DISAPPEARANCE OF THE METAL-LIKE BEHAVIOR IN GaAs TWO-DIMENSIONAL HOLES BELOW T=30 mK

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Introduction

The observation of the metal-insulator transition (MIT) in two-dimensional systems bears great importance of understanding the fundamentally important interaction effects. Despite the large amount of experimental evidences on the metallic behavior, there remains a central question on whether the so-called metal-like behavior, observed at finite temperatures as low as 30 mK, will survive at even lower temperatures. In 2000, Xia *et al* [3] demonstrated cooling of 2D electrons down to 4 mK by utilizing the T-dependence of the peak of the γ=5/2 fractional quantum hall state as an internal thermometer.

Experimental

We adopt the GaAs/AlGaAs heterojunction insulated-gate field-effect transistor (HIGFET). Because there is no intentional doping, the device demonstrates exceptional mobility and density tenability (with a record-low value of $6\times10^8 cm^{-2}$). New remarkable observations have recently been made in 2D holes in these HIGFET devices [2][3]. In this work, we have performed ultra-low temperature transport measurements (down to a base value of 0.5 mK) on very high quality 2D holes in the nuclear refrigerator located at the Microkelvin Laboratory at University of Florida.

Results and Discussion

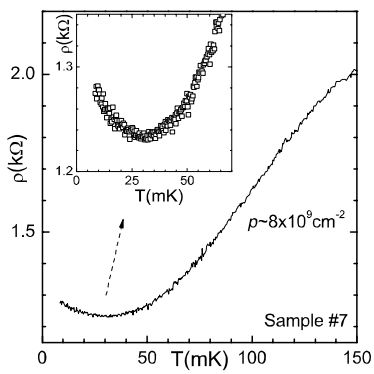

Fig.1 ρ(T) for p=8x10^{9}cm^{-2}.

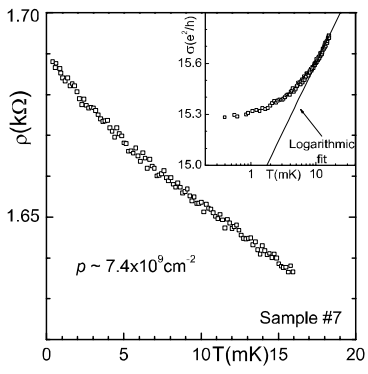

Fig.2 ρ(T) for p=7.4x10^{9}cm^{-2}

Remarkably, for density ~ 8x10^{9}cm^{-2}, following the metal-like behavior (dρ/dT>0) occurs at temperatures above 30 mK [Fig.1], we have observed an upturning of the resistivity with cooling which signifies a crossover into an insulator-like regime (dρ/dT<0) at temperatures below 30 mK, with faster increase rate at lower temperatures. The rising of the resistivity with cooling at T<30 mK persists astonishingly down to the lowest bath temperature of 0.5 mK [Fig.2]. The inset shows the transport is different than the weak-localization correction.

Conclusions

For a fixed carrier density around for p=7.4x10^{9}cm^{-2}, we have observed a crossover from the metal-like state (dρ/dT>0) into an insulator-like state when T is lowered below 30 mK, and this insulator-like behavior (dρ/dT<0) prevails down to a base temperature of 1 mK. These results are possibly implications of an insulating ground state for 2D systems which needs further investigations.

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References

[1] J. S. Xia, E. D. Adams, V. Shvarts, W. Pan, H. L. Stormer and D. C. Tsui, Physica B **280**, 491 (2000)
[2] Jian Huang, D. S. Novikov, D. C. Tsui, L. N. Pfeiffer, and K. W. West, Phys. Rev. B **74**, 201302(R) (2006)
[3] Jian Huang, D. S. Novikov, D. C. Tsui, L. N. Pfeiffer, and K. W. West, cond-mat/0610320 (2006, submitted to PRL)