MAGNETIC GRADIENT-INDUCED VOLTAGE IN Mn-DOPED GaAs FILMS

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Introduction

Ga$_{1-x}$Mn$_x$As has recently received a great deal of attention as a prototypical dilute magnetic semiconductor, due to the large array of possible applications these materials offer. Interestingly despite their extensive study the underlying mechanism of the ferromagnetism is still not fully understood. One of the greatest difficulties with understanding these materials, and also the main reason for their technological promise, is the small carrier density and therefore small ratio of Fermi to exchange energies. It has recently been proposed (cond-mat/0605043) that this small ratio may lead to new and interesting physics. In particular, since there is a strong dependence of the magnetic state on the carrier density, and vice versa, the application of a gradient magnetic field may produce a measurable induced voltage. Such an experiment will not only help to uncover the underlying mechanism of ferromagnetism in GaMnAs, but should also shed light on the ability of these materials to be used as magnetic sensors.

Experimental

The 15 T Oxford DC superconducting magnet, with an NHMFL-built probe at Los Alamos, was utilized to carry out the measurements. The probe was lifted approximately 8 cm from field center in order to achieve a suitable magnetic field gradient (~0.25 T/cm). The temperature was then varied across the ferromagnetic transition temperature. Voltage was measured using a precision nanovoltmeter, in a direction parallel to the applied field gradient, which was also parallel to the magnetic field direction. Two Ga$_{1-x}$Mn$_x$As films with different ferromagnetic transition temperatures (~80 and 120 K) were measured in this way.

Results and Discussion

These initial experiments did not appear to produce an induced voltage in the two Ga$_{1-x}$Mn$_x$As measured. In particular we were unable to observe a voltage above the noise level upon application of the magnetic field. To understand these results we calculated the static magnetic field upon which the gradient field was produced. It appeared that the static field was well beyond the field required to saturate the magnetization in these films. Therefore it appears that the overall magnetization was saturated before a significant gradient in the magnetization could be achieved.

Conclusions

While these measurements did not produce the expected result, we believe they were nonetheless quite useful. In particular these results the difficulty with testing the predictions of reference 1 using a standard laboratory magnetic field setup. Furthermore these measurements also suggest it may be difficult to incorporate Ga$_{1-x}$Mn$_x$As in a magnetic field detection device. Nonetheless, based on these results we are continuing to pursue this potentially exciting avenue of research. Specifically these results suggest that generating magnetic fields locally via photolithography techniques may produce the desired voltage change. If this approach is successful it would provide a new avenue for magnetic semiconductors in magnetic storage devices.

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References