The Metallic State of the Dilute Two-Dimensional Hole Gas in the Strongly Correlated Regime: Failure of Fermi Liquid Theory and Strong Enhancement of Hole-Phonon Coupling

ABSTRACT

Much interest has centered around the metallic behavior observed in two-dimensional systems because there has been a long-accepted theoretical understanding that non-interacting two-dimensional systems are all insulators. We study very low-density ($T$ Fermi $\sim$ 1K) two-dimensional holes in narrow (10nm) GaAs quantum wells to access very high values of $R_s$ $\sim$ 30, the ratio of potential energy to kinetic energy. The goal is to best probe the role that interactions play in the metallic state. Many groups have suggested that Coulomb interaction corrections of a Fermi liquid could account for the observed increase in conductivity at low temperatures. However, these Fermi Liquid corrections imply clear predictions for behavior of the Hall coefficient. Longitudinal and Hall resistivity on the same samples find that the slope of $R_{xy}$ ($B$) increases as $T$ decreases (and also increase as $B$ increases). Thus, Fermi Liquid corrections fail both qualitatively and quantitatively as an explanation for the metallic behavior. Other interesting phenomena in the metallic regime will be discussed, including evidence from carrier heating experiments that the metallic state features an almost 20 time enhancement in the short range Deformation Potential coupling between holes and phonons, whereas long range Piezoelectric Coupling remains unchanged.

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