Exploring the Quantum Oscillations of Novel Materials

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Introduction

Quantum oscillation measurements are one of the powerful techniques used to determine the detailed Fermi-surface topology. This provides us with precise information of quasi-particle excitations that dominate the intrinsic physical properties. In this experiment, we applied the quantum oscillation measurement to novel materials. One is a non-centrosymmetric superconductor realized without *f* electrons. The lack of inversion symmetry results in a novel superconducting state, namely singlet-triplet (parity) mixed pairing state. The unusual superconducting phenomena such as the helical vortex state originating from the parity mixing or the anti-symmetric spin-orbit interaction have been proposed [1]. The recent achievement of single-crystal growth of the material enables us to study in detail, in particular, while focusing on the relation between the anti-symmetric spin-orbit interaction and the superconductivity without the contribution of magnetic *f* electron character. The other material we focused on is a metallic delafossite oxide. Very recently, quantum oscillations of $PdCoO_2$ [2] and $PdCrO_2$ [3] have been reported. Here, $PdCoO_2$ is a nonmagnetic and highly conductive, while $PdCrO_2$ shows an anomalous Hall effect related to its (frustrated) magnetism [4]. Thus, the delafossite oxide shows rich physical properties and it should prove very interesting to explore the electronic structure for an analogous material with another transition metal.

Experimental

We measured a magnetic torque using a micro-cantilever for the non-centrosymmetric superconductor, and a capacitance method for the metallic delafossite oxide. The measurements were performed using a resistive magnet (Cell 12) combined with a ^{3}He cryostat at the NHMFL. The probe we used had a single-axis rotation, therefore, we were able to rotate the sample platform in the magnetic field in order to examine angular dependence of the quantum oscillations.

Results and Discussion

In the inset of Fig. 1, we show quantum oscillations of a novel delafossite oxide up to 30 T. A clear high frequency oscillation was successfully observed for the first time. Figure 1 shows the FFT of the oscillation. Our angular study strongly suggests the system is quasi-two dimensional. Therefore, we conclude that the two frequencies shown in Fig. 1 reflect the maximum and minimum external areas for a single-band Fermi surface. The quasi-particle mass is deduced around 0.8 m_0, where m_0 represents the bare electron mass.

Conclusions

We attempted detecting quantum oscillations of a non-centrosymmmetric superconductor, and a delafossite oxide via torque magnetometry and for the first time we succeeded in observing the quantum oscillation of the quasi-two dimensional delafossite oxide sample. Although there was no clear sign of the oscillation of the non-centrosymmmetric superconductor using the best quality samples available, we would like to try it again at the NHMFL with much purer samples in the near future.

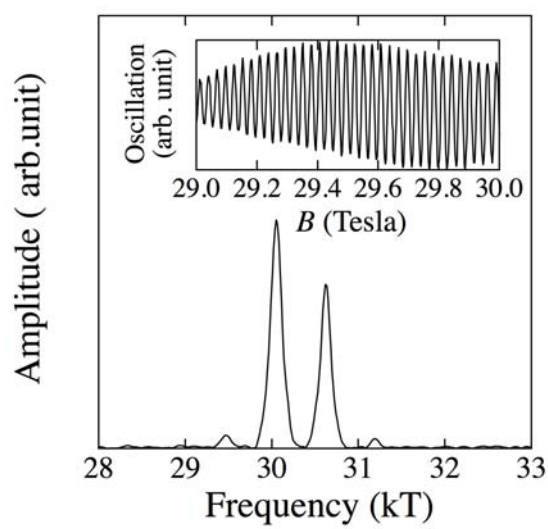

Fig.1 Quantum oscillation of a novel delafossite oxide near 30 T (inset) and its FFT spectrum (main).

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