Scaling of the Anomalous Hall Effect in Low Mn Concentration (Ga,Mn)As Films

S. Shen, X. Liu, Z. Ge, J. K. Furdyna, M. Dobrowolska (University of Notre Dame, Physics);
J. Jaroszynski (NHMFL)

Introduction

III-V-based diluted magnetic semiconductors (DMSs) are of interest due to their ability for controlling the spin degree of freedom, and consequently their potential for applications in spintronic devices. However the basic nature of their magnetotransport properties still contains many open questions. In this context magnetotransport measurements on $Ga_{1-x}Mn_xAs$ – and especially the anomalous Hall Effect (AHE) – can play a major role in clarifying these issues.

Experimental

The $Ga_{1-x}Mn_xAs$ films (x~0.014) used in this work were grown in by MBE at Notre Dame. The conductivity of the samples was varied by varying the growth temperature and/or by Be co-doping. We have carried out AHE measurements at NHMFL on $Ga_{1-x}Mn_xAs$ epilayers in high magnetic fields (up to 18.0 T) using a general purpose superconducting magnet (SCM-2).

Results and Discussion

Using the transverse and longitudinal resistivity results, we calculated the anomalous Hall conductivity σ_{xy} via the relation $\sigma_{xy} = \rho_{xy} / \rho_{xx}^2$ for all samples. We plot σ_{xy} for all five samples as a function of σ_{xx} in Fig. 1 for temperatures below T_C. The plot shows a reasonably good linear fit. For this series of samples we obtain a relation $\sigma_{xy} \propto \rho_{xx}^{-1.5}$. This also means that $\rho_{xy} \propto \rho_{xx}^{0.5}$ or $R_s \propto \rho_{xx}^{0.5}$, giving a scaling factor n = 0.5. We thus note that the anomalous Hall conductivity σ_{xy} is strongly dependent on the degree of localization of the holes.

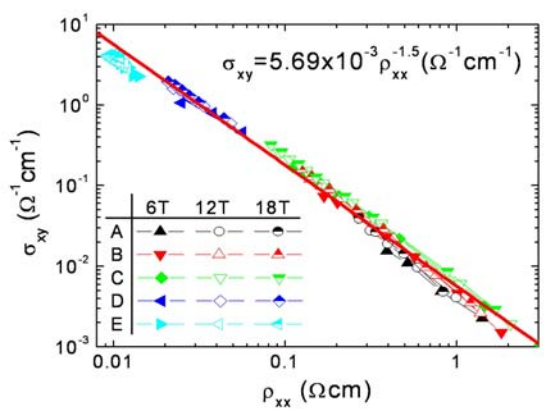

Figure 1. Anomalous Hall conductivity σ_{xy} plotted as a function of ρ_{xx} for five samples studied in this work. For each sample the data were taken at three magnetic fields (6, 12, and 18 T) at various temperatures below T_C.

Conclusions

We have established a self-consistent method for simultaneously determining R_0, c and n. Using the results of this paper, we have obtained a scaling factor n ~ 0.5 that applies universally for all samples studied – a value that is not compatible with either skew or side-jump origins of AHE.

Acknowledgements

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References

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