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Ordinary and anomalous Hall effects of ferromagnetic Mn5Ge3[1]

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It is well know that in ferromagnetic materials, the Hall effect includes two contributions: the ordinary Hall effect (OHE), which is proportional to the applied magnetic field, and the anomalous Hall effect (AHE), which originates from the magnetization of the material. Although both phenomena have been throughly studied, there are still questions about the origins of both OHE and AHE in ferromagnetic materials with complicated band structures. Using ferromagnetic Mn5Ge3 thin films as an example, we investigate the Hall effect experimentally and theoretically. We have separated the intrinsic and extrinsic contributions to the experimental AHE and calculated the intrinsic anomalous Hall conductivity from the Berry curvature of the Bloch states using first-principles methods. The intrinsic anomalous Hall conductivity depends linearly on the magnetization, which can be understood from the long-wavelength fluctuations of the spin orientation at finite temperatures. The *quantitative* agreement between theory and experiment is remarkably good, not only near 0 K but also at finite temperatures, up to about 240 K ($0.8\,Tc$) [1]. The measured ordinary Hall coefficient is found to change its sign as a function of temperature. From a detailed analysis, which includes magneto-resistance measurements, magnetic characterization, and first-principles calculations, we establish that the sign change of the OHE is mainly caused by the mixing of the AHE with the magneto-resistance and differential susceptibility. This work was done in collaboration with Y. Yao, Di Xiao, Q. Niu, and H.H. Weitering.

[1] Changgan Zeng, Yugui Yao, Qian Niu, and Hanno, H. Weitering, Phys. Rev. Lett. 96, 037204 (2006).

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