Field-Induced Topological Anomalous Hall Effect in a Frustrated Itinerant Antiferromagnet

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Introduction

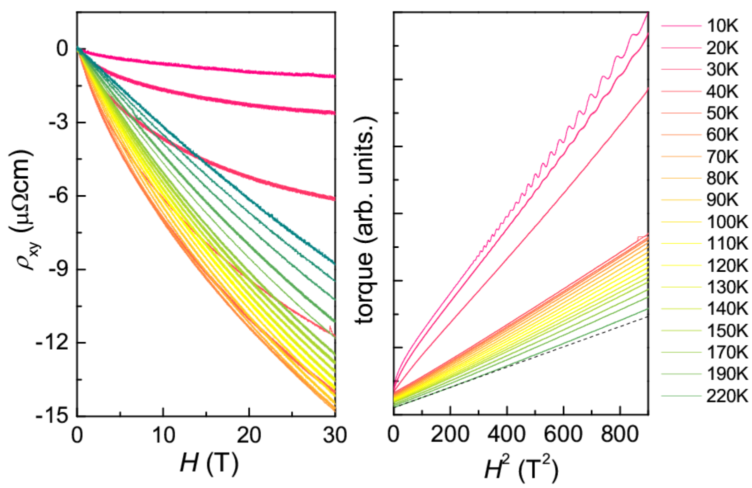
When localized spins are frustrated and form a complex non-colinear spin order with a finite spin chirality, the itinerant electrons, experience the fictitious magnetic field with a finite Berry phase, leading to topological anomalous Hall Effect (AHE). In the frustrated and itinerant antiferromagnets, the topological AHE can be induced even without a long range order, but its effect is usually small in magnitude. $PdCrO_2$ provides a rare example of metallic triangular antiferromagnet with the frustrated and localized Cr spins and highly mobile itinerant electrons in the hybridized Pd $4d^9$ and $5s^1$ states. Recently we observed that the nonlinear field dependent Hall resistivity, resembling the AHE, is developed near and even above T_N, but its nature and origin has not been clarified.

Experimental

Single crystals of $PdCrO_2$ were grown by flux methods. The crystals for transport measurement were micro-fabricated by Focused Ion Beam (FIB) technique in order to precisely determine the current path. The torque magnetometry measurement was carried out using piezo-resistive cantilever. All measurements were done in magnetic fields up to 30 T using a resistive magnet at NHMFL, Tallahassee

Results and Discussion

Figure 1 represents the field dependence of Hall resistivity $\rho_{xy}(H)$ and the torque magnetometry $\tau(H)$ of $PdCrO_2$ up to H = 30 T. In frustrated itinerant magnets, two contributions to the Hall resistivity need to be considered, one from normal Hall effect with a linear field dependence and the other from the field induced topological Hall resistivity $\rho^S_{xy}(H)$. In this case the measured Hall resistivity can be described by $\rho_{xy}(H) = \rho^S_{xy}(H) + R_H^0 H$, where R_H^0 is the ordinary Hall coefficient. Clearly, the nonlinear field dependent contribution $\rho^S_{xy}(H)$ is the largest right above T_N ~ 40 K (orange) and becomes weaker with increasing temperature up to 220 K (dark green). In the same temperature range, the torque signal $\tau(H)$ also exhibits the deviation from the normal H^2 dependence and it also becomes weaker with increasing temperature. This deviation of torque signal is the signature of field-induced partial alignment of fluctuating spins, which are otherwise coupled with each other via short-range correlations. Accordingly the nonlinear Hall contribution becomes weaker. These consistent field dependences of $\rho_{xy}(H)$ and $\tau(H)$ suggest that the short-range and fluctuating spin-texture above T_N induces the field-induced AHE.



T_N the Hall resistivity shows the strongest nonlinear field dependence (orange), while it becomes linearly field-dependent at high temperatures. (b) Field-dependent torque magnetometry at different temperatures. A deviation from the normal H^2 dependence above T_N becomes weaker with temperature.

Conclusions

In conclusion, the field dependent Hall resistivity and torque magnetometry on $PdCrO_2$ shows clear deviation from the normal field dependence, suggesting the short-range spin correlation and the resulting anomalous Hall Effect above T_N ~ 40 K.

Acknowledgements

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References

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