A TUNABLE ANOMALOUS HALL EFFECT IN A NON-FERROMAGNETIC SYSTEM

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Introduction

The transverse, or Hall, resistivity is a direct measure of the sign and concentration of charge carriers in most materials. However, other subtler electronic properties can produce "anomalous" corrections to the Hall resistivity. The underlying mechanisms of this AHE remain the subject of contemporary debate and have aroused renewed interest because of their close theoretical connection to the recently discovered spin-Hall effect and to spin transport in general. Unlike ferromagnetic metals, whose spin polarization is fixed by their chemistry, paramagnetic semiconductors' spin polarization can be smoothly tuned by varying carrier density, magnetic field or temperature in a given sample, providing an ideal opportunity to clarify the mechanism of the AHE. Here, we report the observation of a robust and tunable AHE in a purely paramagnetic two-dimensional electron gas in a magnetically-doped semiconductor.

Experimental

We study the AHE in magnetically-doped two-dimensional electron gases (M2DEGs) derived from a II-VI diluted magnetic semiconductor (DMS). This choice is dictated by several factors: (a) the carriers have an unusually large paramagnetic susceptibility, resulting in a significant spin polarization that enhances the strength of the AHE; (b) the 2D nature and moderately high mobility (due to modulation doping) allow independent measurement of the carrier density through Shubnikov-deHaas (SdH) oscillations; (c) the paramagnetic susceptibility can be tuned by varying the temperature; (d) at a fixed temperature, other properties such as the carrier density, Fermi energy and resistivity are tunable using the electric field from a gate on the sample surface. The samples consist of a modulation-doped single quantum well (10.5 nm thickness) of $Zn_{1-x-y}Cd_yMn_xSe$ (x~0.02, y ~ 0.12) sandwiched between ZnSe barriers. The Mn impurities behave essentially as free spin-5/2 moments with Brillouin-like paramagnetic susceptibility. Polarization of the Mn induces a spin-splitting in the conduction electrons through an *s-d* exchange coupling, giving the carriers an effective *g*-factor far higher than even small-bandgap semiconductors: g ~ 80 in our material at 1.5 K, producing complete polarization of carriers at approximately 1 T.

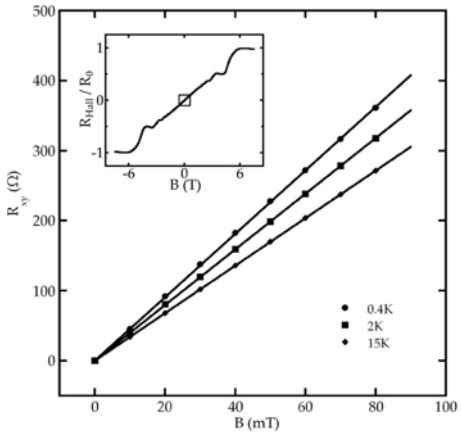

Fig. 1. The Hall resistance of a M2DEG system at a variety of temperatures. The inset shows the Hall resistance out to high applied field, revealing plateaus of the integer quantum Hall effect.

Results and Discussion

The Hall resistance of the system is shown as a function of applied magnetic field in Figure 1. At low field, the Hall resistance is linear in field, with a linear coefficient, R_H, that is normally used as a measure of the sheet density of charge carriers. However, as can be seen clearly in Figure 1, R_H changes significantly between 0.4 K and 15 K. This change of R_H is not accompanied by a change in electron density of the system. We show that this excess Hall resistivity tracks the Curie-Weiss-like magnetization of the sample, which is measured via the enhanced Zeeman shift of the emitted photoluminescence. Further, the strength of the observed AHE in this paramagnetic metal can be tuned by changing the electron sheet density by means of a gate on the sample.

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