Anomalous Hall Effect and Anomalous Nernst Effect in Ga$_{1-x}$Mn$_x$As

YONG PU, JING SHI, Department of Physics, University of California-Riverside, DAICHI CHIBA, FUMIHIRO MATSU KURA, HIDEO OHNO, RIEC, Tohoku University, Japan — We have carried out systematic electrical and thermoelectric transport coefficient measurements on a series of Ga$_{1-x}$Mn$_x$As samples (x from 0.01 to 0.07) with perpendicular magnetic anisotropy. 50 nm-thick Ga$_{1-x}$Mn$_x$As films were grown by molecular beam epitaxy on an InGaAs buffer layer with a tensile strain to induce the perpendicular anisotropy. Below the Curie temperature, we have observed a non-zero transverse thermopower S$_{xy}$ that accompanies the Hall resistance R$_{xy}$. Both S$_{xy}$ and R$_{xy}$ show abrupt jumps as the magnetization switches by an external magnetic field. The square hysteresis loops in S$_{xy}$ and R$_{xy}$ resemble those of the magnetization. Just as the anomalous Hall effect (AHE), the hysteresis loop in S$_{xy}$, i.e. the anomalous Nernst effect (ANE), is a consequence of the spin-orbit coupling in the ferromagnetic materials. We have measured both AHE and ANE over a wide range of temperatures in all samples, and found that the Hall resistance R$_{xy}$ scales with the square of the longitudinal resistance R$_{xx}$. In contrast, the transverse thermopower S$_{xy}$ is independent of the longitudinal thermopower S$_{xx}$ over the same temperature range. These observations suggest that both AHE and ANE are of intrinsic or dissipationless origin.

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