MAR07-2006-000515

Abstract for an Invited Paper
for the MAR07 Meeting of
the American Physical Society

Investigation of the Anomalous Hall Effect in Three Unusual Ferromagnets[1]

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The Hall resistivity (ρ_{xy}), resistivity (ρ_{xx}), and magnetization of three metallic ferromagnets are investigated as a function of magnetic field and temperature [1]. The three ferromagnets, $EuFe_4Sb_{12}$ ($T_c \approx 84$ K), $Yb_{14}MnSb_{11}$ ($T_c \approx 53$ K), and $Eu_8Ga_{16}Ge_{30}$ ($T_c \approx 36$ K) are Zintl compounds with carrier concentrations between 1 x 10^{21}cm^{-3} and 3.5 x 10^{21} cm^{-3}. The relative decrease in ρ_{xx} below T_c [$\rho_{xx}(T_c)/\rho_{xx}(2\ K)$] is 28, 6.5, and 1.3 for $EuFe_4Sb_{12}$, $Yb_{14}MnSb_{11}$, and $Eu_8Ga_{16}Ge_{30}$ respectively. The low carrier concentrations coupled with low magnetic anisotropies allow a relatively clean separation between the anomalous (ρ'_{xy}), and normal contributions to the measured Hall resistivity. For each compound the anomalous contribution in the zero field limit is fit to $a\rho_{xx} + \sigma_{xy}\rho_{xx}^2$ for temperatures $T < T_c$. The anomalous Hall conductivity, σ_{xy}, is -220 $\pm$ 5 (Ω^{-1} cm^{-1}), -14.7 $\pm$ 1 (Ω^{-1} cm^{-1}), and 28 $\pm$ 3 (Ω^{-1} cm^{-1}) for $EuFe_4Sb_{12}$, $Yb_{14}MnSb_{11}$, and $Eu_8Ga_{16}Ge_{30}$ respectively and is independent of temperature for $T < T_c$ if the change in spontaneous magnetization (order parameter) with temperature is taken into account. These data appear to be consistent with recent theories of the anomalous Hall effect that suggest that even for stochiometric ferromagnetic crystals, such as those studied in this work, the intrinsic Hall conductivity is finite at $T = 0$, and is a ground state property that can be calculated from the electronic structure. New measurements on single crystals of the tetragonal compound $Yb_{14}MnSb_{11}$, however, indicate that the intrinsic Hall conductivity can change sign, depending on the direction of the current and magnetic field with respect to the crystallographic axes. These new results will also be discussed within the context of recent theories. Research was done in collaboration with Rongying Jin, David Mandrus and Peter Khalifah.

[1] B. C. Sales et al. Phys. Rev. B 73 (2006) 224435.

[1]Research was sponsored by the Division of Materials Sciences and Engineering, Office of Basic Energy Sciences, U.S. Department of Energy, under Contract No. DE-AC05-00OR22725 with Oak Ridge National Laboratory, managed and operated by UT-Battelle, LLC.