TIME-DEPENDENT CONDUCTANCE FLUCTUATIONS IN THE METALLIC PHASE OF A TWO-DIMENSIONAL ELECTRON SYSTEM IN SILICON

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Introduction

The interplay between strong Coulomb interactions and disorder is believed to be responsible for many surprising and intriguing experimental observations that suggest the existence of a metallic phase in two dimensions (2D) [1]. One of the central unresolved issues involves the role of the electrons' spins. Our studies of low-frequency resistance noise [2,3] in a 2D electron system (2DES) in Si have revealed a dramatic change in the electron dynamics that occurs near the metal-insulator transition (MIT) as it is approached from the metallic side. This change in the dynamics, attributed to glassy freezing, persists even when the electrons are fully spin polarized indicating that charge, not spin, degrees of freedom are responsible for glassy ordering. On the other hand, the origin of the $1/f$ resistance noise observed in the metallic phase has not been understood. In disordered metals at low temperatures, slow atomic motion gives rise to $1/f$ noise via the mechanism of universal conductance fluctuations (UCF) [4]. Such noise is suppressed by a magnetic field B in a very specific way [5]. In order to shed light on the origin of noise in the metallic phase, we have studied the effect of a parallel B on noise, and compared our results to theoretical predictions [5].

Experimental

Measurements of resistance as a function of time for a fixed carrier density n_s and in fixed parallel B of up to 9 T were carried out on a high-mobility ($\mu \approx 2.5$ m^2/Vs at 4.2 K) 2DES in Si using a standard four-probe lock-in technique at 2.7 Hz. The samples and the measurement technique have been described in more detail elsewhere [3].

Results and Discussion

The noise power for n_s in the metallic phase is suppressed by a parallel B, and the spectrum changes from $1/f$ to $1/f^{0.5}$. This suppression of noise suggests that its origin is probably related to the electrons' spins. In case of UCFs, the theory predicts [5] that the variance of conductance, $(\delta G)^2$, will be reduced exactly by a factor of 2 in a parallel B because of the Zeeman splitting, but it does not predict any change in the power spectrum. Figure 1 shows that, in our samples, $(\delta G)^2$ is reduced by almost two orders of magnitude before it becomes more or less independent of B for B>4 T, where the 2DES is spin polarized.

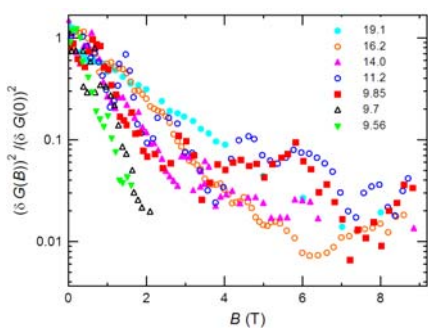

Figure 1. The B-field dependence of the conductance fluctuations for several densities $n_s(10^{10}\text{cm}^{-2})$ from 9.56 to 19.1 at T=0.24 K.

Conclusions

We have established that the $1/f$ resistance noise observed in the metallic regime of a 2DES in Si does not result from the motion of impurities and UCFs, but rather it appears to originate from some type of spin scattering. One possibility includes disorder-induced local magnetic moments, but a detailed mechanism presents yet another puzzle in the understanding of this novel metallic phase.

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