Coulomb Drags in Graphene

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Coulomb drag effect is a mesoscopic effect which manifests many body interactions between two low-dimensional systems, which has served an extremely useful probe the strong correlation in quantum systems. When two electrically isolated conductors are brought close, a current in one conductor can generate friction and drag electrons in the other via Coulomb interaction, thereby causing a charge imbalance in the dragged layer. In this presentation, we will discuss three different experimental observation that manifest novel Coulomb drag phenomena. In the first example, we discuss Coulomb drag between a two-dimensional electron gas in graphene and a one-dimensional wire composed of a carbon nanotube [1]. We find that drag occurs when the bulk of graphene is conducting, but is strongly suppressed in the quantum Hall regime when magnetic field confines conducting electrons to the edges of graphene and far from the nanotube. Out-of-equilibrium measurements show that transitions between quantized charge states of the nanotube induce either strong suppression or enhancement of drag signal. In the second example, we discuss the experimental study of frictional drag effect between two monolayer graphene layers in the quantum Hall regime [2]. We observed strong magneto- and Hall-drag signals which sensitively depend on the Landau level filling of each graphene layer. Magneto- and Hall-resistance of each layer are also measured and compared with the drag results. Finally, we also demonstrate a superfluid condensation of magnetic-field-induced excitons by observing quantized Hall drag effect in graphene double layers spaced by atomically thin hexagonal-boron nitride (hBN) [3]. Bose-Einstein condensation (BEC) is a fascinating way to realize macroscopic quantum coherent states. Only a few physical systems have been known to support this peculiar many-body quantum state: atoms under extremely low temperatures and electrons in the extremely clean semiconductor heterostructures. In our experiment, capitalizing strong Coulomb interaction across the atomically thin hBN separation layer, we realize the magneto-exciton BEC in bilayer graphene double layers whose transition temperature at elevated temperatures. Furthermore, complete experimental control of density, displacement and magnetic fields in our graphene double layer system enables us to explore the rich phase diagram of several superfluid exciton phases with the different internal quantum degrees of freedom.

References

[1] J. -D. Pillet, A. Cheng, T. Taniguchi, K. Watanabe, P. Kim, arXiv: 1612.05992
[2] X. Liu, L. Wang, K. C. Fong, Y. Gao, P. Maher, T. Taniguchi, K. Watanabe, J. Hone, C. Dean, P. Kim, arXiv: 1612.08308
[3] X. Liu, T. Taniguchi, K. Watanabe, B. I. Halperin, P. Kim, arXiv: 1608.03726