In-Plane Magnetoresistivity of Dilute Two-Dimensional Electrons in Si/SiGe Heterostructures

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Introduction

Dilute two-dimensional (2D) electrons in Si/SiGe systems show an apparent metal-insulator transition (MIT) in conductance.\(^1\) On the metallic side, the magnetoresistivity increases with B and saturates when B is high enough so that the spins of the electrons are fully polarized. The ratio (\(R_{lp}\)) of the saturation magnetoresistivity (\(\rho_{sat}\)) to the resistivity at zero magnetic field (\(\rho_0\)) is \(\sim 1.8\) at \(T=0.3\)K, almost independent of the electron density (n).\(^2\)

Our previous experiments showed that, at \(T=20\)mK, \(R_{lp}\) increases sharply as n approaches the critical density (\(n_c\)), where the apparent MIT occurs. Whether this behavior is universal among 2D electron gases in Si/SiGe systems is not clear.

Experimental Results and Discussion

The Si/SiGe heterostructures investigated in this study was grown by molecular-beam epitaxy. The density of the electrons was controlled by applying a negative bias to the front gate, which consisted of a Au/Cr/Al\(_2\)O\(_3\) stack. The transport measurements were carried out in cell SCM1in NHMFL. Two samples with different disorder strength were investigated. The mobilities at \(n=1.3\times10^{11}/\text{cm}^2\) were \(1.9\times10^5\)cm\(^2\)/Vs and \(2.8\times10^4\)cm\(^2\)/Vs for sample A and sample B respectively.

Figure 1 shows \(R_{lp}\) as a function of B for both samples. In spite of the very different \(n_c\) and disorder strength, both samples show strongly enhanced magnetoresistivity near the MIT. When \(R_{lp}\) is plotted as a function of \((n-n^*)/n^*\), where \(n^*\) is the fitting parameter, the data for the two samples can be collapsed reasonably well onto a single curve, as is shown in Fig. 2. The \(R_{lp}\) seems to diverge, not at \(n_c\), but at \(n^*\). The \(n^*\) for sample A is \(2.8\times10^{10}/\text{cm}^2\), which was identified as the percolation threshold density by Lai et al.\(^2\) in a sample very similar to sample A. \(n^*\) being the same as the percolation threshold density and the apparent scaling of the data for the two samples with different \(n_c\)’s and interaction strength suggest that the disorder and inhomogeneity play important roles in the strongly enhanced magnetoresistivity near the MIT.

Conclusions

Our experiments show that at \(T=20\)mK the in-plane magnetoresistivity of dilute 2D electrons in Si/SiGe heterostructures shows strong enhancement near the MIT for both high-mobility and low-mobility samples. The enhancement is likely related to disorder and inhomogeneity in the structures.

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References