Study of Coulomb drag in non- homogeneous dielectric medium

This thesis aims to study the Coulomb drag (CD) phenomena of charge carriers in the bilayer system of a non-homogeneous dielectric medium (NHDM). Several years ago, a non-homogeneous bilayer state was first predicted theoretically, this thesis is based on its discovery and exploration. Transport measurements allow for the direct detection of the interaction in the Fermi-liquid regime. Furthermore, drag resistivity (ρ_D) is an excellent tool for predicting the phase transition, such as out of phase of the bilayer quantum state. It expands the phase diagram's mapping to include the temperature and density imbalance of the planes. For that purpose, a carrier transport model has been formulated and implemented using the Boltzmann Transport Equation (BTE) solution for the weakly interacting regime, at low-temperature limit, large interlayer separation regime and Boltzmann/Ballistic regime.

The net screening between the electron and/or holes is assumed short/long range and weakly interactive as the distance between the carriers is long. The behavior of charge carriers in the layer is non-interactive and assumed Fermi-liquid regime, the interaction between the interlayer and intralayer is assumed. The effective interlayer interaction (net screening) between the charge carriers of the system is studied within the model of random phase approximation (RPA). The RPA method consists very good and consistent results for the high-density regime. At low-density regime exchange and correlation (XC) effects become more influenced and impacted, therefore the static local field correction (LFC) considering going beyond the RPA method. XC effects enhanced the effective interaction and drag resistivity (ρ_D) by assuming the static LFC.

The layer width and interlayer distance dependent local form factors (LFF) is also obtained from the Poisson equation's solution for a multilayer dielectric medium (NHDM). The LFF's impact are key function for predicting the inter- and intralayer potential, which explore and enhances the ρ_D compared to simply measured results of bilayer systems. The impacts of LFF are the co-functions of bare inter and intralayer potential, which yields the dependency of layer separation and dielectric constants of the materials. Generally, the drag resistivity is directly proportional to the square of the temperature (T) and dielectric constant of the barrier (ϵ), inversely proportional to the third power of concentration (n) and the fourth power of interlayer separation (d), may be shown as, $\rho_D = \frac{T^2 \epsilon_2^2}{n^3 d^4}$ for weak interaction, at low-temperature, low/high-density and large interlayer separation limit.

Graphene-based fermions are chiral and having linear and quadratic dispersion relation. Graphene/GaAs based hybrid bilayer system extract more numerical results than bilayer system of 2D-GaAs DQW, cause of chiral fermions and having much better effective mass, mobility, and density of states (DOS), etc... The carriers in the BLG are massive chiral fermions with effective mass m^* and a parabolic dispersion relationship $E_F^{BLG} = \frac{\hbar^2 k_F^2}{2m^*}$ around the Dirac points. Where BLG have greater effective mass than GaAs layer. Hence BLG/GaAs have enhanced results compared to bilayer of GaAs DQW Coulomb drag study of SLG/GaAs hybrid bilayer system extracted more better results compare to BLG/GaAs hybrid bilayer system. The reason for its size in the monolayer system can largely be traced to the vanishing density of states at the Dirac point, implying weak screening of the interlayer potential. The carriers in the SLG are massless chiral fermions with an effect of the linear dispersion ($E_F^{BLG} = \hbar v_F |k|$) around Dirac points.