DETERMINATION OF THE CARRIER DENSITY IN $Ga_{1-x}Mn_xAs$ VIA HIGH FIELD HALL MEASUREMENTS

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Introduction

Since its discovery by Ohno et. al.[1], Mn doped GaAs has been the focus of intense research efforts motivated in part by the potential magneto-optical applications of a material capable of emitting and detecting circularly polarized light. Apart from its potential uses, $Ga_{1-x}Mn_xAs$ also presents a unique opportunity to study carrier-mediated magnetism in a well-controlled environment. Recent optical experiments have shown that the electronic transport in metallic annealed $Ga_{1-x}Mn_xAs$ is unconventional and suggest that the effective mass of the carriers is unusually large [2]. Unfortunately, these measurements only determine the ratio of the carrier density to the mass, and not the mass itself. Therefore we have performed Hall Effect measurements to determine the carrier density. These films are post-growth annealed, which has recently been shown to enhance both the ferromagnetic critical temperature and the carrier density [3].

Experimental

Four-terminal Hall effect measurements were performed on post-growth annealed and unannealed thin films of $Ga_{1-x}Mn_xAs$ with x = 0.052 and 0.073. Unfortunately, reliable hall measurements were only possible in the samples that had been post-growth annealed due to contact effects. Measurements were performed in a 14 T PPMS and a 20 T superconducting magnet system down to 2 K. The magnetic field was swept through positive and negative values in order to separate the resistive and the Hall components of the signal.

Results and Discussion

The hall resistivity (ρ_{xy}) for the annealed $Ga_{0.927}Mn_{0.073}As$ sample is shown in figure 1. The signal is dominated by the anomalous hall effect, wherein an additional term in the hall signal results from the internal exchange field. Nonetheless by extending the measurements to very high magnetic fields we were able to very accurately measure the hall signal resulting from the free carriers. This is demonstrated by the linear fit also shown in Fig. 1 from which the carrier density (p) was calculated via the equation: $\rho_{xy} = MR_A + B/ep$. Here M is the magnetization of the sample, R_A the anomalous hall term, e the charge of the electron and B the applied magnetic field.

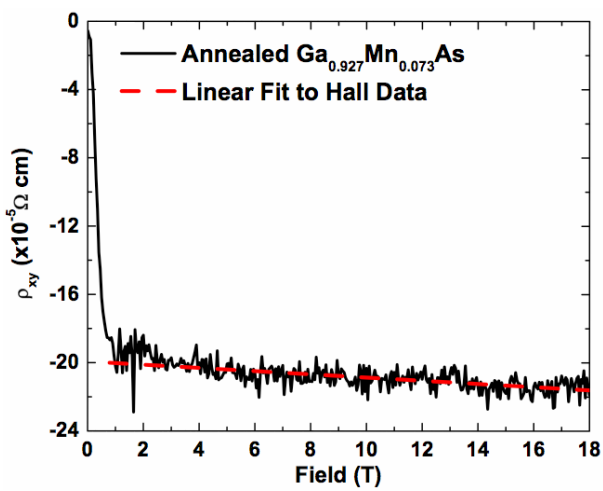

Figure 1: Representative hall resistivity data for the annealed $Ga_{0.927}Mn_{0.073}As$.

Conclusions

By combining these measurements with our previous optical results [2] we were able to determine that the effective mass of the carriers in annealed $Ga_{1-x}Mn_xAs$ is on the order of tens of m_e, which is quite surprising. Furthermore, since the magnetism in this compound is carrier mediated, these results will have strong implications for understanding the mechanism responsible for producing the ferromagnetic order.

Acknowledgements

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References

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