Quantum Oscillations of the Metallic Triangular-Lattice Antiferromagnet $PdCrO_2$

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Introduction

$PdCrO_2$ is a rare example of metallic triangular-lattice antiferromagnets showing an unconventional anomalous Hall effects. $PdCrO_2$ consists of stacked layers of Pd and Cr triangular lattice in a delafossite structure. The Pd layers with mostly Pd $4d^9$ states are responsible for highly two-dimensional metallic conduction. In the CrO_2 layers, the localized S = 3/2 spins of Cr^{3+} ions are antiferromagnetically ordered in a 120° helical magnetic structure. The Fermi surface reconstruction in the de Hass-van Alphen (dHvA) oscillations of $PdCrO_2$ single crystal was observed under static magnetic fields up to 35T. This provides experimental evidence that itinerant electrons in Pd layers are coupled with the underlying 120° magnetic structure of the localized Cr spins.[1]

Experimental

The high-quality single crystals of $PdCrO_2$ are used for torque magnetometry under high magnetic fields in a Bitter magnet (35 T, 1.4 K).

Results and Discussion

Figure 1 (a) shows the oscillatory part of the toque signal up to H = 30 T under different tilted magnetic fields from H // [001] (θ = 0°) to H // [100] (θ = 90°) at 1.4 K. The fast Fourier transform (FFT) for θ = 4° close to H // c is shown in Fig. 1(b). At all tilted angles, the spectrum is dominated by several peaks at F ~ 0.8, ~33, ~10.5, and ~27.5 kT, which we denote as α, β, γ, and δ, respectively [Fig 1(c)-(e)]. These FFT results are in strong contrast to those of nonmagnetic isostructural $PdCoO_2$. Recent dHvA experiment on $PdCoO_2$ reveals two frequencies at F ~ 30 kT.[2] Compared to those of $PdCoO_2$, the cyclotron orbits found in $PdCrO_2$ are much smaller, except the largest δ orbit with F ~ 27.5 kT. Considering that the dHvA oscillations were taken below T_N, this suggests that additional FSs (α, β, and γ) are introduced by the helical ordering of the localized Cr spins. These observations provided clear experimental evidence for Fermi surface reconstruction.

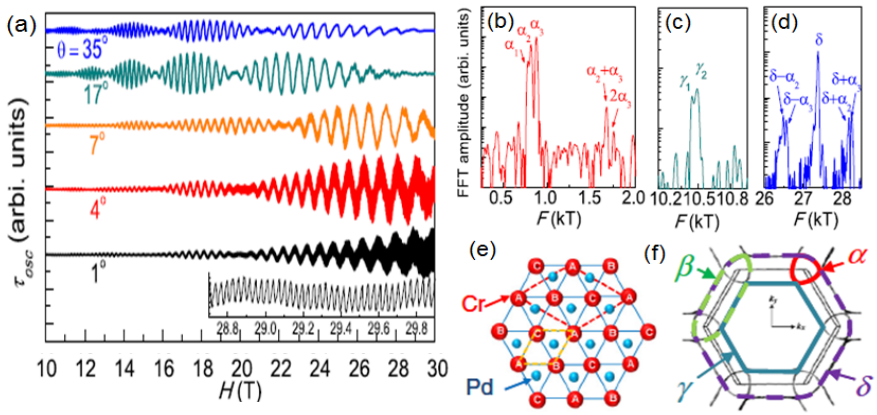

Figure 1. (a) The oscillatory part of the torque single as a function of applied magnetic fields with different angles θ against the c axis at 1.4K. The fast oscillations at high magnetic fields for θ = 1° is shown in the inset. The typical FFT spectra of the dHvA oscillations in the field range from 10 to 30 T, for example, at θ = 4°. An expanded view of the FFT spectra for the different frequencies, labeled as (b) α, (c) γ, (d) δ. (e) A triangular Pd layer stacked with a triangular lattice of Cr with three different types of spin directions. The crystal (magnetic) unit cell is indicated by the orange (red) dotted lines. (f) A cross section of the Fermi surface.

Conclusions

We obtained clear experimental evidence for Fermi surface reconstruction due to the 120° helical spin structure with $\sqrt{3} \times \sqrt{3}$ periodicity of Cr moments. These findings suggest that unconventional anomalous Hall effects could not be understood in terms of the spin chirality, because 120° helical ordering has a zero scalar spin chirality.

Acknowledgements

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References

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[2] C.W. Hicks *et al*., Physical Review Letters, **109**, 116401 (2012).