fermi surface

1. Introduction

Recently, Yamamoto et al. [1,2] synthesized a new layered organic conductor (BEDT-TTF)$_3$Br($p$BIB), where $p$BIB stands for $p$-bis(iodoethynyl)benzene. Reflecting the layered structure, there exists a two-dimensional (2D) Fermi surface (FS) with a distorted elliptic cross-section [1,2]. One of the interesting features is that the supramolecular chain is formed. The supramolecular chain is expected to affect the structure and thus tunes its physical properties such as the topology of FS. X-ray studies show that change of Br($p$BIB) for Cl(DFBIB) causes decrease of period and increase of inter-chain distance in supramolecular chain [2]. According to the band calculation, the anisotropy of the FS is enhanced by change of Br($p$BIB) for Cl(DFBIB), where DFBIB stands for 1,4-difluoro-2,5-bis(iodoethynyl)benzene [1,2]. To investigate the FS and the effect of supramolecular chain on the FS of (BEDT-TTF)$_3$Br($p$BIB) system, we have measured Shubnikov–de Haas (SdH) oscillation and angular dependent magnetoresistance oscillation (ADMRO) up to 14 T for (BEDT-TTF)$_3$Br($p$BIB) and (BEDT-TTF)$_3$Cl(DFBIB).

2. Experiment

Single crystals of (BEDT-TTF)$_3$Br($p$BIB) and (BEDT-TTF)$_3$Cl(DFBIB) were prepared by electrochemical oxidation in an appropriate solvent [1,2]. The resistance was measured by a usual four probe a.c. technique with electric current along the $b'$-axis. The experiments were made by use of a dilution refrigerator or $^4$He cryostat with superconducting magnets. The polar angle $\theta$ is defined as the angle measured from the normal to the 2D plane, and azimuthal angle $\phi$ as that measured from supramolecular chain in the 2D plane.

3. Results and discussion

Fig. 1(a) shows the resistance of (BEDT-TTF)$_3$Br($p$BIB) as a function of magnetic field in the range 7–14 T at...
180 mK. Here, magnetic fields are applied perpendicular to the layers. Fig. 1(b) shows the Fourier transform spectrum in the same field range. Two distinct SdH oscillations are clearly observed, which arise from the two extremal cross-sectional areas of the slightly warped cylindrical FS. The areas correspond to 50.9 and 51.6% of the first Brillouin zone. Two distinct SdH oscillations are also observed in (BEDT-TTF)$_3$Cl(DBFIB). For (BEDT-TTF)$_3$Cl(DBFIB), the cross-sectional areas correspond to 49.8 and 51.1% of the first Brillouin zone. These results are consistent with the band calculation [1,2].

Fig. 2(a) shows the $\theta$ dependence of the resistance at 1.8 K under magnetic field of 13.8 T for various $\phi$ values. When tilting the field direction from $\theta = 0^\circ$, a series of magnetoresistance peaks are clearly observed. The oscillatory structure is observed above 4 T and more prominent with increasing field strength, although the peak position is not influenced by the magnetic field, showing that the oscillatory behavior is not caused by the quantum oscillation, but the ADMRO. The ADMRO is also observed in (BEDT-TTF)$_3$Cl(DBFIB).

Fig. 2(b) shows the polar plot of the ADMRO period $\delta$ for (BEDT-TTF)$_3$Br(pBIB) and (BEDT-TTF)$_3$Cl(DBFIB) [3,4]. The areas of FS are estimated to be 52.5% for (BEDT-TTF)$_3$Br(pBIB) and 48.3% for (BEDT-TTF)$_3$Cl(DBFIB) of the first Brillouin zone. The FS of (BEDT-TTF)$_3$Cl(DBFIB) has a more distorted elliptic shape than that of (BEDT-TTF)$_3$Br(pBIB) as seen in Fig. 2(b). The ratio of the long axis to the short axis of the ellipse changes from 1.06 for (BEDT-TTF)$_3$Br(pBIB) to 1.21 for (BEDT-TTF)$_3$Cl(DBFIB). The result implies that the supramolecular chain can act as a kind of an “anisotropic” pressure effect on the electronic state. These results are consistent with the band calculation [1,2].
4. Conclusion

To conclude, we have measured the SdH oscillation and ADMRO for (BEDT-TTF)$_3$Br(pBIB) and (BEDT-TTF)$_3$Cl(DFBIB). From the analyses of the SdH oscillation and ADMRO, the cross-sectional areas of FS are estimated to be nearly 50% for both salts. Moreover, we clearly show that the FS of (BEDT-TTF)$_3$Cl(DFBIB) has a more distorted elliptic shape than that of (BEDT-TTF)$_3$Br(pBIB), showing that supramolecular chain can act as a kind of an “anisotropic” pressure effect on the electronic state. These results are consistent with the band calculation [1,2].

References