Frictional Drag Between Dilute 2D Hole Systems

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In recent years, drag measurements[1] have attracted much attention in relation to probing the carrier-carrier interactions in double layer systems. The drag resistivity (ρ_D), which arises due to momentum transfer between the layers, is directly proportional to the interlayer carrier-carrier scattering rate. In this sense, the drag is a very powerful tool, and has been used in the past to study the carrier-carrier scattering in a variety of different electronic states. Here, we have studied the drag in a dilute double layer hole system with layer densities ranging from 2.5 to 0.6×10^{10} cm^{-2}. These are the first drag measurements in such a strongly interacting regime with r_s values ranging from 19 to 40. These measurements are of particular interest in relation to the anomalous metallic-like behavior observed in single layer systems, and we would like to point out that the transport in each individual layer in our samples reproduced all the key features associated with the "metallic" phase. An important question in attempting to understand the origin of the "metallic" behavior is what role carrier-carrier interactions play. Drag measurement in this regime can provide insight into this question.

We have studied the drag in the dilute regime as a function of temperature, density, layer separation, and in-plane magnetic field. Our main finding at zero field[2] is that the drag shows a very large 2 to 3 orders of magnitude enhancement over a Boltzmann calculation, for direct carrier-carrier scattering, and the corresponding low density electron results. In addition, at low temperatures, the drag follows a T dependence close to $T^{2.5}$, not the T^2 expected from Fermi liquid theory (Fig 1). At higher temperatures, the drag crosses over to a sublinear dependence, and when scaled by T^2 exhibits a peak (Fig 2). After looking at the density ratio dependence of the drag (Fig 2 inset) we have found that for low temperatures and close layer separation, the drag follows a roughly $(p_1 * p_2)^{-2.5}$ dependence, and does not exhibit any sensitivity to matched density. This observation is inconsistent with phonon mediated[3], plasmon enhanced[4], and 2kf scattering[5] drag processes, all of which have shown sensitivity to matched density. In addition, at higher hole densities (7×10^{10} cm^{-2}), the T^2 dependence is recovered (Fig 1 inset) and the magnitude is within reasonable agreement with a Boltzmann calculation. These observations provide very strong evidence that the large enhancement is related to a novel drag mechanism, which is activated in the large r_s regime.

We have also studied the drag as a function of in-plane field[6]. Our main finding, shown in Fig 3 is that both the single layer in-plane magnetoresistance and the magnetodrag exhibit the exact same qualitative dependence. Both traces show a quadratic increase with field, and a crossover to a weaker dependence at a field corresponding to full spin polarization of the system. This observation is astonishing since the nature of the drag and the single layer resistivity are quite different. We have also observed that the magnetodrag exhibits sensitivity to the density ratio of the 2 layers, exhibiting a maximum at matched density, as is shown in the inset of Fig 3 (b). We speculate that these observations suggest that intersubband scattering processes might be important in the in-plane magnetotransport.

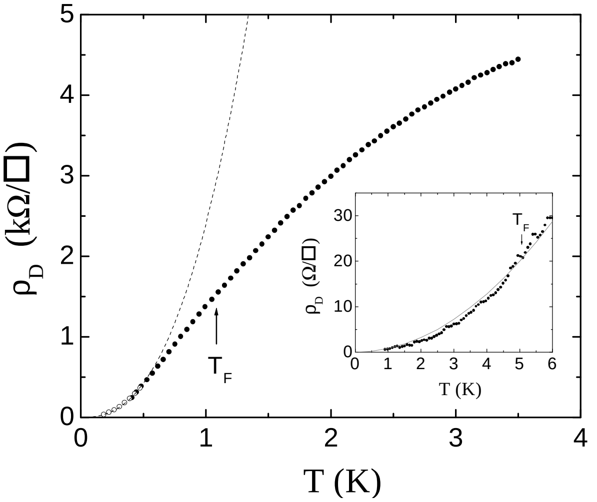

Fig 1: ρ_D vs T for p = 1.5×10^{10} cm^{-2}. Dotted line is the best $T^{2.5}$ fit of the low temperature data. Data with open circles measured in dilution refrigerator. Inset: ρ_D vs T for p = 7.0×10^{10} cm^{-2}. Solid line is the best T^2 fit.

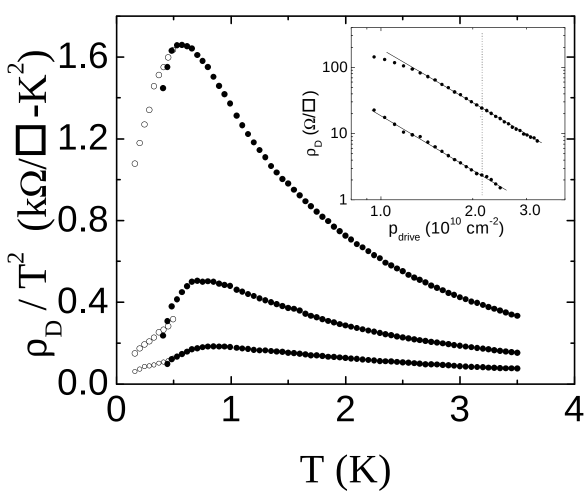

Fig 2: ρ_D/T^2 vs T for from top to bottom 1.5, 2.0, and 2.5×10^{10} cm^{-2}. Inset: ρ_D vs drive layer density on log-log scale for the drag layer fixed at 2.15×10^{10} cm^{-2} at T = 300 (top) and 80 mK. Both data are well described by straight lines with slope close to –2.5. Matched density indicated by the dashed line.

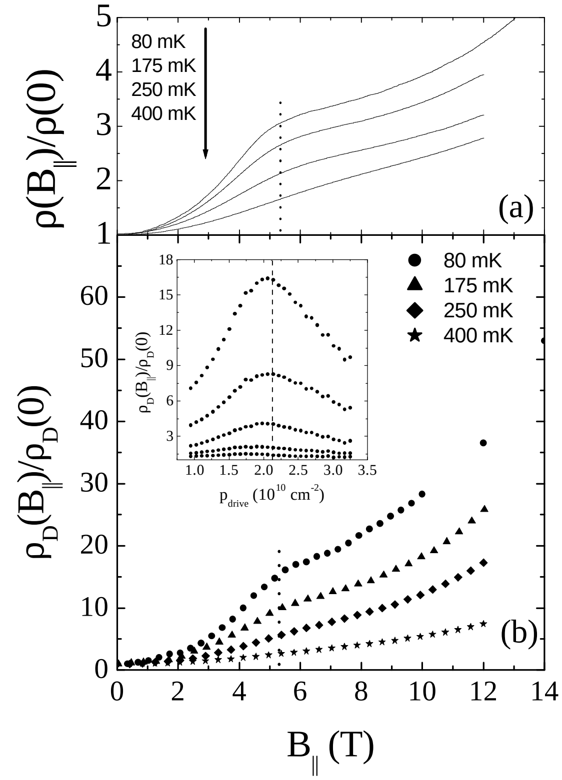

Fig 3: Normalized in-plane single layer magnetoresistance (a) and magnetodrag (b) at different temperatures for p = 2.15×10^{10} cm^{-2}. Inset (b): Normalized magnetodrag vs drive layer density for the drag layer fixed at p = 2.15×10^{10} cm^{-2}, for from top to bottom $B_{\parallel}$ = 14, 10, 5.3, 3, and 2 T.

References

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