Phonon-assisted high frequency hopping conductance in GaAs/AlGaAs heterostructures in the quantum Hall effect regime: Acoustic Studies

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Under conditions of the integer quantum Hall effect (QHE), electronic states are localized at almost all magnetic fields except of close vicinities of the Landau levels' centers. Consequently, static (dc) diagonal conductance, $\sigma_{xx}^{(dc)}$, vanishes at the QHE plateaus. In contrast, high-frequency (ac) conductance, $\sigma_{xx}(\omega)$, remains finite. It is due to electron *hopping* between the states localized at adjacent impurity atoms, i.e. within so-called close pairs [1]. The dielectric response of close pairs is determined by two mechanisms: (i) direct coupling between the the lowest electron states due to ac electric field, and (ii) phonon-assisted transitions. The relative role of these mechanisms depends on frequency ω and temperature T. In general, ac conductance is complex, $\sigma_{xx}(\omega) \equiv \sigma_1(\omega) - i\sigma_2(\omega)$.

In this work, we have determined both components of complex $\sigma_{xx}(\omega)$ in GaAs/AlGaAs heterostructures with electron density $(1.3-7)\times 10^{11}$ cm^{-2} by simultaneous measuring magnetic field dependences (up to 7 T) of attenuation and velocity of surface acoustic waves in the frequency range 30-150 MHz and temperature range 1.5 - 4.2 K.

As it follows from our experiment, at low temperatures and small integer filling factors, $\sigma_2 > \sigma_1$, $\sigma_1 \propto \omega$ and it is almost temperature-independent. These fact are consistent with theoretical considerations based on "two-site" model for hopping conductance [2]. From analysis of $\sigma_1(\omega)$ it is shown that ac hopping conductance in the 2D layer can be effectively shunted by hopping inside the doping Si δ-layer. The contribution of the 2D layer, $\sigma_1^{(2D)}$, was extracted and analyzed. It turns out that in our regime the phonon-assisted mechanism is more important and $\sigma_1^{(2D)}$ can be expressed through the electron localization length ξ as

$$\sigma_1^{(2D)} = (\pi^2 g^2 \xi^3 \omega e^4 / 2\varepsilon_s)(\mathcal{L}_T + \mathcal{L}_\omega/2)^2,$$

where $\mathcal{L}_T = \ln J/kT$, $\mathcal{L}_\omega = \ln(\gamma_0/\omega)$, $\gamma_0 = (4\pi e^2 K^2 kT/\varepsilon_s \hbar^2 V)$, e is the electronic charge, g is the single-electron density of localized states at the Fermi level, that could be extracted from activation transport, ε_s is the dielectric constant, V is the sound velocity in GaAs , J is the Bohr's energy, K is the piezoelectric coupling constant of GaAs. This expression was used to extract and analyze the localization length ξ as a function of magnetic field.

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